Innovative skins and domotic systems: the technological design for residential buildings' energetic efficiency

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ABSTRACT: Comfort and efficiency needs require the realisation of "smart architectures" with a supervised energetic and environmental operations, consisting of dynamic skins: complex systems made up of blocks and filters able to adjust heat, solar radiation, air and vapour flows and also to convert the radiations in energy (heat energy and electricity).

The innovation works above all through the operations of management and control of the skins. Domotic systems, consisting of groups of sensors and computerized control unit, are able to adjust the orientation, the opening or the position of the elements of the façade to optimize the energetic efficiency of the building. Moreover, the technological integration and installation aims making building as a "living being", able to self-regulate to grant the comfort of the users, using exclusively renewable energy.

Some kinds of innovative building skin façades are: parametrical and photovoltaic façades, photocatalytic covers, self-cleaning systems treatments and façades with micro-algae.

This contribute shows the results of a research about the technological systems of façades adjusted by domotic systems, able to comply with more and more ambitious performing targets and more and more restrictive normative requirements, and it suggests a classification that joins traditional functions and innovative performances.

In particular, it is a technological project of a multilevel building placed in the mediterranean area, where the domotic system adjusts the air flows according to the external environmental conditions, reducing energetic consumptions and in the meanwhile contributing to satisfy the indoor comfort performances.

Keywords *Building skin, Domotic system, Technological design, Energetic efficiency*

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1. INTRODUCTION

Either we speak about a curtain, or we speak about a heavy masonry building or made up of concrete or full of glass, the envelope has always played the function of repairing and protection from outdoors. To achieve performance goals imposed on European level for the construction of buildings with nearly zero energy level, the concept of the building envelope has been necessary transformed. In fact, it is turned from the concept of external protection (Passive system) into the regulator active element (Dynamic system).

Even if the discussion about the role of the mechanically controlled environmental systems was born in 1920, the major awareness about the influence generated from the building sector about energy consumption has taken place in 1960 in conjunction with the spread of the 'bioclimatic architecture' concept, and even more in 70s after the energetic crisis. However, we have to wait until 1990 for the full realization of innovative ideas about sustainable buildings envelopes from prestigious architect (Foster, Otto, Rogers and Piano), (Hawkes & Foster, 2002).

If you think that the building represents over the fourth percent of total energy consumption to which the building envelope gives a great contribution, it is also evident that energetic saving can be obtained through simple alteration in the façades systems. In fact, the need to try system of wall that can assure flexible energetic performances and adequate to the weather conditions and indoor wellness needs, have pushed the scientific world to render more strong technological search in this sector. There are often new specimen ration of innovative envelope systems in order to demonstrate how it is possible to adopt, for the vertical and horizontally surface of closures, thanks to which it is possible to manage and control passers flux with dynamic mechanism as if it was an "living organism". The evolution and the development of informatics control system, from home automation to the Building Management System (BMS), have allowed to transfer to the building scale the potentiality of system with artificial intelligence.

2. BUILDING FACADES

Intelligent architectures represent the last frontier of contemporary architectural research, which aims at proposing new dynamic envelope models able to contribute to the reduction of energy needs of buildings, making it strictly dependent from external climate - environmental conditions, and developing all those components that increase the ability to change the conformation in relation to the necessity to control the flux of thermal, bright and sound energy passing through it (Sala & Romano, 2011).

If the possibility of conventional façades to turn is managed by who occupies the building (for example by the simple opening of windows or the manual adjustment of shading devices), the intelligent façades, instead, can turn it-self through instinctive autonomous regulation (Wigginton & Harris, 2002).

Since the need of users and the climatic condition are variable, a performant façades cannot be conceived as static element but as dynamic dispositive able to adapt it-self to different conditions and respond to these changes. For this reason, the intelligent architecture can be defined as a kind of architecture that is able to reconfigure itself if it is

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stimulated by the environment and users. The capacity to provide a dynamic response presupposes that the building is able to “know” the changes having inside and outside, "to choose" effective solution to give a comfortable environment for users, and "to react" according to this choice (Atkin, 1989).

