ADOPTING ECO-EFFICIENCY STRATEGIES INTO MAINTENANCE ACTIVITIES OF EXISTING BUILDINGS

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Summary

This research is aimed at obtaining innovative building components for introducing zero energy principles into maintenance activities of real building stock.

This goal is justified by the awareness that nowadays the building performances, in particular during the lifespan, are one of the main responsible of resources and energy consumption. Especially in the Italian context, where most of the existing buildings are generally made of technological-construction systems which are not fit to minimize energy consumption.

For this reason the research is focused to prove that an environmental-friendly components replacements is a way for an extension of building life span with a high level of eco-efficiency and at the same time it is strategy for improving environmental performances along with whole building life cycle.

After a background analysis concerning the connection between sustainability-maintenance activities and the state of the art of existing buildings using the examination of several existing building thermography investigations, the study has been picked out the building components or subparts, where heat losses are unusual.

Thanks to this analysis, by adopting the Design by Components approach it has been possible to set new requirements for these elements, not just regarding energy efficiency, but also in favour of the inhabitants well-being.

The paper deals with the results collected so far into designing innovative building components/solutions able to combine maintenance activities with energy efficiency strategies.

Keywords: Building Eco-Efficiency Maintenance, Building Components, Design by Components approach

1 Maintenance activities and eco-efficiency of existing buildings

The research began with a background analysis in order to investigate in which way the renovation and maintenance activities could be considered in Italy in regard to two current issues such as the state of the art of the existing building blocks and the building eco-efficiency strategies.

Concerning to the state of the art existing buildings, if 40 years could be assumed as the critical age of a building when could be identified an high level of obsolescence of its technical plants and components, so it will be possible to estimate that in Italy in 2020 more than 80% of existing buildings will be out of date [1].

Obsolescent existing buildings conceived for several use (residential, industrial, commercial, etc) and generally made of concrete framework with an envelope made of brick or concrete panels. In other terms buildings made of materials and technological systems which are not fit to minimize the heat losses and overheating with a consequently high energy consumption and CO2 emissions due to the heating and air conditioning plants. Consequently it is possible to argue that the existing buildings in Italy can be considered as one of the most responsible for resource consumption and environmental impacts, specifically during their usage phase [2].

For this reason, as established by the Italian Legislative Decree (at national and regional levels) which implement the recent European Directive (2002/91/CE), it is introduced the concept of energy certification of buildings for improving the eco-efficiency of buildings lifespan, as it is for the energy label of electronic and electrical equipment.

In order to face the progressive obsolescence of the existing building, in conjunction with a contraction of the new building market, it is possible to underline that in Italy the renovation and maintenance activities have been playing a central role over the years with an increase of the renovation activities and the same time an evolution of maintenance activities from being simple repair works, when the damage has already happened, to a system of preventive and planned activities aimed at preserving the quality and the economic performances of buildings in time [3].

As a consequence, the maintenance procedures have been gradually undertaken as a service strategy and new advanced real estate companies have arisen in the property market, which are specialised in building or facility management services during building lifespan [4].

On the other hand in regard to the environmental sustainability principles, which could be translated in two main eco-efficiency goals such as the minimisation of the resources consumption (material and energy input) and the emissions (solid waste, air and liquid output into the environment) along with its life cycle, a suitable building maintenance procedure can be consider as a strategy for reaching these environmental goals, because it extends the operating lifetime of a building, thereby postponing the time of its end of life (including its demolition and the following waste production and disposal) and, at the same time, deferring the consumption of new resources for the construction of a new one.

From this building life cycle point of view, it is crucial underlining that the maintenance and renovation activities do not have to focus exclusively on the preservation of the current building economical value and functionality but most importantly have to improve the energetic and environmental performances of building lifespan. In this way the renovation activities which involve the replacement of eco-efficient building products could be the right solution able to improve the building energy performances not just during its lifetime, but also along the whole building life cycle.

As a result, we can conclude that the main scenario of this research has been the existing energy consuming buildings and the correlated maintenance and renovation activities involving building components replacement.

2 Building components able to prejudice transmittance performances

Following this background analysis, the research has been carried out through an analysis of several building thermal imaging surveys in order to identify building macro-components or components where heat losses are recurring.

Through the use of the infrared thermography, which is a non-invasive diagnosis technique, it is possible to see the radiating temperature of building structures and elements and as result to detect the main anomalies in the temperature distribution, which generally mark transmittance performances problems in some specific building area generally due to heat losses or dump infiltrations.

