Fondo Europeo di Sviluppo Regionale
ITALIA SVIZZERA - ITALIE SUISSE - ITALIEN SCHWEIZ
UNIONE EUROPEA

BIPV MEETS HISTORY

GUIDELINES FOR THE INTEGRATION OF PHOTOVOLTAIC SYSTEMS IN PRESTIGIOUS HISTORICAL AND LANDSCAPE SETTINGS

Guidelines for the design and installation of integrated photovoltaic systems into protected contexts under the Italian Code of Cultural Heritage and Landscape (Legislative Decree 42/2004) in Lombardy.

Regione Lombardia

in collaboration with eurac research

www.bipvmeetshistory.eu

Operazione co-finanziata dall'Unione europea, Fondo Europeo di Sviluppo Regionale, dallo Stato Italiano, dalla Confederazione elvetica e dai Cantoni nell'ambito del Programma di Cooperazione Interreg V-A Italia-Svizzera

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"BIPV MEETS HISTORY – CREATION OF A VALUE CHAIN FOR PHOTOVOLTAIC SYSTEMS INTEGRATED IN THE ARCHITECTURE IN THE ENERGY RECOVERY OF THE HISTORICAL, CROSS-BORDER BUILT ASSETS"

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INTRODUCTION

THE “ BIPV MEETS HISTORY ” PROJECT

The INTERREG IT-CH “*BIPV meets history* ”project (2019-2022) has set the goal of deepening the potential uses of the integrated photovoltaic systems (**BIPV – *Building Integrated Photovoltaic***) in locations under landscape and cultural protection in the cross-border territories between Italy and Switzerland , with a view to finding possible solutions to the “conflict” between the protection needs of the built heritage built on the one hand, and on the other, the requests for a progressive increase in the use of energy produced from renewable sources arising from European and Italian legislations as well as creating new market prospects for the BIPV supply chain applied in these geographical areas.

The project was carried out by EURAC Research (Italian lead), the University of Applied Sciences and Arts of Southern Switzerland - SUPSI (Swiss lead) and the Lombardy Region.

BIPV - BUILDING INTEGRATED PHOTOVOLTAIC: DEFINITION AND DIFFERENCES WITH BAPV – BUILDING APPLIED PHOTOVOLTAIC

BIPV is a recently introduced photovoltaic technology integrated into building that follows a different logic to traditional photovoltaic. BIPV systems, indeed, are not intended solely as technical devices for the production of electricity from renewable sources, but they are for all intents and purposes the components of the building envelope (roofing, skylights, sheds, shading systems, parapets, curtain walls), which replace the traditional building systems, with the advantage of making active the passive surfaces of a building. BIPV is therefore a multifunctional technology.

In BAPV technology, instead, photovoltaic modules are applied directly to the building by means of mounting structures. BAPVs are independent from the structural parts of the building envelope and fulfil only the function of generating energy. However, with a well integrated architectural and energy design, even using this technology, it is possible to achieve a good degree of aesthetic integration in the housing stock.

BIPV AND THE HOUSING STOCK: A POSSIBLE RELATIONSHIP?

BIPV is the technology that is most easily applicable to the restoration of historical housing stock and landscape heritage. BIPV is, indeed, a custom designed and made technology system which is highly customizable to fit and blend into a wide range of environmental installation contexts. The use of BIPV could therefore be the technical solution for integrating RES (Renewable Energy Sources) into buildings subject to protection.

Among the various application fields of BIPV systems, those that are most eligible when dealing with architectural heritage are:

- pitched roofs;
- flat roofs (walkable, floor applications with non-slip treatment);
- skylights, windows and greenhouses.

The façade application, on the other hand, is difficult on historical-traditional buildings due to the material characteristics of the materials used which are not related to the nature of PV systems glass, while it is a valuable resource for new and/or modern buildings.

CONTENT AND STRUCTURE OF THE GUIDELINES

These guidelines define the first criteria for trying to guide the integration of photovoltaic systems on buildings falling within protected contexts under Legislative Decree 22 January 2004 n. 42 "Code of Cultural Heritage and Landscape" and amendments and additions (hereinafter, the Code) in Lombardy.

The first part identifies the context of application, and provides a brief definition of architectural assets and an introduction to the regulation of landscape's protection and enhancement, with a brief focus on the legislation in force in Lombardy.

