Energy integration for performance intensity public urban spaces[1]

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Abstract

The paper reports some results from the National Research Project 2008 on systemic integration of technologies for renewable sources in the built environment, where the team from the Second University of Naples has studied the context of public open space in a consolidated city. The group has worked on preparing complex protocols for environmental reading of the townscape. According to international scientific literature on the subject, we proposed the definition of the features of the intensity performance spaces for the meta-design of innovative solutions. These solutions are characterized by multi-functionality and adaptability to variable context conditions. Features regarding energy autonomy and the requirements of integration suitability for renewable energy technologies are here studied. The relationship between requirements and strategies for the integration of PV components together with their applicability and potential compatibility in urban open spaces are discussed.

1. Systems to analyze urban open spaces

The evolution of the urban asset, in constant and chaotic increase has lead to reconsider the role of open spaces through updated interpretation codes, by aggregating fulcrums of public and social life organized according to new reactive models thanks to information technology. In order to identify indications for the sustainable design of equipment for such places, it is advisable to read them in semantic, energetic and environmental terms in order to guide the redevelopment considering the complexity of the present aspects.

By referring to the National Research Project on systemic integration of technologies for the production of energy from renewable sources in the built environment, coordinated by G. Scudo of the Politecnico di Milano, one has a more thorough understanding of the topic. The local unit of the Second University of Naples, led by S. Rinaldi, has studied the application in urban spaces, by using a system of three adjoining squares as a case study. According to international scientific literature on environmental design, public space is read through the overlaying of levels which express data regarding physical, material and use, besides mapping of meteo-climate conditions.

Experiences from cities such as Berlin, New York and San Francisco have enabled the construction of a functional protocol for a GIS tool, which is the first part of his complex analysis methodology. In fact, the Berlin Digital Environmental Atlas 08.06 (Edition 2008) reports the solar Energy potentials on roofs and facade surfaces of the town in the chapter dedicated to solar Energy. Whereas, online solar maps of New York City (NYC Solar Map, by City University of New York, CUNY) and San Francisco are interactive tools that evaluate the solar energy potential for every building whose address is typed. Furthermore solar existing panel plants are reported with their energy production, allowing to asses environmental benefits, savings, costs, incentives and revenues for the investments in this sector. Thus, it is impossible to obtain data for open space surfaces in these cases, although the implementation seems quite feasible.

By using shared spaces in our towns according ones ever-changing needs, different groups of people produce a variety of phenomena: mixed, temporary, representation, conflict or pacification uses, which derive from direct or indirect appropriation.

The necessity of a methodological and survey approach is nowadays acknowledged, in order to obtain appropriate design solutions. To find vocations and priorities of the case study places, on the basis of tests carried out according to the protocol and thus reported in the context conditions in GIS, our team has worked towards obtaining a map of the users' needs, in reference to habits and timeframes. In fact, social and technological changes affect the way and time people use public open spaces. To identify flows and patterns of use, we studied the different dynamics on a daily, monthly and yearly survey of the area.

1. This work is the result of collaboration between two authors: Renata Valente has written paragraphs from 1 to 3, Luigi Foglia has written paragraph 4.

