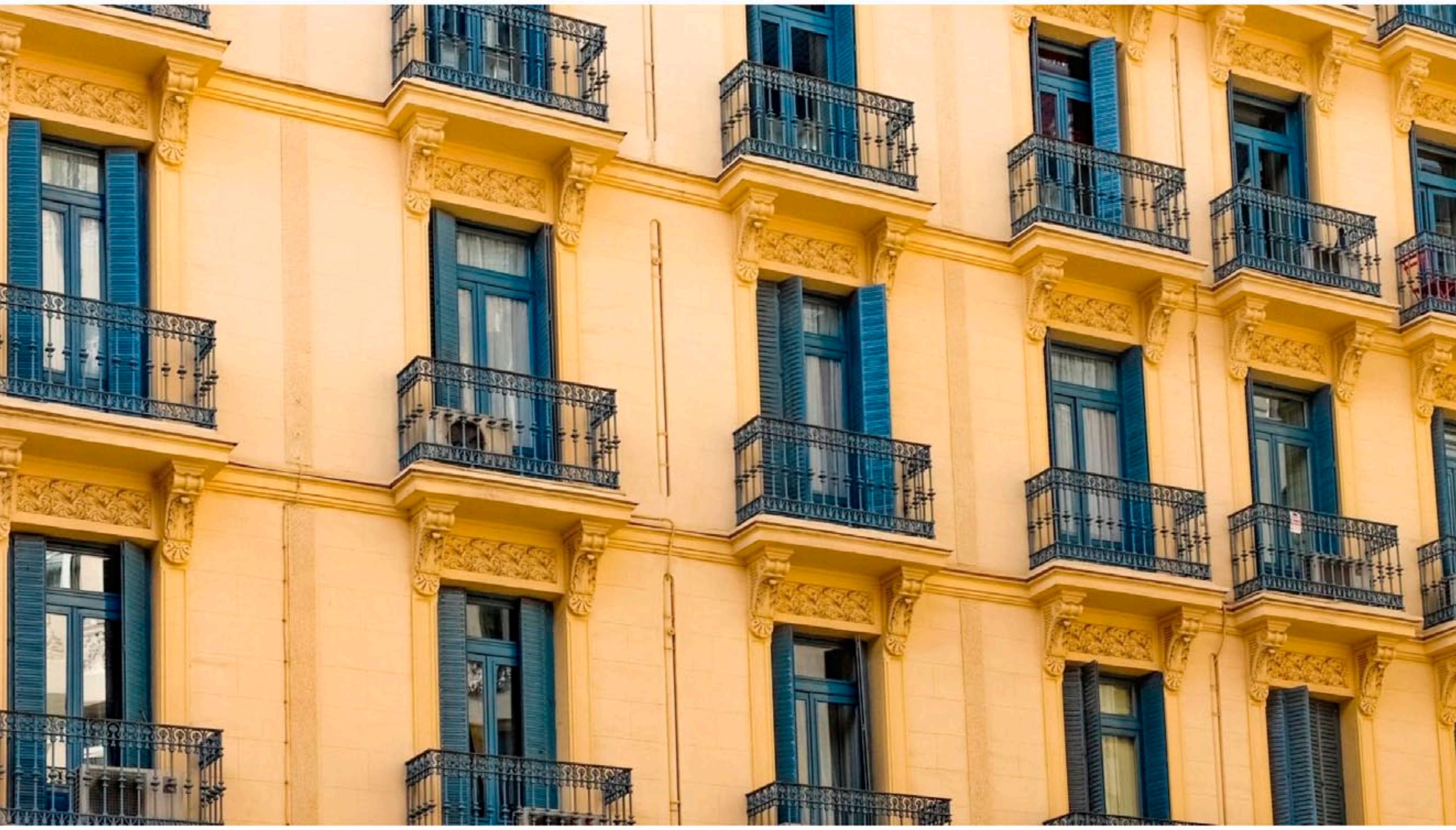

Conference Report

The 3rd International Conference on Energy Efficiency in Historic Buildings

Edited by

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Swedish Energy Agency
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Conference Report

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Nearly Zero Energy Heritage

Taboo or challenge?

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Abstract – Architectural heritage has been considered as one of highest peaks of Italian culture and its universities as a point of excellence in conservation and restoration. However, they have not been able to fully address contemporary challenges, responding to demands of energy saving and raising of comfort levels. The achievement of NZEB standards in historic buildings, especially those protected by the Ministry of Cultural Heritage, is still considered taboo – if not a dangerous technical drift.

An ongoing project on an 18th Century small listed building is animated by a different spirit; here the traditional conservative approach has been integrated with specialists in energy efficiency. The proposed contribution aims to present an example striving to become indicative of best practice, while highlighting in particular the conflicts concerning material conservation, enhancement of cultural significance and needs for new use, as well as the possibility to overcome some cultural barriers through creativity and innovation.

