Smart Cities and Historical Heritage

Giovanna Franco,
Department of Architecture and Design, University of Genoa, Italy
francog@arch.unige.it

Abstract. The theme of smart grids will connote in the immediate future the production and distribution of electricity, integrating effectively and in a sustainable way energy deriving from large power stations with that distributed and supplied by renewable sources. In programmes of urban redevelopment, however, the historical city has not yet been subject to significant experimentation, also due to the specific safeguard on this kind of Heritage. This reflection opens up interesting new perspectives of research and operations, which could significantly contribute to the pursuit of the aims of the Smart City. This is the main goal of the research here presented and focused on the binomial renovation of an historical complex/enhancement and upgrading of its energy efficiency.

Keywords: Renewable Energy, Heritage, Micro-generation, Sustainability, Management

Introduction and State of the Art

Cultural Heritage and the debate regarding is protection are increasingly compared to the concepts of growth and sustainable development, starting from the observation that Heritage, as an expression of civilisation, is the first and clearest cultural reference point for a specific place. The approach to sustainability in the historical Heritage, bearer of cultural values, can be declined with different attitudes (Barthler-Bouchier, 2013; Dvornik-Perhavec, 2014); not by chance, the complexity of the problem is taken into account by environmental certification protocols specifically assessed for the historical Heritage, such as LEED Italy and GBC Historic Building, as its direct consequence. These are important experiences, witness to the essential need for a complex, careful and olistic approach to the ecological footprint of all the interventions, even on historical Heritage (Magrini and Franco, 2016). Within this huge framework, energy efficiency of built Heritage constitutes only one, perhaps the most problematic, of the aspects of the problem, on which today it seems indispensable to compare (Pracchi et al., 2010; Pankhurst et al., 2013; Hartman, 2013, Lucchi and Pracchi, 2013).

A significant portion of historical Heritage, in fact, is still air-conditioned and heated with inefficient plants and recurring to fossil fuels, with high energy costs and significant emissions of pollutants into the atmosphere. Even the European research funding program Horizon 2020 individuated, as priority actions, strategies for energy improvement and thermal enhancement of historical buildings and cultural districts, indicating as specific objectives of research: product and process innovation; the development and validation of suitable environmental performance assessment methods; financial strategies, to make large-scale interventions implementable, especially on public property assets.

Energy Efficiency of historical Heritage in its widest meanings is therefore a topic of international scientific debate as demonstrated in some recent conferences (Kilian et al., 2010; Broström et al., 2011; AiCARR, 2014; Lopez et al., 2014; De Bouw et al., 2016), and of methodological and applied research, to fulfil community goals and the EeB PPP roadmap, Energy efficiency of Buildings - Public Private Partnership (Troy, 2014).

It is unfortunately true that the risk in conceiving new relationship between Sustainability and Heritage in many current realities is all too often reduced just to the mere application of products and technologies to save primary energy, which does not always trigger an effective, conscious and virtuous cultural advance towards the real sustainability of our future life (Staudenmaier, 1988).

On the contrary, the aspiration to a quality that is not only technical opens up new research themes. On the one hand, it can lead to the production of new systems and components, more compatible with existing values, developing a creative approach to architectural design. On the other hand, it opens to the identification and definition of new criteria and guidelines for active protection of architectural and landscape heritage (Changeworks, 2008, Cornwall Council Historic Environment Service, Edinburgh World Heritage, English Heritage, 2008, 2010, Historic Scotland, 2013, MiBACT, 2015).

However, some issues and problems still remain open; they regard the possible inclusion of historical Heritage within urban Smart City programs, to which the research here presented has tried to give a contribution.

Main Object and Aims of the Research

New strategies for public lighting, district heating systems, systems of distributed co-generation, systems of smart energy management, systems of production with the integration of renewable sources are all themes which, for a while now, have represented specific applications of "Smart Cities" programs but, until now, have not had any concrete experimentation on the historical and Cultural Heritage.

From here, we find the first question on which this research is based: is it possible to find space within smart grids for ancient buildings, until now excluded by any planning attempt that goes beyond experimentation on individual products? Consider, then, historical buildings not only as consumers but also as real producers of energy, implementing technology that is already available on the market and transferring them to the sector of renovation and restoration.