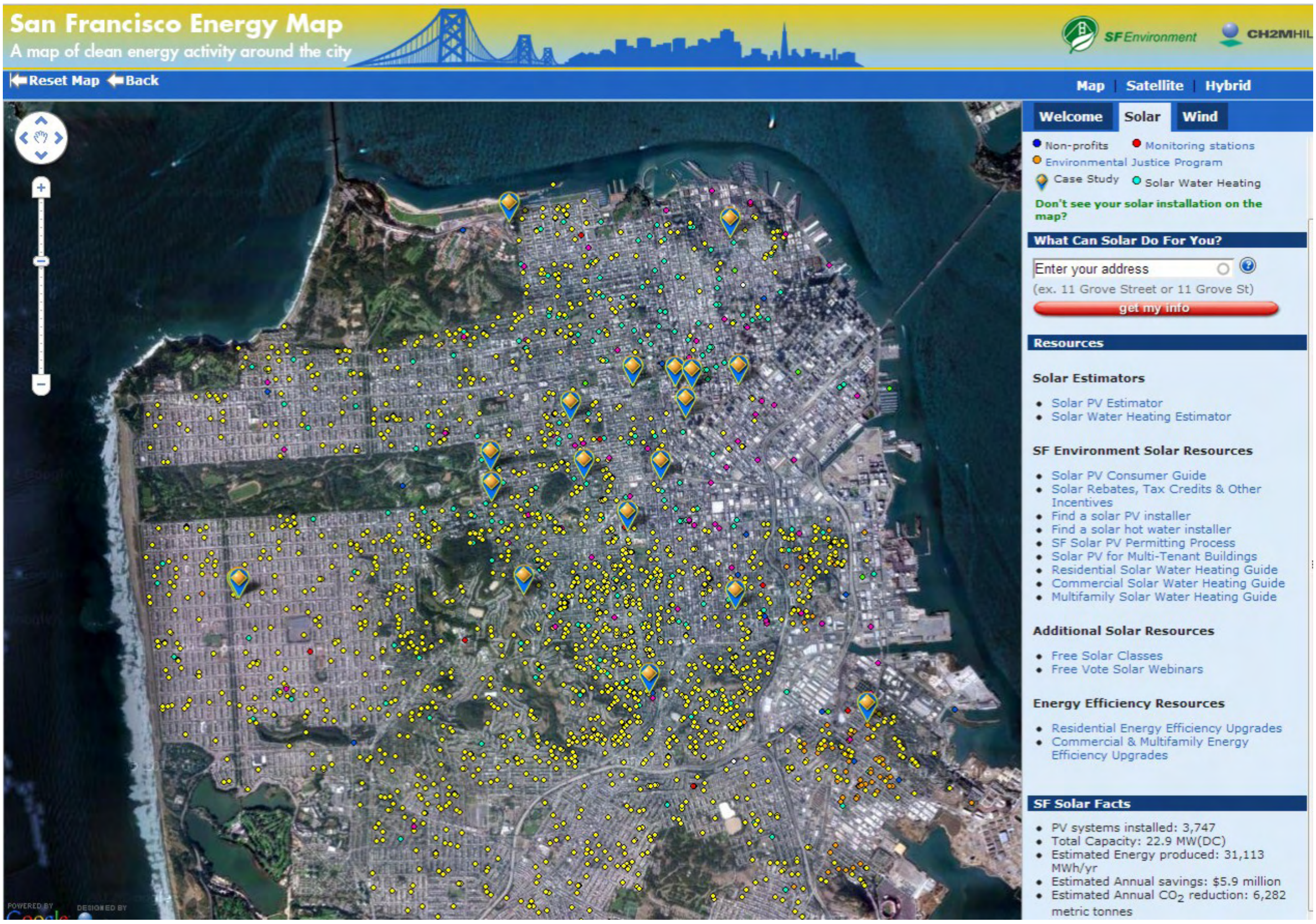

Figure 1 – San Francisco Energy Map. Solar Installations: municipal, residential, schools/libraries, commercial, non-profit organizations, monitoring stations, Environmental Justice Program, case studies, solar water heating (from http://sfenergymap.org).

2. Spaces with performance intensity and energy autonomy

Design ideas that govern the various configurations over time and the method of transformation are necessary to meet the needs dictated by continuously changing scenarios, in order to avoid dysfunctional conditions. To provide customizable, intelligent and responsive small buildings, it is possible to use lightweight construction systems that become dynamic from the original static shape. These artifacts should absorb even chaotic layering of service equipment in open spaces by canceling it, in those situations where operating on the frontiers of existing buildings has not been possible. The described strategies are aimed at creating spaces characterized by four main aspects:

a) possible integration of new required equipments in existing volumes and surfaces, enhanced by assimilating functionality and raising the possibility of use;

b) transformability of the same physical equipment;

c) dynamism of these spatial configurations, powered only by energy from renewable sources;

d) performativity, that is predisposition both to provide a direct benefit and to produce new participatory relationship between users and place. This attributes value in terms of relationships to the outcomes of the induced interventions.

