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Innovative Approach to the Configuration of Smart Buildings

KEYWORDS: smart building, building configuration, Building Information Modelling, client, user

In the construction sector, a strong push for innovation is due to the demand for high quality standards of living that can be related to safety, accessibility, usability, energy efficiency, as well as sustainability in terms of construction and management costs.The demand is becoming increasingly "sustainable" also because it is increasingly aware of the limited availability of resources (fossil fuels, water, etc.) and the simultaneous need for environmental protection. In order to respond to the demands of an increasingly demanding market, we identify the need for an innovative approach with the characteristic of being increasingly "friendly" for the future user.
The work aims in fact, with the help of BIM computerized tools, to develop a prototype project intended to create low-cost and energy-efficient residential typologies, involving the user in a sort of guided path designed to explain, within a pre-constituted grid, its needs, realizing a real configuration of the building, directly related to obtainable estimations, based on:

- use of innovative building materials and components for construction;
- application of strategies for the optimization and rationalization of the activities envisaged during the execution phase;
- extensive use of remote control and management systems and monitoring of performance obtained in the management phase.

The involvement of the client/user in all phases of the building process presumes an innovative approach oriented to the development of all those strategies aimed at empowering and making the user aware, especially in the management phase, depending the achievement of energy efficiency objectives precisely on the user's behavior.

INTRODUCTION

The European reference legislative framework

The European Union pursues the goal of developing a sustainable, competitive, safe and decarbonised energy system by 2050. In fact, by 2050, Member States will have to adopt measures to achieve the long-term emission target of greenhouse gases and decarbonise the housing stock, which accounted for around 36% of all CO_2 emissions in the Union. The Paris agreement on climate changes in 2015 encourages the Union's efforts to decarbonise its housing stock. Taking into account that almost 50% of the Union's final energy consumption is used for heating and cooling, of which 80% in buildings, the achievement of the Union's energy and climate objectives is linked to the efforts of this last to renew its building heritage, giving priority to energy efficiency, using the principle of "energy efficiency first", as well as evaluating the use of renewable energy. The Directive 2010/31/EC imposed on member countries the construction of new buildings with almost zero energy consumption (Nearly Energy Zero Building). The Directive 2018/844/EC modifies the directives 2010/31 and 2012/27/CE and clarifies and implements the objectives for an ideally decarbonised building sectorfor a NZEB building park in 2050. Long-term renovation strategies will have to have clear and measurable objectives, as well as initiatives to support the development of infrastructures for the electromobility. The new Directive also promotes economically efficient renovations, introduces an indicator of intelligence for buildings, simplifies inspections of heating and air conditioning systems. Among the objectives pursued are also to underline those that encourage the use of information technology for efficient buildings, and increase the role of consumers, informing and protecting them from the energy poverty.

The smart building

The current approach of European legislation encourages the construction of smart buildings, where innovative solutions are widely used. Smart buildings are created when these solutions provide for multiple generation systems, managed by supervisory and control systems that make extensive use of Information and Communication Technologies (ICT) and adopt logic that meets economic, environmental and/or of comfort performances, in response to the needs of users. In particular, in a smart building, users are involved in the control of energy flows and all possible user needs are recognized and taken into account in terms of comfort, health, indoor air quality, safety, as well as in the identification of operational requirements.

The current context and the perspectives of the construction sector

In this context, the construction sector has a fundamental role and consequently will have to transform itself facing to the challenge of the energy performances required both for the new building and for the energy requalification of the existing heritage. Technologies, solutions, materials and advanced products are in fact already available on the market, but so that the use of innovative technologies and the consequent investments can find a concrete application it is necessary to develop new models of design approach. In the construction sector, a strong push for innovation is due to the transformation of housing demand from quantity to quality, where quality means more security, sustainability, accessibility and usability. The demand has become "sustainable" also because it is aware of the limited availability of strategic resources (fossil fuels, water, etc.) and of the need to take account of environmental protection. Innovation in the energy and environmental fields and sustainability in construction offer the possibility of minimizing the impact of the building process on the environmental, social and economic context and offer concrete conceptual and operational tools, with which the sector can be restarted. Aiming at the innovation of the building sector, integrating renewable sources and energy efficiency, is a prospect of great opportunities to relaunch the sector that must be pursued by all means.

Work's goal

The work aims, with the help of BIM computerized tools, to develop a prototype project in order to create low-cost and energy-efficient residential typologies, involving the user into a kind of guided path designed to explain, within a pre-constituted grid, its needs, realizing a real configuration of the building, directly related to estimates. The involvement of the client / user in all phases of the building process, assumes an approach innovative and oriented to the development of all those strategies aimed at empowering and making the user aware especially in the management phase, depending precisely on the user's behavior the achievement of energy efficiency objectives.

