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S.O.L.E.H. (Sustainable Operation Low-cost Energy for Hotels). Innovative tools and guidelines for the sustainable hotels' refurbishment

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S.O.L.E.H. (Sustainable Operation Low-cost Energy for Hotels). Innovative tools and guidelines for the sustainable hotels' refurbishment

A Bertolazzi[1], **F Micocci**[2]

[1]Dept. of Civil, Environmental and Architectural Engineer, University of Padua, Via Marzolo 9, 35121, Padua, Greece.
[2]Dept. of Architecture, Univeristy of Thessaly, Pedion Areos, 38334, Volos, Greece

angelo.bertolazzi@unipd.it

Abstract. The target of the "Road Map of Efficient Europe" is to refurbish the buildings stock of the second half of the 20th century that is responsible of the 41% of energy consumption - the 2/3 of this consumption are spent for heating and cooling - with the reduction of greenhouse gas emissions and consumption of raw materials. One of the sectors of the building stock that needs an upgrading for what concern building performances and consumption is the tourism, and in particular hotel buildings that often are in a state of obsolescent because they have failed to update to contemporary comfort requirements. The research that will be presented in this paper with the name "S.O.L.E.H. (Sustainable Operation Low-cost Energy for Hotels)" aims to identify innovative tools and providing guidelines for hotels refurbishment within a framework of environmental and economic sustainability thanks to the exchange of know-how among Italy and Greece. The project's goals are: to identify innovative solutions by stimulating the targeted use of technological tools, to take care of communication for the stakeholder; to make the hotel building stock more efficient and the tourism industry more competitive; to refurbish existing buildings with a view to sustainability and circular economy. The project is a collaboration between Universities of Padua, Venice and Thessaly and it was funded with European Structural Funds. It introduces Innovative and Smart Technologies for the survey, processing and visualization of buildings data, based on the analysis of case-studies from Italy and Greece, and then it proposes a tool for the refurbishment of existing hotel with the support of a communication framework in order to sensibilize stakeholders. Finally, the research concludes with a workshop organized at the University of Thessaly with the scope to investigate alternative solutions of tourism models in order to sensibilize users towards more sustainable and ecologic habits.

1. Introduction

The objectives 7 (accessible and clean energy) and 12 (Consumption and responsible production) of the 2030 Agenda of the European Union [1] indicate the need to improve the efforts for the energetic and environmental redevelopment of the residential building stock realized during 1950-2000. This stock was built mainly with quantitative criteria and therefore it is afflicted by a quick material, performance and environmental aging, because of the poor technology utilized during the construction process. Following recent estimations by the European Union, the recovery of this building stock may bring to the reduction of the 42% of energy consumption, of the 35% of gas emissions and of more than the 50%

of the consumption of raw materials [2]. At the same time, this recovering may bring also an improvement of the general quality of the built environment [3; 4; 5].

Notwithstanding, less than the 1% of the European building stock is renovated every year, with percentage between 0,4% and 1,2% for each country [6]. The principal causes for failing to reach the established objectives are the low economic attraction of such investment because of the hight risk usually embedded in redevelopment interventions, the long span of time that is needed to implement these interventions, the uncertainty of a profitable return of the initial investment and the limited awareness of clients and operators in the construction sector for what concerns redevelopment processes [7]. This criticality is more evident in Mediterranean European Countries, especially in Italy, Greece and Cyprus, if compared to Continental Europe, since the economic context is characterized by lower budgets, geographical and climatic conditions are very different, the productive tissue is less developed and more fragmented. This led at a low incidence of National Legislations that were issued following 2010/31/UE 2012/27/UE Directives on energy efficiency and then updated according to the EU 2018/844 directive.

In Mediterranean Countries, touristic hotel sector plays a crucial role in national economies. In Italy, for example, this sector covers the 13% of the Gross Products and it counts 1.621.000 employees located in 33.000 hotels and 180.000 in other hospitality structures, for an overall offer of 5,1 million beds [8]. In Greece, tourism covers the 12,5% of the Gross Product, and it counts 850.000 employees for 32.806 hospitality structures, for a total of 12 million beds [9; 10]. Most of hospitality buildings – similarly to the residential ones – had been built in the period 1950-2000 before the adoption of the specific legislation that limits energy consumption and promotes energy efficiency. In Italy, the percentage of the manufacts built before the 2000 reaches 82%, while the 12% had been built before 2010. In both cases, the largest part of the existing building stock had been built before the adoption of national legislations that aim to limit energy consumption following the 2010/31/EC. Therefore, it is evident how most of the existing buildings today don't present satisfying energetic performances (figure 1a). In Greece, 83% of the building stock had been built before 2000, while 17% until 2010 and it is not aligned to the European legislation [9] (figure 1b). These data explain the annual high level of energy consumption for hotel if compared with the average value in the European Union that reach the 161 kWh/mq: in Italy this value reaches 215 kWh/mq, in Greece 273 kWh/mq, 272,6 kWh/mq, while in Spain and Portugal it is measured respectively 287 kwh/mq and 296 kWh/mq [11].

