

RESEARCH ARTICLE

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Energy efficiency in historic buildings: a methodological pathway for improving efficiency through a digital platform

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Abstract. Energy performance and comfort condition improvements in buildings is a current issue, fixed by a stringent European regulatory framework that point to reduce emissions from buildings with increasingly objectives of renovation. Especially for historical built, which in Italy represents a large part of the buildings, the renovation must be face as a process, centred on the energetic profile knowledge. This article, part of a doctoral research, elaborates a methodology based on reading multiple energy datasets towards evaluating energy consumption and giving real prospects of improvements. Through the case study of Spelonga – an historical centre in the Marche region – the informative dataset of this process flows into an easy-to-consult digital platform, addressed local administrations to implement the energy governance and more awareness in the planning of the territory.

Keywords: Historical buildings and energy efficiency / integrated digital platform / smart energy systems / ICT

1 Introduction

Nowadays we live an ‘apparent bubble’ of awareness on the location energy efficiency, which is so great that it enters into all speeches. In fact, its use in association with the built environment, or even historic buildings, doesn’t sound strange. Whether we are talking about energy use in the buildings, or the need to control consumptions in the face of rising fossil fuels prices or even the environmental impact of the many emissions generated by construction, the combination of the two terms – energy and efficiency – has so many facets that it takes on so many meanings and, sometimes, leads to linguistic abuse.

Above all, when used as a synonym for energy saving it seems to be an interest of everyone, directly touches economic interests of every family and everyone understands: under this facet, it moves the hopes of many people to improve their family budgets by energetic home renovations, well known ad interventions aimed at the energetic best use and the reduction of bill costs, at this time a very high expense item due to the rise in prices.

In Italy, driven by an energy policy that responds to the urgent agenda of the European Union – known as the *European Green New Deal* and *Fit for 55* package –

the mass media interests regularly focus on the issue of energy efficiency in buildings, creating an ‘unconscious’ awareness in the community. The measures adopted by last governments, which include Italy in the broader European strategy called *Renovation Wave* – translate in *Super Ecobonus 110%* – have given a strong boost to the already existing policy of tax incentives for the residential building energy renovation, formulated as a response to pandemic economic crisis and as a driving force for the recovery in the construction sector. Today this topic is even more promoted as solution to the rising prices of fossil fuels and the crisis of not renewable energy sources: therefore, awareness of energy efficiency in buildings is increasing and many people – driven by the national favourable climate of economic incentives – are investing in measures to improve the energy supply and consumption of their constructions which, in most cases, are outdated and energy-hungry buildings because built before an effective national regulation in this subject.

In Italy, the last upsurge in investments in energy retrofitting is a good indication of a real need to re-qualify buildings, expressed primarily by the holders would benefit of the energetic improvements: considering the period 2020–2023, when tax incentives for residential energetic renovation were reformulated, data processed by the National Agency for Technologies and Energy (ENEA) on the *110% Super Ecobonus* application [1] and reports by

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the Camera dei Deputati [2] show a real increase in energy retrofitting interventions on existing residential buildings from 2000 to 400,000 units.

But this apparent awareness clashes with a stark reality in which there is still too much to be done to improve the energy performance of existing buildings and move towards total decarbonisation in construction: in fact, energy renovation rates in Europe are only around 0.4–1.2 per cent for year [3] and, at this rate, the transition to zero-emission and zero-consumption buildings, which the EU has set for 2050, will take centuries.

The fact that we are confronted with too many old buildings, with problems of indoor comfort and energy performance, is confirmed by the ‘inflated’ and well-known estimations on the Italian building stock [4]. Some numbers of the Italian building stock: out of 15 million buildings (only 13%) are more efficient because have been built in the last twenty years with an up-to-date and European-style regulatory framework in the energy field; almost half (around 50%) were built before 1950 using materials and techniques that could be called ‘traditional’. This last segment should be considered with a certain attention as, due to construction characteristics and technologies that are so far from the current standardization, it could be qualified as ‘historical’ because representing a consolidated identity heritage in historical centres and aggregates. This consists of buildings sometimes have unique architectural features (churches, palaces, monuments, etc.), but for the majority is common or so-called minor buildings and should therefore be treated differently from a mere energy readaptation perspective, even though they present problems for the great production of emissions and consumption of fossil fuels.