The second part sets out the main criteria to consider for the assessment of the different intervention types, by classify the aspects of aesthetic, technological and energy integration. The criteria are the result of a series of briefing sessions, organised within the project, with the Superintendencies of Archaeology, Fine Arts and Landscape of Lombardy (hereinafter Superintendencies), representatives of the Public Administrations and the Professional Associations of Lombardy, as well as of industry producers.

In **the final section**, you will find a diagram illustrating the design process that can guide you to identify the most appropriate design solutions. It also shows a number of digital platforms developed under the project that are an important reference for all operators and from which up-to-date information on the state of the art can be drawn, including technical and building details. Finally, it provides some initial ideas for reflection on life cycle topics and the costs/benefits that integrated photovoltaics can bring to the protection and enhancement of the built heritage and the landscape more generally.

WHO SHOULD USE THE GUIDELINES

The document is aimed at engineers and designers, Public Administrations and local Landscape Commissions to support the evaluation and approval of projects, operators interested in opening up new markets (manufacturers and installers of building components, energy companies, etc.) and end-users.

WARNINGS

With the knowledge that the landscape is an extremely complex and diverse asset, these Guidelines do not claim to provide standardised solutions that can be applied across all occasions. It is therefore essential to assess each case in depth, in particular for projects involving cultural properties (under Art. 10 of the Code), for which the application of standard guidelines is very critical.

THE CONTEXT OF APPLICATION

THE LANDSCAPE: A PRIMARY COLLECTIVE ASSET

The landscape is recognised by the Italian Constitution (fundamental principles, art. 9) and the Statute of the Lombardy Region (General provisions, art. 3) as a primary collective asset, which is to be protected in particular to maintain and enhance the territories' landscape values, even if significant and constant territorial changes occur.

In **the European Landscape Convention** (Florence, 20 October 2000), the landscape is defined as an area, as perceived by local inhabitants or visitors, whose aspect and character are the result of the joint action of natural and human factors. Therefore, the territory must be assessed from the landscape point of view, both on the basis of the collection, reading and interpretation of the physical, natural, but also of the historical-cultural and aesthetic-visual factors.
Knowledge of the landscape and its potential is an essential condition for any action to protect the landscape, in order to identify the compatibility conditions between these resources and any proposed changes.

ARCHITECTONIC PROPERTY UNDER THE CODE OF CULTURAL AND LANDSCAPE HERITAGE

In the current national Italian legislative scenario, the landscape protection and enhancement finds its fundamental references in Legislative Decree no 42/2004 " Code of Cultural and Landscape Heritage" (hereinafter, the Code).

The term "*architectural property*" defines all those immovable objects which are subject to protection under the Code which can be divided into two macro categories:

CULTURAL PROPERTIES	LANDSCAPE ASSETS
Cultural, artistic, historical, architectonic properties– **Art. 10**	Areas of notable public interest – **Art. 136** Areas Protected by law**- Art. 142**

According to Article 10 “ ***Cultural property*** *consists in immovable and movable things belonging to the State, the Regions, other territorial government bodies, as well as any other public body and institution, and to private non-profit associations, which possess artistic, historical, archaeological or ethno-anthropological interest.*”

The architectonic properties subject to protection, as cultural property within under art. 10 are:

- public-owned buildings which have been built for more than 70 years and which possess historical and artistic interest and that are subject to temporary protection until the verification of the existence of artistic or historical interest is completed;
- private-owned property, built for more than 50 years, when it has been verified that it possesses a particularly important artistic, historical, archaeological or ethno-anthropological interest; or

even when they have not been built for more than 50 years, if they posses a particularly important interest in their reference to the political, military, literature, art and culture history in general or as evidence of the identity and history of public, collective or religious institutions.

According to Article 136 of the Code " ***Buildings and Areas of Notable Public Interest"*** *consist of immovable things of outstanding natural beauty or geological singularity, villas, gardens and parks which stand out for their uncommon beauty, complexes of immovable things which constitute a characteristic aspect having aesthetic and traditional value, complexes of immovable things which constitute a characteristic aspect having aesthetic and traditional value, beautiful views considered to be of picturesque quality as well as vantage points and belvederes which are accessible to the public and from which the spectacle of those beauties may be enjoyed".*

The categories of **Areas Protected by Law** in accordance with Art. 142 of the Code, are physical and geographical elements (coastal territories, territories conterminous with lakes, rivers, mountains, volcanoes, glaciers, wetlands), land uses (woods, forests and civic uses), historical evidence (agricultural universities and archaeological areas), parks and nature reserves.