In Europe, tourism contributes for the 5% of global carbon emissions, and the 20% comes from hotel [12]. Hotel structures thus are among the first five typologies of buildings of the construction sector that are responsible for carbon emissions. This fact highlights the great potential in terms of efficiency and energy saving, also in relation to the most recent directives for what concerns the energy efficiency of buildings.

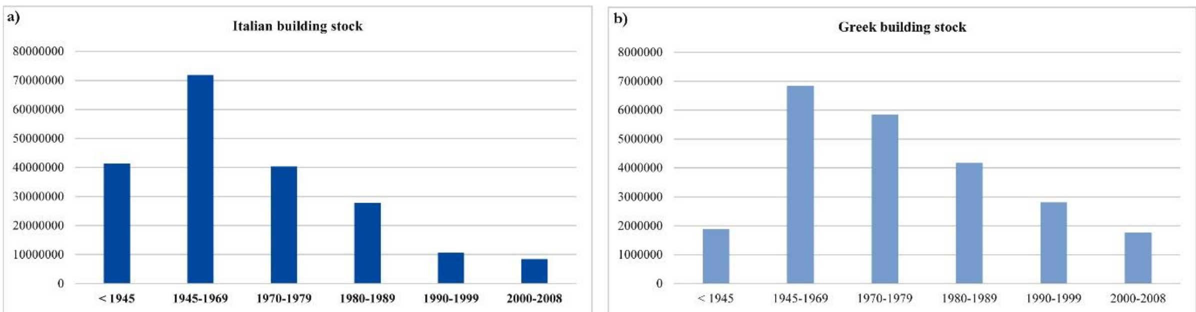


Figure 1 – Building stock analysys in Italy (a) and Greece (b) [Entranze, 2019]

The economic impact and the elevated consumption of hotels sector suggests to focus on this sector, making it the field to experiment innovative technological and economic solutions as well as normative tools that could be able to make the operation of refurbishment economically sustainable. It is important to focus on hotels also because the results would be considered a valid benchmark also for residential buildings because of the close affinity between the two typologies [13].

The hospitality and residential building stock, in consideration of the Italian and Greek cases, present a common crucial problem: the strong unbalance between the very low energetic performances of the building envelop (passive features) and the need for a huge presence of system engineers for refreshments (active features) requires a lot of electric energy to guarantee the optimal living condition of the interior spaces both during the day and the night. This unbalance of buildings' performance requires the need a more constant exchange between interior and exterior, allowing vertical and horizontal natural ventilation. The nature of this performance confirms the very different approach for what concerns the redevelopment processes in Mediterranean Countries from Central and Norther Europe [13].

2. State of the art

Since early 2000s, the buildings energetic refurbishment gained an increasingly key role both at the level of the European Union and of national states. The path taken at the EU level has led to the enactment of Directive 2010/31/EC Energy performance of Buildings. This directive has set energy standards for new buildings as a community goal for 2020 nearly-Zero Energy Buildings (nZEB-2020), i.e. the almost total reduction of energy consumption of buildings, a goal then postponed to 2050.

In 2011, the Roadmap for Efficient Europe identified as a strategic priority of the Eighth Framework Plan the renovation of heritage buildings erected in the second half of the 20th century. The report of the Building Performance Institute Europe (BPIE) of the same year showed that the residential building sector is the sector that accounts the largest quantity of items in terms of extension, energy consumption and CO_2 emissions, since it constitutes 75% of the total built area and it is responsible for 41% of the energy spent for cooling and heating (2/3 of total energy consumed) [14] in the European Union countries and in United Kingdom. To this quantity it should be added the rest of 20th century buildings (schools, public edifices, offices) which not are very energy efficient, reaching 50% of the value of energy spent in the European Union. Regarding building retrofitting, Directive 2018/844/EC, amending Directive 2010/31/EC on the energy performance of buildings and Directive 2012/27/EC on energy efficiency, imposes for the development of long-term national strategies the improvement of the energy efficiency of existing buildings (residential, public and private) in order to reduce emissions in the EU by 80-85% compared to the levels reached in 1990s by facilitating the transformation of existing buildings into nearly zero-energy buildings (NZEBs).