The development of this approach aims to give shape to places rich in perceptual stimuli and interacting potential, that may become basic elements of contemporary urbanity, generating new social cross-identifications. We have defined such places as characterized by "performance intensity", which means they are furnished with extensible quality and potential, related to innovative use. To look for guidelines for these projects is necessary to define a framework of requirements related both to needs classes already identified in the scientific literature for open spaces and to associated to new parameters.

There aren't, however, enough appropriate case studies presenting all the performances required. So we have referred to features of the projects chosen each time as showing one of the aspects related to our goal. Then we have extrapolated and aggregated these features to shape a sort of identikit. This procedure gave rise to a list of characters organized by families. The first of them is related to space (including the characteristics of flexibility and integration), the second to

use (including the usability and the intensity of use), the third to sustainability (examining options for energy independence and reversibility), the fourth to comfort (concerning environmental objective and subjective perceptual aspects) and the last responsiveness (where we include characters related to computerization, sensitivity and interactivity of the proposed equipment) (Foglia, Valente 2011).
Here we discuss the character of energy autonomy for new urban spaces, starting with the discussion on the uses that require electrical potential, exploited for functions that we have distinguished in first and second utility. In the first group we include, in fact, the lighting system, the s.o.s. call points, info points, environmental control units. In the second group, we list services such as wifi and Information Technologies, social and advertising communication and safety and traffic control devices automation, charging of the various computing devices, recharging of electric vehicles, sound and visual art installations. The energy soul of new equipment for performance intensity spaces with integrated renewable energy technologies induces opportunities for scenarios that were unthinkable in the past.

3. Suitability to integration of components for micro-landscape design

Once we have assessed the dynamic and variable nature of the projects to propose, the energy requirement for these transformations leads to explore the possibilities and integration modalities of technologies for the production from renewable sources. These technologies include among the obvious benefits also the chance to not imply physical landline connection works with the urban electric network, favoring the conditions of pavement maintenance.
The requirements for the suitability to integration of PV elements in the built environment have been studied by framing the importance of the management aspects in relation to the maintainability of the integrated systems linked to their durability and reliability over time. This work is included in the Project Guide of the IEA (International Energy Agency) for the application of photovoltaic technologies to so-called Non Building structures (IEA, 2011), already commented in a previous publication (Foglia, L., Valente, R., 2011a.)
To critically study in deep the mentioned requirements, we

Table 1 – Relationship between requirements and strategies for the integration of PV components: the case of coverings in urban open spaces (elaborated by author from the contents of A. Bosco, S. Rinaldi, "Tecnologie di Integrazione," in *Fotovoltaico e Riqualificazione Edilizia*, edited by A. Bosco e A. Scognamiglio (ENEA, 2005): 196).

implementation procedures		overlap	partial replacement	total replacement	addition of technical or spatial elements
classes of requirements	requirements				
technological suitability to integration	constructive compatibility	•	•••	•••	•
	static compatibility	•••	••	•••	•
	materials compatibility	••	•••	•••	•
morphological suitability to integration	chromatic variation	•	•	•	••
	variation of graine	•	•	•	••
	variation of texture	•	•	•	••
bioclimatical suitability to integration	heat recovery/dispersion	•	•	•	••
	control of solar radiation	•	•	•	••

• *low criticality*
•• *medium criticality*
••• *high criticality*

component: *covering*

refer to a 2005 text (A. Bosco, S. Rinaldi, 2005) where authors identified other three classes of requirements, considered as specific definitions of the category of needs. These classes were: the technological suitability to integration, to which compatibility of construction, static and materials refer; the morphological suitability to integration, to which the changes in color, grain and texture are attributed and the bioclimatic suitability to integration with the requirements of recovery and heat dissipation, and control of solar radiation. In the same text the authors distinguished four integration strategies: overlapping, total substitution, partial substitution and addition.