Thanks to the reading of several building thermal imaging related to different kind of building it has been possible to identify the recurring heat losses bridge which are corresponding to some specific building macro-component/subparts able to be classify in two main categories, such as (Fig.1):

- constructive heat loss bridges: which are due to an incorrect design process or to a not correct built on site during the construction phase and so they could be avoidable, such as: part of the external wall under/over windows, windows and doors (including ledges, fasteners, shutters and frames integrated into the wall), drain gutters and pipes of the rainwater collection system, smokestacks connected to the heating system;
- geometric heat loss bridges: which are due to the building structure and are unavoidable such as roof ledges, string-course bands, balconies and terraces, where there are overhang elements or the internal edges where there is the connection between attics, walls and floor surface.

Fig. 1 Usual heat loss bridges corresponding to building macro-components or subparts

Therefore these identified critical building components and subparts, where the constructive heat loss bridges could be avoidable and solvable (Fig. 1), will be the specific objects of the research design activities in the following phases.

3 Design by Components applied to the building components

After delineating the research scenario and identifying the specific object of the study, this research phase is aimed at developing new concept project for these critical building elements, so that they could meet both eco-efficiency and maintenance requirements.

The Design by Components (DbC) methodological approach will be therefore adopted in order to pursue this crucial purpose. Such approach has been conceived at DIPRADI Department in order to design really innovative and environmentally-friendly products, where the man is at the centre of project (Fig. 2).

Specifically, by adopting this method, the design process starts from a critical analysis where the product is dismantled (concretely or abstractly) so as to better understand its constituent parts (both materials and components).

A follow-up meta-project phase is then carried out, including several kinds of analysis about different and interrelated aspects such as: the macro-components and components scheme, the functional scheme explaining the connection between the composition and the functionality of the object under study, the analysis of the correspondence between its function and shape, a sensory and perceptual scheme, a components lifetime scheme illustrating the main replacement and maintenance activities, an analysis of emotional relationships between the user and the object and a background analysis of the other similar products with the same function.

Thanks to these several analysis and schemes and by the adoption of an holistic point of view, as it is suggested by the DbC, the designers are able to understand mutual connections between the main functional groups and to define an essential scheme of the product under project in order to point out the problems and strengths, priorities and emergencies and finally to define the main needs and the subsequent guidelines and requirements system which have to be satisfy in the development of new product concepts [5].

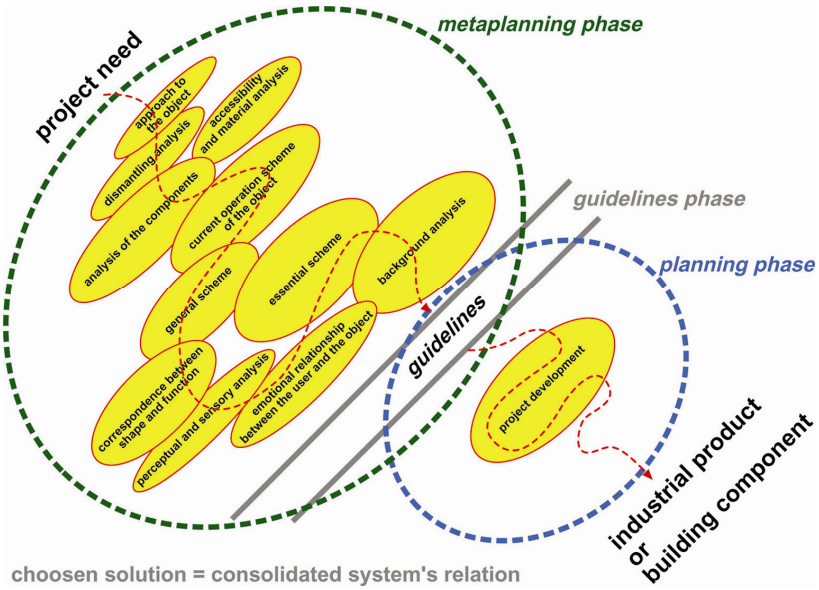

Fig. 2 Design by Components (DbC) methodological approach scheme

On the awareness that a nowadays several building components could be taken into account as an industrial product, because they are produced by manufacturing industries, delivered to construction sites and finally built on site by simple assembling works, these building products could be the way for a know-know transfer between two fields, Industry and Building&Construction, which look so distant. They could be the a common field of study where is possible a critical confrontation between building and industrial design cultures and process design.