Parametric façades, photovoltaic façades, photocatalytic envelopes, treatments for self-cleaning systems, façades systems with micro-algae, are only few types of innovative building envelope.

2.1 Definitions

Although the literature on the intelligent envelope is still lacking, there are many definitions about intelligent buildings e intelligence façades. It is difficult to find a single definition because each author highlights some factors compared with others. For this reason, in fact, is possible to identify four categories of definition about the intelligence of buildings, elaborated in relation to (Table 1):

- System and technology used
- Performances
- Users role
- Costs.

For example, the definitions based on the façade system, shows the main technological aspects used in the construction system, like the automation, system of control, communication and networking (Leifer, 1988).

Instead, a definition of sustainable and intelligent façade based on guaranteed performance, it will have to consider different performance criteria, for example solar protection, control of daylight and shielding systems, active control of air and ventilation, the use of renewable energy source, control of the quality of the internal air, adoption of passive design strategy, auto regulation of systems. Also the possibility to react in relation to the façades by users, is very important to define an intelligent envelope; in fact, these systems, allows to the users to replace the system according to personal preference, certainly, in condition that the replacement doesn't compromise building performances in general.

Table 1. Summary of Definitions_ Classification for Intelligence in Buildings (Source: MASRI, 2015)

System and technology used	- Integration of several resource management systems; - Focus on technological aspects; - Change to the configuration through informatization system; - Change of the building management system algorithms.	Leifer 1988, Wong et al. 2008, Atkin 1989, Atkin and Brooks 2009
Performance	- Readjustment of the performance according to different internal and external conditions; - Algoritmo modification based on environmental data; - Reports on the energy consumption of the building and the interaction of the occupants; - On the basis of feedback data.	Wigginton and Harris 2002, Selkowitz 2001, Elkadi 2012, Masri 2015
The role of the users	- Adaptation to 'standards' of human comfort; - Possibility of human replacement; - User interaction with the system.	Wang 2009, Clements-Croome 2011
Costs	- Maximizing investment and operation; - Life cycle approach; - Maximize productivity, and reduce costs.	Smith 2002, Wong and So 2002

2.2 Dinamic building envelope: design and applications

Contemporaries convertible systems mainly refer to a climatic adaptability, characterized by the versatility of electronic devices and the lightness of building systems in order to have a lower energy expenditure and less time in turning. The extensible structures represent a type of extreme interest, as they allow different conditions of use and functional reconfigurations of various kinds.

It examines a number of examples of applications, not only contemporaries, about the concepts of intelligence, dynamism and responsiveness in architecture. It wants to be a demonstration of the strong interest and experimentation that characterized the architecture over the years, thanks to the strong interest that this research raises.

The examined study cases, are examples of different types of intelligent dynamic facades, identifiable in the following groupings (Table 2):

- Passive dynamic facades with integrated sensors
- Passive dynamic facades that use the materials properties
- Parametric dynamic facades with integration of sensors
- Active dynamic facades with integration of the energy production from renewable sources (photovoltaic or micro-algae).

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Table 2. Best Practices of Dynamic Envelope

Facades category	Cases study	EQUIPMENT OF AUTOMATION SYSTEMS	MATERIAL REACTIVITY	ENERGY PRODUCTION FROM RENEWABLE SOURCES
Passive dynamic facades with integrated sensors	*- Institut du Monde Arabe, Jean Nouvel;* *- Campus of Justice in Madrid, Norman Foster.*	YES	NO	NO
Passive dynamic facades that used the materials properties	*- Hygro-Skin Pavilion, Universität Stuttgart*	NO	YES	NO
Parametric dynamic facades with integration of sensors	*- Al Bahar Towers in Abu Dhabi City, Aedas Architects*	YES	NO	NO
Active dynamic facades with integration of the energy production from renewable sources (photovoltaic or micro-algae)	*- "Bio-adaptive faCade"- BIQ House, Arup*	YES	NO	YES