From the point of view of the development of intervention and operational methodologies aiming the building refurbishment, the activity carried out within the 7th Framework Plan achieved important results from a regulatory point of view, for the regularization of the energy requalification process. This has also made it possible to obtain, in addition to the norms, a wide range of options for the realization of new envelopes (insulating cladding for exterior walls, coating ventilated wall claddings) already adopted in European countries as evidenced by the Technical Guide for the issuance of ETAs to ETICS (External Thermal Insulation Composite Systems) or the Guidelines for European Technical Approval of External Thermal Insulation Composite. Alongside these frameworks, some project pilots have been founded by European Structural Funds to share good practices in the field of existing residential buildings refurbishment (SOLANOVA, 2006) and hotels (XENIOS, 2001).

The H2020 programme, following the FP7 results, focused efforts on processes and tools for the nZEB refurbishment of existing public and private residential buildings (SouthZEB, 2014; HELIMED, 2014; ABRACADABRA, 2016), public buildings (RePublic_ZEB, 2015) and schools (RENEW SCHOOL, 2017; ZEMedS, 2016).

In particular, the XENIOS project, related to the energy efficiency of hotels in the Mediterranean area, aimed to provide a methodology for a preliminary analysis for a first assessment of where and how to integrate the most cost-effective energy efficient practices, technologies and refurbishment systems, including also the possibility to raise awareness towards the advantages of using RES and RUE technologies [15]. The project saw the implementation of software based on existing European methodologies for apartment (EPIQR) and office (TOBUS) buildings. This tool allows a quick preliminary analysis of the hotel, for an easy assessment of the condition of the building (envelope, systems, quality of the interior) and the potential for saving energy and natural resources. The tool provides the user with a first estimation of investment costs and financial savings to promote the use of RES and RUE (calculation of energy consumption, energy saving assessment and related basic information and data on available technologies, legislation, etc.).

From the point of view of the analysis of the existing building stock, on the other hand, the projects have a particular relevance TABULA (Typology Approach for Building Stock Energy Assessment, 2009-12) and EPISCOPE (Energy Performance Indicator Tracking Schemes for the Continuous Optimization of Refurbishment Processes in European Housing Stocks, 2013-16). The main goal of TABULA was the creation of a harmonized structure of European building typologies which, starting from residential construction, also involved other building categories. Based on the 'National Building Typology' – that consists of a set of model residential buildings with typical energy characteristics –, two levels of upgrading have been identified (basic, by the application of measures commonly used within the country, and advanced, by the introduction of interventions that reflect the best available technologies). Additional information on the frequency of building and plant types had made it possible to use the typological classification as a model for estimating the energy performance of the global building stock on a national scale. The standard buildings had been used for each country as a mean to disclose the energy performance and energy saving potential achievable by refurbishment of the building envelope and heating systems.

EPISCOPE, on the other hand, aimed to make energy saving processes in the European housing sector more transparent and effective aiming to ensure that the objectives were achieved by corrective or improvement actions. In this context, the building types taken as a reference scenario have also been expanded to exemplify the energy performance levels that can meet national requirements.

The main criticality of the refurbishment tools lies in the difficulty of its application by the users. In all the cases studies, in fact, the database understanding, the use of software and the interpretation of the data collected remained confined to the technical specialists in the sector, while the client, (generally made up of people without specialized technical knowledge) was excluded. At the same time, professionals, despite having more knowledge and skills, remained on the sidelines of the topic and their ability to operate is limited on the basic project rather than an integrated refurbishment process. These shortcomings, in addition to those already identified, are the main causes for the failure to achieve a sufficient rate of refurbishment (low economic attractiveness, uncertainty of economic return, opacity of the energy market). All these critical issues are amplified in the Mediterranean countries, where the appropriate financial instruments to overcome market failures are lacking, as well as technical tools needed to improve the know-how of operators in the sector – owners, businesses, professionals – and to guarantee basic economic sustainability that make upgrading projects accessible to wider sections of society.

3. Objectives

The S.O.L.E.H. (Sustainable Operation Low-cost Energy for Hotels) project – Innovative Tools and Guidelines for the Sustainable Renovation of Hotel Buildings was funded by the European Structural Funds (ESF) under the POR-FES 2014-2020 of the Veneto Region and saw the collaboration between the University of Padua (DICEA, DII and FISSPA), IUAV University of Venice (DCP), University of Thessaly (DA and IELEBED) and various business partners.

