USE OF PHOTOVOLTAICS IN HISTORICAL BUILDINGS: AN ARCHITECTURAL APPROACH

A. Scognamiglio*, E. Di Munno**, V. Temporin** & M. L. Palumbo**
*ENEA, Portici Research Centre, piazzale Enrico Fermi 1, 80055 Portici (NA), Italy
**InArch, via Crescenzio 16, 00193 Roma, Italy
mail to: alessandra.scognamiglio@enea.it; phone +39 081 7723304 fax +39 081 7723344

ABSTRACT: The attention of the public for energy conservation is influencing the field of Architecture, and implies a new regard to the energy consumption of existing buildings, too. As a consequence, in historical cities, architects are asked to re-design buildings in order to improve their performance. For this re-design, very often, new energy production technologies might be used, and Photovoltaics is eminently suitable for this use. Nevertheless, despite its potentialities, and despite much research carried out in the past years, many barriers to the use of Photovoltaics in historical buildings still exist. As a result, its use is quite limited. Its use is still a big challenge for architects and the public also sees it with suspicious. This paper represents a contribute to the need of a better understanding of this condition, and tries to construct a new perspective from which "Photovoltaics" and "historical buildings" are no longer a striking matching. The proposal of the paper is an architectural approach, which considers the energy issues and also the need for a new Aesthetics taking into account the energy performance of buildings. The aim of the paper is stimulating a wider discussion involving architects, the public, and researchers.
Keywords: BIPV, Design, Eco-buildings, Renovation

1 INTRODUCTION

Renovation of existing buildings is an important field in Europe where many historical cities exist. In particular, in Italy, the building maintenance market can be considered about the 70% of the total construction market [1].

Often building maintenance is needed since many buildings were not designed to optimize their energetic performance. In fact, at the time they were built (before 50s) the energy consumptions were not so high. So, these buildings could easily use oil for their operation, without paying attention to the energy consumption and to the environmental costs.

Nowadays, as a consequence of the energetic crisis and due the new environmental consciousness, new regulations focus on the energy standards of buildings. So, in the case of historical cities, architects are asked to re-design the existing buildings, to reduce their energy consumption.

The integration of new technologies for energy production into the building envelopes can help in improving the building energy performance. Photovoltaics is eminently suitable for this use [2].

There are many reasons why Photovoltaics is suitable to be used for the re-design of the envelopes of existing buildings. From the technological point of view the wide availability of BIPV products allows a good choice of the appropriate components. From the energetic point of view, the appropriate choice of photovoltaic components allows to improve the thermal performance of the envelope. From the visual point of view, Photovoltaics is suitable to create images fitting the contemporary Architecture visual repertoire [3].

But, despite all the potentialities of Photovoltaics, many barriers to its use still exist in the case of historical buildings. In fact, the integration of Photovoltaics in historical buildings is still a critical issue for both architects and the public, since the matching between Photovoltaics and historical buildings is perceived striking from the "aesthetical" point of view.

So, the question is, again: If these barriers exist, why do they still exist? How can we remove them?

An architectural approach is useful for a better understanding of this subject, and to structure a new perspective with the hope that this new perspective can contribute to promote the use of Photovoltaics in historical buildings.

2 PRELIMINARY CONSIDERATIONS

The contemporary energetic consciousness implies the need to re-design existing buildings characterized by high consumptions of energy. This need generates different design attitudes depending on the nature of the building that has to be re-designed.

Among historical buildings it is possible to make a distinction between valuable and not valuable buildings.

In fact, even in valuable historical cities, like Rome, a huge part of the buildings is not valuable from the artistic or architectural point of view. These not valuable buildings are historical, as well as the valuable ones, because they are part and parcel of the architectural quality of the city. In fact, they have grown organically, forming the historical image of the city itself, and the public is used to the image of the city that these buildings generated. We can define such buildings "ordinary historical buildings".

In the case of valuable historical buildings the re-design asks architects to learn how to use a contemporary and innovative visual repertoire, preserving the traditional image of buildings.

Whereas in the case of "ordinary" historical buildings, the re-design gives architects the possibility to learn how to match energetic aspects and the formal aspects into a new Aesthetics.

Ordinary historical buildings are good opportunities to experiment with the use of Photovoltaics, due to the possibility of re-designing their envelope. In fact, since these buildings are in a sense "historical", but not valuable, according to the building local regulations, the sustainable re-design can imply the re-design of the envelopes. This makes the use of building integrated technologies for energy production easy, and the use of

Photovoltaics suitable [4; 5]. Due to these reasons, the context of experimentation chosen for the research proposed in this paper is the one of ordinary historical buildings.