This article, which is part of doctoral thesis research, attempts to address the multiple aspects of what is well defined as *miglioramento energetico* of historical buildings, better translate in energetic improvement, renovation, requalification, or retrofitting. Focusing only on existing buildings – more specific historical – knowledge and evaluation of building performance are indispensable to base any renovation perspectives, assessing the criticalities, peculiarities, and opportunities for intervention.

This research also aims to reflect on the possibility of integrating the knowledge acquired from using various levels of information systems relating to the built environment (territorial, environmental, etc.) with that of energy efficiency management in a smart energy data management system.

The objective is to ensure free access for all users, both professionals and individual citizens/owners, to acquire an ‘energy picture’ of their building and increase awareness of the potential and most effective interventions.

Approaching the issue of smart cities, the need to interoperate the big amount of data and information related to interventions in buildings, this study formulates a hypothesis of an energy management platform that relates through a spatial information system (such as GIS) intelligent modelling in BIM environment and analytical-diagnostic data. An application on in the case study of a small village in central Italy, Spelonga in Arquata del Tronto, hit by the 2016 earthquake.

2 The energetic ‘state of health’ of the buildings in Italy: problems and materials for research

Energetic renovation of existing buildings is a topic of extreme urgency, both for our country and on a large continental or world scale. The current moment is characterised by worsening economic crises and pressing climate changes: as a result, the United Nations and the European Union are directing member states towards to limit energy consumption, reduce soil waste and cut the supply from exhaustible energy sources. To achieve these targets, a strict legislative framework has been established by the UE: this framework is binding, guides programme-strategies, and is premised around pursuing environmental, social, and economic sustainability.

If we have to quantify the scale of possible actions only Italy, almost the half of our residential built is older than 50 years: easy to observe that, from a strictly energy point of view and in respect to current legislative prescriptions or performance standards, a large part of building stock performs poorly because it was built before any effective national regulation in the sector. Looking further at the eras of these constructions almost a third (27%) was built before 1945 and less than a quarter (15%) before 1915: these slices take ‘historical connotation’ certainly because of its age [5] but also because of the materials and construction techniques, which are different from those introduced after the Second World War, and finally due to the cultural values and meanings they sometimes brought.

Then, could be added that most of these constructions constitutes the connective tissue of historical centres and villages of the Peninsula, defining the visual and landscape identity of our country.

Therefore, if it is clear that the Italian building stock is elderly and requires widespread action for energy requalification, also due to the natural processes of deterioration and obsolescence affected them, it’s equally clear that the problem of inefficiency imposes a necessity to treat with greater critical awareness this heritage of the past, which sometimes constitutes a patrimony with multiple value entities in its material entity that is not always protected.

The current theoretical debate – extraordinary increased in last decade [6] – points in the direction of energy improvement trying not to transpose to historical constructions measures of adaptation to the performance parameters foreseen for the new: this guarantees that the project on the existing building doesn’t come to distort the original character of the building as it came to us, imposing the purposes of conservation to that of a pure efficiency improvement. A reasoning that acquires even more value in an economic context that is facilitating and incentivising renovation and impose on the majority of interventions that fall within the so-called ‘ordinary practice’, such as the envelope thermal insulation or insertion of a heating-cooling system or the replacement of fixtures or the windows substitution.

On the wave of a growing political, social, cultural and economic awareness of the need to intervene on historic buildings, energy efficiency and building conservation actions now seem to be able to walk on a path that was

initially traced and for which improving, by increasing comfort conditions and saving opportunities, also means constituting a valid safeguard for the maintenance and material transmission of this building consistency to future generations: in a most extensive meaning, energy improvement could support the multiple values conservation on the historic built environment in a sustainable way [7].

3 Enhancing building performance through a methodological path: from knowledge acquisition to dissemination

Working on a historical structure differs from working on a standardised building and this perspective underpins the objective of this thesis research: to create a methodological approach, based primarily on an understanding of the technological and material features of existing buildings as a vital tool for directing potential interventions with the aim of enhancing energy performance.

This approach comprises several phases, from understanding the buildings to diagnosis and potential interventions and includes buildings as a whole.