The project, focusing on the macro-trajectories envisaged by the call Smart and sustainable buildings and cities and Energy management of buildings, addressed the issue of energy requalification of hotel buildings. The short-term goal of the project was to provide two fast, effective and complementary tools: one to allow hoteliers to decide whether to undertake the redevelopment process, the other to allow professionals to support hotel owners in the decision-making process and then in the building process.

In the first case, the S.O.L.E.H. tool was designed as an evaluation tool, by a multidisciplinary and international research, for the collection, processing and visualization of data relating to the building redevelopment both in-put and out-put, and then adapting them to the different interlocutors (professionals, stakeholders, owners, investors and companies). The implementation of this tool was accompanied by a path dedicated to the communication of the redevelopment project to intercept different areas of society, increasing its awareness and therefore its ability to operate in the market and contributing to the implementation of new strategies for refurbishment.

In the second case, instead, the project set a series of operative guidelines for the energy retrofit of the vertical architectural envelope and its components for hotel buildings. These guidelines are used to outline the technological and regulatory horizon of the main redevelopment strategies, allowing architects and engineers to make accurate choices and to effectively support hoteliers in the decision-making process.

The medium-term objectives were, on the one hand, to stimulate the construction sector, starting from the business and professional world, introducing innovative and smart technologies able to facilitate the redevelopment process and, on the other hand, to formulate a benchmark that allows to transfer, with appropriate modifications, the project achievements to residential construction.

4. S.O.L.E.H. Methodology

As previously mentioned, the S.O.L.E.H. tool is addressed to hotel business owners as they are the first promoters of the building process, who often do not have the necessary skills and knowledge related to upgrade their hotel. Compared to existing decision-making tools developed by previous research projects, the recipients are the owners of medium-sized structures, not belonging to large hotel chains and therefore with fewer economic and technical means.

The areas on which the project focused were: the passive component of the building (building envelope), the active component (systems and plants) – both in the analysis phase and in the implementation of data – and the communication strategy of the project (tools and guidelines). The process – according to a precise workflow (figure 2) – led to the implementation of the tool and can be divided into four main phases, linked to each other from a logical and methodological point of view, which correspond to the different actions of the S.O.L.E.H. project: 'Analysis and building techniques for hotels energy refurbishment', 'Performances of building envelopes and technology design', 'Energy modelling for building and systems' and 'Communication management for hotel refurbishment'.

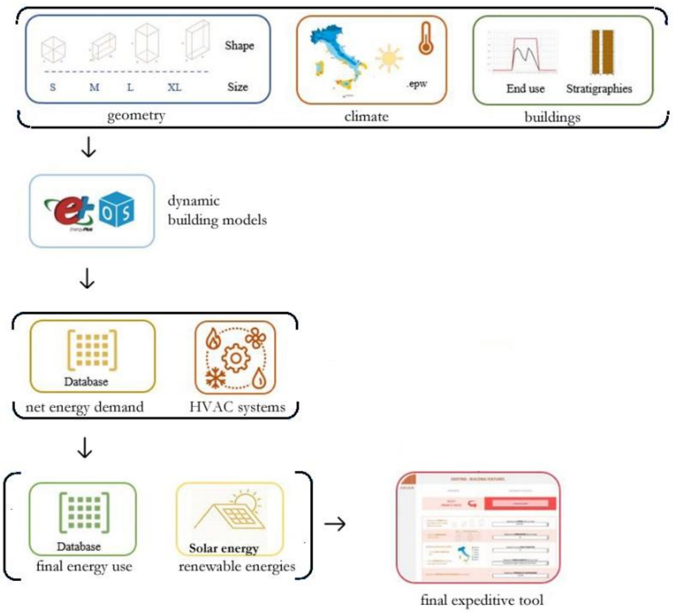


Figure 2 – S.O.L.E.H. project workflow

4.1. Action 01: Analysis and building techniques for hotels energy refurbishment

The first action saw the analysis of the functional and constructive typological aspects of the hotel construction of the years 1950-2000. The first step was the identification of the age of hotel buildings: in Greece 83% of accommodation facilities date back to the period under review, of which 79% in the twenty years 1960-1980 [11], while in Italy 75% was built in the same period of which 82% between 1960 and 1981 [16].