THE CLIENT/USER KEY ROLE

In view of the above, the role of the client/user is essential and strategic for the pursuit of the objectives set out and clarified by the Directive 2018/844/EC. In this paper we aimed to centralize the role of the client/user not only for the achievement of the objectives of the Directive, but also for the respect of the relationship between technological choice and estimate of the relative cost, also including this last aspect in the in the area of sustainability. From this point of view, it is necessary to make the client/user aware, as a fundamental operator of the building process, from the initial moment to the building management phase. In fact, it is believed that an efficient management during the operation phase is essential to ensure the expected results, as well as a correct design choice. The following is a summary of the working methodology developed in the various phases that can be summarized as follows:

1. Definition of the spatial functional system, of the technological packages used and of the elements useful for the purpose of estimating;
2. Creation of families in Revit of the studied elements;
3. Generation of the abacuses in Revit, from which to extract the necessary quantities to be included in the estimate sheet;
4. Definition of rules through the STR-Vision software, thanks to which, once the Revit model has been imported, an instant parametric estimate can be generated.

	REFERENCE GRID								
FUNCTIONAL - SPATIAL	Residential type	Detached	Semidetached			Terraced			
	Number of users	1	2	3	4	5	6	7	8
	Number of adults	1	2	3	4	5	6	7	8
	Number of children	0	1	2	3	4	5	6	7
	Day area	Living - Kitchen - Dining	Living + Kitchen - Dining			Living + Kitchen + Dining			
	Master bedroom	0	1			2		3	
	Single room	0	1			2		3	
	Double room	0	1			2		3	
	Studio/Office	0	1			2		3	
	Bathrooms	1	2			3		4	
	Garage	Single in	Double in			Single ext		Double ext	
	Other spaces								
ASPECT	Tyoe of fixtures	PVC	Wood			Aluminium			
	Floor finishing	Whole ceramic	Whole wood			Ceramic for day area and wood for nigh area			
	Shielding system	Blinds	Blackout curtains			Shutters			
	Number of floors	1	2			1 with loft			
TECHNICAL-ENERGY	Type of structure	X-Lam wood	Concrete			Brick			
	Type of installation	Radiant floor				By air			
	Transmittance values opaque surfaces	Minimum of legislation				Best values			
	Transmittance values of fixtures	Minimum of legislation				Best values			
	Plot possesion	Yes				No			

Table 1: Reference grid to identify the needs of the client/user in the case of a residential building

Useful documents for briefing

The first step to realize the involvement of the client/user was to implement a reference grid useful for identifying needs. In fact, it is well known that a correct focusing of needs sets the premises for a correct design that guarantees an optimal use of technological resources and, consequently, an optimal use of energy resources in the management phase.In the briefing the client/user can fill the reference grid, marking the desired box. The table can be supplemented, possibly by more descriptive documents, in which, by answering open questions, the identification of users' needs is completed. The grid illustrated in table 1, will allow to identify the building to be designed, from an environmental, technological and functional/spatial point of view.

DEFINITION OF THE TECHNOLOGICAL SYSTEM

It is established that the following conditions must be met as a priority:

- the default building complies with the provisions of the D.M. 06/26/2015;
- for each package the thermo-hygrometric verification of the technological packages is satisfied;
- the type of foundation used and its size depending on the size of the same;
- the production of energy is entrusted to a photovoltaic system with power greater than or equal to 4KWp.

The client/user has the possibility to choose respectively for vertical structures, among the following three technologies:

- structural partitions in reinforced concrete with disposable formwork

WINDOW Family
Window – 1 door – roller blind
Window – 1 door – blinds
Window – 1 door – blackout curtain
Window – 2 door – roller blind
Window – 2 door – blinds
Window – 2 door – blackout curtain
French window – 1 door – roller blind
French window – 1 door – blinds
French window – 1 door – blackout curtain
French window – 2 door – roller blind
French window – 2 door – blinds
French window – 2 door – blackout curtain Velux

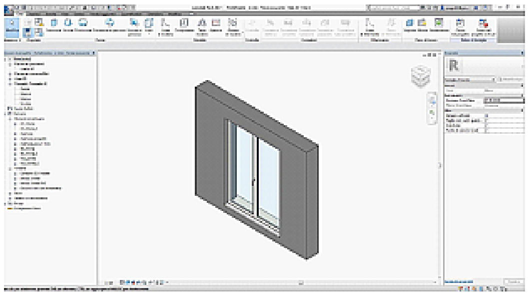


Figure 1: Example of displayed return of the window family

in eps;

- rectified brick;
- wooden panels in CLT.

Compatibly with the choices made for the vertical structure, for the roof structure, the possibility of choosing between a wooden structure and reinforced concrete is given. The client/user can then choose the type of frame and any finishing components.