Keywords – NZEB; cultural heritage; values; energy efficiency; conservation

1. INTRODUCTION

The concerted drive on the part of the Italian government to encourage recourse to energy efficiency measures in building restoration, also with a view to achieving “Nearly Zero Energy Buildings” standards, bestows upon scientific research and technology a fundamental role, especially with regard to cultural and historical heritage. The most advanced dedicated study and experimental field finds itself faced with the double commitment of predisposing and adapting procedures, analysis methods and restoration more suited to the construction and architectural features of historical buildings and to make the actual achieving of virtuous examples possible.

The juxtaposing of the terms “energy efficiency” and “preservation”, to date somewhat distant from each other in the Italian context, must not, nonetheless, be considered as a mere exercise in technical application. Nor are they mere exclusive technological transfer; rather, they stand for the triggering in a slow process of cultural advancing, which requires considerable synergic commitment.

Supported by various financing channels, the culture of Italian architecture heavily involved in restoration and preservation of the country’s historical monument heritage has been set objectives over the past few years which, traditionally, did not belong to its specific sphere of interest [1]. With a co-ordinating role of multidisciplinary working groups, both organizations appointed to safeguard, and experts in the field of architectural restoration, have intensified study initiatives. The aim has been to draw up guidelines [2] and inform and communicate on their own research activities [3] so as to make other players aware – these latter still somewhat sceptical with regard to such issues.

Over and above scientific studies respecting the *diktat* of their sectorial character, the demand felt today is the opportunity to refer to *best practice* [4]; such may make attitudes and technical methods employed in the field explicit, if the purpose is to improve the thermal behaviour of the historic building and to implement renewable energy sources (which until only a matter of years ago were considered veritable taboos in a restoration project). Various are the players this awareness-making process may be 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.

The opportunity to introduce energy efficiency measures in historic heritage (already completed or in the process of completion) can be an essential basis for convincing owners to invest more in similar intervention. At the same time, the diffusion of case studies could raise awareness among Italian protection organizations so they can authorize technical operations such as insulation and solar panel insertion, without compromising protection and safeguarding of historical material characteristics in buildings dating back to the past. The case study here presented can serve to make owners and technicians aware on several counts: the building is private and listed, with all intervention requiring the approval of the Municipality and the Regional Superintendence of Archaeologies, Fine Arts and Landscape. This case is particularly significant from the point of view of design and decision making process, since energy improvement – not mandatory by regulation – is part and parcel of the restoration and reuse project.

2. A PRACTICALLY ZERO ENERGY RESTORATION PROJECT

The very effort to show a practical case study and not only a theoretical example, is one of the basic aims of a restoration and reuse project for a small historical

1 Up to 65 percent of the total cost of insulation and improvement of glazing systems (for a total amount less than 100.000,00 Euros) from the Ministry of Economic Development.

building boasting unique architectural features and recognized as a listed building protected by the Superintendence of Archaeologies, Fine Arts and Landscape.[2] It is a building of which the history remains scarcely known, even though it occupies a most central position in the city. The property of the Genoese Municipality from 1889 to 2004, it was then purchased by a private concern, which was fully aware of how unique the building and acquisition were. The purchaser then determined to programme a lengthy process (ongoing) of restoration and reuse, including energy enhancement, tending towards the excellent.

The first and foremost purpose of the operation is to instil new life into the building by way of a reuse and preservation project focusing on overcoming the state of abandon the building had been wallowing in for several years, restoring dignity and value to an important urban episode, unveiling its hidden history and opening some parts to the public – in forms and ways compatible with its being private property. Despite the new function, residential (a flat) and offices of a professional activity, the idea came about that it should become an experimental laboratory for processes and technologies for energy saving and seismic improvement – possibly satisfying Nearly Zero Energy Building standards for existing buildings in climatic zone D (Table 1). This approach is quite a novelty since for this type of building it is not required to satisfy technical standards.

Table 1. Italian Zero Energy Building definition for existing residential buildings (2019-2021)

Thermal transmittance U (W/m²K)					
Ground floor	*External wall*	*Roof structure*	*Maximum primary energy [kWh/m²y]*	*Share of RES for energy production*	*Electric energy from PV (kW)*
0.29	0.29	0.26	30	50 % (Thermal)	2

In itself the idea embodies more than one challenge:

- the contrast between the features of the historical building, never employed for residential purposes, and the demands of inhabiting in terms of comfort and energy saving;
- the willingness to modify in the least measure possible the material nature of the construction, despite having to insert new installations and equipment;
- the possibility to create a round table comprising different specialists, not always in complete agreement on the same objectives of safeguarding and preservation of existing values both material and immaterial;
- the “sustainability” target of the whole operation from the social, cultural, economic and environmental points of view.

2 The building avails of monument protection status and it must remain open to the public in the basement area and the roof terrace, with a landscape protection order on the adjacent garden and on its archaeologically precarious nature – it stands on an area featuring several historical stratifications.

Hence, the interest motives in this initiative are different. Not least of all, the most repetitive nature of going round and round a long process to be subject *in itinere* to quality checking – similar to the logic of industry.

