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Visibility Assessment of the Integration of Technologies from R.E.S. in Sensitive Urban Environments. Proposal for a Simplified Graphical Tool.

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Abstract
The architectural integration of technologies from renewable energy (r.e.s.) in sensitive environments, should respond to the double requirement of the urban heritage and landscape conservation and energy savings in buildings. The conflict that can be generated in responding to these needs can be limited by identifying simplified tools, easy to use from single people, designers and administrators involved in evaluating the visual impact of each proposal. The graphical tool described in the paper can be useful to check simultaneously the visibility of a solar system on the roof varying its inclination, building height and distance of the observer who is in front of the building with the integrated solar panel, for example a preserved building subjected to protection.

Keywords:
SH3-1: Environment, resources and sustainability
SH3-2: Environmental change and society
Architectonic integration
Solar systems
Visual impact

1. Knowledge, skills and experience of the research team

This paper reports the contribution of the team within the Research PRIN "The systems integration of technologies from renewable sources in the built environment" carried out between 2010 and 2012 and coordinated by prof. Gianni Scudo of Politecnico of Milano, which included the participation of the University of Florence, Genoa and Napoli II.
This research is only a part of the themes that characterize the research activities of a group of researchers and professors of the SSD ICAR12 (architectural technology sector) within the Department DAStU of Politecnico di Milano.
The group, which, in addition to the writer, is represented by Profs. Gianni Scudo and Alessandro Rogora, carries on research on topics involving the built environment and the urban

space from different points of view, and specifically, themes characterized by an eco-friendly approach and oriented to the verification of environmental performance of spatial and technological configurations.
Simplified tools to assess environmental performance and thermal comfort were developed with regard to the urban space. Among them, COMFA+, for example, developed in 2007 for the calculation of the heat balance in outdoor spaces, and the graphics for the determination of the mean radiant temperature -MRT-, one of the outcomes of RUROS research[1].
The integration of technologies from r.e.s. (Renewable Energy Sources) in building systems is another field of research that has historically involved Prof. Scudo and more recently Professor Scudo together with prof. Rogora who promoted and developed a research financed by ENI on the integration of luminescent solar components on components and advanced envelope systems.
The Research PRIN was founded with the aim to develop a methodological integration process in the three areas involved in the determination of planning scenarios: the procedural field, i.e. of the process; the area of the decision making, i.e. the field of the project; the field of economic application, i.e. the product. The aim is also to systematize process criteria, technical information and analytical tools for the systemic integration of technologies from r.e.s. in projects concerning the built environment transformation.
All this was done through the collaborations and connections between the disciplines of Architectural Technology and Technical Environmental Physics. It represented an opportunity for research partners to develop criteria and strategies for the integration of solar systems in sensitive environments, such as town centers and protected buildings, but, above all, to realize a sort of tools box useful for designers and public administrators who are involved in this field.
In particular, this contribution represents an experience in terms of cross-referenced research in various issues already addressed by the research group. It focuses on estimating the insertion of technologies from r.e.s. (mainly solar collectors) on buildings roofs located in sensitive contexts, through a very simplified tool useful first to the owner of the building, but also to those who design the insertion, and administrators who verify the visual impact before giving the permission to intervene.

2. Applications of technologies from r.e.s. in sensitive urban environments. An overview

The research fits in the context where it is very clear the necessity to protect the valuable environments i.e. to preserve the urban heritage, the cities and the landscape, and where at the same time it is equally clear, in our cities, the need to save and produce energy, for example, through the integration of solar systems in buildings.
In these areas it is perceived the strong resistance by those who would like to keep unchanged the image of the city while on the other side is increasingly evident the need for the individual building to be orientated towards energy self-sufficiency in order to reduce consumption of the too energy-consuming city. In these contexts, the insertion of solar collectors must ensure a balanced integration, at the building scale as well as at the larger scale of the landscape. In other words, insertion must respond to requirements given by the law, but also due to the visual perception and image preservation of the building or the urban area, as well as a landscaped glimpse.
Cases of proper insertion offer cause for reflection, in terms of approach used to minimize

the visual impact for the observer in the site where the building is located, as well as to determine the energy potential of the area, taking into account the surfaces (especially the roofs) of buildings.
Currently in Italy this type of checks are based on preliminary investigations sometimes very sophisticated, because the insertion of technologies from r.e.s., often following the construction of the building, is subject to the binding opinion of the authority.
In relation to the Italian regulatory framework, we can briefly say that in 2010 guidelines on authorization of plants powered by renewable energy sources were approved by the Regions[2], with the aim of making the widespread of technologies from r.e.s. easier and easier However, this important reference legislation which delegates to the Regions the procedure for implementing at the territorial regional scale, raises many doubts and leaves open uncertain scenarios: this mandate excludes the local authorities, and merely identify unsuitable areas, where it is totally prohibited the use of such technologies and does not allow to evaluate acceptable and respectful of the environment assumptions. In this context defined by law it is interesting to note that there are Regions that have adopted the recommendations of the guidelines *in toto* by making coincide not suited areas with the areas listed in the guidelines as an example. In other cases Regions decided not to adopt this law and to continue to operate under their own autonomy.
However, the issue today should no longer be put in terms of "if and where" but "how" we must integrate a solar system in sensitive contexts, historical valuable buildings and places that represent the memory and historical identity of a population. Today we also find interesting examples of application on buildings under the protection of the Superintendent that considered the question of an energy retrofit in an absolute rigorous way and with good results from all points of view.
We consider one of the best known examples the project of solar system integration in a part of the roof of the historical building in Naples, the *Real Albergo dei Poveri*, one of the largest palaces in Europe, located in the historical center of the city, since 1995 in the UNESCO World Heritage List (ii and iv criteria).
In 2002, the City of Naples, owner of the building, has initiated a complex renewal program, entrusting the work to European multidisciplinary team of professionals, highly skilled engineers and architects[3].
The project took into account the punctual consolidation of vaults and walls, the restoration, where possible, of collapsed elements, the elimination of incongruous additions and reconfiguration of rooms and top walls, the preservation or the renovation of flooring, the protection from the elements of roofs and walls, the preservation of plasters and stone materials, and original bricks, the implementation of a flexible system of the plant system; the original materials such as tuff, brick, limestone, are reused, the old wooden window frames were restored, as well as the ancient cisterns to collect rainwater.
Regarding the roofs green cover were used, and, on the corridors at the last level, the current cover in reinforced concrete were replaced by a transparent one with integration of photovoltaic cells (fig. 1).
Verification from an environmental point of view has shown a reduction in the production of energy due to an adjustment to the building envelope (in terms of inclination and orientation). Compared to the theoretical production, the productivity decreased by 16.9% reaching a specific productivity of energy equal to 1269 kWh / kWp year.
Another important question remains open and unsolved by the regulations; it is related to