This articles proposes a brief overview of the two-yearly research on an historical monumental complex, the *Albergo dei Poveri* in Genoa which, given its dimensions and particular collocation in the urban context, may be assimilated into a real urban district (Figs. 1, 2, 3). Built between the mid-seventeenth to the mid-nineteenth century, it is owned by a private institution and al-

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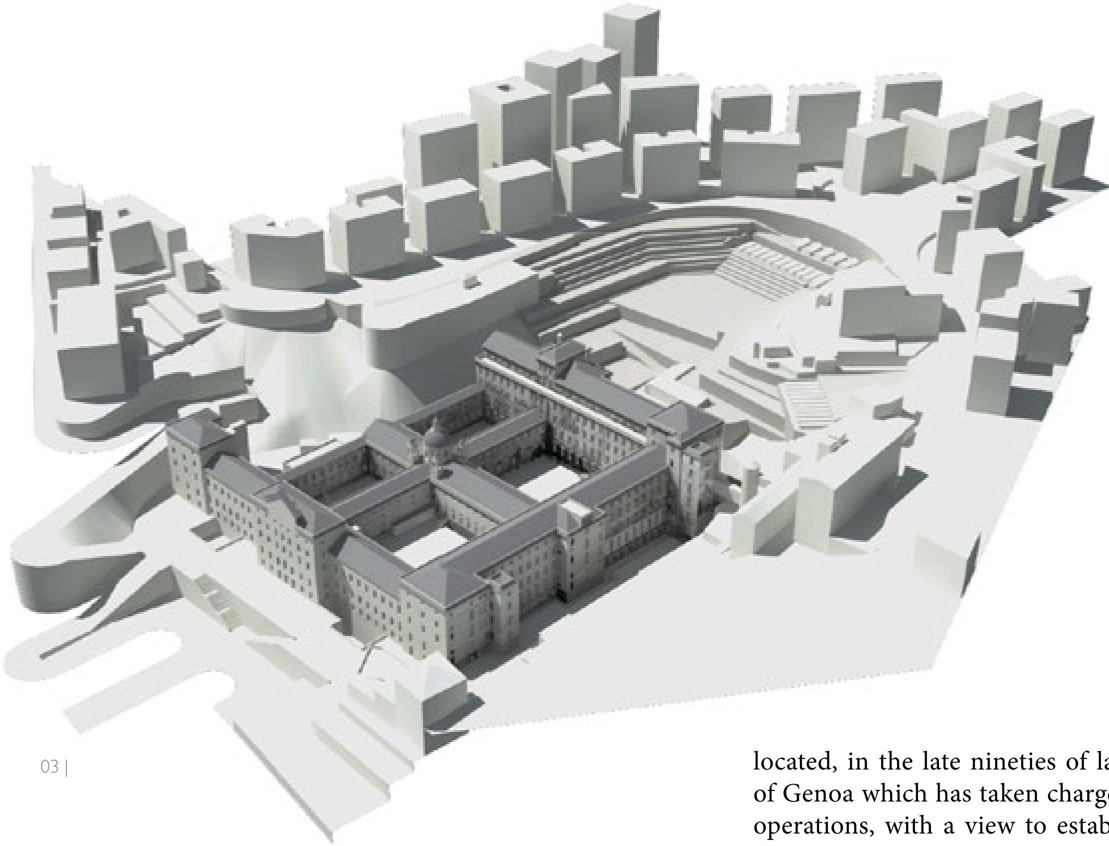

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01 | Aerial view of the centre of Genoa. Highlighted the monumental historical complex of the *Albergo dei Poveri*, the Valley *Carbonara* and other university buildings seen as a District

02 | View of the *Albergo dei Poveri* from the north side

03 | Model of the complex of the *Albergo dei Poveri* and of the *Valletta Carbonara* (Macchioni, E. 2013)