From a typological and functional point of view, the analysis showed a predominance of block buildings – regular or not – with 2/4 up to 6 floors, followed by the terraced type with residential modules arranged 'to scale' or 'aligned' with 2 floors. In the first case, the building is identical to the residential block type with a central stairwell that serves all the floors on which the rooms or studios are distributed. In the second case, however, each element has its own stairwell (which can serve several units one per floor, whether they are rooms or studios).

From the constructive point of view, on the other hand, 63.1% of Greek hotels are made up of buildings with at least two floors, with reinforced concrete structure, infill in solid bricks, single or double layer, or hollo-bricks – depending on the year of construction – and floors in solid reinforced concrete or masonry, according to the multi-storey building type [11]. Of this building stock, 35% has no insulation, 20% double-layer walls with only cavity as insulation and only 22.5% has been thermally insulated with an external coat (expanded polystyrene or, more rarely, rock wool) as a result of redevelopment operations. Roof insulation is generally lacking, except for high-category hotels (< 5 stars) [17].

In Italy, on the other hand, 66% is built with a reinforced concrete frame with masonry floors and infill with solid and hollow-brick blocks, single or double layer. As far as the building envelope is concerned, 45% has no insulation. The infill structures consist of simple or double brick blocks or layer with cavity, sometimes replaced by insulating material [18].

The analyses carried out within Action 1 served to define the 'typical buildings' to be included in the tool and on which the energy simulations of the 'as-built' building have been made.

4.2. Action 2: Performances of building envelopes and technology design

The second action focused on the analysis of energy retrofit interventions of the building envelope. This activity was carried out following the comfort criteria and in compliance with current Italian and Greek regulations, with an analysis of the life cycle of the materials and their environmental impact, currently certifiable, to guarantee the sustainability of the retrofit intervention [19].

The analysis then focused on the state of art concerning the vertical architectural envelope and its components of Italian and Greek hotel buildings. Subsequently, the research deepened the main technological solutions for the building envelope upgrading within the period examined. The different existing building products on the market were also taken into consideration, analyzing their environmental impacts.

Finally, the hypotheses of vertical architectural envelope refurbishment in terms of different intervention (overlapping, replacing and adding and/or subtracting layers and/or elements to the existing envelope) were investigated. Once the general intervention strategy was identified, it was possible to choose which executive interventions to use for perimeter closures (materials, construction techniques), fixtures and shading systems. The overall goal was to make the enclosure into an element capable of reducing energy consumption through: (1) the collection and storage of thermal energy from solar radiation; (2) natural cooling and limiting solar energy input and indoor heat production; (3) the use of solar radiant energy for the natural illumination of indoor spaces according to the standards of visual comfort. The intervention strategies for hotel construction in Mediterranean countries, given the favorable climatic conditions, also provide to produce renewable energy from a photovoltaic (PV) system to be installed both on the façade and on the roof of the building.

The set of interventions was then used to build a series of pilot scenarios to be applied to the 'typical' buildings identified in the previous action.

4.3. Action 3: Energy modelling for building and systems

The third action focused on the study and energy modelling of viable solutions to improve the energy performance of the hotel sector. In particular, the intervention focused on sustainable strategies for the active component of the building, namely the HVAC system dedicated to air conditioning and the production of domestic hot water. The first phase of the research was focused on the dynamic simulation in the EnergyPlus environment of the ideal energy needs (heating and cooling) of the 'typical' buildings of the years 1950-2000 identified in the previous action, intended as pilot scenarios. In the second phase, the expeditious analysis tool had been developed and subsequently translated into Excel VBA to evaluate the effects of the suggested retrofit actions to be implemented on the scenarios.
The analysis of the retrofit systems was divided into two phases:

1. energy modeling, in the OpenStudio/Energy plus+ environment, of the different pilot scenarios based on both the results of Action 1 (typological, functional, constructive aspects of 'typical' buildings) and those of Action 2 (technological solutions for the energy requalification of the building envelope and systems). This led to the development of a database for the implementation of the tool in relation to the choice of retrofit interventions.
2. energy modeling, in the OpenStudio/Energy plus+ environment, of retrofit scenarios (technological solutions proposed for the energy requalification of active and passive components) applied in two real case studies. This allowed to validate and verify the method by the comparison with the heating and electricity bills supplied for the two hotels.

To maintain the smart and intuitive character of the tool, two input data matrixes were built, one for the state of the art and the other for retrofit proposals, containing the energy needs of 144 'typical' hotel buildings, obtained by combining the different combinations between: geometry (shape and size of the hotel), climatic zones, year of construction. For what concerns geometry, the shapes and dimensions to be considered were chosen on the basis of the results of previous actions (table 1).