Such a summary table of the relationship between strategies and integration requirements, can be constructed also for each of the categories of components of urban open spaces we have already proposed (Valente 2010). These are: coatings, quints, roofing and tectonic, excluding that relating to objects. We propose here table 1, where, unlike what happens in the reference work, more conditions of low criticality of the application appear, specifying that the bioclimatic suitability to integration regards the possibility of conditioning the microclimate next to the considered element.

This way it is possible to study the relationships between space components, needs systems, energy requirements and performance of any selected technologies, reporting on the steadily improved performances from applied research, as described in the following section. In addition, the passage from the conception of open spaces as passive energy systems (terminals of the power grid) to complex active systems (with inflows and outflows) leads to rethink the relationships between space and energy in the direction of dematerialization. By creating self-sustaining hub (connected or off grid) to supply the needs in every place, the energy management dependent from small locations rather than large power plants might be safer, although more complex. In the interim, the gradual replacement of traditional lighting elements with PV technology models (if not be eliminated through the integration of light in architectural elements) may be preceded by the connection of the current ones with plants on roofs or walls of bus shelters, kiosks and parking lots.

Figure 2 – Ameglia (La Spezia, Italy). One of three prototypes of stand-alone photovoltaic shelter made in 2004, as part of the Italian German PVACCEPT research project funded by the European Commission. This project is based on the integration in the architectural historic environment and landscape (photo R. Valente).

Figure 3 – Ameglia (La Spezia, Italy). Detail of photovoltaic trellis wiring. Five 2.40 m x 0.30 m module strips for each pergola facing south / east at an angle of 30 ° above the horizon, support the semi-transparent thin film with a pattern of 10% of holes which produce up to 240 Wp (photo R. Valente).

4. Applicability and potential compatibility of the PV technologies with urban open spaces

This is a study to identify analytical criteria concerning the applicability of the photovoltaic technologies for the performance model of urban open spaces, aimed towards energy autonomy. These technologies are both currently in production and/or in experimentation.
Therefore we would like to identify and connect the performing aspects (linked with the energy production) with the peculiar characteristics of the urban open spaces. This connection must be carried out according to the principles of both the potential compatibility and the maximum integration and non-interference with the uses. Therefore, the elaboration of an operational methodology which aims at reading/systematizing data and knowledge, is required. This model supports the design choices considering the possibility of integrating PV technologies for the energy autonomy and the peculiar characteristics of the new spatial evolutionary structures.
Main PV systems available on the market and in experiments (table 2) can be classified, establishing relationships among the data concerning the technology of reference (photovoltaic generation, basic technology, cells) and the applications prevailing on the different supporting typologies. In order to obtain an adequate implementation, both the market and the research offer different application solutions for each specific technology. The different typologies of support and treatment of the cells and modules can influence both the

Table 2 – Categorization of the main PV systems available both on the market and in experiments.

PV generations	Basik technologies	PV cells typologies	Prevailing applications on supporting typologies
First	Crystalline silicon	Monocrystalline silicon	- Rigid solar panels
		Polycrystalline silicon	- Rigid solar panels
Second	Thin film solar cells (TFSC)	Cadmium telluride (CdDe)	- Thin films solar cells on flexible substrates - Printed thin films solar cells on flexible substrates - Laminated thin films *cut-to-size*
		Arsenurio di gallio (GaAs)	- Thin films solar cells on flexible substrates
		Copper indium gallium selenide (CIS or CIGS)	- Thin films solar cells on flexible substrates - Thin films printed/preforated on flexible substrates
		Amorphous silicon (a-Si)	- Thni films solar cells on flexible substrates - Preforated thin films on flexible substrates
Third	Nanocrystalline silicon	Nanocrystalline silicon	- Paints - Gels
	Quantum Dots	Nanocrystalline silicon	- Nanocrystalline silicon thin film
	Multijunction	Multijunction	- Thin films solar cells on substrates
	Beam splitting	Concentrated PV cells	- Rigid solar panels integrated with optical lens
	Superlattices	Multijunction	- Thin films solar cells on substrates
	Microcells	Spherical micro solar cells (Sphelar)	- Semitransparent thin film on flexible substrates
	Organic	Hybrid (DSSCs)	- Thin films solar cells on flexible substrates
		Organic (OPV)	- Thin films solar cells on flexible substrates - Flexible PV textiles - Printed on substrates
		Dye sensitized	- Transparent and semitransparent thin films on flexible substrates
		Multiuse pigments	- Transparent and semitransparent thin films on flexible substrates