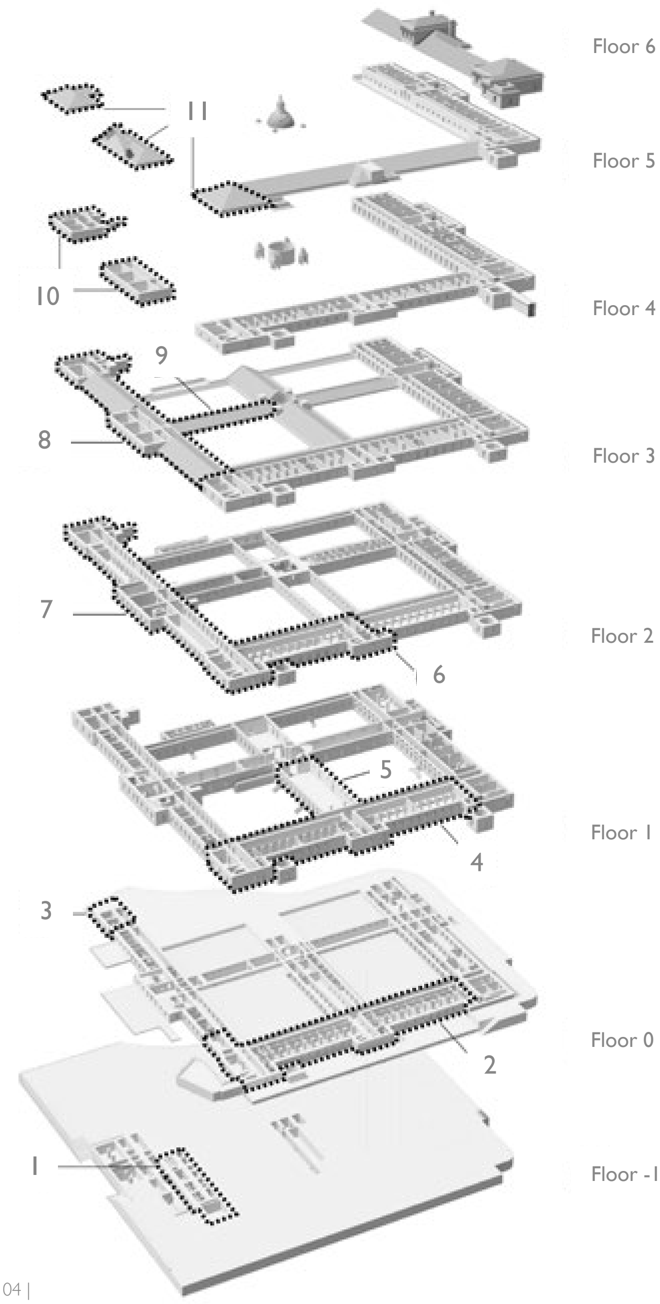
located, in the late nineties of last century, to the University of Genoa which has taken charge of the renovation and reuse operations, with a view to establishing the teaching and departmental headquarters of the faculties of humanities. Currently, only a small part of the available spaces has been recovered (Table 1, Fig. 4); the remaining part, especially in the northern wing, is exposed to the degradation actions, waiting for its restoration and reuse. For this reason, in 2011 the University entrusted the Post-Graduate School in Architectural Heritage and Landscape (under the scientific responsibility of the author and prof. S.F. Musso) with a campaign of studies and research preliminary to the complete restoration and reuse of the complex. From here, the idea of including it in the programs of Genoa Smart City, proposing the project to the Liguria Region (which financed it), to the Rector of the

	Surface (gross) m²
Renovated area	18,750
Area to be renovated and reused	48,000
Total area of the complex	66,750
Area of Valley *Carbonara*	25,000

Tab. 1 | Total surfaces of the complex of the *Albergo dei Poveri* and the Valley *Carbonara*

Electricity E_{EL}	Thermal energy E_{THERM}	Primary energy E_{PRIM}
kWh_{el}	kWh_{therm}	Tep
956,000	2,496,000	428

Tab. 2 | Quantification of the overall demand of the portion of the complex to be renovated



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04 | Identification of the spaces already in use as University. 1. Technical plants. 2, 4, 7. Classrooms. 3, 8, 10. Department of Political Sciences. 5. Aula Magna. 6. Library E. Vidal. 9. University Language Laboratory. 11. Services (Macchioni, E. 2016. Graduate in Architectural Heritage and Landscape, University of Genoa)

University, to the Mayor of the city, to the Superintendent of the Ministry of Cultural Goods (MiBACT). The proposal contemplated the ambitious challenge of overcoming prejudices, conflicts and cultural taboos between the field of Architectural preservation and the one, more technical, of Energy Efficiency in buildings. Main aim of this challenge was the attempt to attribute to the monumental complex the role of a new "pole", as an energy producer at the service of the nearby "University District" (*Palazzo Belimbau* and *Palazzo Serra* in *Piazza della Nunziata* and other university buildings in *via Balbi*, among which are the headquarters).
In order to arrive at a pilot program capable of representing a best practice experience transferable to other contexts, it was necessary to synergistically study a number of aspects involving also different stakeholders who shared common objectives of preservation, enhancement and improvement of Cultural Heritage. The feasibility study focused on the possible improvement of thermal performance and micro-generation; it would not have been possible without the work carried out by the group headed by the Post-Graduate School (working on historical and archive inquiry, survey laser scanning campaign, diagnosis of materials, construction techniques and structural behaviour, technological deficits, monitoring of environmental conditions and of old technical plants and nets). At the same time, with another ministerial financing (PRIN Programme), the same monumental complex was used as experimentation field to apply the BIM model, identifying and solving problematic issues related to the application, to the built heritage, of an instrument created to optimize the new construction procedures (Fig. 5). Only in this way, merging all the research synergies, it was possible to answer the numerous and complex questions raised by the whole project.