3. ARCHITECTURAL FEATURES AND HISTORICAL VALUES

The building stands in the centre of the city in an area which over these past two centuries has undergone numerous transformations. Tradition has it that it dates back to 1825, but in reality the sisters of Saint Martha had it built on their land probably at the end of the eighteenth century with a view to using it as a "belvedere". Evidently the attraction was the building's spiral staircase in a cylindrical tower on the corner, leading to a flat terrace from which you can enjoy a totally unique 360° view.[3] The building, which is situated in grounds rising above the present level of the access-yielding street, boasts trapezoidal design and three floors above street level and one floor partially a basement. The dimensions as they appear on the building plan are rather unassuming; originally there was merely one room per floor, looking out through large arch openings, devoid of shutters so as to enjoy the view as from a loggia. The vertical structures are stone load-bearing walls.[4] Horizontal edifice shows brick vaults in pavilion shape with lunettes except for the roof terrace – demolished after World War II and rebuilt in reinforced concrete (Figure 1).

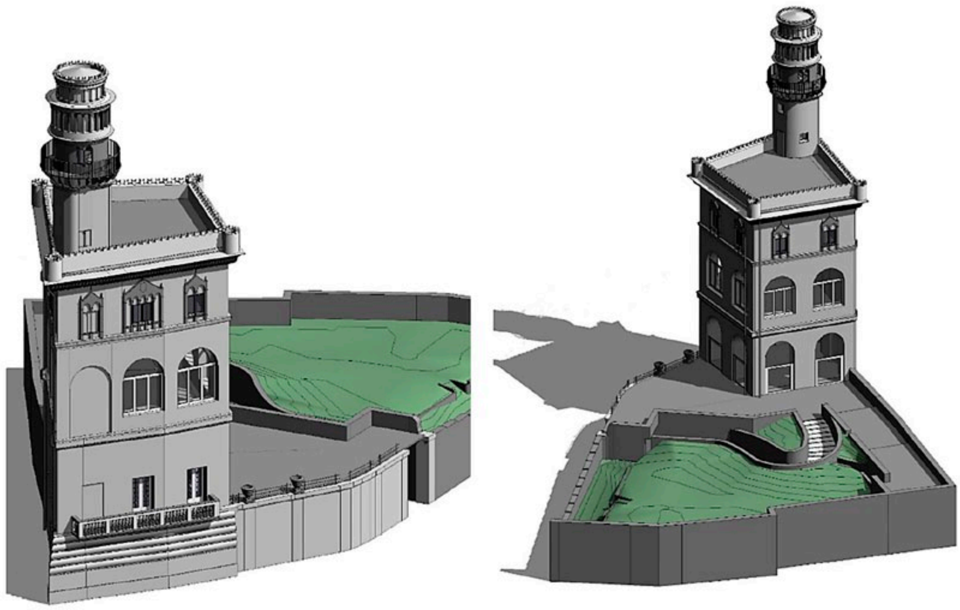

Figure 1. BIM Model of the building (west and east façades).

3 The historical information prior to sale of the building was summarily detailed; lengthy archives research carried out by Santamaria of the State Archives Genoa has led to the revealing of a hitherto unknown history.

4 A sturdy wall of Middle Ages building characteristics allows us to suppose that the building was erected around some already existent constructions belonging to the city's very first fortifications. Such a hypothesis is also substantiated by chemical analysis completed on mortar samples removed pursuant to wall coring.

The study on the history of the building and its transformation, especially after the Second World War, was particularly important. It highlights which parts are original, which were added to change the image in keeping with the taste of the time and which are fairly new (1973–1978). The last certainly bear less historical legacy and material value and are, thus, suitable for intervention comprising major modifications.

The first major transformation took place in 1821, when the mayor of that time purchased the property for his own leisure and called upon the municipality architect Carlo Barabino as well as Michele Canzio, the expert scenographer and decorator, to change the external appearance – but not the structure – after a neo-Gothic style. In 1889 the heirs of Marchese Serra sold all his property, including the enormous garden, to the local municipality. Bombing during World War II heavily damaged the roof – later to be replaced by a hollow-core concrete structure – and the outer plastering. Neglect and total abandon, as well as acts of vandalism and squatting, reduced the property to such a deplorable state that in 1973 the municipality commissioned to have the property restored. In keeping with the culture of the era, restoration was of a distinctly reshaping nature: complete external and internal re-plastering with concrete mortar and heavy steel reinforcement in at least one of the two vaulted areas. In 1978 further internal renovations were effected so as to house a small museum, with extensive use of reinforced concrete structures, somewhat detrimental to any attempt to detect seventeenth/eighteenth century origins.

In short, such was the state of affairs at time of building abalienation. The quasi-total absence of documentary material and the evident incomplete unreliable nature of the existing survey encouraged the owner to invest (time and finances) into a long period of analysis and familiarizing. Indeed, this is necessary both to fill a void in urban historiography and to orient and direct the project of reuse, restoration and energy improvement based on the difficult search for a balance between new needs and preservation of the meanings and material values of what the building had been before.