The work continued in-depth analysis and study of the price incidences of buildings already built similar for technology and performance. Prices have been associated with technological packages and parameterized to surfaces. In this way, the client/user responding to the format is not only able to define the desired building but also its cost. The item of the construction of the building site has been inserted by default and its cost calibrated according to the size of the building thus obtaining a real online estimate.

DIGITISATION OF THE BRIEFING

Following the above logic, the second step of the work consisted in the online transfer of this methodology. To this end, a digital platform has been specifically designed to allow the client/user, within the constraints set out above, to make the functional/spatial, environmental and technological choices proposed and define the level of energy performance of the building. In this way, the client/user responding to the format is not only able to define the building that meets his needs, but also its cost, thus obtaining a true online estimate. This data necessary for both the designer and the manufacturer are thus available directly on the network. This computer system will also allow to control costs throughout the life cycle of the building through the use of BIM tools. The whole process has been implemented through Revit (BIM software). The families of the elements and packages most used in buildings were created, and the schedules were managed by formulas contained in spreadsheets; in this way has been possible to improve the computation process.

FAMILIES CREATION

Revit families are used to create building models. Each family has very precise and measurable parameters. It must be specified that the designer must choose what kind of family to use to represent a certain element of reality. Usually the names of the families indicate the purpose of the family itself (i.e. the Wall family indicates that with that input key a wall can be created), but the use of a key is not univocal and can be useful for the creation of other elements. By way of example, in Figure 1, the family of windows and French windows specially designed is shown.

SCHEDULES CREATION

Revit schedules, realized for all construction elements, are summary tables useful to computation. The peculiarity is that these schedules, in order to extrapolate the necessary information, must be set with specific grouping and filtering formulas, so as to exclude irrelevant information. Thus, ordered abacuses have been created that can facilitate computation. In this way, the completion of the final spreadsheet for the creation of the estimate is easier and faster. Furthermore, in the case of project variants, the quantities of the abacuses are instantly updated.

COMPUTING IN STR-VISION

STR-Vision is a software for the management of orders and for the metric-estimation computation of orders. One of its strengths is the interoperability with BIM, as with the import of the Revit model in STR it is possible to generate computations and complete estimates. The work that was performed at this stage was to allow communication between Revit and STR. To do this, we worked in the STR environment so that the software would recognize the Revit families, extracting from these the desired quantity correctly. The process took place as follows:

1. Creating a model in Revit with all the useful families present in the model itself, in order to create a file that contains all the families, ready to be imported and recognized in STR (figure 2).
2. Export of models in .IFC 2x3 format.
3. Opening of STR-Vision.
4. Creating a Catalog of Rules. Before creating the rules, we need to create a Catalog (on System Settings) that will serve as a container to the rules.
5. Creation of articles: it is in fact necessary to create all the articles to be used. The articles are found in a Price List created ad hoc in the "Price list" section. Each item has a unique Reference Code, a short description, a unit of measure and a price. These are the basic parameters that each article must have. Articles can be added, modified or deleted at any time, paying attention to the hierarchy that commands them. Subsequently the families of the Revit model will have to be "connected" with these articles, in particular to the unit of measure of the article.
6. A new Project has been created, which can be found in "Projects and Orders". Only once created a new project, it will be possible to import the IFC model created in Revit. In "IFC models" you can add the .ifc file and, once active, use it.
7. In the Budgeting section, we must now do the so-called "Collections", that is, make sure that STR detect the families of the .ifc model linking them in the List Items.
8. The imported model is displayed and proceed with the measurements. The measurements must be made by setting the search conditions, filtering and selecting the information useful in the selected family (cubic meters, square meters, descriptions, etc.). Once the surveys have been generated, they will be connected to the chosen family.
9. Finally all Rules to compute families have been created.
10. Once this is done, you can use these rules for any future estimate, of course only if the same families will be used in Revit.
11. It goes therefore in the BIM section and the Parametric Estimate is used. Once the Catalog is loaded all the rules created are loaded and the automatic estimation of the software can be started. STR generates the Automatic Collections at this point.
12. After generating the surveys, a print template has been created and the estimate can be printed and presented.