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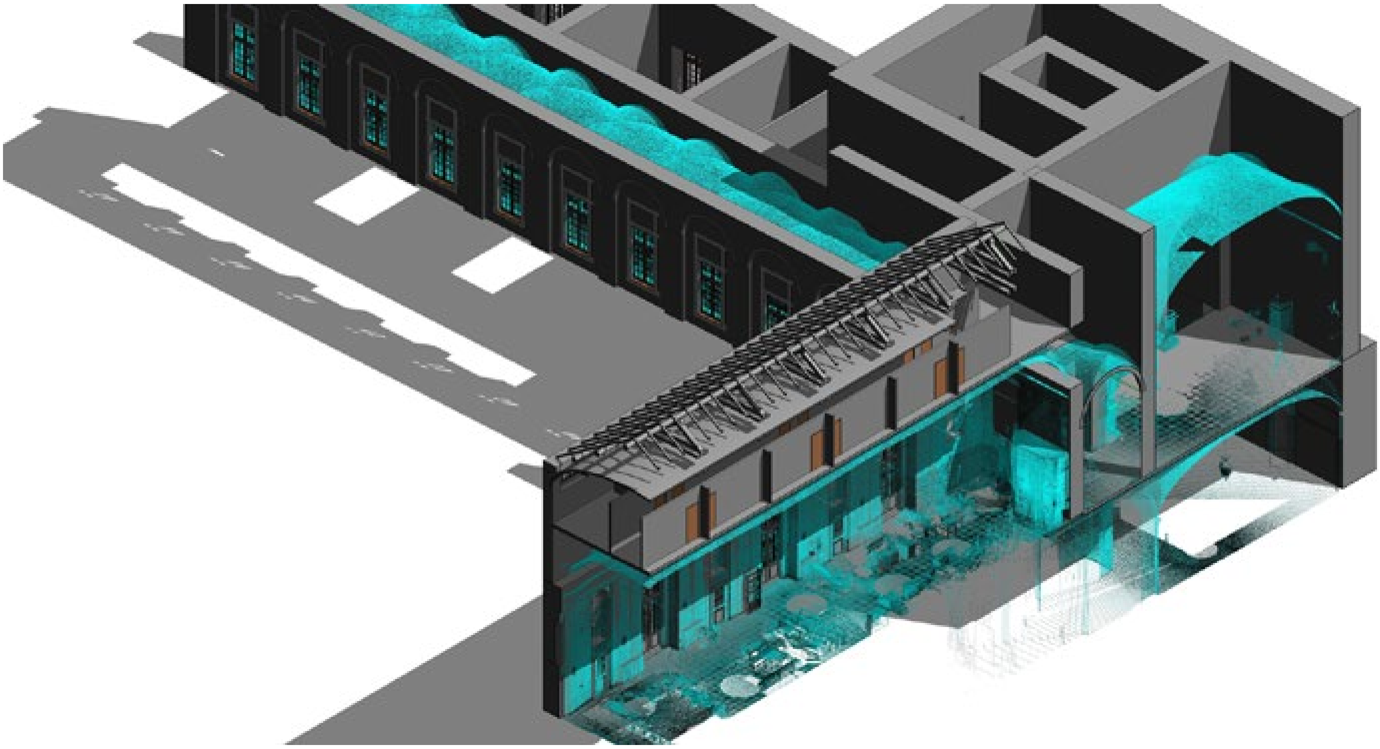