4. INQUIRY THROUGH MULTIDISCIPLINARY COMPETENCES

Given that the bibliographical information was rather summarily reported and in some points contradictory, a private/public archive-oriented inquiry was launched, as well as a concurrent drive to obtain surveys of the building and annexed garden, using different methods (topographic, tape-measured, digital plane photo-grammetric, PhotoScan). The superimposition of photo-planes of the prospects with iconographic (1823) and photographic (1926) representations has allowed “reading”, albeit virtual, of the rich decorative apparatus, irremediably deteriorated by neglect and damaged during war bombing (1973) (Figure 2). Despite the absence of original plaster, completely replaced after 1973, the hypothesis of insulating the building from the outside was excluded from the beginning – such a type of intervention being in stark contrast with preservation criteria.

In order to substantiate some hypotheses on developmental stages emerging from archives enquiries (reference is to walls predating the eighteenth century,

Figure 2. Different constructive phases, external plaster and openings: 2006, 1973, 1926.

the era in which the building was erected, and to the dating of wall and vault creation) a series of tests both archaeological (foundations) and architectural (sample takings of plaster at delicate points submitted for chemical analysis so as to date them) have been carried out, thus comparing direct and indirect sources. Along with testing and digging, there has also been coring, vertical perforations to verify the nature and substance of the ground around the building. Indeed, an early idea shared by owner and technicians alike comprised the option of recurring to geothermal energy to satisfy thermal and electrical needs.

Table 2. Thermal transmittance of the building envelope – current state

U (W/m²K)				
Ground floor	*External Wall ground floor*	*External wall first floor*	*External wall second floor*	*Roof structure*
1.26	1.45	1.65	1.72	1.12

Table 3. Surface and volume – current energy demand

Total surface S m²	393
Volume V m³	2150
Envelope surface S_{env}	1280
Surface /Volume	0.59
Current Global Energy Performance Ep_{gl}	380.25 kWh/m²y
Current Envelope Energy Performance Ep_{env}	230.45 kWh/m²y

Since the building has not been used for almost ten years, no environment-oriented monitoring has been applied, nor has it been possible to examine real energy consumption to evaluate thermal behaviour. Materials and stratigraphy of elements allowing heat to disperse have been identified (floor covering, external walls, windows, roofing) to evaluate its related thermal transmittance (Table 2). In keeping with Liguria Regional Law n. 22 (29/05/2007), national Law D Lgs n. 102/2014 and European Directive 2010/31/EU (Table 3), the global energy performance and the energy performance for the envelope indices have been estimated in the current state and before any improvement.

5. ENERGY STRATEGIES: GOALS AND TECHNIQUES

Right from project beginning the owner had expressed the intention to respect the NZEB standards with a global energy performance forecast of around 30 kWh/m^2y. He sought to involve all interested professional parties in the preliminary design process and invited them to make also the architects from the Superintendence aware of such goals.

To satisfy the demand for renewable sources, a geothermal heat pump, applicability of which had been previously verified with archaeological essay and vertical coring in the soil, will produce thermal and electrical energy. The latter exceeds the required quota of 50 % (Table 1) and reduces CO_2 emissions to 5 kg/m^2y (compared to an estimate which could be around 150–200 kg/m^2y in the current state). This technology certainly impacts less on the existing buildings – if compared to solar energy powered panels, which are often incompatible with the preservation of architectural features. A small surface of pavement photovoltaic panels, respecting regulation requirements, could be installed on the flat roof terrace – hidden from view. Since the application of this technology on historic buildings is a controversial issue, it will be necessary to set out by verifying the attitude of the interested safeguarding organs. In any case, historical and archival analysis has revealed that the re-construction of the flat roof in reinforced concrete dates back to 1973; none of this particular part of the construction, unfortunately, had been spared WWII bombing. A heat pump will power floor radiant panel heating; this intervention previews the removal of flooring and subfloor – both renewed in 1973 and not original. A mechanically driven ventilation installation to check inside comfort conditions (relevant humidity, overheating) and domotics installation to check inside comfort (plants and dimming of windows) have also been previewed. Another criterion shared by the project group, as well as by the client, is the minimum interference between new channelling and the new vertical and horizontal wall structures, entrusting to the new dividing walls (conceived with “dry-stone wall” technologies) the role of net restraint. Vertical passages will be reduced to a minimum number, examining a technical “loop”, required for the installation of a new lift.[5]

5 The lift will be installed in a type of wall-surrounded cavity and hence will not be visible on the ground floor, where the single vaulted area will remain completely empty – as it was originally.

The horizontal flat structures (floor and ceiling) remain within the limits of transmittance laid down by regulations (previewed U-values equal to 0.20 W/m^{2}K): the interspace between ground floor slab and soil, completed in 1973, will be filled with mineral insulation material while the flat terrace structure, in a poor state of preservation and devoid of historical architectural value, will be demolished and rebuilt with a light insulated steel structure. Windows and external opening will be replaced: the existing ones were added after 1973, hence lacking in any documentary historical value as well as proving to be quite ineffective, while the new ones will have low-emissive double-glazing, respecting the minimum requirements of technical legislation (even lower, between 1.2 and 1.4 W/m^{2}K).