An emblematic example of "Dynamic Housing", which entered in technologically efficient architectural history, is the Institut du Monde Arabe, designed by Jean Nouvel, who was able to synthesize traditional Arab architectural elements in modern design that evokes the architecture of the Middle East. Main feature of the building is the system of metal panels on the south facade, well received by the client as it declines in a modern key an important element of the Arabic architecture - the mashrabiya - and it allows to maintain a constant amount of light transmitted inside.

This facade is provided with sensors placed on each panel, able to detect the quantity of light incident on it and, by means of a microcontroller, adjust the opening of the metal strip. With such a mechanism, which simulates the diaphragm of a camera, the entry of light in the environment is regulated (Fig. 1).

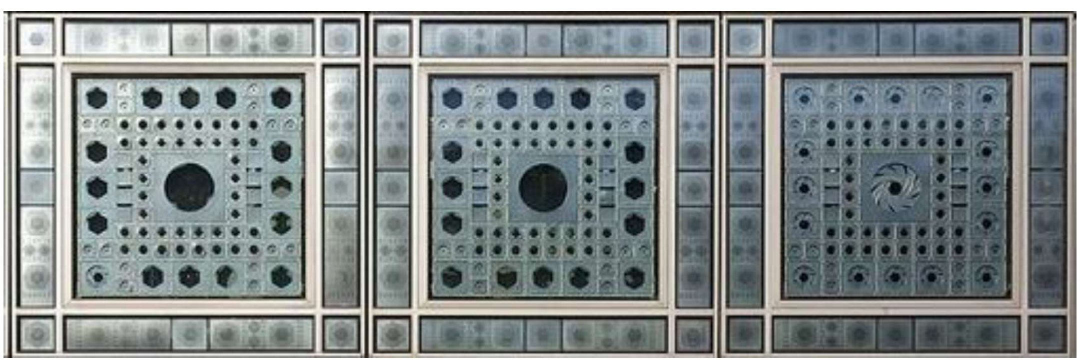

Figure 1. Institut du Monde Arabe. Source: *http://www.imarabe*.org

Another type of passive dynamic facade is the Hygro-Skin pavilion project, designed by the Stuttgart University. This example is very significant, because, while most of the research and applications of interactivity between architecture and the environment is based on the use of electronics applied to inert materials, this project uses the response ability of the material itself. In this particular case, in fact, it is used the wood hygroscopicity, in order to

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realize a membrane able to open and close in response to weather changes, without any necessity of electrical energy or any kind of mechanical or electronic control. With this system, the structure of the material itself is the sensor, processor and also actuator (Fig. 2).

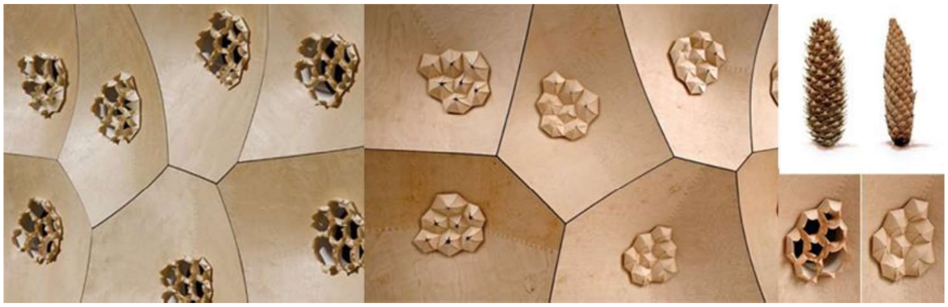

Figure 2. The HygroSkin-Meteorosensitive Pavilion. Source: *http://inhabitat.com*, 2013