aesthetic result of the module in terms of design flexibility and the production efficiency.
The Final 2005 Report of the "PVACCEPT" European research, coordinated by the Faculty of Architecture/Design (Udk University of Berlin), shows a datum underestimated up to now. Some factors related not only to the components but especially to the cells and the production modules can directly influence the photovoltaic acceptability within the urban contexts, often damaging the actual energy performances.
The experimentations, aimed at increasing the values of design flexibility in terms of clearness and "customization" of the modules in a thin CIS film, dot printed and/or silkscreened structure, actually highlight a decrease that is proportional to the treatment of the surfaces (averagely to be estimated around 20%) of the performances of an untreated module.
In the next step of the research, the relationships among the uses noticed in the urban open spaces, the related energy requirements and their spatial implications – in terms of possible locations of the interventions and occupation of the surfaces – are analyzed concerning the prevailing applicable PV technologies. In the analytical model (table 3) we refer to the basic and spontaneous uses (Gehl 1996) in the urban open

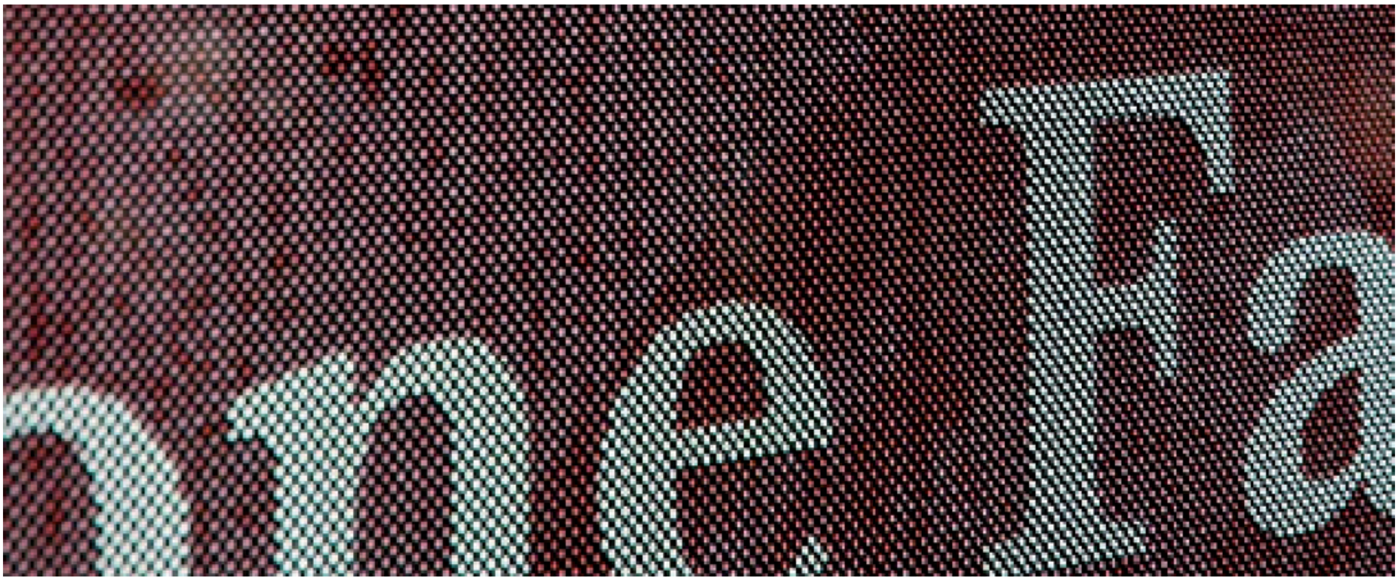

Figure 4 – Printed and perforated thin Film PV module CIS. Demo Object produced by Würth Solar and tested on La Spezia Castle according to the research program PVACCEPT.