Consequently, as it is made for an industrial product, the design of the building components could be regarded as a complex systems, which are decomposable into functional and then essential schemes, to be analyzed afterwards using a similar

methodological design approach in order to outline building solutions for the identified building components where the heat loss bridge could be avoidable.

In short term they should be the way by which put into practice the DbC into the building design process phase.

3.1 Meta-planning phase of building component design process

Concerning the first identified weak building component, the wall under/over the window, the meta-planning phase has began, with its dismantling from an abstract point of view, in order to understand its main macro-components such as: the wall under the window, where generally a heater is located, the window frame and the rolling shutters box (Fig. 3).

Focusing on the first macro-component, the wall under the window, the meta-project phase has been gone in with the preliminary analysis of the two aspects:

- the main critical issues and problems, which stress this building part and are able to influence the interior well-being. Specifically on this building macro-component has been identified the following recurring matters: heat loss bridge in the area of the rolling shutters box and in the wall portion under the window, where the wall has a reduced thickness generally in conjunction with an insufficient thermal insulation layer, cold air infiltration and hot air losses through the windows frame due to air tightness of gaskets in the windows frame and damp infiltration due to atmospheric elements and consequently building up of condensation inside the wall materials.
- needs which have to be satisfy by this building part in order to separate interiors from the outside elements, ensuring at the same time a fixing temperature and a good level of thermal inertia in the interiors. In order to gather this main function several requirements have to be satisfy such as: safety, usability, healthiness, perceptual comfort, building life cycle management and inhabitants well-being. The last two points, building life cycle management and inhabitants well-being, have the most influence on the building eco-efficiency performances.

Following this preliminary analysis, the building macro-component under study has been in details investigated in order to identify the different component or functional groups which are connected within a system of mutual relationships (Fig. 3).