ILLUSTRATION OF ON LINE USE OF THE PLATFORM

In succession are shown below, for example in the case of residential building, the various steps that the client/user must directly perform on a hypothetical on line platform, in order to be able to create a preliminary estimate. The first page of a building site specifically created in order to allow configuration by the client/user, should show an image in which he can choose the type of residence as shown in Figure 3.
After this step, the client/user must choose the construction technology of the vertical structure, and of the roofing. Three systems are foreseen for the vertical

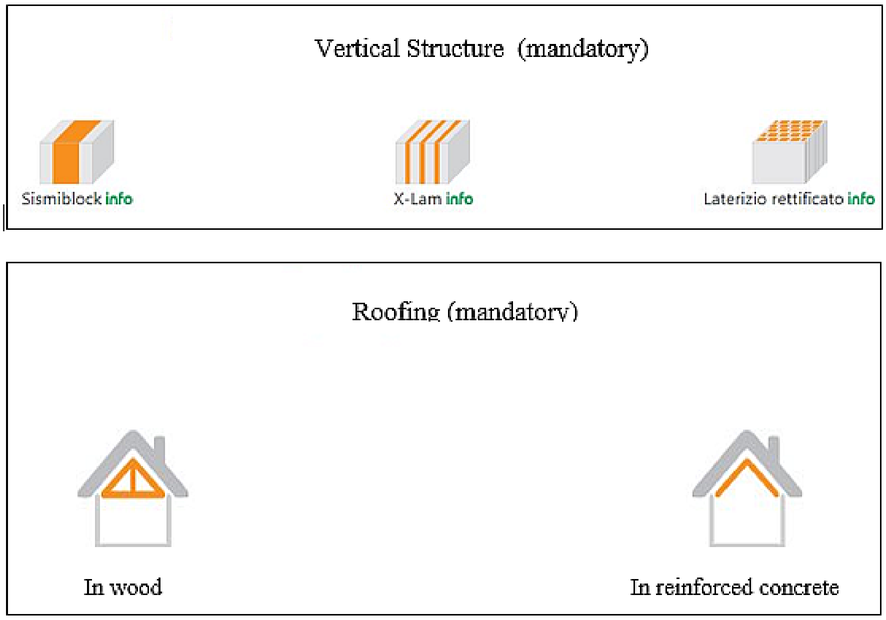


Figure 3: Initial screenshot in which the client/user can choose the type
Figure 4: Screenshot for selecting the vertical structure technology and Roofing

structure: partition in reinforced concrete with disposable formwork in eps (icon on the right in Figure 4), in clt (central icon of Figure 4), in rectified brick blocks (icon on the right of Figure 4) and for roofing systems: wooden or reinforced concrete structure.
The next step involves the definition by the client/user of the surfaces of the environmental units, such as living room, kitchen, living-dining room, laundry and power plant, garage and porch.
A final step consists in the choice by the client/user of the type of electrical and thermo-mechanical system, of sewage and sub-services and of the number and size of the bathroom w.c.unit allowing the choice in relation of the dimension between three types, small equal to 4 sqm 4, medium 6 sqm and big 8 sqm, as illustrated in Figure 5.
Now the estimate can be printed in a summary sheet. In this way, through simple steps on one side, the client/user has configured his home and quantified the cost, on the other hand the designer and/or the manufacturer has, in a clear and documented manner, knowledge of the exact needs of the client/user.

DESCRIPTION OF THE NZEB RESIDENTIAL BUILDING AS ARESULT OF THE GUIDED DESIGN

The case study, designed from scratch, and chosen for the present work is a semidetached house, Figure 6. The building is spread over 2 floors above ground, and consists of two units that share the central spine wall. It is assumed to be located in the province of Treviso. The basic dimensional data of the building and the rooms are summarized below. Altitude 6 meter. above sea level, in the climate zone E.
On the ground floor there are porch, garage and laundry room and the following environmental units: entrance, living room, kitchen, hallway, bathroom.
On the first floor there are the following environmental units: hallway, two double bedrooms, a single bedroom, a walk-in closet, a bathroom and a lodge.