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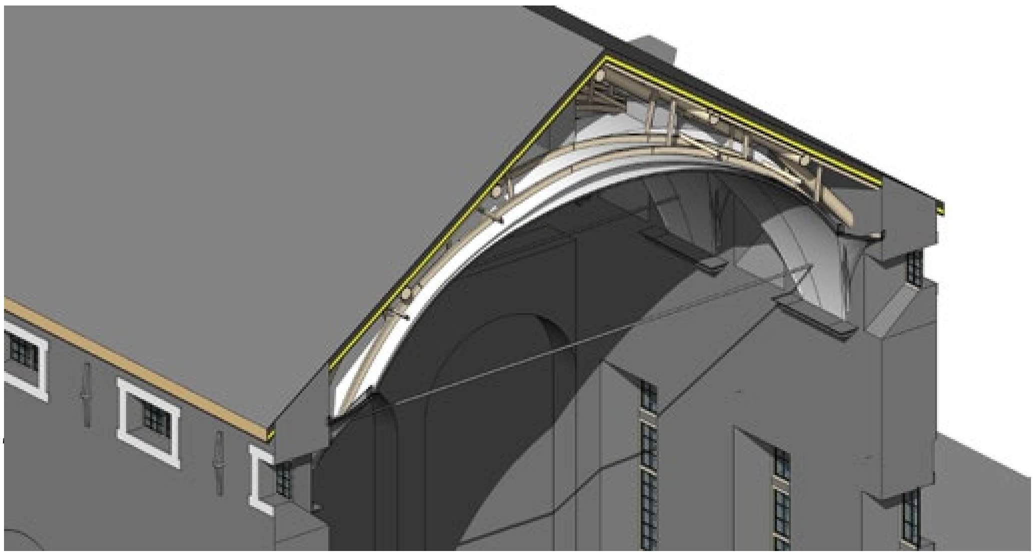

05 | Laser scanner survey and 3D modelling (BIM Autodesk Revit) of the south wing. (Babbetto, R., 2014. PhD course in Architectural Preservation, Politecnico di Milano)

06 | Thermal improvement of the roof (BIM model, Babbetto, R. 2015)

Methodology: principles, phases and tools

In order to tackle such a complex issue, a multidisciplinary research group was set up, with expertise on architectural design and restoration, building physics, thermodynamics and plant engineering, which was joined by an industrial partner. One of the objectives of the work was also to implement a technology on the market (specifically, the gas micro-turbines for the co-generation produced by *Ansaldo Energia*). Already at the very preliminary stage some strategic choices have been made, that is to adopt technologies compatible with the preservation of existing architectural features also demonstrating the possibility of resorting to sources powered by renewable energy.

The methodological approach has been "systemic", which tends to reach the optimization of the systems rather than the maximization of one with respect to the others. This has meant giving up the satisfaction of the requisites imposed by national legislation, above all in terms of thermal performance, in favour of a simply enhancement, compensated from micro-generation.
After an energy audit (thermal behaviour of external walls, windows and roofs and quantification of energy needs), the most appropriate passive technologies were identified. The envisaged actions would have referred, in particular, to the smart use of energy for the liveability and management of that heritage, to energy saving for its heating, cooling, and for the necessary energy supply of the other plant equipment and to a possible autono-