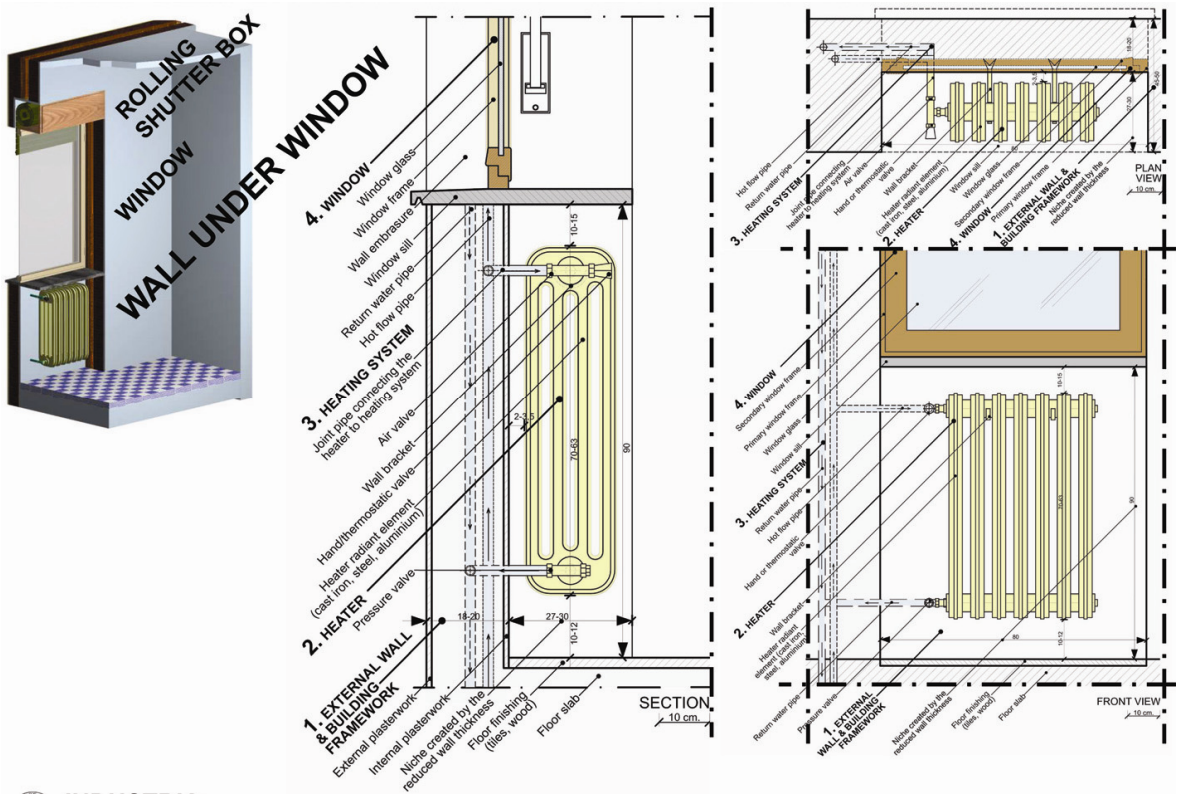

Fig. 3 Macro-component scheme and detailed scheme of the wall under the window components.

Therefore these mutual components relationships has been explored by means of several functional schemes, which could be organized in connection with the following four main components:

- External wall and building framework schemes: which make an analysis of the different typologies and materials useful for external walls and building framework of the existing buildings;
- Heaters schemes: which analyze aspect such as the expressive features of the different kinds of existing heaters and the current trends into designing new heaters, the method to calculate the heat output power of heater, the hot air convective flow circulation in a room, the operating modes of heat transfer and exchange of a traditional heater (Fig. 4);
- Heating system schemes: which illustrate the different ways by which the heaters are connected to the hot water central heating plant, such as vertical distribution of the heating columns or the horizontal distribution of heating pipes as network;
- Window frame schemes: which explore the several typologies of window available on the market or generally adopted in the existing building, the problems connected to the use of continuous window sill, the correct window location into the wall embrasure.

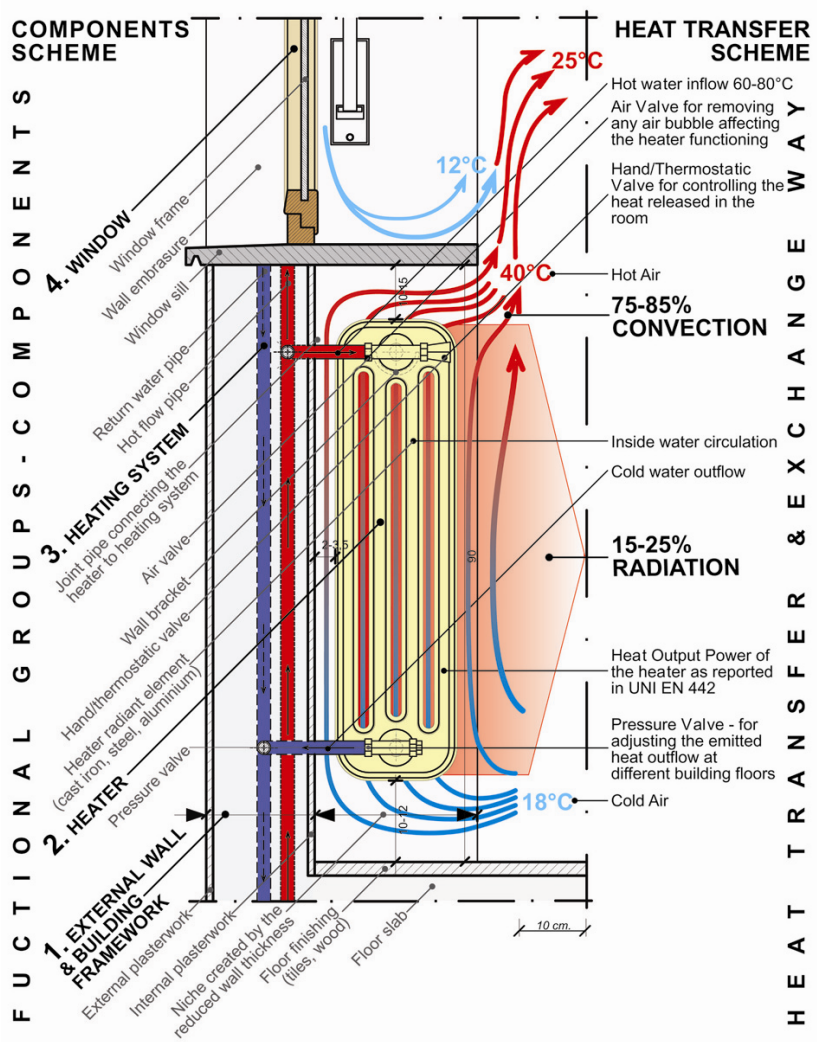

Fig. 4 An example of functional scheme concerning the heat transfer way of a traditional heater.