3 APPROACH

No doubt that, if we think of historical buildings, on one hand, and of new technologies, like Photovoltaics, on the other hand, their matching can look striking from the visual point of view.

Nevertheless, no doubt that, also if we think the energy technologies we have, on one hand, and the unsatisfying energetic performance of many buildings, on the other hand, their matching can look striking from the logical point of view.

In the recent years much research has been carried out in order to improve the performance of Photovoltaics in terms of good compatibility with Architecture. This research focused mainly on the aesthetical appeal of Photovoltaics itself (BIPV components), on its technological compatibility with building technologies, and on good criteria for the use of Photovoltaics in new buildings as in existing ones.

These considerations suggest that the widespread negative perception of the use of Photovoltaics in historical buildings is not only a problem of contents but also a problem of perspectives.

So, in order to answer the questions regarding the existing barriers to the use of Photovoltaics in historical buildings, we have to go deeper in the reasons for the negative perception the public associates with their matching. In particular, we have to re-think the aesthetic categories, so to consider not only the visual aspect, but also other building features, which do not have visual evidence. In particular, the present aesthetic perspective does not take into account the building energetic performance, but refers exclusively to a visual architectural image.

The approach of this paper is trying to overcome the barriers to the use of Photovoltaics in historical buildings by structuring a new perspective, which smoothes their, heretofore, rough relationship. This new perspective has to take into account the traditional aesthetic issues (mainly visual), and the energetic performance too.

This approach is architectural, and sees the re-design of historical buildings as an occasion to design (eco)buildings, in which the use of Photovoltaics is suitable also to contribute to a new Aesthetics of performance.

4 MAIN CONTENTS

First some theoretical elements are given, in order to introduce the shift from the traditional aesthetical perspective (from which the relationship between historical buildings and Photovoltaics is rough) to a new aesthetic perspective including both the aesthetic and energetic issues (Aesthetics of performance). This shift is possible if traditional buildings are re-thought and re-designed as (eco)buildings.

Subsequently, as an example of real attempt to experiment with this theoretical approach, an account of the research carried out at the InArch Master "Designer of sustainable architectures" is given. This account includes the design method; the overview and description of some projects focusing on Photovoltaics; the way the public has been involved in the Master's themes.

The common thread is trying to give elements useful to re-define the relationship between Photovoltaics and historical buildings. The hope is to open a wider discussion on the idea of building "conserving" and on the use of Photovoltaics in historical buildings (in Architecture in general), involving architects, researchers, and the public.

5 THEORETICAL REMARKS

5.1 Photovoltaics / Historical buildings: a matter of shape and Aesthetics

If we look at the relationship between Photovoltaics and historical buildings, we have to think about Aesthetics. In fact, the reason why the matching between Photovoltaics and historical buildings looks striking for the public, concerns with the aesthetic criteria used when looking at these buildings.

In particular, the public can understand and recognize the "historical" shape because this shape is based on a certain well-known architectural code. The public shares this code, even if this depends on architectural parameters that can change through different ages. As a consequence the public likes historical buildings and their shape, and does not want any change in their image. This kind of shape is conceived as fixed, and "self-referential", based on rules that come from the architectural discipline, such as geometry, harmony and relationship with the site.

The shape of historical buildings depended on the function, but the idea of function did not include heretofore the function of "saving energy". No wonder for this, since these buildings were conceived when the energetic problem was not urgent, and, on the same time, when only a few energy technologies existed. So, obviously, issues external to Architecture, like energy, were not taken into account, and the Aesthetics generated by the use of new technologies, neither.

5.2 From buildings to (eco)buildings

Now Architecture has to face also energetic problems which were not yet known up until 20-30 years ago. Furthermore, new technologies can to be used for the building envelopes in order to achieve good energetic performances. As a "logical" result buildings should no longer be conceived as "buildings", but they should be designed as "(eco)buildings".

The (eco)building allows the same or better functionality of a traditional building, satisfying the needs of the inhabitants, but using less energy. The design process of an (eco)building is more complex than the one of a traditional building. In fact, in the case of the traditional building, the different systems that are part of the building are not really linked each other. Whereas, in the case of the (eco)building all the project parameters are closely related. As a consequence, in the design process, the interaction of many parameters has to be taken into account: for instance building/climate, building/systems, system/users, users/building [6].