Despite efforts made regarding maximum enhancement and preservation of material authenticity, there emerge some conflicts evidently opposing demands, especially in applying of internal wall and brick vault insulation. The external walls and the brick vaults of the ground and first floors were, in fact, built in the 18th century, as is evident from historical archival examination: the bearing structure in irregular stone is still original, while the cement plaster finishing outside and inside are completely new (reconstruction in 1973). Another constraint of a material nature (the choice being the client's) concerns the type of insulation to be used. To adapt to the material characteristics of the historical construction (stone, brick and lime mortar) it is preferred to use compatible materials of the same mineral origin (insulating panels based on calcium silicate hydrates or lime-based thermo-plaster with cellular glass aggregates to replace internal cement plaster dating back to 1973), even though their thermal performance is less efficient than synthetic insulators (expected external wall U-values between 0.36 and 0.41 W/m^{2}K, counterbalanced by the low U-values of windows and flat floors). To insulate the vaults and solve existing thermal bridges, a double system will be used: passive (inserting mineral insulation in the empty space between the extrados of the vaults and the wall) and active (in the form of heating supplying resistance above the vault cornice).

6. CONCLUSIONS

The experience conducted to date with this small project of reuse and restoration is by no means devoid of the complex problems which must be faced when working on the historical heritage, but it is significant for the fixing of the procedure and involvement of all interested parties. The latter include the architect and archaeologist working in the Superintendence and in charge of the authorization process. From the first design phase and decision making process, what can be underlined as a meaningful approach is a logic of "compensation" and "balancing" concerning different values (restoration and NZEB standards *in primis*), which also means striking a balance between conservation and transformation. Original materials, elements and architectural forms, which have been afforded a historical and "witness" value, will be preserved and appreciated; recent construction elements (1973–1978), mainly in concrete and reinforced concrete, will be replaced with more compatible and, in thermal terms, even more efficient, enhancement materials. The creative attitude typical of the architectural design process will also involve technical equipment (i.e. PV floor) in co-operation with thermal engineering.

Other in-depth considerations will follow this first project phase, especially in the choice of the most appropriate materials and technologies, with not only financial but also environmental evaluation assessment. Indispensable will be both the phases of executive planning and delivery, which should feature a highly qualified workforce. Nevertheless, the real success of this intervention cannot be decreed before complete execution and verification by way of annual monitoring during ensuing management stage.

7. ACKNOWLEDGMENTS

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Energy efficiency improvement in historic urban environments

From decision support systems to co-creation strategies

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Abstract – Urban strategies addressing affordable improvement of citizens' comfort, fight against fuel poverty and better housing, have been proved to be important to keep historic cities inhabited and cultural values alive. Urban scale energy retrofitting requires flexible methodologies that facilitate evidence based decision making for policy makers and practitioners. Working in this direction, EFFESUS developed an incremental decision support system which works with different levels of information and offers energy strategies which are suitable for a wide range of historic urban environments. However, the universality of the approach did not consider the socioeconomic dynamics that can be triggered when a more local and systemic approach is adopted. Understanding the historic city as a unique ecosystem, nonlinear dynamics and evolutionary development can be used as leverage to unlock latent local capacities and activate the territory. Innovative eco-renovation strategies for traditional energy conservation measures from a life cycle perspective, are ways to work with local produced solutions linked with new local business models. ENERPAT is testing this approach. Three living labs have been created in Porto, Vitoria and Cahors as demonstration buildings and long-term thinking frameworks including stakeholders of the whole value chain. The solutions based on local materials that are being monitored have been decided by co-creation strategies using multicriteria methodologies, including criteria as social acceptance, socioeconomic development and circular economy. In this paper, EFFESUS and ENERPAT approaches and implementations are described and compared from different perspectives: multi-scalarity, 3D city models use, multicriteria methodologies, life cycle assessment, required information, stakeholders' involvement and expected impact. The analysis shows the complementarity of the outcomes and frames their use in different phases of the decision-making process to support the development of inclusive and sustainable strategies that can boost local economies.

Keywords – historic cities, co-creation strategies, life cycle assessment, stakeholder involvement, systemic approach

1. INTRODUCTION

Urban strategies addressing affordable improvement of the citizens' comfort, fight against fuel poverty and better housing, have been proved to be important to keep historic cities inhabited and preserved [1]. Urban conservation is also fundamental for the global sustainability as it maximizes the use of existing materials and infrastructure, reduces waste, and preserves the historic character [2]. The process of updating our built heritage faces the complex challenge of balancing the requirements of the need of upgrading to the current standards of liveability and sustainability with the needs and constraints of the preservation of its integrity and cultural values.

The project EFFESUS (**E**nergy **Eff**iciency for **E**U Historic Districts' **Sus**tainability) addressed this challenge through a data driven approach based on a decision support system and multiscale data models, as the growing complexity and heterogeneity of the existing urban information make proper information management crucial for the comprehensive sustainable rehabilitation processes [3]. The EFFESUS approach had clear benefits: incremental decision making, cost effective data management, applicability in a wide range of European cities and evidence based decision making. But one of its limitations was that it did not consider the socioeconomic dynamics that can be triggered when a more local and systemic approach is adopted.