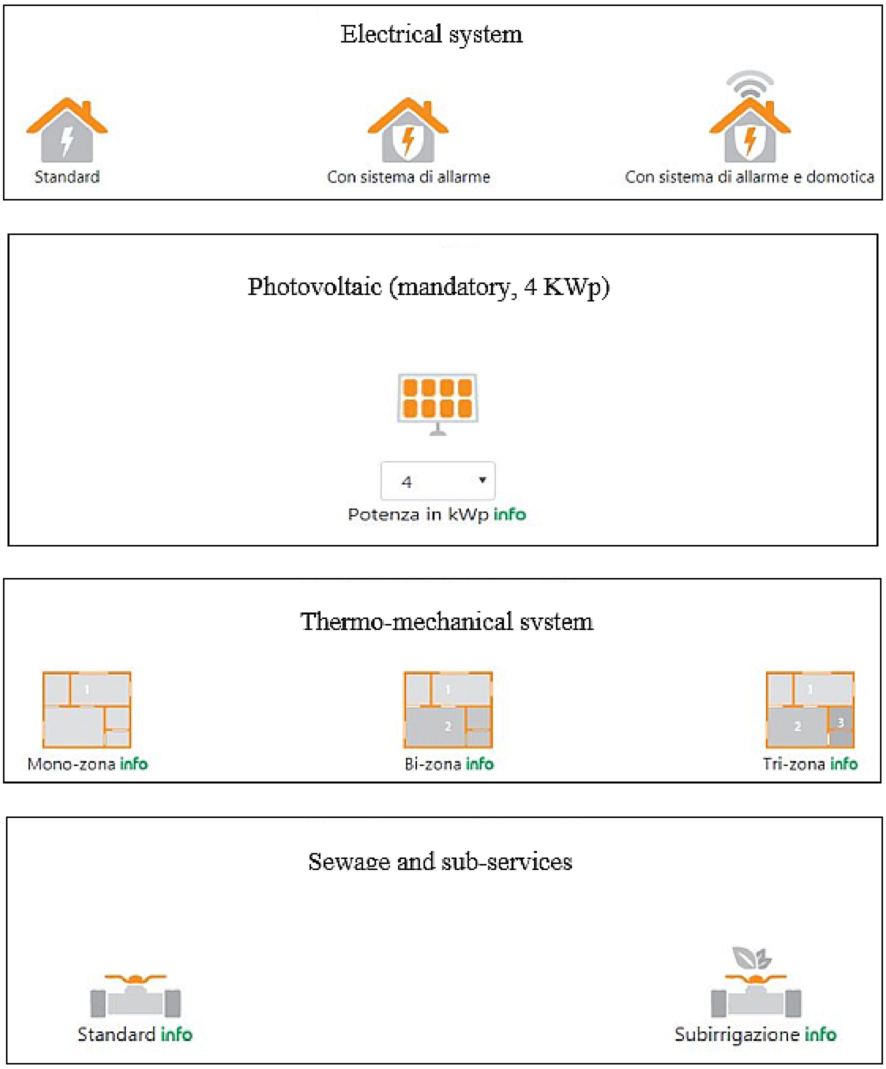


Figure 5: Screenshot for selecting the system type
Figure 6: Semi-detached house model realised in BIM

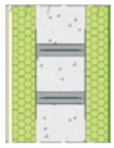
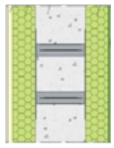
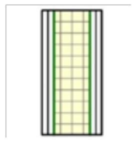
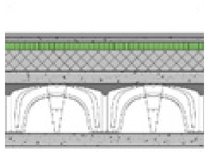
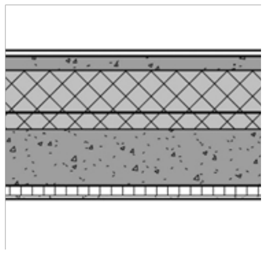
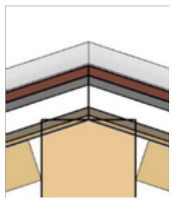
MODEL IN REINFORCED CONCRETE AND EPS		
Element	**Description**	**Image**
Load-bearing perimeter wall and wall between heated –unheated rooms	External plaster - 7 mm External EPS - 124 mm Reinforced concrete - 192 mm Internal EPS - 64 mm Plasterboard finishing - 12,5 mm	
Load-bearing internal wall between heated-unheated rooms	Plasterboard finishing - 12,5 mm External EPS - 64 mm Reinforced concrete - 192 mm Internal EPS - 64 mm Plasterboardfinishing - 12,5 mm	
Internal wall	Plasterboard double layer - 25 mm Metal and stone wool structure - 75 mm Plasterboard double layer - 25 mm	
Floor on the ground	Floor finishing - 15 mm Screed - 50 mm Nylon Foam polystyrene - 60 mm Integrated systems lightweight screed - 170 mm Casting completion - 100 mm Plastic Iglù Formwork- 400 mm Lean concrete foundation 100 mm	
Slab floor	Floor finishing - 15 mm Screed - 50 mm Nylon Lightweight screed - 170 mm Casting completion – 60 mm Airfloor slab floor in concrete and Polystyrene – 200 mm Metal structure – 35 mm Plasterboard slab – 12,5 mm	
Roofing	Elyforma metal layer – 45 mm Metal structure – 30 mm Polyurethane – 100 mm Mineralised wood wool 35 mm Vapor barrier Wooden boards – 21 mm Wooden roof beams	
Windows	PVC	
Air conditioning	Heatingpump + Accumulation + ATU	
Photovoltaic	4 kWp photovoltaic system	
Electrical	Electricalsystem + AAL system	

Table 2: Model in reinforced concrete and EPS

Analysis of construction techniques, materials and components

The construction techniques, materials and components considered for the 3 design models are analyzed. The evaluations on the choice of the technological packages analyzed are shown: Load-bearing walls in reinforced concrete and EPS, in CLT and wood fiber, in brick and stone wool.