5.3 A vision of the (eco)building

If we look at the way the most of our traditional buildings work, we can observe that they are a kind of "black box" where several different resources (at least energy, mainly in terms of electricity and gas, water and food) have to be carried (often from far away), to be used and thrown away as waste, in a blind line of growing entropy. These buildings consume resources and produce waste, but do not take into account the general balance of the ecosystem.

In order to contribute to the balance of the ecosystem, we have to overcome this old idea of the building, to conceive a new vision of the building. Using some concepts from the field of Biology, a building can be seen as an organism, a "living being", characterized by a proper "metabolism". This metabolism is the link between the building, and the way it can positively or negatively work in the general environmental context (ecosystem). This way, the "living building" can be designed so that its metabolism works positively, by orienting its performance on desired behaviors (mainly energetic). Such a building can be defined (eco)building [7].

5.4 Shape(s) of (eco)buildings and problematic issues

The shift from building to (eco)building influences the concept of "shape", too. In fact the shape of the (eco)building has to allow a good energetic performance and it has to be the result of the best interaction between the different design parameters. So the shape is longer "self-referential". In fact, the envelope is conceived as an interface generating positive actions and reactions, by achieving a good performance in terms of energy balance for the whole life cycle. As a consequence, in the architectural (eco)building code, shape has to be "relative" to performance. In other words, we can longer not to speak about "shape", but we should rather speak about "shapes".

This shape is a critical issue for architects, because it is no longer based only on a certain architectural (aesthetical) code; so, the traditional tools of Architecture are not sufficient. The choice of the right shape among different possible shapes depends on performance criteria. Parametric simulation codes are useful in order to design the appropriate shape, and to predict the performance of the building.

If the shape of the (eco)building is a problem for architects in terms of design, it is even worse for the most of the public in terms of aesthetical perception. In fact, the public is not yet used to the new formal aspects the (eco)buildings present.

This requires to work on the design process, but also on a new Aesthetics, taking into account both traditional issues and performance issues. A new Aesthetics is possible only if architects learn how to design (eco)buildings and their shapes, and, meanwhile, if the public understands deeply the meaning of some images related to the use of new technologies (i.e. Photovoltaics) with regard to their performance.

5.5 Photovoltaics / historical buildings / (eco)buildings

The energy saving oriented re-design of historical buildings is an occasion to re-think the buildings themselves, and the whole design process according to a sustainability oriented perspective. Historical buildings can be morphed into (eco)buildings by means an appropriate design process, which can take into account the use of Photovoltaics, too.

This morphing process can be considered the first step to smooth the relationship between Photovoltaics and historical buildings. In fact, if historical buildings are morphed into (eco)buildings, Photovoltaics can be seen as an inseparable part of them. This shift allows to look at the image of the whole building, and not at the image of Photovoltaics itself. Photovoltaics can be seen as an image for the performance of the building.

The proposed architectural approach elevates the subject "How to use Photovoltaics in historical buildings" from a only technical/only energetic/only visual perspective(s) to the cultural, architectural perspective, that is: how to re-think buildings and their design process, taking into account their energetic behavior, and the Aesthetics related to their performance? What is the role of Photovoltaics for the new Aesthetics of performance?

6 PHOTOVOLTAICS / HISTORICAL BUILDINGS / (ECO)BUILDINGS: EXPERIMENTATIONS

6.1 Context

The approach presented in this paper has been experimented in the frame of the post graduate master "Designer of sustainable architectures" at InArch (Italian National Institute of Architecture) in Rome. ENEA (Italian National Agency for New Technologies, Energy and the Environment) is involved in some specific teaching modules of the Master, and, in particular, with regard to the use of Photovoltaics in Architecture.

According to the approach of this paper, the general theme of the Master is to propose an innovative use of technologies in Architecture, aimed to re-think buildings as living beings which can evolve through an appropriate design process. As a consequence of this approach, a good design has to generate the fittest relation between shape and performance. Passive and active energy strategies and the use of renewable energy technologies, such as Photovoltaics, are a main focus of the Master [8].

The projects developed by students, refer to the urban renovation of the historical peripheral area named "Pigneto", in Rome. This is a largely self developed area, grown between the beginning of the 20th century and the 70s, and now characterized by a quite strong gentrification trend. It was born as a peripheral area of the city, but now it is considered a historical area. Three quite small, residential buildings, in particular, were selected as case studies for the re-design process. These buildings can be considered representative of the main typology of ordinary historical Italian buildings.