Starting with knowledge, it is essential to focus on sharing ‘factual’ information about the buildings’ condition, which can be best achieved by providing open access to energy data: a brief review of the literature suggests that the open world and big data environment in which we live is rapidly evolving during the last decades with continuous improvements in the collection of buildings energy information (energy demand, consumption, emissions, performance etc.) and organization of various types of datasets at urban scale [8].

In the perspective of *smart city* [9] and *smart mentoring* being able to freely use a mass of information about the places we live and the building we inhabit, and these allows to plan and govern better the territory in which vital events develop. So, there are more accessible levels of energetic information in the buildings condensed in models that involve different users and potential applications, starting from the ‘technicians use’ to the owner’s control or the urban or politic planning. For buildings – both single and in aggregate – the integration of a wide range of energetic knowledge data into a model – or better into a Building information modelling (BIM) – allows to manage functionality and efficiency during the life cycle, even if it’s a historic building: nowadays Historic Building Information Modeling (HBIM) is an open field for practice research and experimentation of interoperability implementation in the energetic field [10].

The accessibility of open-source and web-based data on energy consumption in buildings has been increasingly widespread also in Italy, due to the introduction of the “regional energy cadastre” by national law 90 of 2013, accessible through the ENEA Siape system [11] and, additionally, individual municipalities or urban have organized various WebGis to map the energy consumption from the buildings within their respective territories: is taken as a mere example the municipality of Bolzano which has developed an integrated system of information inclusive of the energetic consumption [12].

In this study the access and the sharing to a structured information base is aimed not only at professionals in the field – including designers, technicians, and administrators – but also building owners: in fact the aim is to improve the cognitive awareness of individuals residing in and benefiting from the building, which will guide efficient interventions, through access to operational and propositional lines, to achieve maximum efficiency.

Back to examining data and information in historic buildings, which presents a considerable number of uncertainties: these include irregular wall sections, discontinuity in materials and construction techniques, and lack of homogeneity in the masonry core, all of which impact the hypothesis of conducting a global energy assessment according to the standard energy pre-evaluation software. In fact, the primary software tools employed for energy modelling and assessment meticulously apply calculation methods tailored to newly built structures. This is achieved through the analysis of a case study primarily derived from recent advances in the field.

The aim of this research is not to provide certificates or evaluations on the existing building’s energy performance, but to establish a methodology that starts from the context understanding, also by means of a semantic and environmental reading of the housing core of insertion, and goes on to a deeper knowledge of the architectural organism (in terms of materials, construction techniques, components, etc.) which is only possible through an historic research and a geometric-architectural survey.

Then proposes the evaluation of the building’s energy behaviour, which is based on the instrumental diagnostic survey, but also on the indirect one, by means of research into consumption trends, in terms of heating, from which it is possible to deduce the amount of energy lost through the envelope.

From developing a database on the energy status of the building, aimed to create a prototype open data platform for managing energy in a case study: Spelonga, a historic village in the municipality of Arquata del Tronto, which suffered partial destruction in the 2016 earthquake (Fig. 1).

By dynamically transposing the three steps of the approach, the platform seeks to provide all levels of users with two lines of interpretation: the first one is a reading of the data; the second one guides to operational and propositional lines. For the latter, before arriving at the expected results, it provides a series of information much broader than the final energy consumption data, ranging from the climatic awareness of the site to the spaces of the hamlet to be examined, up to the geometric and semantic reading of the model of the building to be intervened upon, and a planned case history of possible interventions for energy improvement.

4 Proposal of an inter-operable platform for Spelonga village

The platform proposed consists of many elements in which the main one is the database, the container of all the information datasets in .xlsx format: to facilitate the visualisation, the datasets were managed in a GIS



Fig. 1. Spelonga.