The historical landscape is the complex result of changes in the use and development of the city [4]. Historic cities are the product of evolutionary self-organization processes articulated around their territorial, environmental and climate context in the beginning and around their built environment at a later stage. Traditional cities have been considered as complex systems since the sixties [5] [6], as ecosystems where living entities (for example citizens, associations, business, local government) interact amongst them and with the buildings and infrastructures through information, energy and material flows, human connections and business dynamics. These interactions modify the structure of this ecosystem and the physical structure that supports the system (built environment and infrastructures). Some of these changes, steadily, make the historic urban areas learn and evolve through the adaptation to new circumstances and challenges making them complex adaptive systems (CAS). A CAS is characterized by spatial heterogeneity, non-linearity, multi-scale interactions and co-evolution, and the capacity to self-adjust as response to changes [7][8]. The preservation of our built heritage in this framework cannot be a passive process, but rather a process of evolutionary improvement of historic urban systems [9]. The historic areas should continue the process of adaptation and improvement that has allowed survival through the time, since it's their adaptability that ensures their sustainability [10].

Energy improvement in historic urban areas can be understood as one of these adaptive processes, where different operating agents (such as owners, tenants, architects, local government) try to update the building environment to more modern standards for different reasons: to improve comfort, to fight against fuel poverty, to reduce the energy bill or climate change mitigation. This improvement is usually studied as a disconnected and a linear process, neglecting its functional complexity and unpredictability. The conventional process is frequently initiated by the local government trying to improve the livability of their historic centers, attract new population or prevent depopulation. The historic built environment is then transformed to improve its energy performance and sustainability and the results are monitored and assessed. However, other non-linear effects are not evaluated: the material and energy flows of the city have changed, the real estate dynamic is altered (the value of buildings can be increased, but gentrification processes can be triggered too), investment can be attracted to the historic area, local economies can be boosted (if local solution are used), surrounding territory can be activated (if local materials are chosen), cultural identity can be preserved, and high value jobs can be created. These non-predicted effects are combined properties that are more than the sum of the characteristics of individual system elements. This is one of the characteristics of complex systems known as "emergence". But how we can design a decision-making process to benefit of this emergence, when the outcomes cannot be totally controlled and the results of the interventions are unpredictable? Or as Marshall states "*The paradoxical challenge of planning then becomes one of how to 'plan' a kind of complexity that seems to have arisen 'naturally' in traditional cities, without planning*" [11]. One of the possible responses to this challenge is the participative, collaborative and iterative approach to engage urban agents in a process more similar to evolution than to design [12]. The optimization of complex environments needs bottom-up feedback and local knowledge is only available to the agents on the ground [13]. This is especially relevant in the improvement of the sustainability of the historic areas and buildings as local materials, climate, techniques and values are essential inputs. The ENERPAT project (Co-creation of Energetically efficient territorial solutions of Patrimonial Residential habitat Ecorenovation in SUDOE historical centres) is testing an approach where eco-renovation strategies that develop traditional energy conservation measures from a life cycle perspective, are a way to work with local produced solutions linked with new local business models. Three living labs have been created in Vitoria (Spain), Cahors (France) and Porto (Portugal) as demonstration buildings and long-term thinking frameworks, including stakeholders of the whole value chain.

In the next sections, EFFESUS and ENERPAT approaches and implementations are described and compared from different perspectives: multi-scalarity and 3D city models use, considered indicators, life cycle assessment, required information, stakeholders' involvement and expected impact. The analysis shows the complementarity of the outcomes and frames their use in different phases of the decision-making process to support the development of inclusive and sustainable strategies that can boost local economies.

2. FROM A DATA DRIVEN APPROACH TO SYSTEMIC ECO-RENOVATION

Historic urban environments are not going to be strange to the key environmental and socio-economic drivers of change over the next 30 years: climate change, rising energy prices, social inclusion, information technology, global competitiveness, resource scarcity, changing patterns of consumption and demographics, insufficient or inappropriate built environments, and outdated or ill-adapted systems of planning, management and operational practice, among others [14]. They are going to have to face these challenges through rehabilitation strategies that must be respectful to their cultural values, but also coherent and compatible with their technological, architectural and constructive characteristics.

EFFESUS was a four-year research project funded by the European Commission under its Seventh Framework Programme investigating the energy efficiency of European historic urban districts and developing technologies and systems for its improvement. The project, with 23 partners and 7 case studies, developed a Decision Support System (DSS) as an ecosystem of tools and methodologies to support evidence based diagnosis and decision making. Part of this ecosystem was a data model, two software tools and a methodology that supports the selection and prioritization of energy efficiency strategies. The multiscale data model is the EFFESUS model: a 3D georeferenced model based on the standard CityGML, which uses the extensibility of the standard to develop the previously identified four specific domain extensions (energy, cultural heritage, indicators and dynamic extensions) in order to provide all information requirements regarding the historic city (a detailed description of the model can be found in [1]). In order to facilitate the implementation of a modelling strategy, a categorization tool was created. This web application uses information from the multiscale data model to perform a categorization of the building stock and support the selection of sample buildings (a detailed description of the categorisation methodology and web application can be found in [15]). Santiago de Compostela (Spain) and Visby (Sweden) were selected for the full implementation and validation of the DSS.