Their main features are: they are made by using traditional building technologies (local stone and concrete); the roofs are flat; their energy consumptions are quite high, due to the single pane windows, to the absence of thermal insulation and to many thermal bridges.

We named these three buildings "case 1", "case 2" and "case 3".

Figure 1: Ordinary historical buildings / case study 1

The case 1 (fig. 1) is a three-storied building, built in the 30s. It has an underground floor, and a mansard on the roof. The massive framework is made of tuff framing walls. The main entrance of the building is on the Northern side, from a small square facing the district. On the Southern side of the building there is a private garden with some fruit trees that can be used by the inhabitants. The residential units are six, each one area is about $50m^2$ except the one in the mansard ($35m^2$). The energy consumption of the building is about $274kWh/m^2year$.

Figure 2: Ordinary historical buildings / case study 2

Figure 3: Ordinary historical buildings / case study 3

The case 2 (fig. 2) is a four-storied building, built in the 50s. The framework is made of concrete; the foundations and the ground floor are made of tuff, and the other two floors are made of concrete. On the Southern side the building faces a square (not used by the inhabitants of the district). On the Northern side it faces a traffic street. Each floor houses a residential unit large about $90m^2$. The energy consumption of the building is about $136kWh/m^2year$.

The case 3 (fig. 3) is a four-storied building, built in the 30s; the massive framework is made of tuff and bricks framing walls. The building faces a public space on the Southern side. This public space is now used as a parking area, but is becoming (according to a municipal project) the access for a new metro-station. On the Northern side the building faces a private courtyard, with two houses in very poor conditions. The residential units are six; each one area is about $65m^2$. The energy consumption of the building is about $191kWh/m^2year$.

6.2 Re-design requirements and constraints

With regard to the energy issues of the re-design, students are specifically asked to improve the performance of the buildings selected as case studies. In particular, the building energy consumption has to meet the requirements established for the label energy class A (energy consumption $<30kWh/m^2year$, that is oil energy consumption $<3l/m^2year$).

According to the building code of the city of Rome, in order to meet the new needs of the inhabitants and in order to allow the energy consumption reduction, the students can use an “addition”. The addition is a new volume (new space) added on the building envelope. By designing such an addition, students can take into account the new needs of the inhabitants of the building (depending on new house-lifestyle), as well as the need for the solar collection to improve the building performance.

Some constraints have been given the students for the re-design project in order to add new technologies while preserving the “historical” perception of the building and its relationship with the district. The specific constraints depend on the most emblematic feature the building presents, in terms of recognizability for the perceived image of the district.

In particular, the part of the building that is the most visible for the inhabitants of the district cannot be modified. On the contrary, the parts of the building which face private spaces (for instance private gardens or courtyard) can be modified since they do not change the district general image. The modifications on these "private" parts allow introducing new building integrated technologies, in particular, Photovoltaics.

The specific constraints depend on the case study.

In the case 1, the Northern facade cannot be modified; the addition can be placed on the roof and on the Southern façade, which faces the private garden.

In the cases of 3, as well as in the case 1, the Northern façade cannot be modified. So, the addition can be placed on the Southern façade or on the roof. The Western and Eastern facades are blind, and they can be modified according to the project requirements.

In the case 2 the main constraint is the structure, so the concrete framework cannot be modified. Facades can be re-designed but they have to be placed at the maximum distance of 1,5m with respect to their original position. The addition can be placed on the facades and on the roof.

6.3 Shape(s) of the envelope: method and tools

According to the above illustrated (eco)building design approach, with regard to the envelope, and the shape(s) it can assume, boundaries are still the place where all the aspects taken into account in the design process come together. But, of course, the boundary is conceived as an "interface", which can mediate, for example, between the solar radiation and the energy needs of a building. As a consequence, geometry (that means also shape) is still a tool of design, but in terms of the processes it has to mediate. The use of Photovoltaics is conceived according to this theoretical frame.

To investigate deeply the relationship between shape and performance a parametric approach has been used. The aim is to understand how each specific variation (parameter) can influence the whole system (for example how the shape or dimension of a window can change the climatic condition of a room). Through the support of a 3d parametric modeller together with software for the thermal and fluid dynamic evaluation of buildings, we tried to bring together the architectural design and the design of specific energetic behaviour (performance). With regard to the Photovoltaics the simulation code PVSyst 4.31 has been used to design the systems and to evaluate their energetic performance.

6.4 Projects overview

We will describe four projects designed by students of the Master, where the energy strategy clearly informed the design strategy and the final configuration of the building as an active "producer" of solar energy.