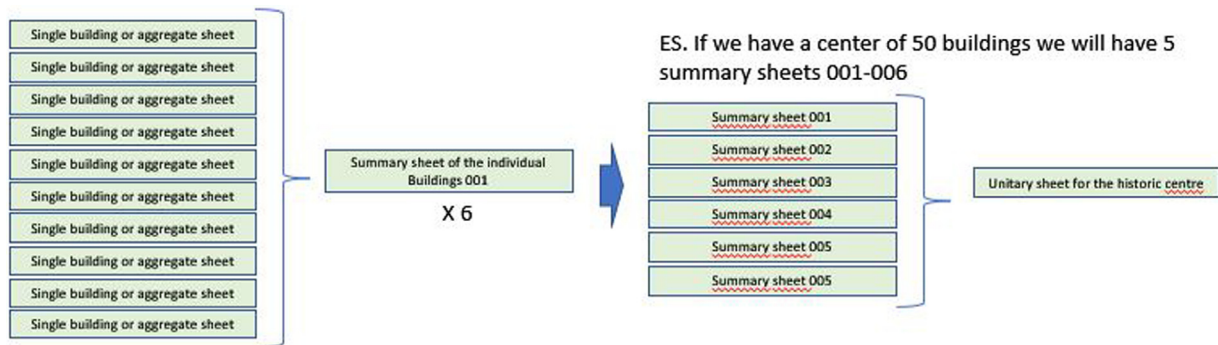


Fig 2. Methodological scheme of the platform structure.

environment through the use of the open source software Quantum Gis.

This open source software also offered the possibility of integrating BIM modelling of single buildings and more plug-ins, dealing a complete view of the interoperability of information systems.

The structure is presented in the form of a tree (Fig. 2): for convenience and an easy information management, each building, or agglomeration of several buildings, has been divided into clusters (maximum of ten buildings), allowing an overall view of the urban aggregate and at the

same time an in-depth examination of the individual building.

Accessibility is ensured by a web page presentation, which totally traces the outlined methodological steps (knowledge and analysis, diagnosis, intervention): to that is added the level of results, as the projection of the achievable efficiency measures to provide an idea of the economic resources to be employed.

The borough was analysed by levels of detail, starting from general data concerning the entire urban environs and the environmental context, up to several levels of reading

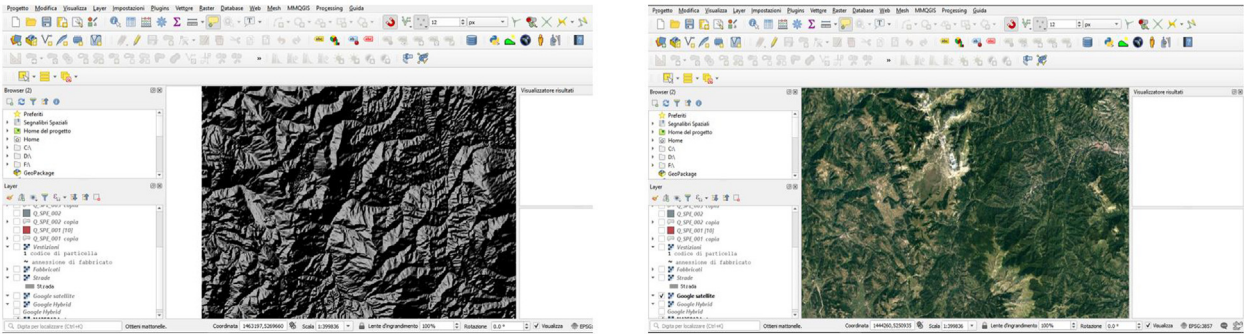


Fig. 3. Viewing of DTM file and satellite imaging overlay.