The Al Bahar Towers, located in Abu Dhabi, designed by Aedas Architects group, instead, constitute an emblematic example of parametric facades, characterized by a geometric game modules that enable the creation of complex curved shapes. The facade proposes a modular grid able to respond to solar exposure and to the changing incidence corners during the different days of the year. The screen is placed on an independent frame from the glass surface, and is composed of triangles covered by glass fiber. Each component independently reacts to the stimuli coming from the sun and their behavior has been studied in such way to adjust the amount of light in relation to the daytime and night-time hours (Fig. 3).

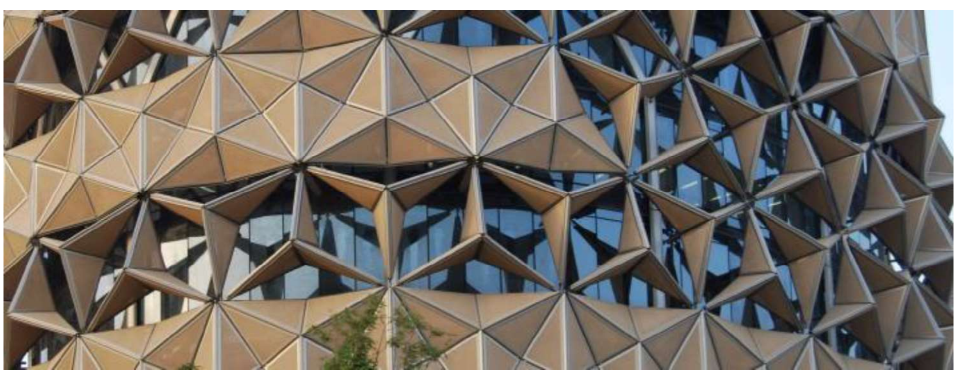

Figure 3. Al Bahar Towers. Source: *http://www.ahr-global.com/Al-Bahr-Towers*, 2012

In addition to the so-called "bio-inspired" facade systems, the research moves towards increasingly advanced systems that not only artificially mimic natural processes, but aim to make the building an independent living organism, through the integration of the dynamic biology in systems, materials and components. Of this type of systems, definable as "bio-adaptive façade", an example is the case of the BIQ House, designed by Arup. This intelligent facade system consists of a series of bioreactors with micro-algae that triggering the process of photosynthesis, biomass and simultaneously produce thermal energy, bringing the building energy consumption close to zero. In addition, the direct exposure to the sun accelerates the proliferation process of algae which, growing in

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number, they increase not only the amount of energy produced, but they create a natural insulating layer between inner and outer turning into a natural brise-soleil. According to different weather conditions the building performances change, turning itself into a real living organism (Fig. 4).