Table 3 – PV technologies for autonomous performance intensity spaces. Relations between noticed uses, energy needs and space involvements.

Prevailing uses RUE 06 Emilia Romagna	Connected prevailing needs	Approximate energy needs IEA Report 2002 Task 7	Applicable PV technologies	Required productive surface (1 kWp) AREA Science Park/CETA 2005	Connected *micro-landscape design* components Valente 2010
Waiting	- Seat/psycho-physic comfort - Shelter/environmental comfort - Illumination/visual comfort - Recognisability	- Average (500 - 1000 W)	Crystalline silicon	Low (<10 m2)	- Shelters - Objects - Tectonics
			Thin film	Average (10-15 m2)	
			Nanocrystalline	High (>15 m2)	
			Quantum dots	Average (10-15 m2)	
			Microcells	Low (<10 m2)	
			Organic	High (>15 m2)	
Socalization	- Seat/psycho-physic comfort - Leisure/psycho-physic comfort - Shelter/environmental comfort - Illumination/visual comfort - Acoustic comfort/acoustic barriers	- Hight (1000 - 10000 W)	Thin film	High (>15 m2)	- Coverings - Wings - Shelters - Tectonics
			Nanocrystalline	Average (10-15 m2)	
			Quantum dots	High (>15 m2)	
			Multijunction	Average (10-15 m2)	
			Beam Splitting	Low (<10 m2)	
			Superlattices	Low (<10 m2)	
			Microcells	Average (10-15 m2)	
			Organic	High (>15 m2)	
Transit	- Illumination/visual comfort - Paths recognisability/stream - Usability/signage - Safety/equipment - Acoustic comfort/acoustic barriers	- Low (0 - 500 W)	Crystalline silicon	Low (<10 m2)	- Coverings - Wings - Shelters - Tectonics
			Thin film	Low (<10 m2)	
			Nanocrystalline	Low (<10 m2)	
			Quantum dots	Low (<10 m2)	
			Multijunction	Low (<10 m2)	
			Superlattices	Low (<10 m2)	
			Microcells	Low (<10 m2)	
			Organic	Average (10-15 m2)	

spaces as classified in the Building Urban Rule (RUE 2006) of the municipalities in the Region Emilia Romagna (Italy): *Waiting, Socialization, Transit, Recreation, Events, Representation, Relax, Trade, Filter* and *Technical Management*. Considering the different typologies of the prevailing uses identified, those concerning *Waiting, Socialization* and *Transit* are analyzed. Such a selection has been made in order to offer a minimum-example scenery of the features of functional/needing compatibility (*Waiting, Socialization*) and diversification (*Transit*) shown by the widest and the most implementable records. The specific uses are linked with the connected prevailing needs, mediated by the studies related to the open spaces (Dessì, 2007) and the outdoor environmental comfort (ITACA Protocol, 2004). The uses and the connected needs find spatial explanation in the elements of micro-landscape design composing the urban open space (Valente, 2010). At the same time this can show the usable surfaces for the implant of the productive PV technologies and then indicate the location of the interventions.

Subsequently, the related energy requirements are analyzed, illustrated by the Tables of "Guide of Design" elaborated by IEA (International Energy Agency) for the application of the photovoltaic technologies to the non-building design (Foglia, Valente, 2011). Ranges of values are distinct as follows:

Low energy requirement (0. 500 W);
Average energy requirement (500. 1.000 W);
High energy requirement (1.000. 10.000 W).