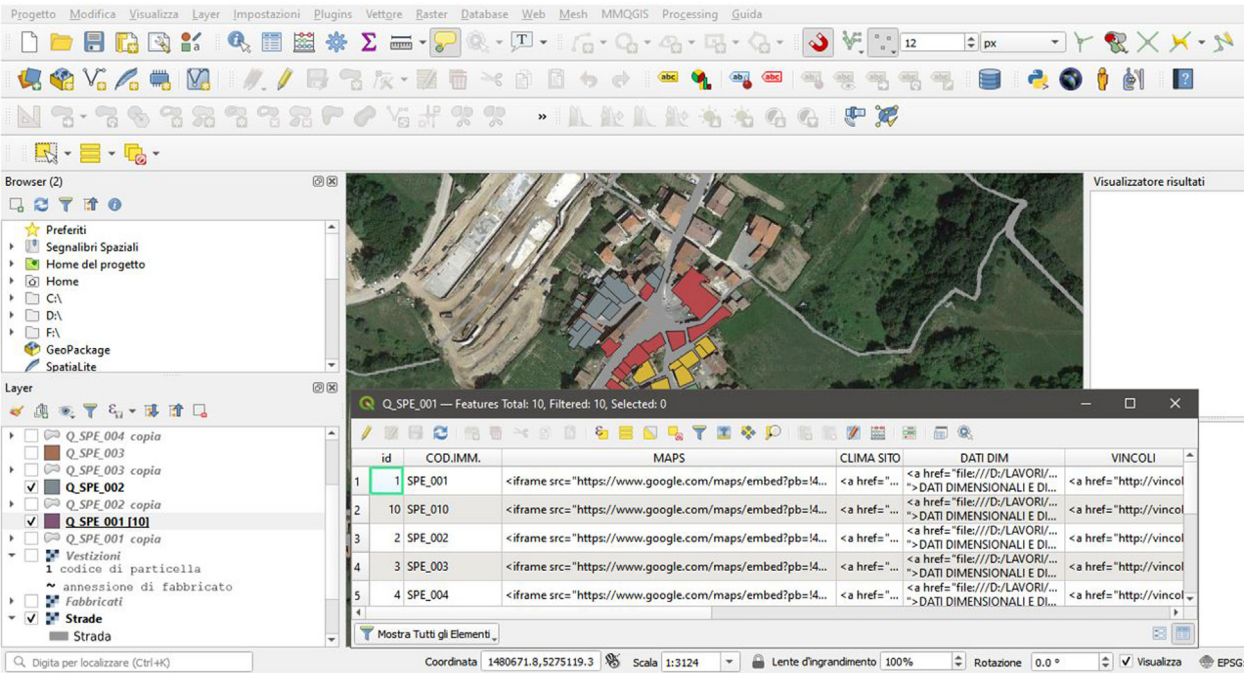


Fig. 4. Iframe in the schedule of shapefile.

detail: these recall the concept of LOD (level of details) according to the CityGML multiscale modelling standard [13], structured in 5 progressive learning levels.

Making use of application plug-ins, including those for the integration with *Google street view* and *Autodesk's Fusion 360*, and referring to external hyperlinks (*Iframe*), the individual cluster tabs were structured, as visible in Figure 3.

Using the possibilities offered by the *Iframes*, to detail the building analysis and diagnosis phase, calculation sheets have been drawn up in *xlsx* format, which attempt to converge the physical-material data of the building envelope components. In fact, in an effort to come as close as possible to an energy assessment system that is not too standard, due to the fact that the building has historical material-constructive characteristics, a set of tools have been designed (in tabular form for wall transmittances, floor transmittances, floor transmittances and a summary table of window and frame transmittances) through which

it is possible to obtain a prevaluation of building performance (Figs. 4 and 5) and the expected lines of improvement: this is achieved by correlating and interpolating the thicknesses of the walls with the physical characteristics of the most common insulating materials.

Furthermore, as reflection of diagnostic level and start to the next methodological step of the interventions, a summary sheet was prepared, which repeats the level of detail of the tree structure, in which the calculation results are projected and specifically related to consumption (heating, acs, electricity), plant efficiency, the total envelope surfaces subjected to intervention with the relative costs, the installation of any solar and photovoltaic panels also with the relative costs and finally the total intervention costs for the cluster (Fig. 6).

The summary sheet for each individual building provides information on the dimensional and geometric characteristics of the buildings by reading the BIM model