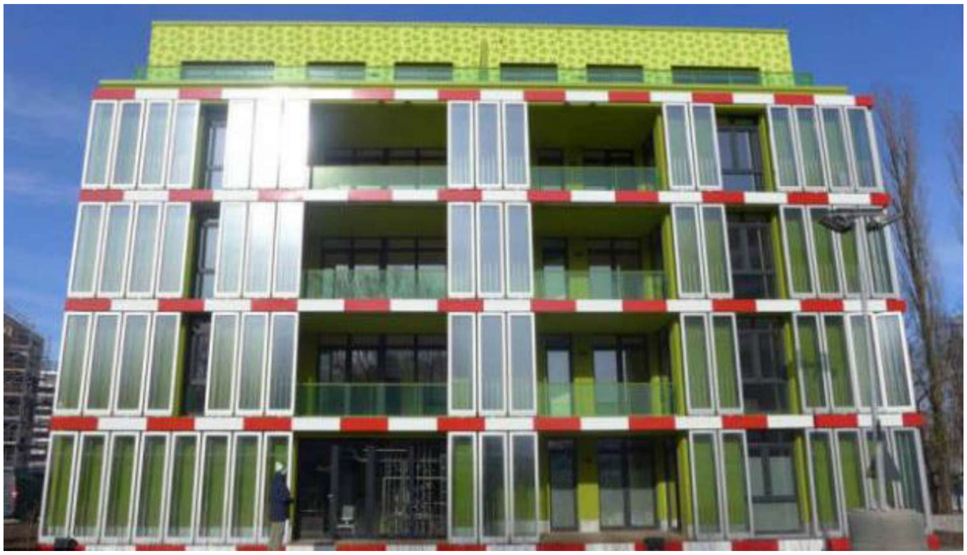

Figure 4. BIQ House, Arup, "bio-adaptive façade". Source: *http://www.arup.com*, 2013

3. TECHNOLOGICAL DESIGN FOR A VENTILATED ENVELOPE

3.1 Wooden multilevel building suitable for the Mediterranean climate

Building in the Mediterranean climate means to answer from a technological point of view to specific climatic and functional needs:

- Compact shape to guarantee a more advantageous ratio between surface and volume in respect of thermal dispersions in winter;
- Small opposed openings on the walls exposed to south and north (porous surfaces) to favour the natural ventilation in summer;
- Variable structures' spaces (portico, loggia, patio, filtering spaces, greenhouses) that are closed in winter and open in summer to reduce the thermal overhang between indoor and outdoor;
- Vaulted roof or dome that favour the activation of convective motions for the internal ventilation;
- External painting with light colours to reduce the absorption's coefficient of thermal energy.

Considering all these building strategies, a multilevel building, not yet realized, is designed to optimize the envelope performances (using wood with the X-lam building system) in respect of the climatic conditions of the Mediterranean area. Building type is in line and considers two housing units per floor, 100m2 each and four floors high. On the two prevailing and opposed façades with a south-north exposition there are the openings, and the other two façades with an east-west exposition are blind, and this permits the planimetric aggregation of the building units and a more efficient control of transparent surfaces' shades.

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To improve the natural cooling conditions in summer and the passive heating in winter, is possible to design in the central part of the building, an integrated technological system consisting of a ventilated wall and roof with a single pitch where there is an installation for the energy production from renewable sources. In the gap of the ventilated wall, the air flow creates a chimney effect because of the pressure and density' level variations, caused by the temperature difference of the air that goes from a high density area to a low density area: warm air (lighter and less dense) goes up and out thanks to the openings on the top of the building, while cold air (heavier and denser) goes in through the openings near the base to substitute the expelled air. Therefore, the air goes in from the lower grill at the outdoor temperature and goes up through the gaps cooling the wall expelling the accumulated warm air thanks to convective motions (Figs 5 - 6).

"The ventilated wall coverings represent one of the main options of opaque modern external finishing, in particular if it is combined with a high performance isolation layer. They are particularly recommended and employed in big and high buildings, and in all those buildings where the research of functionality, image, high performance, efficiency and the highest level of sustainability of the architectural and building envelope is the main design's target" (Lucchini, 2000).