The projects develop different attitudes towards the existing buildings and they solve the issue to tap the solar radiation using different geometrical approaches. These projects show very clearly a shift from shape as an occurrence to shape as an active device to generate performances, and for all of them, the use of Photovoltaics influences greatly the image of the building (Aesthetics).

The projects are named, respectively: Degreen (F. Lampis, M. Leo. E. Petriglia), ReInVERSO (R. Russolillo, D. Lucafò. S. Chiergia), Parassita in divenire (M. Cogodda, G. Ottaviano, P. Trudu), Captabilità (A. Altamura, A. Bellantuono, M. Costantino).

Degreen (fig. 4) chooses to keep just the North facade of the existing building separating it from the new construction through the new distribution system, whereas all the apartments are now looking towards the internal garden through big glazed walls (which can be closed greenhouses in winter and open terraces in summer). The new metal structure sustains photovoltaic modules located so to optimize the solar radiation and not to shadow each other. On the same time the whole design strategy allows a good reduction of the energy consumption.

Parassita in divenire (fig. 6) chooses on the contrary to work much more on the envelope, or actually, on a second envelope, keeping as much as possible the existing building and structure as it is and covering it with a new active and "performative" skin made of transparent, opaque, and photovoltaic glass and movable panels. As well as for the previous projects, also in this case the design strategy allows a remarkable reduction of the energy consumption.

Captabilità (fig. 7) shows again a kind of "superficial" attitude which allows to preserve most of the existing building and its character but, on the same time, it shows also very clearly a sort of geometrical revolution as one of the building facade as well as the roof have been distorted or re-modeled and covered with a new skin to allow and optimize solar radiation capture. The same shifting geometry informed the piazza design, so to emphasize the presence of the threes, inviting people to rest and seat around them, in a sort of wood carpet that mediate between the natural element and the artificial ground.

Figure 4: Degreen / case 1 / design: F. Lampis, M. Leo. E. Petriglia / the Southern façade with Photovoltaics

Figure 5: ReInVERSO / case 1 / design: R. Russolillo, D. Lucafò. S. Chiergia / South facade with Photovoltaics

Figure 6: Parassita in divenire / case 2 / design: M. Cogodda, G. Ottaviano, P. Trudu / the Southern facade

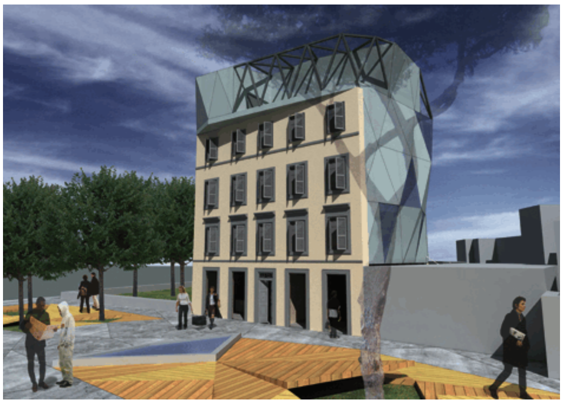

Figure 7: Captabilità / case 3 / design: A. Altamura, A. Bellantuono, M. Costantino / East facade and roof with Photovoltaics

In ReInVERSO (fig. 5) the design strategy focuses on the decision of moving outside the distribution system, so to make room for the apartments inside the building generating on the same time new open spaces, terraces, outside. This movement aims to generate a new relation between closed and open green spaces, working as well as a social condenser (meeting space) and a bio-climatic optimizer (terraces are designed to maximize sun capture in winter and shadows in summer). Transparent photovoltaic panels cover the upper terrace and standard modules are hosted on the building roof.

6.5 Architectural use of Photovoltaics: detailed projects description

6.5.1 Degreen / Shading Photovoltaics for lightness

According to the project constraints of the case 1, Degreen chooses to keep the Northern facade separated from the new construction through a large air space useful for the building insulation and ventilation. On the South facade a new metal structure sustains photovoltaic modules located so to tap optimally the solar radiation without any self-shading effect. The whole design strategy allows a good reduction of the energy consumption, which has been evaluated to decrease from 274kWh/m^{2}year (before the renovation) to 15kWh/m^{2}year (after the renovation).

The optimal position of Photovoltaics allows generating the maximum possible energy, and, from the visual point of view, allows emphasizing the design approach of the project. This approach, interprets as “heavy” the old Northern massive façade, which people remember as an element of recognizability (and of permanence) of the historical building, and sets a “light” facade on the South against the “heavy” one of the Northern side. The new added Southern facade is light not only because the image of the used materials is “light” (glass, metal, and Photovoltaics), but mainly because it is new, and so not yet in the public’s memory.