Finally an analysis of components lifespan with an indication of the different kinds of maintenance activities to keep it functional and their frequency has been carried out.

Thanks to these analysis schemes, illustrating the object under project (wall under the window), we can therefore identify the mutual connections between its components and then stress the main critical situations by means outlining new concepts for an innovative building component (Fig. 5).

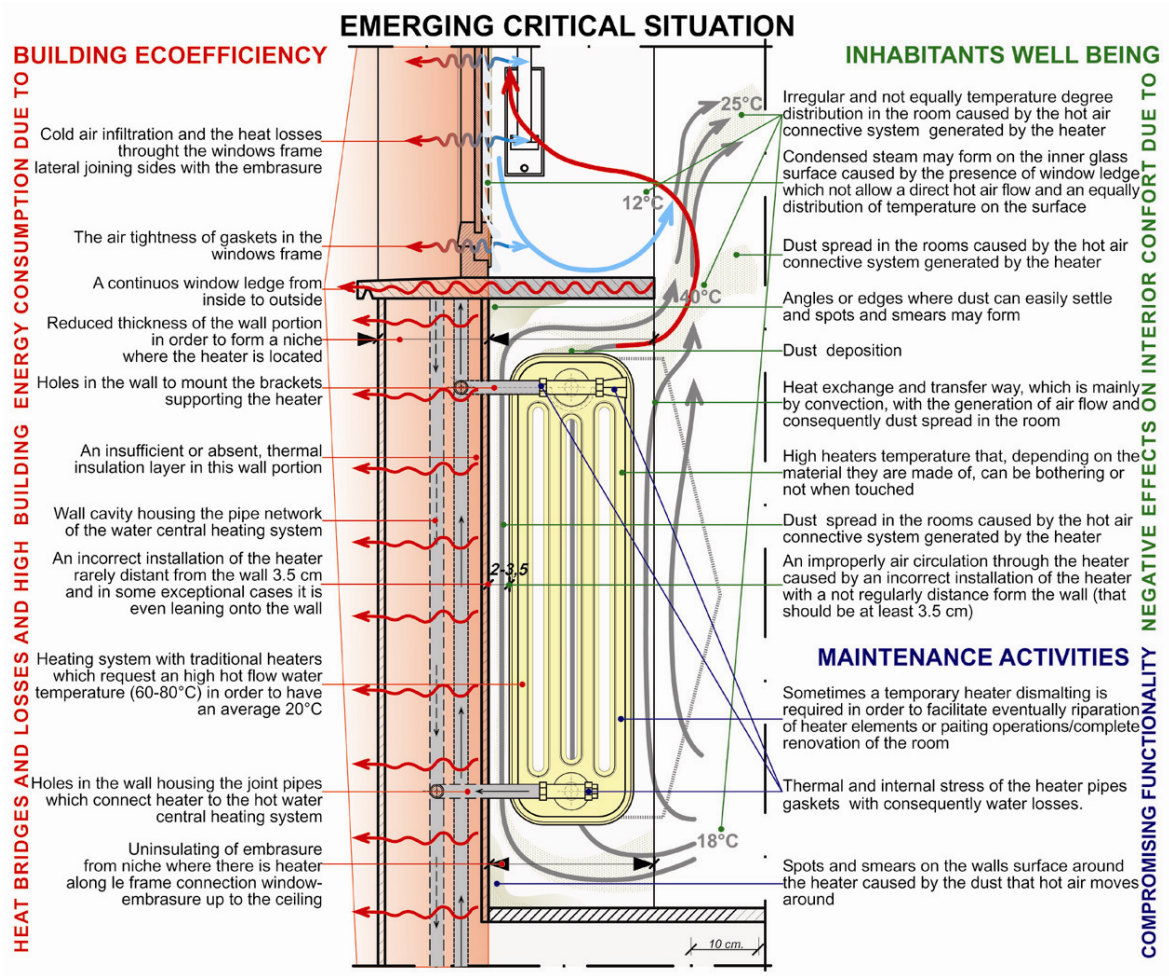

Fig. 5 Emerging critical situations scheme, which arises from the several analysis of the functional groups and their mutual relationships.