Concrete model with disposable formwork in Eps

The model with reinforced concrete bearing walls considers 16 possible types of wall. The reinforced concrete is cast into EPS formwork, which act as both a formwork and an insulating layer. The thickness of the internal insulating layer in EPS is 64 mm, the external insulating layer provides the following possible thicknesses: 64 - 94 - 124 - 184 [mm]. For reinforced concrete, the expected thicknesses are: 142 - 162 - 192 - 250 [mm]. Considering the minimum transmittance value equal to 0.26 W / m2K as foreseen by the D.M. 26/06/2015 for buildings in band E of the year 2021, all the walls are compliant. The nZEB stratigraphy of the project is shown in table 2. As regards the external thickness of EPS insulation, it was decided to use the 12.5 cm one for both the external walls and between the heated and non-heated rooms. For the spine wall located between the 2 garages (ground floor) and between the two bedrooms (first floor) there are provided coats of 6.4 cm on both sides because between environments that have the same temperature does not occur heat exchange.

Wall in Cross Laminated Timber and wood fiber

The model provides the supporting structure in CLT that can vary in thickness and the layer of insulation in wood fiber that can vary in density and thickness. The package has been studied varies with the thickness of the layers, at steady state and at periodic system stabilized, to check if there are phenomena of superficial or interstitial condensation and it has been verified that the optimal solution is that that foresees for every technical element the following stratigraphy:

- Load-bearing perimeter wall: External plaster - 7 mm, Hard wood fiber - 40 mm; Wood fiber - 80 mm; CLT - 100 mm; Acoustic wood fiber – 50 mm; Plasterboard finishing - 12,5 mm;
- Load-bearing internal wall between heated-unheated rooms: Plasterboard finishing - 12,5 mm; Acoustic wood fiber – 50 mm; CLT - 100 mm ;Acoustic wood fiber – 50 mm; Plasterboard finishing - 12,5 mm;
- Internal wall: Plasterboard double layer - 25 mm; Metal and stone wool structure - 75 mm; Plasterboard double layer - 25 mm
- Floor on the ground: Floor finishing - 15 mm; Screed - 50 mm; Nylon; Foam polystyrene - 60 mm; Integrated systems lightweight screed - 170 mm; Casting completion - 100 mm; Plastic Iglù Formwork- 400 mm; Lean concrete foundation 100 mm;
- Slab floor: Floor finishing - 15 mm, Screed - 50 mm; Nylon; Lightweight screed - 170 m; Acoustic cladding; CLT load-bearing slab floor – 180 mm, Metal structure – 35 mm; Plasterboard slab – 12,5 mm;
- Roofing: Elyforma metal layer – 45 mm, Metal structure – 30 mm; Polyurethane – 100 mm; Mineralised wood wool 35 mm; Vapor barrier; Wooden boards – 21 mm; Wooden roof beams.

This stratigraphy is optimal for transmittance (0.27 (W / m²K), for winter comfort (0.18 W / m²K), for summer comfort being the decrease factor of 0.055 and a time displacement equal to 17 hours. Also the acoustic comfort is optimal, having a soundproofing power of 39.7 dB. This stratigraphy is also