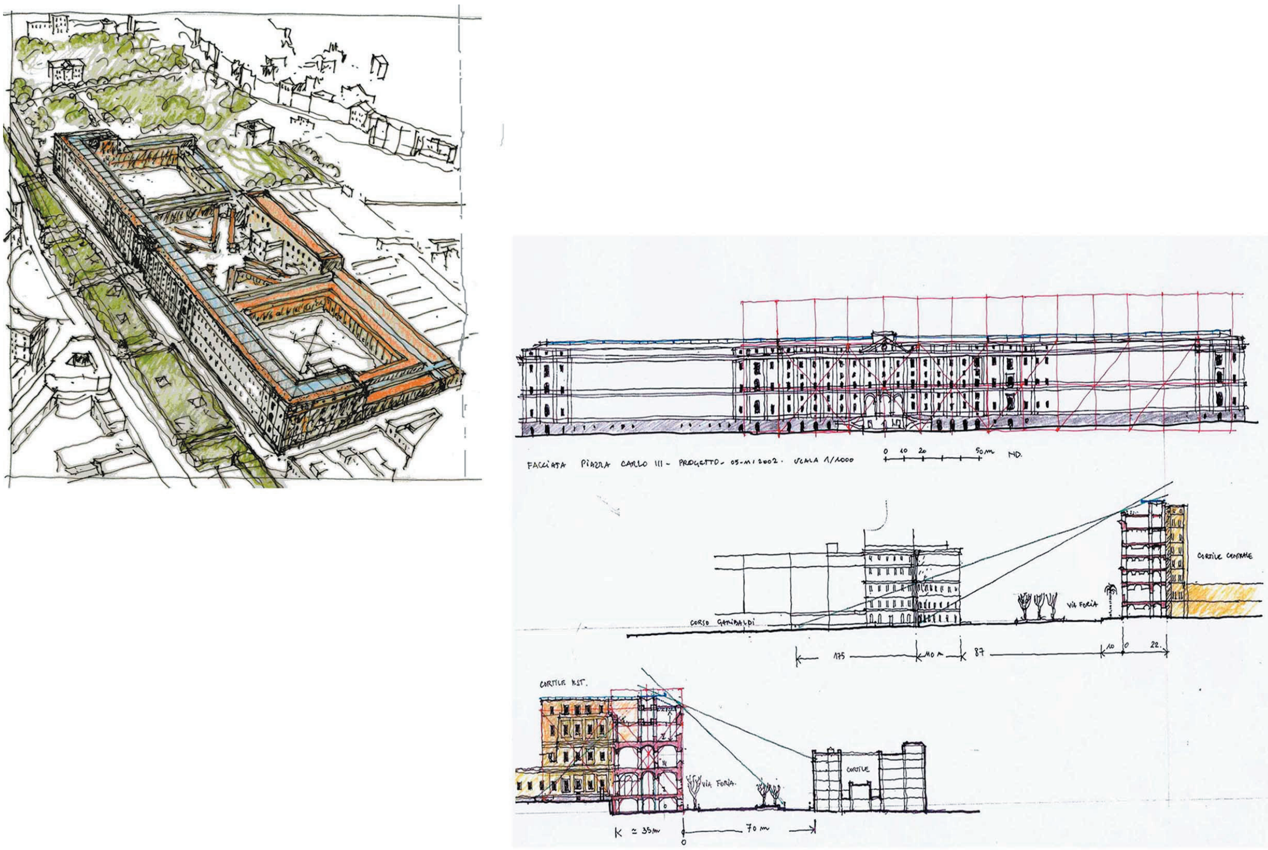

Fig.1. Sketches related to the restoration project of the Real Albergo dei Poveri in Naples, perspective view of a bird (left) and related to visual impact of photovoltaic roof from the street (drawn from table.21 of the final project, right image). Source: www.b5srl.eu.

the instrumental aid, necessary for the evaluation of this type of impact. Sophisticated tools that can be adapted to different contexts are nowadays available. The problem can be approached from two perspectives: on the one hand we need tools useful to those people that carry on the project, to check, and possibly, change it, making it more acceptable.
On the other hand there is the government that has to provide itself with tools for the assessment and control of the proposed projects. Also in this case the solutions may be different and vary depending on the degree of difficulty and complexity of the environment in which the plant should be inserted.
“Methods and techniques should not be based on mere energy efficiency of production and transport but must be related to the territorial analysis, and therefore we need to develop tools that integrate the two instances in them also in spatial terms.” This is the object of an interesting research study based on an integrated approach between energy issues and the territorial ones proposed by Eng. Casini, of the department DESE of the University of engineering in Pisa who worked on the city of Pisa.
To implement this approach we need first of all a 3D reconstruction of the city, or part of a city, aimed firstly at highlight areas, and in particular the roofing, which for exposition and inclination are more suitable for installation of solar collectors and therefore suitable to responding to energy and hot water needs, and where at the same time it is irrelevant or very low the visual impact for a tourist who is strolling through the streets of the historic city.
For the three-dimensional reconstruction the LiDAR satellite data are very effective. They are obtained through a kind of scanning on a plane that allows the reconstruction of the