ENERPAT, partially funded by the INTERREG SUDOE program, is a 3-year ongoing project that addresses the challenge of finding energetically efficient solutions for the historic urban areas from the perspective of systemic eco-renovation and local techniques, considering Life Cycle Assessment (LCA), circular economy and co-creation perspectives. In the core of the approach is the idea that the improvement of energy efficiency and comfort can function as a central piece of the ecosystem of complex interactions between social, technical, ecological and economic forces. The eco-renovation approach from ENERPAT relies on a systemic innovation as the European Commission describes it: "*innovation that aims at responding to a societal challenge by obtaining a system-wide transformation through affecting the system's economic, social and environmental dimensions as well as their interconnections*" [16]. Through innovating in local solutions and using local materials, ENERPAT aims to activate the surrounding territory, mobilize resources (materials) and local competences and capacities.

The evolution from the EFFESUS to the ENERPAT approach, is the expansion from a concept that considers material, energy and information flows to one that includes the former, but also takes into account more political, physical and social processes. The change sought in EFFESUS is a crucial one but limited sectorally (to improve the energy efficiency and living conditions to keep the historic city conserved and alive). ENERPAT aims for a more ambitious transition where the building retrofitting system of the historic city is transformed to a more sustainable, resilient and economically dynamic one (through the co-creation of innovative eco-rehabilitation solutions that are sustainable from the whole life cycle perspective and are based in local material and techniques to boost new local business models).

3. DECISION MAKING PROCESS: DSS VS. LIVING LABS

The end user of the EFFESUS DSS is an expert, working for the local government, who uses the tool to select the best energy retrofitting strategies for a specific historic city. In order to optimise the available data, different levels of decision making (LoDM) are possible within the tool. These LoDMs range from low levels (LoDM 0 and I) where only general information regarding the city is necessary and just generic strategies are provided, to medium-high levels (LoDM II and III) where the development of an external data model is necessary to structure the information and provide tailored strategies. The two highest levels can be considered as part of an incremental strategy of use of information: LoDM II addresses the agile generation of a basic functional model and LoDM III operates with a fully complete model.

ENERPAT uses co-creation strategies to decide the solutions that would be tested in the living-labs. The process of co-creation was originally conceived as a business strategy for identifying new forms of customer engagement and has since been applied to urban management to interact with citizens and stake-holders as a way of “creating new solutions, with people, not for them”. In urban contexts, the concept has evolved to address the socio-technological transition and the experimentation to develop new solutions to answer the complex challenges that cities face (e.g. sustainability, climate change or resilience). The type of living lab developed in ENERPAT has features of the “*Urban living labs”,* focused on specific urban contexts and problems. Central to this concept is the “*transition arena*” that offers an informal, well-structured space to a small group of diverse stakeholders or “*change-agents*” [17]. In ENERPAT the transition arena has been decided locally and included the whole value chain: local government, research organisations, practitioners, craftsman and construction workers and local solutions providers. This group of change-agents worked in different workshops to select the best solutions to be tested in the living labs. Local universities, closely connected with the historic cities, provide scientific background, they test the solutions in laboratory before the installation in the demonstration buildings and monitor and evaluate the results.

The different decision-making processes developed in both projects represent the differences between the principles of traditional modernist urban planning and the self-organization as it is described by Rantanen & Joutsiniemi [18]. The EFFESUS decision making process is set to look for mono-functional, techno-structural solutions using partial optimization strategies where the improvement of energy efficiency is considered as a separate activity in the process of organizing the city efficiently. Instead, the ENERPAT process uses the interlocking and overlapping of spaces to enable stakeholders to interact and evolve using a holistic rather than comprehensive approach trying to change the whole rehabilitation system.

4. CRITERIA AND SOLUTIONS

Three main axes that influence the historic cities energy sustainability were considered in EFFESUS: efficient resource management, liveability improvement and conservation of cultural values. The followings six criteria were identified: indoor environmental conditions, embodied energy, operational energy, economic return, impact in heritage significance, and fabric compatibility. The DSS calculated quantitatively the impact in operational energy of each strategy and considered qualitatively indoor environmental conditions improvement, embodied energy of the solution, and the required degree of economic investment. An Analytical Hierarchical Process (AHP) was used to introduce the end user preferences in the system. The impact on the heritage significance was used as filter to discard solutions [19]. DSS automatically prioritised solutions from a database of 77 energy conservation measures previously characterized by experts.

In ENERPAT the solutions were not selected, instead they were created. Criteria and indicators were used to make stakeholders think about the different qualities of the possible solutions and to discriminate the ones not aligned with the project goals in order to focus the discussion on a short list of solutions. To the criteria proposed by EFFESUS, energy poverty, logistical easiness, socio-economic development, and citizen acceptance were added. The LCA was broadened (and focused), specifically including the proximity of the materials and circular economy concepts. The final solutions were selected in each living lab by consensus based on the local materials and solutions suitable to be improved and local business models developed. The solutions were basically focused on the improvement of the building envelope using locally available materials and the involvement of local business interested in developing innovation around them, for example the use of hemp mixed with lime in Cahors or cork in Porto. Currently, the baseline of the energy performance and comfort is being monitored in the demonstrator cases and a separate LCA assessment is being carried out to compare the sustainability of the original rehabilitation system ("business as usual") with the proposed new one.