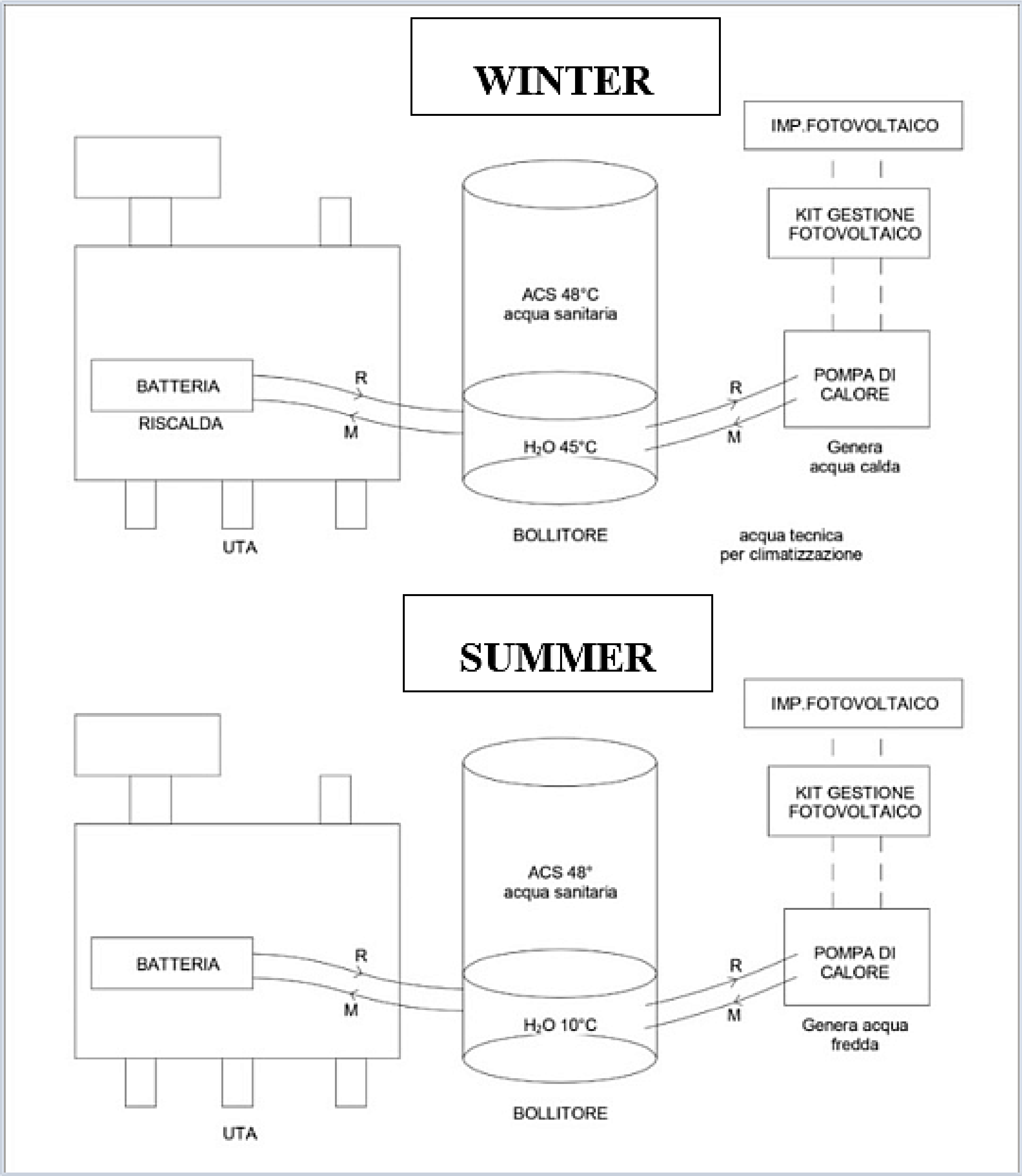


Figure 7: case study project systems scheme
Figure 8: AAL system scheme

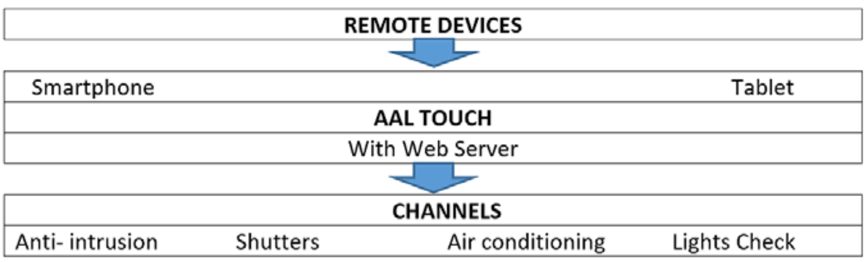
used in design between the heated and unheated rooms (between living room and garage

WALL IN BRICK AND STONE WALL

The model provides the load bearing structure in Poroton Brick, rectified, which can vary in thickness and thermal insulation in stone wool equal 10 cm. The following cases are considered: Poroton 25 + stone wool + Poroton 12, Poroton 30+ stone wool, Poroton 38, Poroton 45, Poroton 44. The potential of the brick walls without insulation was also evaluated.

THE INSTALLATIONS OF THE CASE STUDY PROJECT

The building in nZEB project is composed of the following systems: Air Treatment Unit, Heat Pump, Photovoltaic, Induction cooker, Ambient Assisted Living (AAL) Kit. The heat pump is equipped with an external monoblock, with two pipes (supply and return) connected to two accumulations (a tower of 90 lt and 300 lt) located in the technical room. The lower accumulation is the accumulation of hot / cold (water at 45 ° C in winter and at 9 ° C in summer), the upper one provides domestic hot water with a capacity of 300 lt. The lower 90lt storage tank is equipped with a circulation pump that allows hot / cold water to be sent to the ATU (Air Treatment Unit), throughout the building (first floor and ground floor). The heat pump has a capacity of 9 thermal kilowatts, i.e. 9.5 kW/ h for heating and a power of 6 kW for cooling. During the design phase it is necessary to make sure that these powers are higher than the requirements in kW of the net requirements of the systems requested by the user, as specified by the calculation software. The part of generation is therefore entrusted to the heat pump, which is equipped with 2 kettles. From there the pipes that connect to the air-conditioning terminals depart. The smaller air handling unit can process 500 m^3/h of air, the larger one can treat 1000 m^3/ h in the supply. The system scheme is shown in Figure 7.