Table 1. Data input for S.O.L.E.H. tool.

Total areas	**Shape**	**Climate zones**	**Stratigraphy**
St < 350 mq	cube	A, B, C = Palermo	S1 = 1950-1970
350 mq < St < 750 mq	tower	D = Rome	S2 = 1970-1990
750 mq < St < 2500 mq	short parallelepiped	E, F = Venice	S3 = 1990-2000
St > 2500 mq	tall parallelepiped	G = Athens	
Table 1			

This analysis had been used to determine the net energy demand for heating/cooling and domestic hot water (DHW). Through a dynamic simulation with EnergyPlus and its OpenStudio interface. The interaction of the occupants with the building – i.e. the internal thermal inputs, the hours of operation of the HVAC system and the temperature set-points – has been set according to the international standard ISO 18523-1. For the modelling of the energy retrofit interventions, the same procedure was followed and a new matrix of net energy requirements was calculated considering the different possibilities proposed for the redevelopment of the building envelope.

As part of the project S.O.L.E.H., two different photovoltaic technologies for the modules were considered, i.e. monocrystalline or polycrystalline, as they represent today the most widespread and efficient alternatives for the production of photovoltaic energy. To calculate the potential production of photovoltaic electricity, the European Standard UNI EN 15316-4-3: 2018 was followed, comparing the amount of electricity produced with the total amount of electricity required by the building for heating, cooling and DHW needs [20].

4.4. Action 4: Communication management for hotel refurbishment

Finally, the fourth action focused on the communication aspects of the redevelopment project, trying to understand how sustainability and energy efficiency can interact with the hotel sector, also considering the growth of ecotourism, understood as a socio-economic movement [21].

The role – and the main challenge – of the S.O.L.E.H. project within the ‘social system of energy retrofit’ was to act as a privileged interlocutor in which it was possible to bring together the apparently distant actors of the same system: tourists, hoteliers and professionals [22].

In order to facilitate the communication and involvement of a growing number of actors belonging to this social system, the research subsequently focused on the individual dimension, trying to understand what are the motivations and the needs that can stimulate a hotelier to undertake the process of energy redevelopment.

In the hotel sector, as well as in the residential sector, the role of the client appears passive and segmented due to top-down decision-making dynamics, instead of bottom-up ones [23]. The centrality of the individual, as client and user are necessarily dictated by the passage from the technical-mathematical code of professionals to that linked to the perception of non-technical users.

Within the categories previously identified, the hotelier appears to be the link at the base of every interaction, both because he is the one who attracts the demand of the tourist and because he is the promoter of the refurbishment process, where he works together professional technicians. The S.O.L.E.H. project has therefore focused on the hotelier to investigate the motivations and needs behind his choices in the field of redevelopment. The objective of the survey – carried out on a sample of 887 hotels in Veneto, Tuscany, Lombardy, Piedmont and Umbria – was to analyze the sensitivity and perception of a specific sample of people that answered to a questionnaire. This sample, in continuity with what emerged from Action 1, was that of the small hotel (two or three floors) family-run and inserted in an urban or natural landscape, inside the frame of time of the emanated period (1950-2000).

The questionnaire was aiming at understanding what are the needs that govern the decision-making process of the hotelier to undertake the redevelopment project and what are their priorities within the same redevelopment. The results saw both economic (reduction of energy consumption, 76%) and commercial (offering better comfort conditions to customers, 64%) prevail. As far as the choice of interventions is concerned, at least 30% indicated as priority the interventions on the active component (systems) and on the envelope (fixtures and thermal insulation) (figure 3).

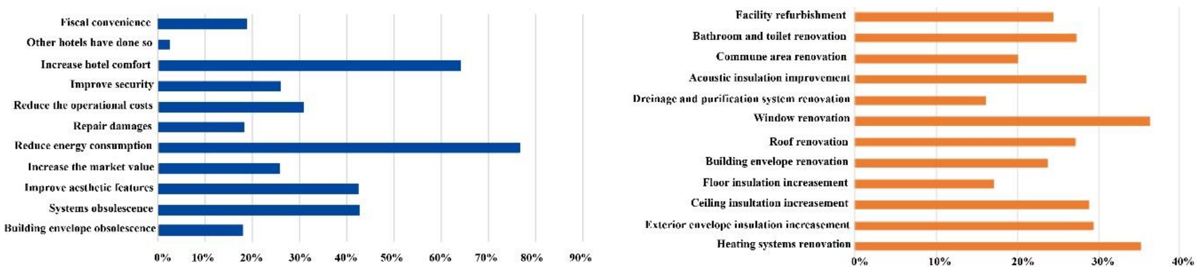


Figure 3 – Survey of main decisional factors in a retrofit action (left) and hoteliers’ needs in a retrofit action (right) [Muneratti, 2022]