According to this approach from heavy to light to lighter, to lightest, Photovoltaics is designed so to dematerialize itself contributing to fragment the Southern facade. It is remarkable that the image of Photovoltaics is light, despite standard (opaque) photovoltaic modules have been used. In fact the whole composition of the photovoltaic system contributes to the general effect of fragmentation of the South façade towards the garden.

From a chromatic point of view the dark surface of the photovoltaic modules suites the general image of the building; from an energetic point of view, the shading effect of the opaque modules on the South facade contributes greatly to the energy consumption reduction.

The photovoltaic area is about $100m^2$, and the nominal power of the photovoltaic system is about $17kW_p$. In order to maximize the production of the system, high efficiency modules have been chosen (Heterojunction with Intrinsic Thin layer, efficiency about 17%) and they have been optimally tilt for the latitude of Rome (tilt=30°, azimuth=0°).

The simulations show that the energy production of the photovoltaic system is about 23MWh/year, which is enough to power all the electric needs of the building.

6.5.2 ReInVERSO / Photovoltaics as an icon for sustainability

As well as Degreen, according to the case 1 project constraints, also ReInverso do not touch the Northern façade of the building. The main theme of the project is a sort of osmosis between the building itself and the public space on the Southern side. This osmosis is obtained by virtually sliding along some chosen directions some elements of the existing building toward the Southern garden. The elements resulting from this sliding process are new elements added on the Southern façade, designed so to allow different uses and to enrich the space of the garden. A metal frame sustains the new additions, which give the building new room for the houses, as well as greenhouses and wooden terraces improving the energetic behavior of the building.

The terraces, since can host a private garden, have the effect to “bring” part of the garden in the upper floors of the building. So, green is no longer only on the ground, but also in the external spaces of the building.

Photovoltaics is integrated into the two upper levels of the terraces, and at the roof level. It is part and parcel of the building energy strategy, that is self-sufficiency oriented. Photovoltaics powers a heat pump, and earth pipes are used for cooling.

Apart from the energy production, Photovoltaics has also an eminent role from the architectural point of view.

In fact, if the semitransparent modules of the Southern façade allow controlling the building daylight (improving the building energy consumption), the opaque standard modules used on the roof are visible on the Norther façade, too (fig. 8). This way, the presence of so unusual building elements (photovoltaic modules) in the composition of the Northern façade, pique the attention of the public, and suggests the existence of “something new” on the private side of the building. So Photovoltaics works as an icon for sustainability.

Figure 8: Reinverso / the Northern facade

The nominal power of the photovoltaic system is about $29kW_p$ for a total area large about $244m^2$ ($19kW_p$ for $163m^2$ standard polycrystalline modules; $9.6kW_p$ for $81.4m^2$ semitransparent glass-glass modules). In order to allow the use of standard modules for the roof, a special metal frame has been designed. Due to architectural reason, the module tilt is 0°, so they are horizontal to fit the project needs. This way the energy production of the system has been evaluated to be about 22MWh/year.

The whole design strategy allows a good reduction of the energy consumption, which decreases from $274kWh/m^2year$ (before the renovation) to $14kWh/m^2year$ (after the renovation).

6.5.3 Parassita in divenire / Photovoltaics for dynamic semi-transparent patterns

According to the case 2 project constraints, the project does not touch the existing building, but it prefers rather to dress the envelope using a new active skin. This new skin is designed so to react to the weather conditions as well as to the climate conditions depending on the year seasons.

The design of the new skin is conceived so to emphasize not only its reactive attitude, but also its relationship with the old building. So, different grades of relation can be obtained by using different materials. These materials can establish different degrees of relationships with the building and with the external space, depending on their nature. For instance, glass panes with different transparence degrees allow to graduate the introspection between external and internal space; photovoltaic glass-glass modules react to the solar radiation by producing more or less energy depending on the Sun; opening windows can mediate between internal and external spaces in terms of ventilation and air exchange.

So, despite the single elements of the façade are fixed, the general image of the façade is dynamic, since it changes according to the external conditions and to the needs of the inhabitants.

Photovoltaics is perfectly integrate; it’s naturally part of the facade composition, being just a module of the façade pattern. It is placed between the opaque glass modules and the transparent ones, showing an intermediate degree of transparency.