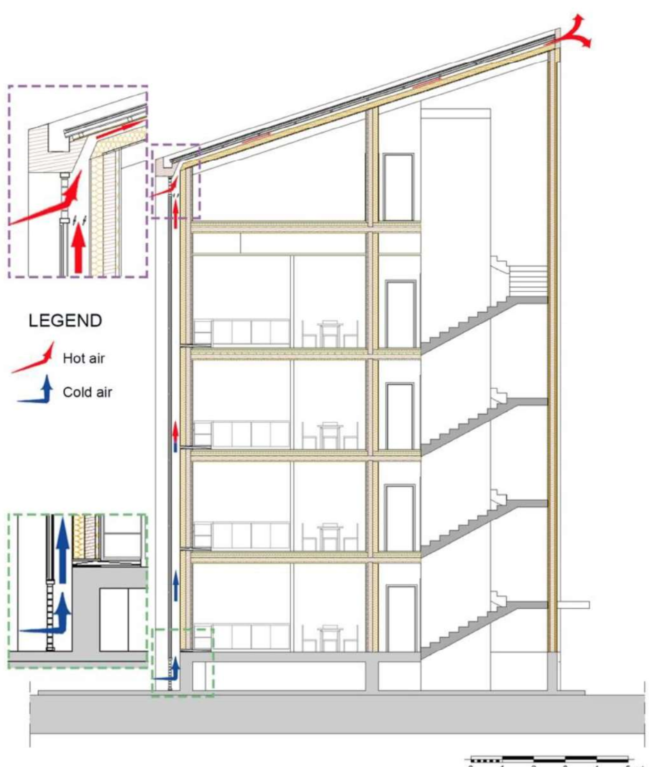

Figure 5. Natural ventilation system in summer. Source: A. Della Cioppa. 2015

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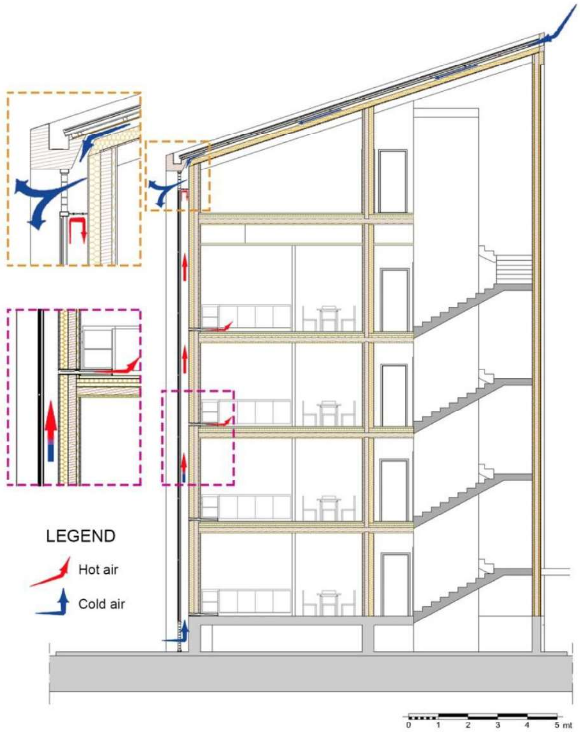