pitched roof[4].The approach proposed by Eng. Casini and experienced in the Municipality of Pisa provides subsequently five stages. The first, carried out with a GIS system, it is necessary to evaluate the energy potential of the area, through the calculation of the incident solar radiation.
Successively from the most sensitive places, in this case the top of the Tower of Pisa, the riversides and other tourist routes, the parameter of visibility is evaluated. The next phase combines algebraically the results of the visibility with those of incident solar radiation on the roofs, determining the real availability of the surfaces, net of the surfaces visible from the touristic viewpoints.
The last step is to match the energy demand and supply, i.e. the appropriate defined areas and the energy needs, in this case the summer needs for hot water to be covered by solar collectors on the roof (fig.2).

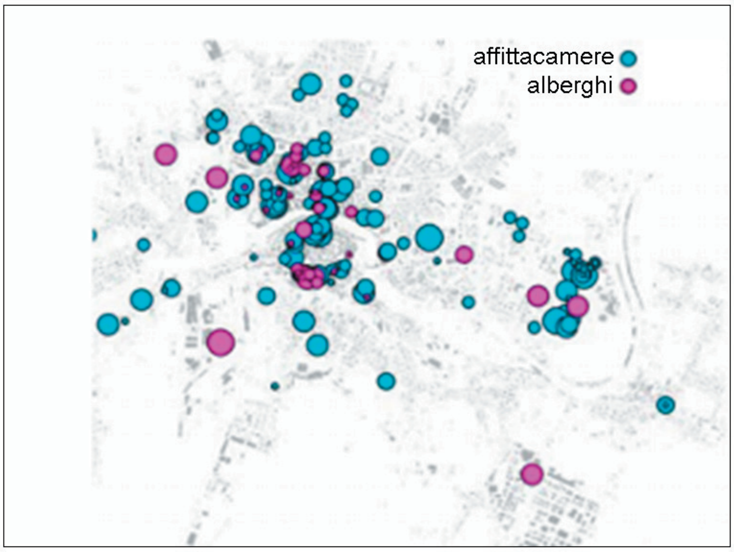

Fig. 2. Use of GIS for the representation of the demand for domestic hot water in summer for the hotels in Pisa (left), and selection of residential buildings (right, in green) suitable for the installation of solar panels, i.e. not visible and sunny in the roof. Source: C. Casini.

As described (Casini, 2011), the specific results from the analysis carried out have shown that most of the hotels are able to meet their needs with solar thermal technology without causing significant visual impacts to the urban context where they are included, whether in the center or in outlying areas. In addition, the use of GIS software has allowed to combine statistical data (municipal registry office), energy (hot water demand in the residential and tourist sectors) and territorial (physical form of the city) in an innovative way.
This contribution reports part of the work carried out in the research PRIN. It was based mainly on the restitution of the state of the art about the presence and use of simplified graphical tools easily available and understandable by individuals, designers and administrators. There is indeed a very fertile ground because it is a common topic of research, often EU funded, since the late 90’s and still encouraged by local and supra-local administrations.
One of the most important and complete research programs relates the Task 41 Solar energy & Architecture of the IEA Solar Heating and Cooling Programme which has deeply analyzed the issue of the criteria and guidelines for the integration of solar systems, considering, between possible technological solutions, the applications in sensitive contexts, as well as tools designed for designers who use CAD tools to design for example additions of solar systems on buildings. Another one is the task 51, on solar energy in urban planning with a part relating to the integration of solar systems in architecture.
Among the research centers that have examined the issue of simplified graphical tools there are the SUPSI of Lugano and the LESO of the University EPFL of Lausanne, both in Switzerland, that have been working for years on both the product and its integration, and the visibility of the intervention from the facing urban space.
The work carried out by the SUPSI, in particular from BiPV competence center based in Canobbio, has allowed to develop a method for assessing the impact of solar technology on buildings of historical and cultural interest. The work, entitled “Development of technical and architectural guidelines for the integration of solar systems in historic buildings”, was commissioned by the city of Bellinzona and is developed from a set of criteria already taken into account in some of the cantons in Switzerland.
The existing criteria are mainly based on the geometry and positioning of the solar panels on the roofs. The research has identified other criteria, focusing in particular on the visual impact. One of the first requirements for improving the architectural quality of new and existing buildings that include the installation of solar systems, is to define and then try to reduce the formal limitations that negatively characterize the installation, in order to identify the most appropriate solutions. They represent a set of suggestions to approach the project of integration of technologies from renewable energy sources on the buildings. It is the objective requirements which do not exclude the analysis of each specific case and which is especially crucial in buildings or historical areas in which the intervention proposal must be evaluated from different points of view. The requirements taken into account are: the co-planarity, respect of the line, the shape, the grouping of elements, accuracy and visibility (fig. 3).
The criteria described above are accompanied by a series of recommendations, not mandatory, subjective, and referring to the visual characteristics of the installation.
The laboratory LESO of the EPFL has developed a software that helps to clarify the concept of quality of the architectural integration through a quality evaluation method. It is designed for the authorities involved in the implementation of the acceptability requirements at local level, based on the concept of criticality (fig. 4).