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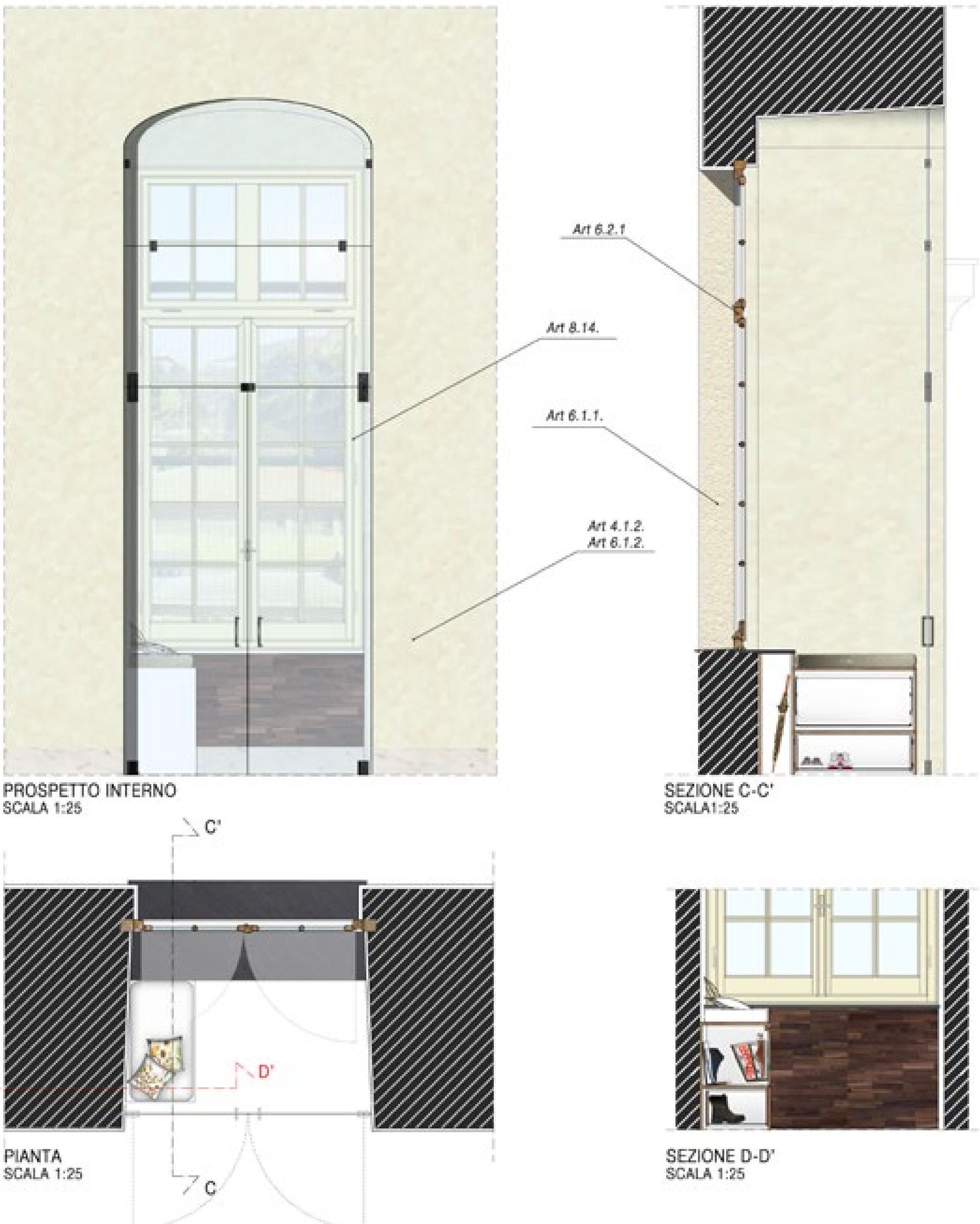

07 | Proposal for a new window system in the northern wing, doubling the existing one (Bresolin, G., Stagnaro, I., Tomasetti, G. 2012)

mous energy production inside them or around (widespread micro-generation), always in compliance with the existing protection obligations.

The successive phases previewed an assessment of the effectiveness after the application of these technologies in terms of energy savings and, as a last stage, a global energy balance.

A specific research activity then concerned the definition of compatibility criteria between new technologies (with a specific study on photovoltaics) and the conservation of the material and testimonial values of the historical complex (Changeworks, 2009; Dessì, 2013; English Heritage, 2009; Franco, 2015; Giallocosta and Piccardo, 2014; Historic Scotland, 2014; Moschella, 2013; Munari Probst, 2012, Polo Lopez, 2014; Scudo, 2013).

In more detail, the feasibility study has been organized in the following phases:

1. Calculation of the energy requirement for the building envelope on the portion of the complex still to be recovered (around 135.000 m^3) and in current situation, using a steady state method software in compliance with national and regional laws and regulations.
2. Validation of the calculation assumptions through a comparison with the current consumption of the already recovered part of the complex, which exhibits the same morphological and constructive characteristics as the parts still to be recovered.
3. Calculation of new energy requirements, based on the new uses set out, account being taken of low consumption technologies, such as led lighting (Table 2).
4. Identification of the most suitable energy improvement interventions on the so called “building envelope” (mostly insulations) compatible with the morphological and architectural

Floor	S	V	PTHERM	A	B	C	D
	m²	m³	W	%	%	%	%
Ground	2,848.29	15,653.46	132,608	0	0	-4.49	-29.32
First	5,386.,75	45,953.53	459,081	-1.58	-5.74	-2.43	-23.60
Second	4,061.86	23,305.34	289,454	-3.37	-15.39	-2.95	-22.02
Third	4,312.80	22,140.82	191,532	0	0	-3.59	-29.30
Fourth	3,683.66	19,123.43	240,915	-5.10	-18.92	-2.75	-20.10
Fifth	1,558.95	6,778.12	131,734	-9.04	-37.68	-2.18	-14.19
Sixth	407.76	2,108.32	49,922	-8.56	-33.09	-2.04	-13.84

Tab. 3 | Percentage variations of thermal power in the different insulation scenarios. S Net surface, V Net volume, PTHERM Thermal Power, A (Insulation of the roof), B (Insulation of the attic floor), C (Insulation of the outer perimeter wall in the sub-window portion), D (Insertion of a new internal window/door)

features of the complex; assessment of the resultant benefits in terms of energy saving.