RECURSIVE WALL CALCULATION WITH INSULATING LAYER																						
EXTRUDED POLYSTYRENE (XPS) $\lambda=0.04$																						
Calculated data	U initial masonry	Initial R masonry	Masonry thickness	Insulation thickness (m)																		Insulating conductivity
	(W/mq K)	(kmq/W)	(m)	0,03	0,04	0,05	0,06	0,07	0,08	0,09	0,10	0,11	0,12	0,13	0,14	0,15	0,16	0,17	0,18	0,19	0,2	
				resistenza termica isolamento																		0,040
				0,03	0,04	0,05	0,06	0,07	0,08	0,09	0,10	0,11	0,12	0,13	0,14	0,15	0,16	0,17	0,18	0,19	0,20	
BASIC VALUES				SPESORE DI ISOLANTE NECESSARIO																		
				trasmissione termica con isolante																		
	0,70	1,429	1,881	0,46	0,41	0,37	0,34	0,31	0,29	0,27	0,25	0,24	0,23	0,21	0,20	0,19	0,18	0,18	0,17	0,16	0,16	
	0,75	1,333	1,755	0,48	0,43	0,39	0,35	0,32	0,30	0,28	0,26	0,24	0,23	0,22	0,21	0,20	0,19	0,18	0,17	0,16	0,16	
	0,80	1,250	1,646	0,50	0,44	0,40	0,36	0,33	0,31	0,29	0,27	0,25	0,24	0,22	0,21	0,20	0,19	0,18	0,17	0,17	0,16	
	0,85	1,176	1,549	0,52	0,46	0,41	0,37	0,34	0,31	0,29	0,27	0,25	0,24	0,23	0,21	0,20	0,19	0,18	0,18	0,17	0,16	
	0,90	1,111	1,463	0,54	0,47	0,42	0,38	0,35	0,32	0,30	0,28	0,26	0,24	0,23	0,22	0,21	0,20	0,19	0,18	0,17	0,16	
	0,95	1,053	1,386	0,55	0,49	0,43	0,39	0,36	0,33	0,30	0,28	0,26	0,25	0,23	0,22	0,21	0,20	0,19	0,18	0,17	0,17	
	1,05	0,952	1,254	0,59	0,51	0,45	0,41	0,37	0,34	0,31	0,29	0,27	0,25	0,24	0,22	0,21	0,20	0,19	0,18	0,18	0,17	
	1,10	0,909	1,197	0,60	0,52	0,46	0,42	0,38	0,34	0,32	0,29	0,27	0,26	0,24	0,23	0,21	0,20	0,19	0,18	0,18	0,17	
	1,15	0,870	1,145	0,62	0,53	0,47	0,42	0,38	0,35	0,32	0,30	0,28	0,26	0,24	0,23	0,22	0,21	0,20	0,19	0,18	0,17	
	1,20	0,833	1,097	0,63	0,55	0,48	0,43	0,39	0,35	0,32	0,30	0,28	0,26	0,24	0,23	0,22	0,21	0,20	0,19	0,18	0,17	
	1,30	0,769	1,013	0,66	0,57	0,50	0,44	0,40	0,36	0,33	0,31	0,29	0,27	0,25	0,23	0,22	0,21	0,20	0,19	0,18	0,17	
	1,40	0,714	0,940	0,68	0,58	0,51	0,45	0,41	0,37	0,34	0,31	0,29	0,27	0,25	0,24	0,22	0,21	0,20	0,19	0,18	0,18	
	1,50	0,667	0,878	0,71	0,60	0,52	0,46	0,41	0,38	0,34	0,32	0,29	0,27	0,26	0,24	0,23	0,21	0,20	0,19	0,18	0,18	
	1,60	0,625	0,823	0,73	0,62	0,53	0,47	0,42	0,38	0,35	0,32	0,30	0,28	0,26	0,24	0,23	0,22	0,21	0,20	0,19	0,18	
	1,70	0,588	0,774	0,75	0,63	0,54	0,48	0,43	0,39	0,35	0,32	0,30	0,28	0,26	0,24	0,23	0,22	0,21	0,20	0,19	0,18	
	1,80	0,556	0,731	0,77	0,64	0,55	0,49	0,43	0,39	0,36	0,33	0,30	0,28	0,26	0,25	0,23	0,22	0,21	0,20	0,19	0,18	
	2,00	0,500	0,658	0,80	0,67	0,57	0,50	0,44	0,40	0,36	0,33	0,31	0,29	0,27	0,25	0,24	0,22	0,21	0,20	0,19	0,18	
	2,10	0,476	0,627	0,82	0,68	0,58	0,51	0,45	0,40	0,37	0,34	0,31	0,29	0,27	0,25	0,24	0,22	0,21	0,20	0,19	0,18	
	2,20	0,455	0,598	0,83	0,69	0,59	0,51	0,45	0,41	0,37	0,34	0,31	0,29	0,27	0,25	0,24	0,22	0,21	0,20	0,19	0,18	
	2,30	0,435	0,572	0,84	0,70	0,59	0,52	0,46	0,41	0,37	0,34	0,31	0,29	0,27	0,25	0,24	0,23	0,21	0,20	0,19	0,18	
	2,40	0,417	0,549	0,86	0,71	0,60	0,52	0,46	0,41	0,38	0,34	0,32	0,29	0,27	0,26	0,24	0,23	0,21	0,20	0,19	0,18	
	2,60	0,385	0,506	0,88	0,72	0,61	0,53	0,47	0,42	0,38	0,35	0,32	0,30	0,28	0,26	0,25	0,23	0,22	0,20	0,19	0,19	
	2,80	0,357	0,470	0,90	0,74	0,62	0,54	0,47	0,42	0,38	0,35	0,32	0,30	0,28	0,26	0,24	0,23	0,22	0,21	0,20	0,19	
	3,00	0,333	0,439	0,92	0,75	0,63	0,55	0,48	0,43	0,39	0,35	0,32	0,30	0,28	0,26	0,24	0,23	0,22	0,21	0,20	0,19	