AMBIENT ASSISTED LIVING (AAL) PROJECT

The project of the nZEB case study foresees the AAL system. It is calibrated according to user needs and aims to simplify the management of the home digitally, in order to offer a friendly service to the user. Therefore, according to the user's choices, Figure 8, the appropriate terminals will be installed. Building Automation offers the building the following functionalities:

- Video surveillance/Anti-intrusion: in order to satisfy the need for security, the AAL system can be connected to cameras and sensors placed in strategic positions of the house.
- Lighting: the AAL manages the lighting system of the house, giving the user the possibility to choose which lighting fixtures to turn on/off (ON/OFF), to choose the lighting times, and the intensity (function of dimming).
- Thermoregulation: from the AAL touch and from the remote application, it is possible to manage the temperature and humidity in each thermal zone of the building. Also in this case the on/off time can be programmed. In the thermoregulation function, meetings were held between the suppliers to understand what protocol to use in the communication between the home automation system and the air conditioning system.
- Energy saving: the management of lighting fixtures, and the air conditioning system allows for energy savings. The dimming function in particular allows the intensity of the lights to be dimmed according to the light comfort already present in natural lighting environments. Consumption is monitored by the Load Control function.
- Motorization: this feature allows automatic control of blinds, shutters, Venetian blinds, gates and windows. In most cases it can be used if users are elderly or with motor disabilities. In the case of nZEB with very high energy efficiency, the automatic motorization generates the opening/closing of certain windows to create natural ventilation whenever the ambient operating temperature exceeds the comfort temperature.
- Audio / Video: to satisfy the need for entertainment, it is possible to distribute audio and video signals.
- Since the various system components, as commonly happens in practice, come from different supplier companies, a single AAL touch has been studied, able to dialogue with all the components in order to have a single building management. For this purpose, it is possible the use of the Konnex protocol (KNX). In fact, it is the first open building automation standard, operating with an event notification logic.

CONCLUSIONS

The present work, shows how it is possible to provide the client /user with a smart tool whereby, through an online platform, starting from the definition of their needs comes to outline the future high-performance building, both functional /spatial, environmental and technological, as well as its cost. A route has been designed that the client/user can carry out independently for subsequent steps. The consequences of this approach are manifold. First of all, it contributes to making the client/user aware of the advanced technologies that will be installed in the building work, a fundamental step for the optimal use of the same during operation. Secondly, this approach helps to make the planning and execution phase shorter, thanks to the fact that much of the technological design and verification of the same has been carried out upstream, with the optimization of the process and therefore with the reduction of costs of the work against a high quality of the same. The future development of the research lies in the further implementation of this approach both in the online interface and in the interoperability of the BIM software used.

Bibliografia
Bibliography

AA.VV. (2015). *Innovazione e sostenibilità nel settore edilizio "Costruire il futuro", Quarto rapporto dell'osservatorio congiunto*, Feneal Uil - Filca Cisl - Fillea Cgil Legambiente.

Buckman, A.H., Mayfield, M., Beck, S. B.M. (2014). "What is a Smart Building?", *Smart and Sustainable Built Environment*, Vol. 3 Issue: 2, pp. 92-109, https://doi.org/10.1108/SASBE-01-2014-0003

De Groote, M., Volt, J., Bean, F. (2017). *Smart Building Decoded*, Buildings Performance Institute Europe, BPIE.

De Groote, M.,Fabbri, M.,Volt, J., Rapf, O. (2016). *Smart buildings in a decarbonised energy system*, Institute Europe, BPIE.

Eastman, C. M., Eastman, C., Teicholz, P., & Sacks, R. (2011). *BIM handbook: A guide to building information modeling for owners, managers, designers, engineers and contractors*. John Wiley & Sons.

Ghaffarianhoseini, A., Berardi, U., AlWaer, H., Chang, S., Halawa, E., Ghaffarianhoseini, A.& Croom, C. D. (2015). *What is an intelligent building? Analysis of recent interpretations from an international perspective*, Architectural Science Review, 59:5, 338-357, DOI: 10.1080/00038628.2015.1079164.

IBR, Intelligent Building Report. (2016). *Il ruolo ed il potenziale di mercato delle soluzioni smart nel contesto italiano*, Energy and strategygroup, Politecnico di Milano.

World Economic Forum. (2016). *Shaping the Future of Construction,A Breakthrough in Mindset and Technology*, Geneva, Word Economic Forum.

World Economic Forum. (2016). *Environmental Sustainability Principles for the Real Estate Industry*. Geneva, World Economic Forum.

World Economic Forum. (2017). *Shaping the Future of Construction, Inspiring innovators redefine the industry*, Geneva, Word Economic Forum.