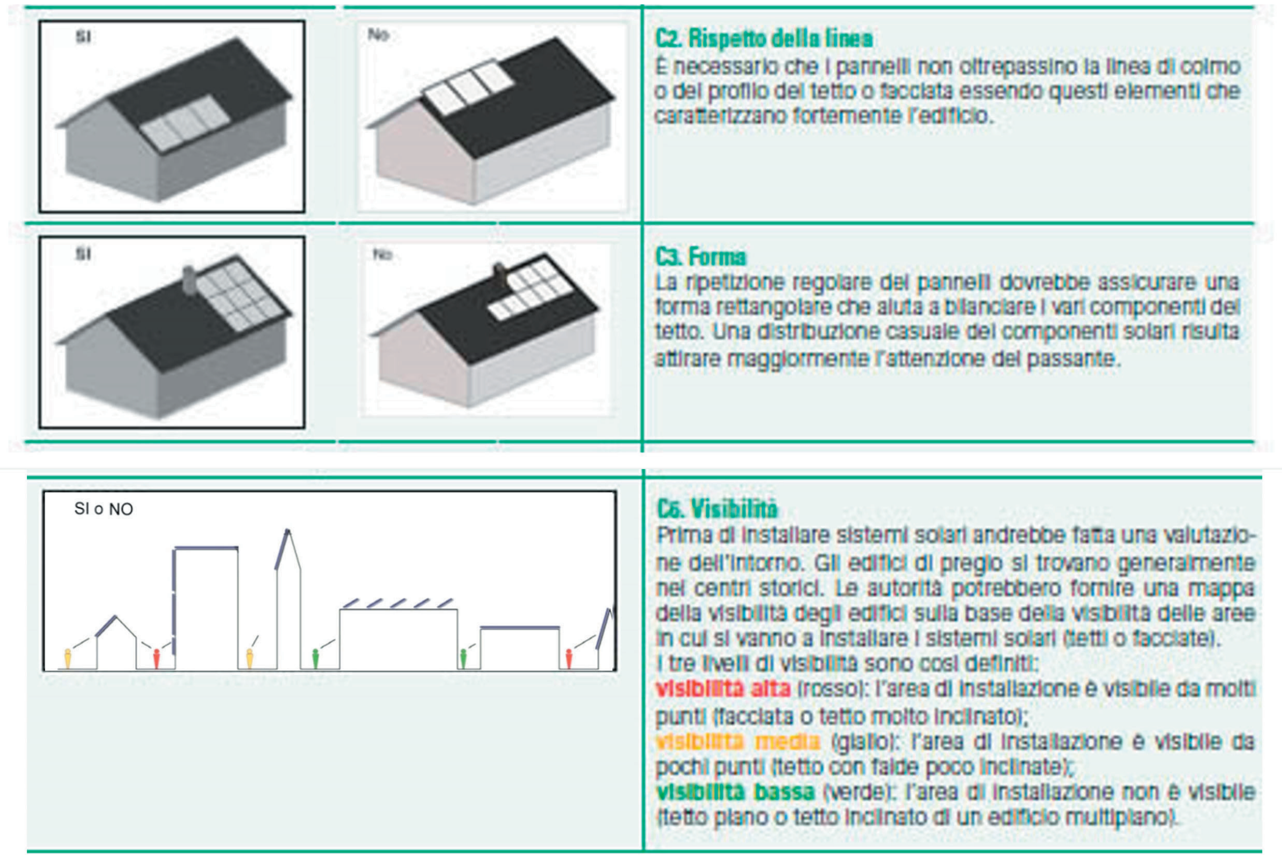

Fig. 3. Three of the seven criteria identified by SUPSI for proper integration of solar system on the roof, respect of the line, form and visibility. Source: SUPSI, Lugano.

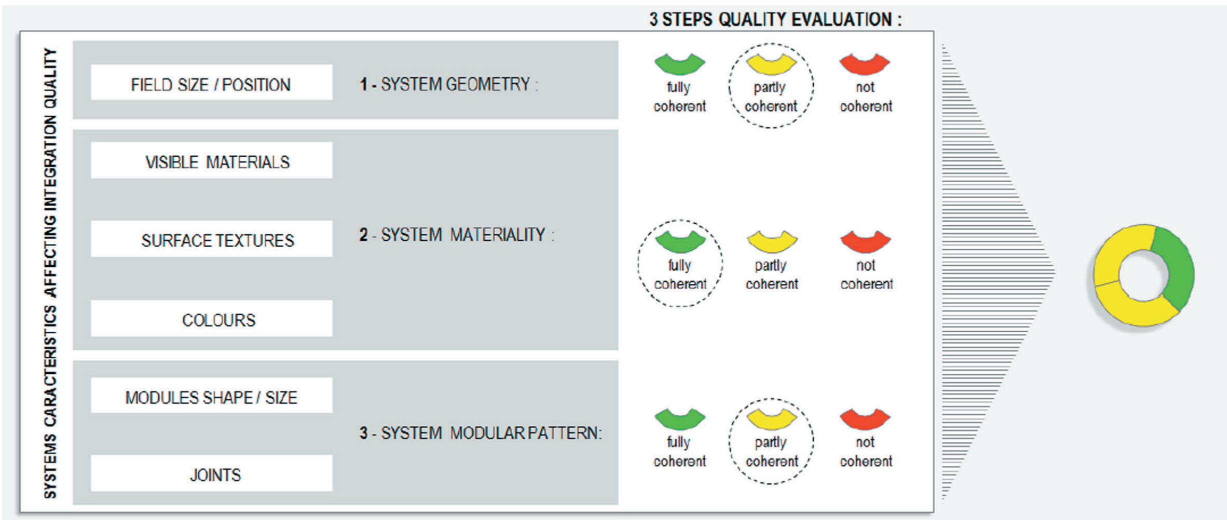

Fig. 4. Part of the tool LESO-QSV concerning the quality evaluation steps and resulting graphic representation. Source: LESO, EPFL.