These indications have highlighted how preferences focused on the best cost/benefit ratio – also in terms of image return – but not in integrated strategies, which would guarantee better results in the long term. In other words, hoteliers have identified ‘soft renovation’ interventions as priorities, rather than ‘deep renovation’ ones. Considering these results, the S.O.L.E.H. tool and the guidelines have therefore focused on communicating to potential clients and technicians the potential and risks associated with the 'deep' renovation.

5. S.O.L.E.H. Results: tool and guidelines

The interdisciplinary and coordinated research between the four actions led to the implementation of a tool with an interface facilitating the use by hoteliers. The tool is based on an interactive Excel sheet by which it is possible to enter the data of the hotel (active and passive component) and obtain indications on potential energy and economic savings in different retrofit scenarios.

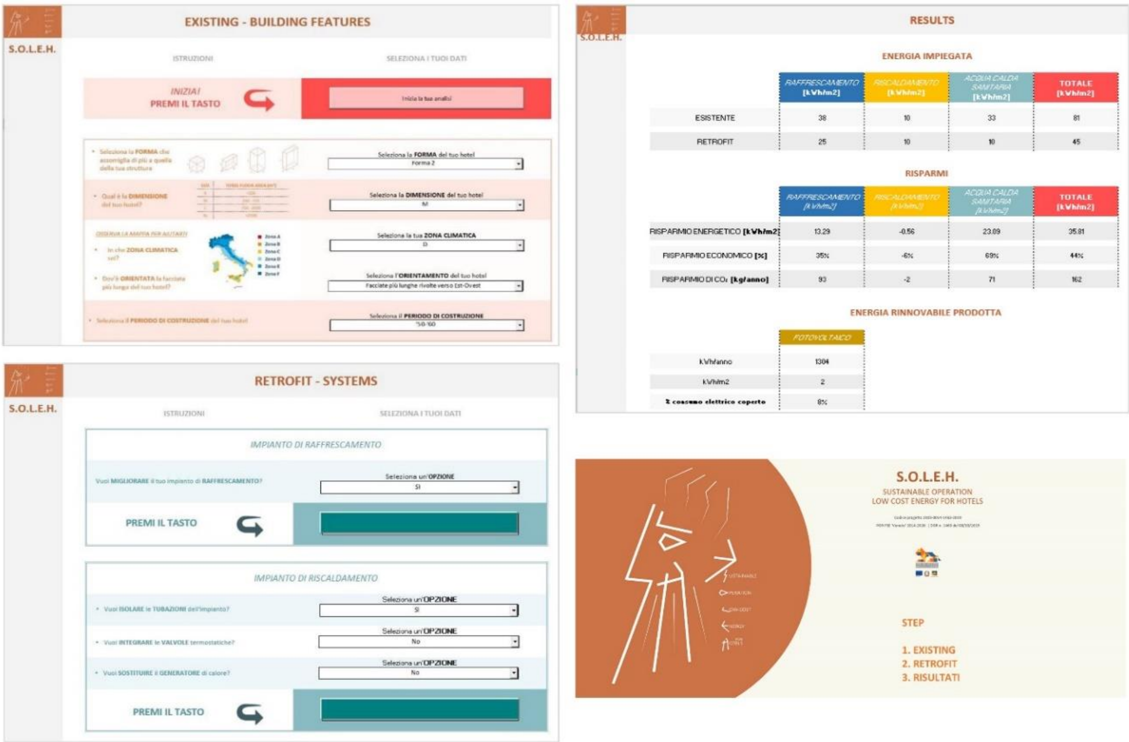


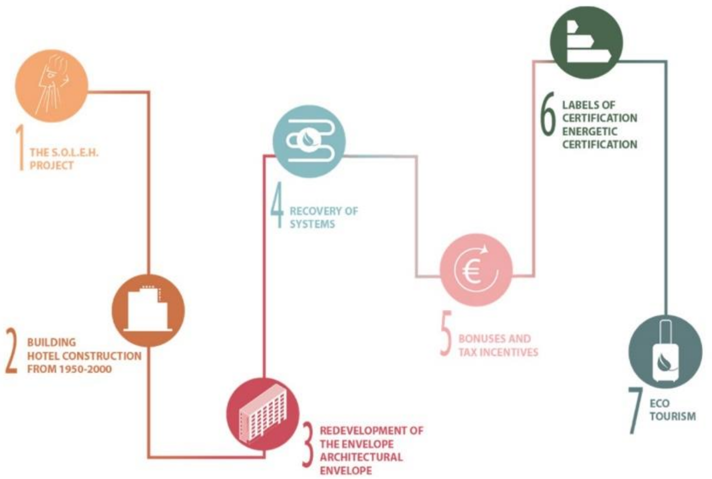
Figure 4 – S.O.L.E.H. tool, general layout [S.O.L.E.H. team, 2021]

S.O.L.E.H. tool is organized into six sections (figure 4):

1. **S.O.L.E.H. Project:** it is the first section and contains the reference data of the research and a brief indication of the steps to follow for the compilation of the spreadsheet.
2. **Existing, characteristics of the existing building:** in this section it is possible to select the characteristics closest to the state of the art of the architectural envelope of the hotel in question. The parameters of the building to be inserted are: the definition of the shape of the building, directly related to the form factor (S/V), i.e. the compactness of a building obtained from the ratio between the dispersing surface and the volume of the building; the size range, understood as a percentage of the conditioned zones; the climatic zone, defined by geographical location; orientation, identifying in a simplified way the length of the longest side of the structure; the construction period, which is automatically related to the average transmittance of the building envelope, which is greater for older constructions.
3. **Existing, systems:** in this section it is possible to select the systems available in the hotel (cooling, heating, domestic hot water) whose efficiency parameters are obtained from technical and regulatory data sheets.
4. **Envelope retrofit:** in this section it is possible to find the retrofit solutions that hoteliers can choose and subsequently evaluate in terms of costs / benefits. The choices are: the complete renovation of the thermal insulation, the replacement of the fixtures (soft renovation), insertion of photovoltaic systems and possible integration into the envelope (deep renovation);
5. **Plant retrofit:** in this section it is possible to identify the retrofit solutions for each type of system, according to parameters associated with improved performance data according to UNI-TS 11300 and UNI EN 15316;