VERTICAL OPAQUE STRUCTURES	
CLIMATIC ZONE	ULIM PRICE TAG FROM JAN 1, 2021
A-B	0,4
C	0,36
D	0,32
E	0,28
F	0,26

Fig. 5. Interpolation tool of the insulation.

SUMMARY SHEET URBAN AGGREGATE OR HISTORIC CENTER		SUMMARY SHEET URBAN AGGREGATE OR HISTORIC CENTER	
IDENTIFICATION DATA		IDENTIFICATION DATA	
Municipality	Arquata del tronto_Spelonga	Municipality	Arquata del tronto_Spelonga
Province	AP	Province	AP
zip code		zip code	
DATI AGGREGATO		DATI AGGREGATO	
Property id 1	SPE_001	Property id 1	SPE_001
Property id 2	SPE_002	Property id 2	SPE_002
Property id 3	SPE_003	Property id 3	SPE_003
Property id 4	SPE_004	Property id 4	SPE_004
Property id 5	SPE_005	Property id 5	SPE_005
Property id 6	SPE_006	Property id 6	SPE_006
Property id 7	SPE_007	Property id 7	SPE_007
Property id 8	SPE_008	Property id 8	SPE_008
Property id 9	SPE_009	Property id 9	SPE_009
Property id 10	SPE_010	Property id 10	SPE_010
PLAN WITH INDICATION OF THE PROPERTIES ANALYZED		CONTESTO CLIMATICO	
		Degree Days	2549
		Climatic zone	E
		GENERAL DATA HEATED ROOM	
		Volume	mc 13300
		Vertical dispersing surface	mq 5760
		Horizontal dispersing surface	mq 2220
		Dispersing glass surface	mq 110
		TOTAL VALUES	
		Consumption	Detected Estimated Improved
			Kwh Kwh Kwh rid. %
		Heating	0,00 0,00 0,00 40,00%
		ACS	0,00 82755,56 32190,00 38,90%
		Electricity	0,00 127138,15 688,00 0,54%
		ESTIMATION OF EFFICIENCY COSTS	
		Surfaces subject to intervention	Cost €
		Vertical dispersing surface	mq 5760,00 € 155.520
		Horizontal dispersing surface	mq 2220,00 € 22.200
		Dispersing glass surface	mq 110,00 € 7.000
		Any passive solar systems	
			Cost €
		DHW Solar Panels	mq 2,20 € 19.800
		Photovoltaic solar panels	mq 2,00 € 18.000
		TOTAL	€ 222.520

Fig. 6. Clusters and finally total intervention.

in Revit (Fig. 7). With another integrated tool based on excel calculation, which use the geometric exported data from the model, the heating energy requirements of the existing state and the improvement achieved by the assumed interventions are calculated (Fig. 8).

The description through the use of individual interoperable sheets in a GIS environment actually takes on a unitary interpretation through the creation of a web based application which, through the drop-down menus of the individual

methodological steps, accompanies all the aforementioned user levels to progressively acquire awareness of the state of affairs and intervention hypotheses of the buildings.