5. Feasibility investigation on inserting cogeneration plants (micro gas turbines for the production of thermal and electrical energy), considering the needs and requirement of new previewed uses (point 3); insertion of PV glass to glass cells on the old greenhouses in the Valley *Carbonara*.
6. Calculation of the whole energy balance deriving from the application of the considered technologies.

Main results

The feasibility study demonstrated the correctness of the adopted strategy and has come to rather precise technical indications, in terms of necessary insulations and sizing of the micro-turbines and PV cells.

As concerning the enhancement of thermal behaviour of the old complex, the greatest benefits in terms of energy saving may be achieved by improving the performances of the roof (intervention A) (Fig. 6) and the under-roof environments (the attic floor, intervention B). With regard to perimeter walls, account has only been taken of the insulation of the portion under the window, less thick than the rest of the wall and more exposed to infiltration-originated humidity (intervention C), in order to save old lime plaster, both internal and external, to be restored. A significant gain can also be achieved by improving the performance of external doors and windows; for conservative reasons, it was preferable to think about their restoration plus the insertion, in the thickness of the wall, of a new certified window (intervention D) (Fig. 7). All these techniques have been evaluated in terms of energy gains (Table 3).

Concerning the cogeneration system, the optimal use presupposes a continuous full-load operating regime within the 24-hour cycle (maximum performance) and an "onsite" consumption of the entire electricity and heat produced.

During the winter period, part of the thermal energy consumption might be covered by a first unit operating for 4,344 hours (24 hours/day for 6 months) and by a second unit operating for 2,172 h only (12 hours/day for 6 months from 8h00 to 20h00) (Table 4). Added to this is the energy produced by PV, to be used both by the *Albergo* its self and the neighboring university buildings (Fig. 8).

Conclusions

Based on the methodology adopted in this work, recently published (Franco and Magrini, 2017), new researches have been set up on the Energy Efficiency of the monumental historical Heritage in the region and in other Italian contexts, sensitizing owners and managers of prestigious property estates. Various are the players this awareness-making process is addressed to:

- Owners, be they public (or religious) or private organizations, often oblivious to the most recent scientific issues but interested in "sustainable" management (also financially) of the heritage they are responsible for, as well as the possibility to access financing in the form of incentives and fiscal relief.
- Technicians and professionals. These two categories may, for example, be compelled to undertake permanent professional training programmes offered by dedicated recognized organizations.
- Superintendence officials representing the authorities appointed to evaluate and approve proposed projects on the basis of tried and tested preservation practices.

ETERM-CHP N°1+2	EEL-CHP N°1+2	Nh-CHP N°1+2
kWhth/year	kWhel/year	kWhel/year
1,456,908	872,400	8,724

Tab. 4 | Overall data on energy production through the use of two cogenerators

08 | Restoration of the greenhouses system with glass PV cells (photo-simulation) (Macchioni, E. 2016)

Considering Cultural Heritage not only as a petrified memory of the past, but also as an active resource for the future, reusing and valorising it, means changing how we think of preservation; no more merely the purely aesthetic perception of production and landscapes as they are, but considering it now as a process of revitalisation for the benefit of all, with all the challenges this entails.

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The research, financed by Liguria Region, was offered to the University of Genoa (in the person of its Rector and Building Manager), who is in charge of the management of the historical complex of the Albergo dei Poveri as well as owner of other monumental buildings, some of them actually under renovation and restoration (Palazzo Belimbau in Piazza della Nunziata). Those responsible for the maintenance, management and future development of the Athenaeum building stock, on the basis of the feasibility study presented here, have started a fruitful dialogue with the Protection Authorities to include also historical heritage in Energy Efficiency and energy saving programs. This feasibility study has also been presented to the university commission in charge of electric energy saving, in order to merge all these research and studies proposals into a coherent and common framework.

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