The nominal power of the photovoltaic system is quite small, it is about $4kW_p$; the silicon thin film technology has been used for the modules, but the dimensions of the modules have been designed according to the project requirements. The photovoltaic area is about $100m^2$, the half of this area is integrated into the façade, the other half part on the roof.

The total production of the photovoltaic system has been evaluated to be about 5.1MWh/year; this way Photovoltaics can power only the energy consumption due to the common needs.

The whole design strategy allows a good reduction of the energy consumption, which decreases from $252kWh/m^2$year (before) to $28kWh/m^2$year (after).

6.5.4 Captabilità / Photovoltaics for a contemporary geometric skin

According to the case 3 project constraints, Captabilità does not touch the Northern facade, but modify the Easterb and Western blind facades.

The approach of the project takes into account the formal aspects of Photovoltaics in terms of new geometries. In fact, a fractal new skin based on triangle "gets dressed" the building, acting like a new geometrical cloak. This geometrical cloak wraps not only the building, but the piazza, too, allowing unifying into a same geometry the building and the public space.

The use of the fractal geometry based on triangle, requires using photovoltaic modules suiting the chosen geometry. Since these kind of modules are not yet been developed, they are not available on the market. As a consequence the simulation of the energetic production of such modules can only been performed by taking into account a suitable technology, and using for the simulation standard commercially available modules corresponding to the designed active area. For this reason the evaluation data are not so precise. Supposing to use hetero-junction with intrinsic thin layers glass-glass modules, the roof photovoltaic system (about $80m^2$) has been evaluated to produce about 13MWh/year, and the one on facade ($70m^2$) about 5MWh/year. So the total energy production has been evaluated equal to 18MWh/year.

6.6 The public's involvement for a new Aesthetics

At the end of the Master, as part of the process of construction of a new aesthetic perspective, the results of the Master have been shown to the inhabitants of the district Pigneto. The aim was to establish a better understanding of the energetic themes also concerning with the images they can generate.

Figure 9: Pigmenti / The public's involvement for a new Aesthetics / bringing (eco)buildings toward the public

Figure 10: Pigmenti / The public's involvement for a new Aesthetics / showing the public new ideas, technologies and images

A special two days event named "Pigmenti" has been organized, and the Municipality which the district Pigneto belongs to, supported InArch for this initiative (in Italian it is a mix between PIG(neto) and MENTI – that is "minds" -, which means "pigments").

Pigmenti really, physically, brought the ideas developed in the field of Architecture directly toward the public, through the exhibition of the re-design projects developed for the district by the students of the Master (fig. 9).

This way the public can get used to the new shape(s) of (eco)buildings. As a result the public can look at historical/(eco)buildings from a new aesthetic perspective. If the public, gradually, gets used to new ideas coming from the scientific and architectural fields, it can judge the use of new technologies on the historical buildings not like an insult, but, rather, like a good opportunity for a better life (fig. 10).

7 PHOTOVOLTAICS FOR A NEW AESTHETICS OF PERFORMANCE

If geometry, harmony, composition, are something we (the public) can judge at a first glance, establishing if we like or if we do not like a certain building, it is not the same with performance.

So, even if from a theoretical point of view, according to our energetic consciousness, a building can be considered better than another one if it has a better performance, we do not have a visual code we can refer to, in order to translate the performance into an aesthetical category.

As a consequence, we cannot formulate a judgment on a certain building only by sight and also taking into account its performance. We have to know some data to understand if we like it or if we do not like it.

This condition of incapacity of correct judgment of an (eco)building, is likely to be temporary. In fact, after the construction of many and many sustainable building, also the performance will be included into a certain visual repertoire, which will generate a certain Aesthetics. We do not yet know, which will be this visual repertoire. Nevertheless, we can reasonably imagine that, since technological components such us photovoltaic modules or wind mills are already now icons for sustainability, they will work as signs of a new active behavior of the (eco)buildings.

According to this vision, Photovoltaics can play an important role in the future, with regard to the construction of a new Aesthetics for performance. In fact, due to its recognizability, and due to its capacity to produce electric energy, it is closely related to the energetic consumption of the building. So, if now a small photovoltaic generator reminds the public the idea that the building works in a traditional way (it consumes oil), in the future the same image will remind the public that the (eco)building has a good performance. In fact, a quick glance at the photovoltaic generator will give the observer a first easy measure of the performance of the (eco)building. Is Photovoltaics too big? This case the building does not have a good performance (negative perception) / Is Photovoltaics really small? This case the building has a good performance (positive perception).