The software shows examples (more than 100 emblematic cases) that display the visual impact of some installations, based on a predefined set of quality requirements and offers at the same time the authorities a model to evaluate the quality of additions (fig. 5).

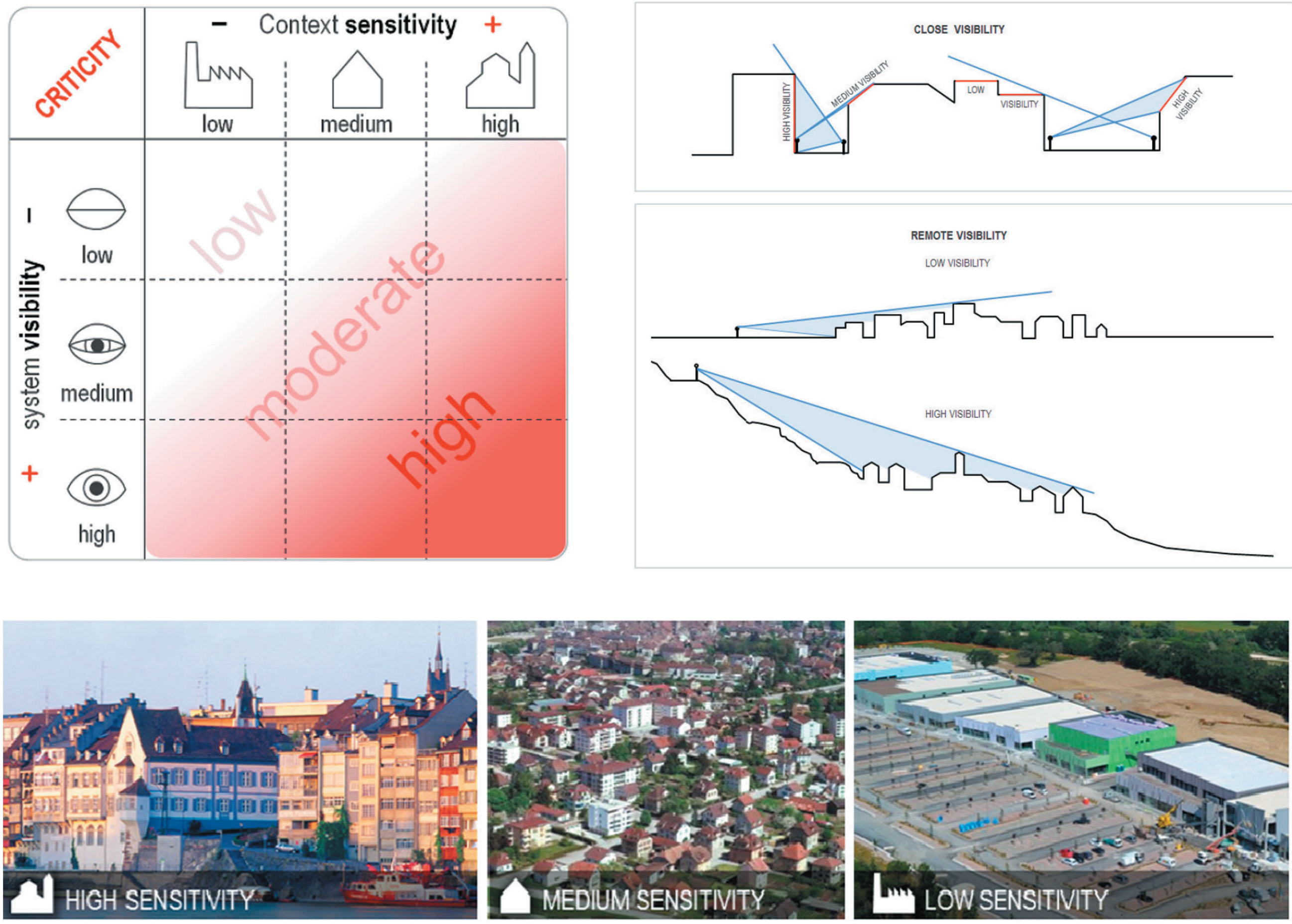

Fig. 5. Part of the software LESO-QSV that shows the “Criticity” grid crossing urban context sensitivity with building surfaces visibility. Source: LESO, EPFL.

3. The verification of the visibility of the solar system on the roof: a simplified graphic tool
In light of the analysis carried out, and especially regarding the need for simplified tools for the visual impact assessment, a graphical tool has been developed that evaluates the proposal of integration in the roof, varying the distance of the observer, the roof pitch and height of the building.
It is meant primarily for a project designer to verify the degree of visibility from the street; or even an institution that needs to verify that the project meets certain requirements related to the visual impact.
It is possible, through a single reading, check the possible visual impact. This is the first step but it is critical to later identify the configuration that the selected system should have, i.e., as the SUPSI researchers say, to identify criteria for the requirements of an insertion respectful of the context, whether we talk about building, an urban area, or a larger landscape.
Figure 7 illustrates a type of graph that combines 3 variables, and can be used to verify the impact that a technology placed in the roof (for example, a solar panel) has from the road or from the square, however, from a frontal position with respect to the roofing element. This

method identifies a point at the center of the roof that could represent the solar panel. The variables that can be measured simultaneously are: the distance from the building, the building height and the slope of the roof

Overall it is taken into account 4 different heights and 4 of different roof inclinations (figg. 6, 7).