5. REQUIRED INFORMATION, MULTI-SCALARITY AND 3D CITY MODELS

The urban interventions in valuable and vulnerable environments such as historic districts must be carefully planned and managed to ensure that the new interventions are respectful with the heritage values in all the scales. A multiscale approach that considers the multiscalarity of energy and heritage significance, makes it possible to develop location-specific heritage significance impact assessment, i.e. to systematically link the impact of one solution with the heritage value of the specific element that is impacted. Then, interventions that were initially considered unacceptable at the building scale could be considered suitable at the component scale [1].

Both projects have in common a multiscale data model based on the standard CityGML that aims to be the reference model for the diagnosis, decision making and management of the energy efficiency in historic urban areas, integrating energy and cultural heritage information. Both projects used the model specifically to calculate the impact of the selected strategies at urban level, but the used methods are different. EFFESUS is using "sample building" modelling strategy through a categorization method and tool: it categorises the building stock, chooses one building as representative of each typology and then extrapolates the results to the whole historic district [15]. ENERPAT will use the same model to extrapolate the results of the monitoring of the living labs. The three demo buildings (living labs) are being monitored by sensors in order to assess the impact of the new solutions at building level. The model will be used to assess the applicability and impact at urban level of theses tested solutions.

One of the big differences between the two approaches is the level of required information (and the ambition of the expected results). With the EFFESUS DSS, once the data are included in the model, the assessment of the solutions is an almost automated process. The time required for data collection and generation of the data model is very much dependent on the availability of data and the size of the area to assess. From the beginning of the process until the final results are obtained, an estimated average timeframe would be around two weeks for a medium-sized district. The process described in ENERPAT could take around three years if the whole process is considered: adapting the methodology, selecting the stakeholders and the demo buildings, setting the living labs, co-creation process, installation of the solutions, monitoring (and co-monitoring), analysis of the results and extrapolation.

6. RESULTS and complementarity

The following table summarizes the comparison of the two projects and their methods.

Table 1. Summary of the comparison between EFFESUS and ENERPAT

		EFFESUS	ENERPAT
PROJECT DATA	**Duration**	4 years (2012–2016)	3 years (2016–2019)
	Funding	Seventh Framework Programme	INTERREG SUDOE
APPROACH		Data driven	Systemic eco-renovation
DECISION MAKING		Through a DSS	Through co-creation strategies
REQUIRED RESOURCES	**Time**	Low-Medium	High
	Staff	Low	Medium
SOLUTIONS		Universal	Based on local techniques and materials
3D MODEL	**Use**	Feeding the data for decision making and extrapolation	Only extrapolation
	Modelling strategy	Sample building	Living labs
INDICATORS	**Considered indicators**	Energy performance (quantitative) Indoor environmental conditions, embodied energy, operational energy, economic return, impact in heritage significance and fabric compatibility (qualitatively)	The EFFESUS indicators + energy poverty, logistical easiness, socio-economic development and citizen acceptance
	Assessment	Calculations	Monitoring + calculations
	Monitoring by sensors	No	Yes
	LCA	Through the characterization of the solutions	Specific study of the whole system
STAKEHOLDERS´ INVOLVEMENT		Limited	The whole value chain is involved through living labs
EXPECTED IMPACT		Improvement of energy efficiency and comfort	Systemic change and territorial activation

The comparison of the two approaches clearly shows the difference between them in terms of ambition, required resources and used methods and tools. ENERPAT addressed a valuable systemic perspective but EFFESUS developed some useful tools that can be integrated through the co-creation strategies and help decision makers. As Colander and Kupers stated "*complexity policy is contextual and consists of a set of tools, not a set of rules, that helps the policy maker to come to reasonable conclusions*." [13]. The EFFESUS model and approach have been proved to be useful for early-stage urban energy decision making [1]. At this stage a long list of solutions can be easily evaluated through the DSS in order to provide to the co-creation process with data for an informed decision in coherence with the recently approved European Standard, EN 16883 (Guidelines for Improving the Energy Performance of Historic Buildings).

7. CONCLUSION

This paper has described the approach of two different projects with a similar goal: the improvement of energy efficiency and sustainability in historic urban environments. Although the projects were close temporally (when EFFESUS finished ENERPAT just started), the evolution from one to another can be seen as a change in the way we see historic cities and their energy improvement: from a linear, mechanistic view, to one based on nonlinear dynamics, evolutionary development, and systems thinking. However, the results of the projects are complementary. The EFFESUS DSS can be highly beneficial for the early stages of an urban energy retrofitting process and provide evidence to the co-creation strategies within the ENERPAT approach. To adopt the ENERPAT strategy, a high political commitment and long-term vision is required. Should it be adopted as an evolutionary strategy, it could be deployed step by step in an incremental and controlled way. Benefits that can be obtained could significantly transform the system of the historic city improving its sustainability and liveability, reinforcing its local economy, preserving its cultural values and including all the stakeholders in the whole process.

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