5 Conclusions

The line adopted in this thesis research is based on how to organise one of the many possible methods of interventions



Fig. 7. View of cataloguing in Revit of building components.

Project Heat Dispersion - QP			
INPUT data			
ΣUA	Specific heat loss	W/K	669,02
F1	Temperature factor	adim	1,008
N	Number of spare parts now	-	1,00
V	Ambient volume	mc	742,00
F2	Temperature factor	adim	2,829
t _c	Resultant internal temperature	°C	17,58
t _{ao}	Outside air temperature	°C	0,0

Q _p	Project Heat Dispersion - QP	24042 W
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	Annual energy requirement for pre-construction heating	61282 Kwh
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n°	description	Area	Coeff. U	A x U
1	exterior wall	199,1	1,350	268,799
2	cover	82,5	1,900	156,807
3	windows	20,4	4,850	94,860
4	Ground retaining	82,5	1,800	148,554

Evaluation of energy savings for heating following interventions on the envelope			
ΣUA_{lim}	Specific heat loss with U values Limit	W/K	123,24
ΣUA_{HE}	U-averaged specific heat loss	W/K	396,132
ΣUA_{HLS}	Specific heat loss with improved U-values	W/K	244,659
No	Optimized number of air changes	-	0,50 <i>pari a 1/2 N</i>
V	Ambient volume	mc	742,00
t _{ai}	Indoor air temperature	°C	20,0
t _{ao}	Outside air temperature	°C	0,0

Annual energy requirement for post-construction heating	Limit	48758 Kwh	
	Improved	42568 Kwh	
Energy saving for heating	Limit	12524 Kwh	-80%
	Improved	18714 Kwh	-69%

"OPTIMIZED" BUILDING FEATURES

Project climate zone

E

Coeff U limit according to energy certification guidelines

OP VERT	0,26	COVER	0,22	GROUND	0,26	WINDOW	1,4
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Superfici disperdenti

n°	description	Area	Coeff. U limit	Coeff U medio	Coeff U migliorata	A x U limit	A x U	A x U
1	exterior wall	199,1	0,260	0,805	0,250	51,769	160,284	49,778
2	cover	82,5	0,260	1,080	0,240	21,458	89,132	19,807
3	windows	20,4	1,400	3,025	1,300	28,560	61,710	26,520
4	Ground retaining	82,5	0,260	1,030	1,800	21,458	85,006	148,554
5								
6								
7								
8								
9								
10								
11								
12								
13								
14								
15								
TOTALI		384,6				123,244	396,132	244,659

Fig. 8. Heating energy requirements and possible interventions.

to improve the efficiency for historic buildings: emerges that, while it's possible to align with the objectives proposed by the regulations, an excessively rigid interpretation of the evaluation models and performance indices in force would risk directing any hypothesis towards a sort of therapeutic obstinacy on the existing building, pursuing at all costs the increase in performance and alignment with a satisfactory energy class.

Today's the theoretical approach on energetic efficiency in historic buildings reveals more clarity than in the past, not exempting buildings from the possibility of improvements and embracing the vision of integrated conservation through the practice of energy improvement.

The drafting of a methodology and a platform that follows the same path makes it possible to verify the potential of a historic building in a broader manner and, with a view to intervention, to choose the most effective one that gives the best response in terms of energy and therefore economic.

The methodological proposal outlined undoubtedly represents an evaluation and prediction suitable for the urban scale, considering the informative limitations inherent to historic buildings: in fact, despite the many software packages in use, there is still a difficulty related to energy modelling and related performance knowledge.

The need emerges for an opening of research lines that more strongly support professional training, and also academic training, with a systemic scientific framework that involves the various disciplines operating in the field: at the centre is the reality of the project that sees the designers involved with a deployment of their professional knowledge and that in the field of operations on the existing must rely on personal sensitivity.

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Conflicts of interest

The authors declare no conflicts of interest.

Data availability statement

The data that support the findings of this study are available from the corresponding author, [A.P.], upon reasonable request.

Author contribution statement

A.P. conceived of the presented idea and developed the theory and performed the computations, G.L. supervised the findings of this work.

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