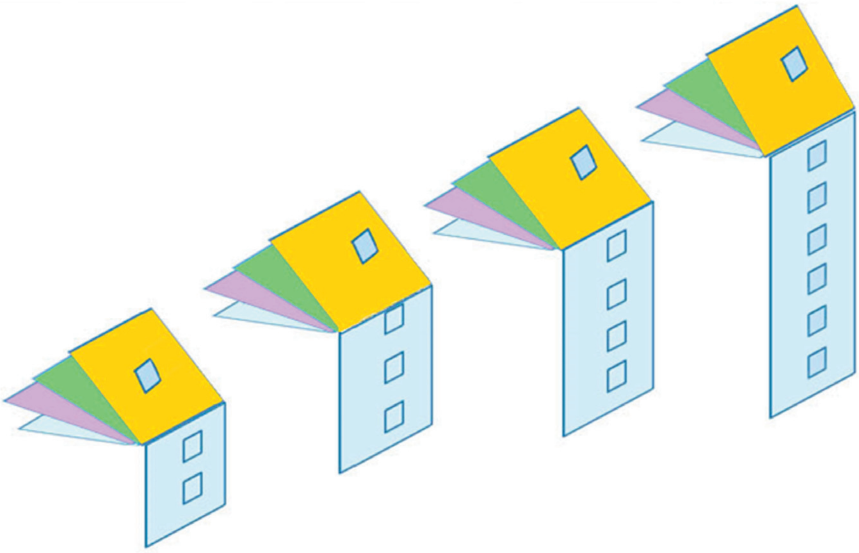

Fig. 6. Diagram of the buildings of 7, 10, 13, 18 meters high, with pitched roofs of 15 °, 30 ° and 45°, taken into account for the verification of the visibility of the solar collector on the roof. Source: developed by author.

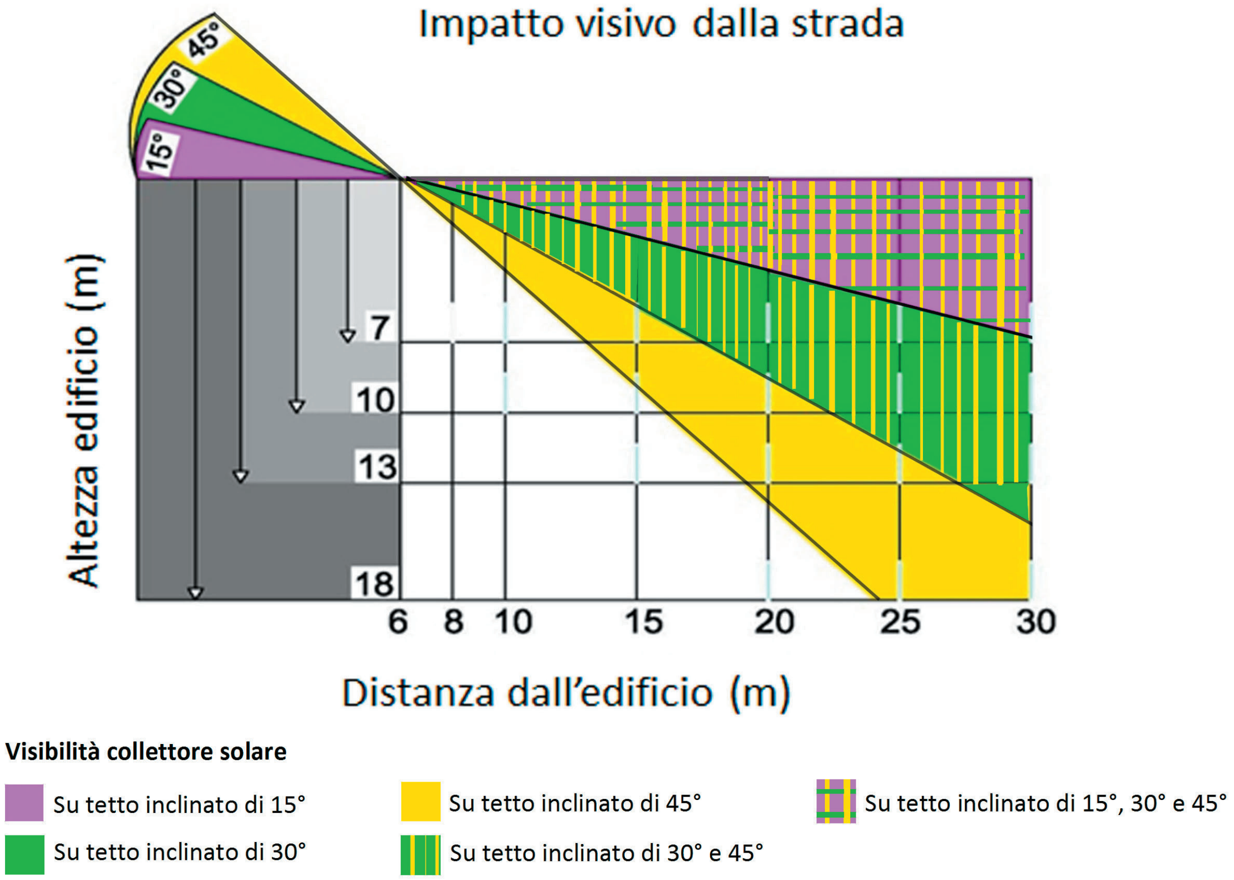

Fig. 7. Scheme for the check for visibility from the street of an element on the differently inclined roof. The scheme concerns the verification varying the distance of the building and its height Source: developed by author.

As can be seen in the figure, the different inclinations of the roof are also recognizable by the different colors: pink for the inclination of 15°, green for the inclination of 30° and yellow to the inclination of 45°. The color shown in the rectangular cells, highlights the fact that in the cell that represents the combination of building height and distance of the observer, the element placed in the roofing is or is not visible; if so, for which roof pitch. Clearly in the case of the flat roof, where the collector is not tilted it is not visible.
Considering a tall building less than 7 meters, the panel placed on a 15° sloped roof is not visible from a distance of less than 30 meters (as can be seen looking at the intersection of the horizontal line indicating the height of buildings and the vertical line indicating the distance from the building).
In the building 10 meters high, from 17 meters distance(between 5 and 20 meters) it would be possible begin to see the panel on the roof pitched of 45° (yellow area), and starting from 22 meters if the roof is tilted by 30° as indicated by the yellow and green area.
At a distance of 10 meters from a building of 10 meters high, the panel is never visible, in fact the cell is not colored (figg. 8, 9, 10).