3.2 Need, requirement and guidelines system

Once the meta-planning phase is concluded, it has been possible to point out four main needs that should be satisfy during the project development, such as:

- the reduction, or the complete elimination of heat losses due to irradiation through the wall and window;
- the preservation of internal comfort;
- a quick and easy installation and maintenance operations;
- the reduction of the environmental impacts.

From each identified need derive requirements, guidelines, meta-project sketches and notes focused on the specific building macro-component under study.

In other words, in this process design phase, as suggested by DbC, we able to elaborate a needs, requirements and guidelines system scheme by means guide the following phase of the project development (Fig. 6) [6].

NEEDS	REQUIREMENTS	GUIDELINES
1. Reduction of heat losses due to irradiation through the wall	- Improving the wall insulation	- Using further insulation layers such as thermo-reflective slim insulation or other form of insulation with thermal conductivity low values - In case of building renovation (destructive intervention) ensuring a correct stratification of wall elements
	- Reducing the gaps in the wall contributing the heat losses bridges	- Avoiding screw anchors for securing new component into the wall and using components self-supporting - Avoiding heater installation directly into the wall - Avoiding continuous window sill, using solutions for thermal shearing perfomances - Arranging a correct thermal insulation of the wall embrasure - Improving the airtightness of the primary and secondary frames of the window
	- Substituting the heater	- Opting for an element granting a better output against a lower flow temperature - Respecting the minimum distance suggested of 3,5 cm. from the wall
2. Preservation internal comfort of the room	- Ensuring a uniform temperature distribution on the room	- Locating the heater in a correct position in the room
	- Preventing the condensation steam from building up on the inner window surfaces	- Avoiding positioning window sill or other elements which deviate hot air flows - Locating the window in the correct middle position (middle embrasure) of the wall embrasure
	- Avoiding dust deposition which is spread in the room by the hot air flows form the heaters	- Reducing or rouding the edge niche where the heater is positioned
3. Foreseeing an easy and quick installation and maintenance activities	- Preserving the existing heating system	- Avoiding to change the position of joint pipes connecting the heater to the heating plan
	- Adapting to the different shapes and size of the wall niche	- Using a system of components to be adapted to the different shapes - Adopting reversible joints and fastening system easily assembling/disassembling
	- Facilitating component disassembling	- Using reversible joints and fastening system which facilitate disassembly and materials separation
	- Facilitating maintenance and cleaning activities	- Using reversible joints and fastening system - Planning to move the heater without disconntecting it form the heating system
4. Reducing environmental impact	- Selecting components with a low environmental impacts along the whole life cycle	- Using materials derived from renovable resources - Adoping materials whose manufacture processes include a fraction of recycled resources
	- Reducing environmental impacts during the production, distribution and installation phase	- Reducing manufacturing and installation scraps and waste - Using local materials in order to reduce the transport emissions - Foreseeing easily stackale packging in order to optimize the trasnport and delivery

Fig. 6 Table of the needs, requirements and specific guidelines system that should be satisfy during the planning process of project solutions able to improve the performances of the wall under the window.

3.3 Project development phase

On the basis of the needs, requirements and guidelines system, in this ongoing process design phase new concepts project are drawing, which are mainly concerning the building component shape and configuration [7].

In other words the project development is guide by the respect of needs and guidelines system and will be aimed at including the largest numbers of meta-project sketches and notes (Fig. 7).