Figure 6. Natural ventilation system in winter. Source: A. Della Cioppa. 2015

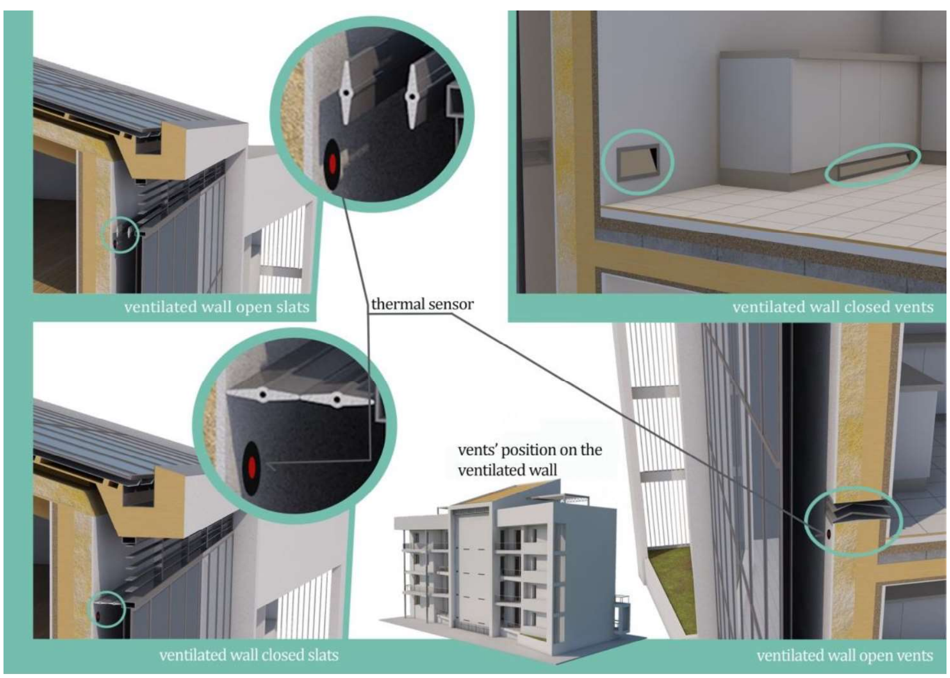

Figure 7. Domotic system. Source: A. Della Cioppa. 2015

The domotic system guarantees the automatic control of thermal-regulation devices. It activates (thanks to thermal sensors that measure the different external temperatures) the opening/closing of the layers that according to the needs extract or insert air in the

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kitchens. The layers' opening temperature varies according to the season inserting "warm" air in winter and "cool" air in summer (Fig. 7).

All the system guarantees energy efficient performances and suitable from a bio-climatic point of view to this specific climatic context, with the surplus value of integrating innovative technological solutions in buildings with a wooden building system (Lavagna, 2010).

4. CONCLUSIONS

Ventilated walls and envelopes guarantee shelter from atmospheric agents and improve energy performance. The installation of these systems on the façades and on envelopes of new buildings or existing ones produces remarkable advantages in terms of durability and maintenance, reducing the incident energy load in summer and neutralising the heavy rain effects on the envelope in winter, above all concerning exposed and isolated buildings.

In thermal-energy terms, thanks to the ventilation in the space between walls and to the insertion of a soundproof layer and to the reflection of a solar radiation percentage, ventilated walls and envelopes guarantee a thermal load reduction obtaining a relevant reduction of electric energy consumption for summer air conditioning. Moreover, holding heat back in the space between the walls, they ensure a cost reduction for heating in winter.

The domotic system here illustrated allows optimizing the ventilated walls and envelopes performance increasing the ventilation in summer with grid and thin layer's opening and reducing airflows closing the openings in winter that guarantees greater heating of the air in the space between walls.

To sum up, a building to be considered a "quality" building has to ensure energy consumption reduction and the satisfaction of indoor comfort conditions. The technological innovation, eco-friendly and energy sustainable, contributes to optimize performances. More than being original "at any price", it is important to develop and pursue the ability to insert in the system needs and knowledge for a real and widespread design process' innovation.

For sure, it is not enough to integrate a photovoltaic or solar thermal system in the cover to build an energetically efficient building, but it is needed to find building solutions (materials, systems and elements) that use raw materials and building systems controlling all the life-long (... and over!) environmental and energy cost, aiming to a bio-compatible and eco-friendly architecture.

References

- Atkin, Brian. 1989. *Intelligent Buildings: Applications of IT and Building Automation to High Technology Construction Projects*. Halsted Pr.
- Lavagna M., 2010. "Progettare con il clima, progettare nel contesto: tipologie, tecnologie e cultura materiale" CIL 133 FOCUS.
- Leifer D. 1988. "Intelligent Buildings: A Definition." *Architecture Australia*, no. 77 (May): 100–102.
- Olgyay V., 1963. *Design With Climate: Bioclimatic Approach to Architectural Regionalism*. First Edition edition. Princeton University Press.
- Lucchini A., 2000. "Pareti ventilate ad alte prestazioni - Teoria e soluzioni".
- Romano R., Sala M., 2011. *Building envelope innovation: smart facades for non residential buildings*. TECHNE -02-2011.
- Wigginton, Michael, and Jude Harris. 2002. *Intelligent Skins*. Oxford: Butterworth-Heinemann.