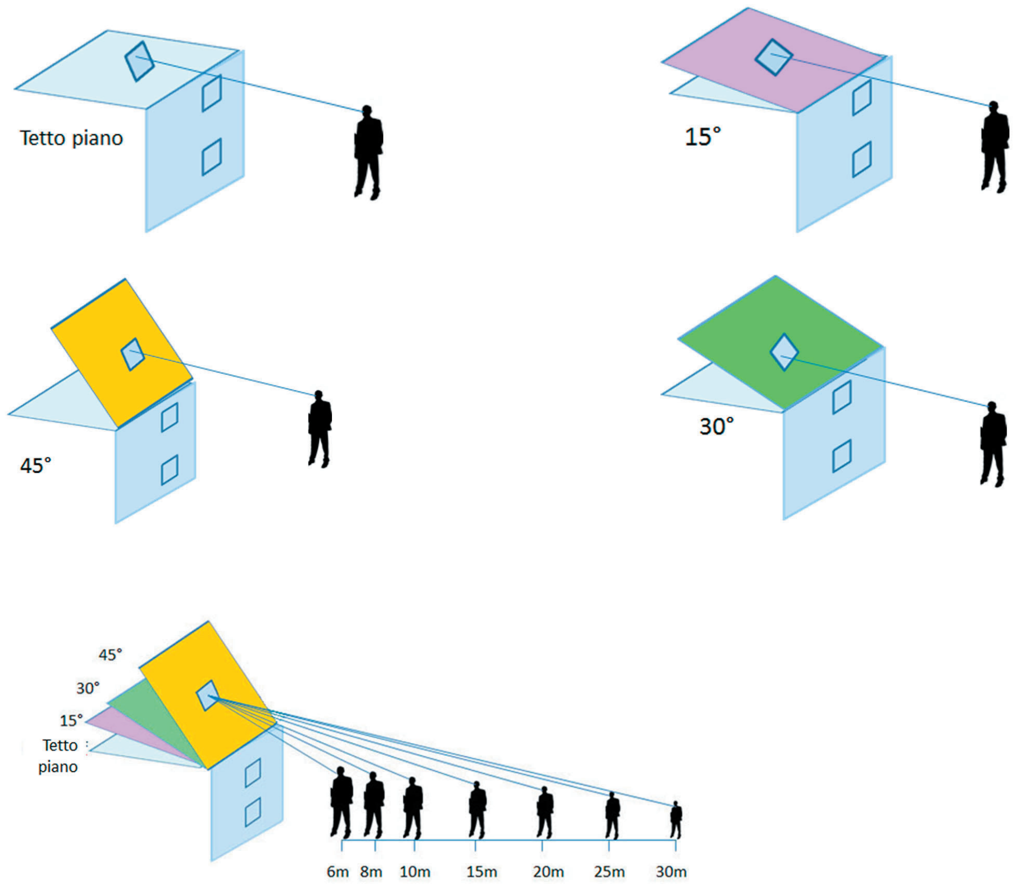

Fig. 8. The visual impact of the solar collectors can be evaluated for different roof pitch (flat roof, 15°, 30°, 45°) at different distances from the building (6 to 30 meters) of the observer. Source: developed by author.

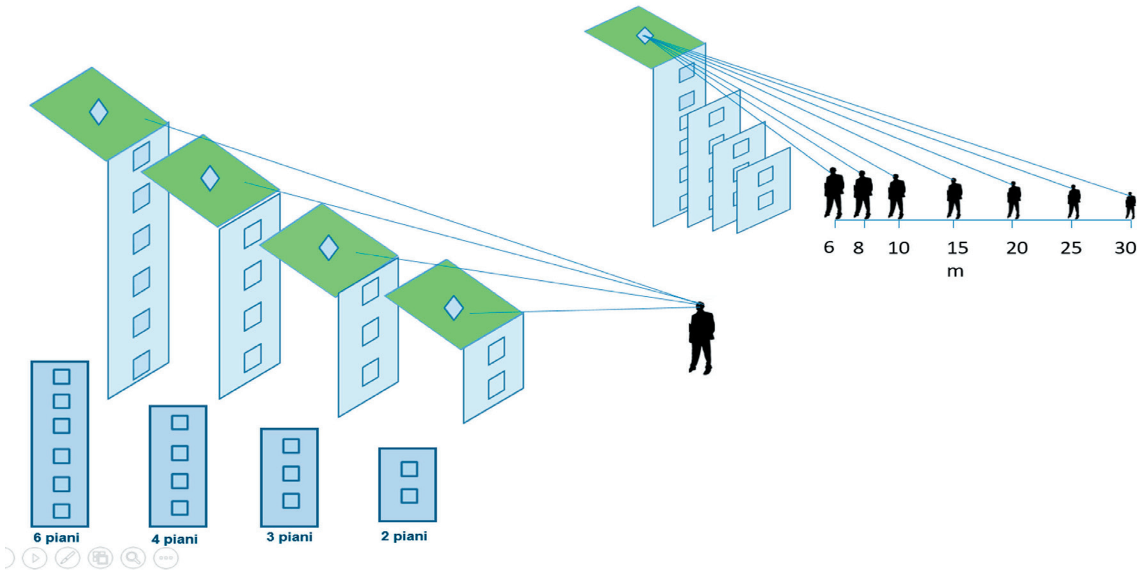

Fig. 9. The visual impact of the solar collectors can be evaluated for different heights in the building (2, 3, 4, 6 floors) and from different distances (6 to 30 meters) of the observer from the building. Source: developed by author.