6. **Results:** in the last section are finally reported the results derived from the data entered in the previous sections. Here the user can observe the energy needs required for the various redevelopment scenarios, divided by heating and cooling, production of domestic hot water and the contribution of photovoltaic energy.

The S.O.L.E.H. tool has been supplemented by a set of guidelines (figure 5) designed for professionals and technicians who support the hotelier in the decision-making process. Moreover, it is a smart tool designed to overcome the communicative opacity present in the field of building redevelopment. The guidelines have been organized as follows:

1. Introduction and state of art of hotels building stock;
2. Building hotels 1950-2000;
3. Building envelope refurbishment;
4. Systems upgrade;
5. Economic features;
6. Labels of energy certification (Casaclima, Green Building Council);
7. Good practices and eco-tourism;
8. S.O.L.E.H. tool guide.



9.

10. Figure 5 – SOLEH guidelines [S.O.L.E.H. team, 2021]

6. Conclusions and future developments

The S.O.L.E.H. project produced two complementary operational tools designed to overcome the main obstacle that arises in the initial, and crucial, phases of the redevelopment process starting, involving the main actors. Both are analytical tools that provide support to understand the potential economic and environmental benefits of energy retrofitting to foster an effective dialogue between owners and designers but does not replace the analyses and the project that must be done for each specific case study. The results that are provided by the S.O.L.E.H. tool is not to be considered absolute numbers and must be reviewed later case-by-case. At the same time, the guidelines must be the starting point for a redevelopment process in which technological choices are integrated into an overall reasoning of the architecture of the building envelope.

In order to improve the efficiency of energy refurbishment, the next step will be the implementation of a web page with the same interface as the Excel sheet: this on the one hand will allow the implementation of the database itself in line with the S.O.L.E.H. tool intended as an open source, implementable over time. On the other hand, it will facilitate users’ access to energy simulations, also allowing a faster diffusion within the hoteliers' associations.

This last aspect assumes a key role because it would allow a better efficiency of the instrument itself, but at the same time it can start a conscious process of sustainable architectural redevelopment of hotels that in the Mediterranean countries has a significant impact on society, the environment and the landscape, the true and main resource of the Mediterranean countries.

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