In addition to this, the attention is focused on the applicable PV technologies, analyzed on the basis of the extension of the surface necessary to produce a kWp. Such data – found in the 2005 *report "The photovoltaic technology, state of the art and potentiality of its use in the production processes"* made by CETA (Centre of Theoretical and Applied Ecology) and by Science Park AREA – are classified according to dimensional ranges:

Surface of a reduced production (< 10 m2);
Surface of an average production (10-15 m2);
Surface of a high production (> 15 m2).

In the last section (table 4), the layout of a synthesis model is introduced, aiming at the intersection of the data related to the performing aspects of the PV technologies, declined on the basis of the applicability and potential compatibility, with the specific features of autonomous performance intensity spaces. Here, four production technologies have been analyzed, selected on the basis of the three photovoltaic generations of affiliation and on the basis of the diversification of the proposed technological approaches. The systematization of data is organized in a hierarchical structure, according to macro-categories. In the "passport" category, different technologies are filed on the basis of the status of the development process (in production, in experimentation). It has been chosen not to limit the records to the actual market supply, but to extend it to the most recent experimentation in progress, in order to give a wide reference that is both a support and a stimulus to the designer. In the "typology" category, the photovoltaic generation of affiliation and the specific typology of the module are considered, according to the indications given by the GSE: rigid, flexible and special. In the "production" category, the potential production is analyzed according to the parameters of the surface of the production required, the (specific, non-specific) orientation and the productive skills according to the different ways of (direct,

Table 4 – Relations between PV technologies and autonomous performance intensity spaces features.

PV technologies	Passport		Typologies		Energy production				Applicability				SIPA
	Developer, year	Status	Generations	PV Modules	Performance	Required productive surface (1 kWp)	Orentation	Solar radiation	*Micro-landscape design* components	Potential Integration	Customization	Cautions/ interaction users	Potential compatibility
Crystalline silicon Monocrystalline *_Sharp*	Sharp, 1981	In production	First	Rigid Solar Panel	18%	Low (<10 m2)	Specific	Direct	Shelters Objects	Partial	No	Yes	- Wide usability - Uses - Energy self-sufficiency - Reversibility - IT
Amorphous silicon thin film (aSi) on substrate*_Sharp*	Sharp, 2006	In production	Second	Flexible substrates	9%	High (>15 m2)	Nonspecific	Direct Diffuse	Coverings Wings Shelters Objects	Total	Yes	No	- Flexibility - Integration - Wide usability - Uses - Energy self-sufficiency - Reversibility - Environmental Comfort - Psycho-physic Comfort - IT
Spherical microsolar cells_Sphelar	Kyosemi Corporation, 2010	In testing	Third	Flexible substrates	19%	Average (10-15 m2)	Nonspecific	Direct	Coverings Wings Shelters Objects Tectonics	Total	Yes	No	- Flexibility - Integration - Wide usability - Uses - Energy self-sufficiency - Reversibility - Environmental Comfort - Psycho-physic Comfort - IT - Sensibility - Interactivity
Nanocrystalline silicon paint_ *Photon Inside*	CNR Bologna, 2006	In testing In production	Third	Special	6-8%	High (>15 m2)	Nonspecific	Direct Diffuse	Coverings Wings Shelters Objects Tectonics	Total	Yes	No	- Flexibility - Integration - Wide usability - Uses - Energy self-sufficiency - Reversibility - Environmental Comfort - Psycho-physic Comfort - IT - Sensibility

diffused) solar radiation. Concerning the "applicability" category, this analysis considers as descriptive parameters the applicability of the PV technology within the micro-landscape design above defined and the features of (total, partial) potential integration, according to the indications given by the GSE. Moreover, this study considers the parameter of the "customization"– that is the design flexibility and the possibility to suit the PV module to the needs required by the specific application *in situ* - and the parameter of the "precautions of users' interaction", which describes the technological requirement for a safe use of the module.

The last category concerns the potential compatibility with the specific features (Foglia, Valente, 2011) of the *autonomous performance intensity spaces,* here called "SIPA". In this section, we show the potential suitability and the attitude of the solutions analyzed to be integrated in the interventions of rehabilitation for the new urban open spaces, according to the logics of compatibility and non-interference.

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