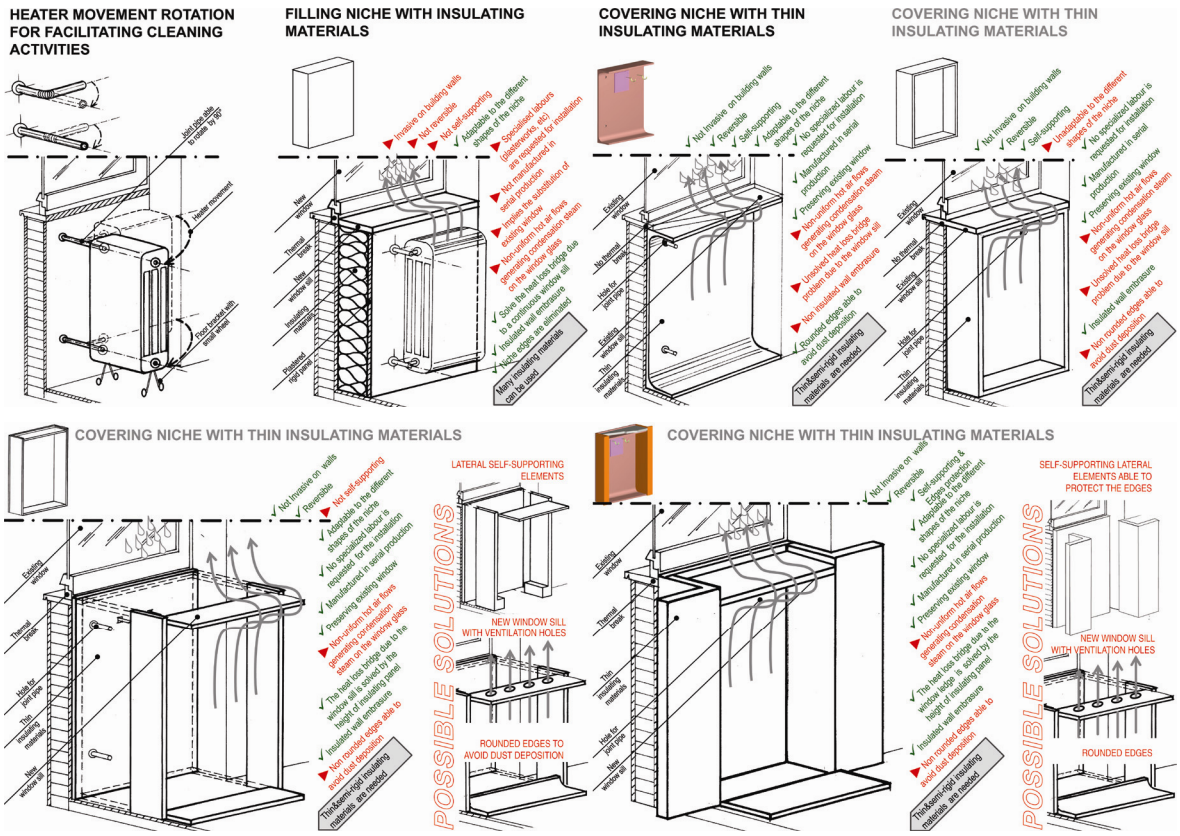

Fig. 7 Meta-project sketches under development in order to outline innovative building components following the guide of the needs, requirements and guidelines system scheme.

In conjunction with outlining the most appropriate configuration for the new concepts, a material investigation is making by consulting MATto, which is a material library actually including more than 500 samples of new generation material.

The innovative aspect of MATto is making available and environmental material profile in conjunction with a perceptual and sensorial analysis, which could be comparable with the traditional materials analysis provided by other well-know databases and material library (CES2009, Matrec, etc.) (Fig.8).

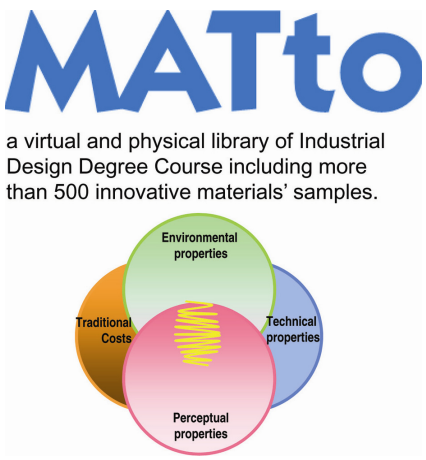

Fig. 8 MATto logo.

Actually the material exploration is focused on innovative insulating materials in comparison with the traditional insulating materials. Innovative insulating materials, such as: the thin thermo-reflective insulating materials made of multilayer of PE and aluminum, the aerogel blanket (Fig. 9).

By the MATto support it is possible making an evaluation of materials, which is based on some specific requirements that should have to be satisfy by the project materials.

In this way, with the choice of correct material and shape combination it will be possible to outline the final concept project for a new building component adoptable in the wall niche and able to combine the sustainability and maintenance needs.

Fig. 9 Analysis scheme of some innovative insulating materials which could be adopted by the project of building component solutions.

4 Conclusion

Thanks to this real application of DbC for outlining new concept useful for buildings part, wall under window, we can conclude that the DbC could be used also to tackle the design of building component.

In this way the architect and the designers, by means of defining the families that the previously outlined objectives are bound to, and then after the analysis over their nature and mutual relationships, will be able to finally choose the most appropriate meta-planning configuration and face the following planning definition and execution phases.

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