So, Photovoltaics, due to its specific features, is suitable to be in the future an easy measure (by sight) of the energetic electric metabolism of the (eco)building.

8 CONCLUSIONS

The relevance of the discussion of the Master's results in the architectural contemporary context is that, despite the great potentialities of Photovoltaics to be integrated into building envelopes, this is still a big challenge for architects when they deal with ordinary historical buildings. A challenge not also in terms of energy balance between the energy consumed and the energy produced, but also in terms of design.

In fact, on one hand, potentially, Photovoltaics can morph traditional buildings into cool innovative building, matching Photovoltaics to Architecture, and performing innovative new images for Architecture. On the other hand, in the case of historical buildings, even if Photovoltaics has become a symbol of sustainability both for architects and for the public, it is still perceived as an external, added technology.

Photovoltaics is still seen as a not proper architectural material, as well as a not proper target of research and language. In fact, the effort of architects, in this case, is supposed to focus more on the conservation of a traditional image of buildings, often contrasting with the use of new technologies integrated into the envelope.

As we have tried to shown here, our research and teaching activity aims to de-construct this old notion and attitude toward conservation trying to push forward a new sensibility and consciousness. This sensibility allows thinking of conservation as including a wider idea of preserving, and actually restoring, our complex and living environment in a deeply ecological consciousness.

Furthermore, if the issue a new ecological way of living or inhabiting our planet is today one of the most important questions at stake, cities play an important role in solving the energetic problems of the future [9] Architecture, as well as design in general, cannot but to define a new aesthetic code where the idea of beauty is immediately related to the kind of impact, or footprint, every object (or building) is going to have. To touch the ground gently, to use whatever kind of resources in a soft and clever way, to think about our ecosystem as a complex balance of relationships between the living and the not living, have to be our main goals as designer, as well as our main criteria of judgment looking at whatever kind of human product (or construction).

So, even looking to a new or renovated building our questions have to be: how does it work? How does it relate to the complex environment it has to live in and with? How does it sustain people's life and life on the planet in general?

Of course we are talking about a quite radical shift of the aesthetic principles, but this is exactly what we need. From this point of view we can still learn a lot from one of the father of the ecological consciousness, Gregory Bateson. As he said: “By *aesthetic, I mean responsive* to the pattern which connects.” This is what a new aesthetic has to look for: pattern which connects. In architecture this means to look for all the possible ways we can connect each building to the fluxes of the global metabolism of the planet [10].

9 ACKNOWLEDGEMENTS

The authors would like to thank Beatrice Fumarola, Giulia Di Matteo and Federica Crola for their support to the Master organization.

The authors would like to thank also all the students of the Master, and, in particular: Fabrizio Lampis, Manlio Leo, Emanuela Petriglia, Rossella Russolillo, Daniela Lucafò Simona Chiergia, Marinella Cogodda, Gianpiero Ottaviano, Paolo Trudu, Alessandro Altamura, Alessandro Bellantuono, Matteo Costantino.

10 REFERENCES

[1] F.IN.CO.-ENEA, Libro Bianco « Energia-Ambiente-Edificio », Milano 2004, pp. 44-46.

[2] A. Scognamiglio et al., Renovation of social houses: a good opportunity for building integrated PV technologies, Proceedings of the 20th European Photovoltaic Solar Energy Conference.

[3] A. Scognamiglio, C. Privato, Starting points for a new cultural vision of BIPV, Proceedings of the 23rd European Photovoltaic Solar Energy Conference, pp.3222-3233.

[4] A. Bosco, A. Scognamiglio, Fotovoltaico e riqualificazione edilizia, ENEA, 2005.

[5] A. Scognamiglio et al., Fotovoltaico negli edifici, in press.

[6] M. Citterio, L’Ecobuilding: l’edificio come centrale energetica/macchina bioclimatica, in J. Lima, Perché si diffonda la pratica di un'architettura come ecologia umana. Studiosi a confronto. Scritti in onore di Paolo Soleri, in press.

[7] M. L. Palumbo, New Wombs Electronic Bodies and Architectural Disorder, 2000.

[8] A. Scognamiglio, E. Di Munno, M. L. Palumbo, V. Temporin, Sustainability for the dialogue between traditional buildings and new technologies, Proceedings Cisbat 2009, pp. 137-142.

[9] D. Fisk, Renewables and the future of sustainable urban development, Proceedings Cisbat 2009, pp. 15-19.

[10] M. L. Palumbo, Paesaggi Sensibili. Architetture a sostegno della vita, in press.