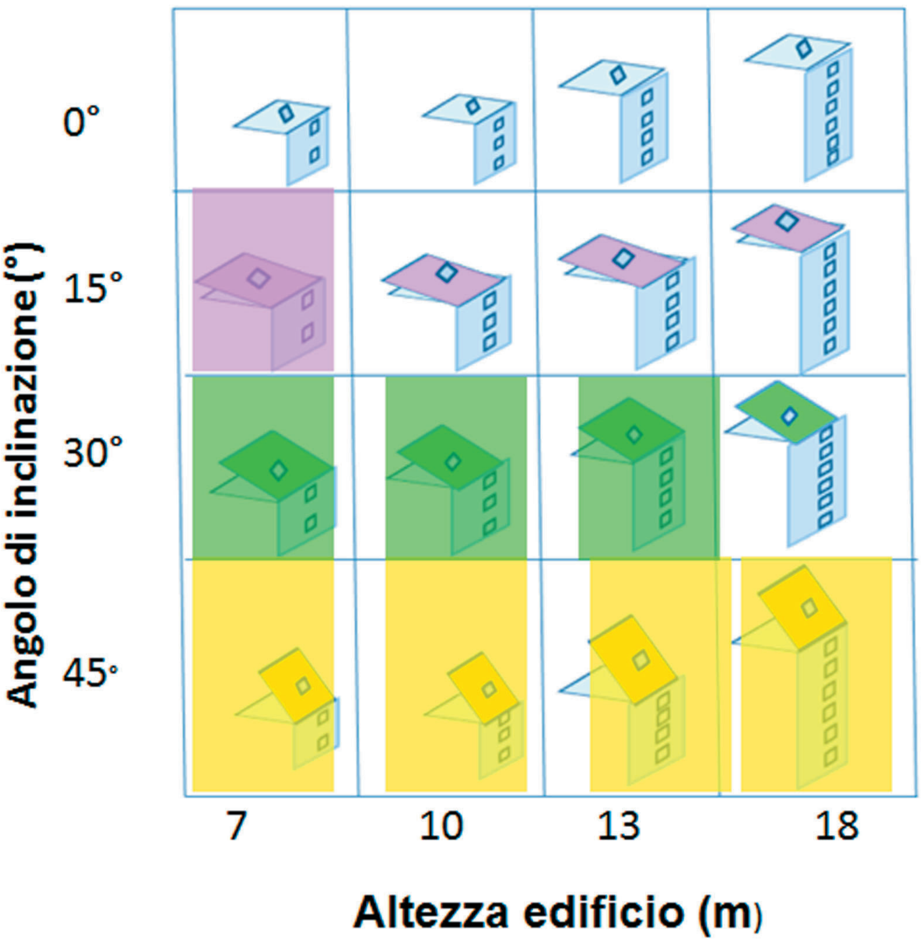

Fig. 10. Visibility of solar panels at 30 meters distance. The solar panels are visible in two-story buildings (7 meters) when the roof is 15° tilt. The collector is also visible when the roof pitch is 30° and the buildings are about 13 meters, and when the roof is inclined at 45° in buildings tall up to 18 meters. Source: developed by author.

4. Conclusions

The simplified tools to assess the visual impact of installations from r.e.s. in our urban areas have an increasingly important role in mitigating the conflict between the need for conservation of our urban heritage and landscape and the need to reduce the environmental impact of our cities, more and more energy consumer. The sophisticated instruments (as described for example in the case of the University of Pisa), which allow a precise and reliable verification of a particular specific case, often require specific expertise, both in the realization of the analysis, both in the interpretation of the results, for example, by the authorities. Other instruments are sufficiently simplified to be used in a widespread manner by individuals, designers and authorities who must approve an intervention (think of the work of the SUPSI and LESO). This approach goes towards of the Italian national legislation, designed to encourage a wider use of technologies from r.e.s. in the national territory.

However, the law leaves no possibility for the evaluation of interventions in sensitive environments that meet the two requirements of preserving harmonious picture of the place and make a positive contribution in terms of energy, as can be verified by the local authority. The proposed instrument takes into account the three aspects simultaneously - inclination of roof, building height, observer's position - that determine the visibility of the element in coverage. This is a first step, but a prerequisite to the element choice and to its placement in the roof. Aspects related to the size, shape, color and texture are also important aspects that make possible a harmonious integration into a contemporary context in constant evolution in the respect of memory of the original image of an architectural work.

It is important to continue the work so as to include in a simplified tool the degree of acceptability of an energy retrofit of this type that can vary depending on the type of landscape, of "environmental" culture of citizenship and administrations, in order to cross the quality parameter of the component designed and methods of integration with the three parameters already taken into consideration.

Notes

1. RUROS means Rediscovering Urban Realm in Open Spaces. It was a research funded by the V framework EU Programme, concluded in 2004 and coordinated by the research center CRES in Athens, which the mentioned research group was partner.

2. (Decree September the 10th 2010: guidelines for the authorization of plants powered by renewable sources), provided by law 387/2003.

3. The professional team was composed by: RTP Croci-Repellin, Prof. Eng. Giorgio Croci, Arch. Didier Repellin, Arch. Francesca Brancaccio, Arch. Nicolas Detry, Arch. Laurence Lobry, Arch. Pascal Prunet, Eng. Mario Biritognolo, Eng. Giuseppe Carluccio, Prof. Arch. Paolo Rocchi, consultant of the B5 srl company.

4. The laser-scanner is composed of a transmitter, namely a laser, a receiver, represented by a telescope, and a data acquisition system.

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