LANDSCAPE LEGILSATION IN LOMBARDY

The territory of the region is very diverse and heterogeneous and has an invaluable historical and cultural heritage, also recognised globally: about 58% of the regional territory is subject to landscape protection under the Code, while 22% is included in a National or Regional Park or Nature reserve. The presence of Natura 2000 network sites (SCIs, SPAs, SACs) equal to 16% of the territory is also significant.

Lombardy is also the first Italian region by number of UNESCO sites, 11 out of the 53 recognised sites in Italy and, at the same time, it is also the most populated region with more than ten million inhabitants concentrated in the central part of the plain and in the foothill area; there is no doubt that such a structure creates great environmental and infrastructure pressures and challenges.

Regional Landscape Plan (PPR):

Approved in 2010 [1], the PPR constitutes a specific section of *the Regional Territorial Plan* (PTR) but has its own identity and unity. The PPR is the instrument through which the Lombardy Region pursues, throughout its territory, the landscape's protection, enhancement, and promotion objectives (in line with the European Landscape Convention), in an integrated way with the other instruments of territorial governance. The PPR has a dual nature as a framework for local planning tools and a landscape legislative instrument which provides protective measures to safeguard and enhance the most important areas, such as lakes, rivers, waterways, irrigation and reclamation networks, mountains, historical centres and nuclei, geosites, UNESCO sites, routes and places of scenic value and to enjoy the landscape. The PPR identifies degraded areas and the means for their optimum landscape redevelopment; moreover, with a view to the widespread landscape protection and enhancement, the PPR **recognises the whole territory of Lombardy as a landscape value,** indicating a specific methodology for the protection of areas not subject to specific landscape protection. [2]

[1]: It is noted that a general revision of the regional territorial plan, including the landscape component, is under way (approved by DGR no. XI / 7170 of 17/10/2022)
[2]: PPR legislation – part V – Landscape examination of projects.

Regional Law 11 March 2005, No. 12 ''Law for the Government of the Territory'':

By unifying the legislation, this law aim to define the rules to govern the Lombard territory, specifying the forms and methods for the Region and the local authorities to exercise their competences. This law unifies the different sectoral regulations related to the planning of the territory (e.g. town planning, construction, hydrogeological protection, etc.), as a "single text". In particular, Title V of *part II* governs the performance of tasks relating to landscape assets by the Region.

D.G.R. 22 December 2011 no IX/2727 "Criteria and procedures for the exercise of administrative functions in the field of landscape property in implementation of r.l. 11 March 2005, no 12 "

The main objective of the D.G.R. is to provide a tool to all local authorities by dictating criteria, guidelines and procedures to facilitate the exercise of their respective landscape competences. The main contents and indications of the document relate to: methodological path for landscape assessment of projects (chapter 1), identification of landscape protection objects and areas (chapter 2), assignment of landscape competences to local authorities (chapter 3), landscape criteria for certain specific categories of works and interventions (chapter 4), administrative procedure in the field of landscape (chapter 5), regional surveillance and support (chapter 6). Finally, the appendices to the document which contain the forms and documentation for the projects presentation (Appendix A) and the data sheets of the landscape constitutive elements (Appendix B) form an integral part of the regional measure.

D.G.R. 8 November 2002 no 7/11045 "Guidelines for Project Landscape Review ":

A method is proposed to be applied to all projects that affect the appearance of the places and, therefore, not only to building projects. The main objective is to bring the landscape to the attention of operators, by spreading a common language among designers, municipal engineers, administrators. The method shall define *the site sensitivity class* and *the degree of the landscape incidence of the project* in order to arrive at the definition of the project's landscape impact level by the intervention proposer. The PPR reiterates the requirement for a landscape examination of those projects which alter the state of the places and the exterior of buildings throughout the regional territory (except the areas subject to protection under which the procedures set out in the Code and the R.L. 12/2005 apply).

D.G.R. 30 December 2009 no 8/10974 "Guidelines for the Landscape Design of Utilities Infrastructure and Power Plants":

They contain guidelines to guide the integration of plant and utilities infrastructure projects in the landscape and they are broken down by plant type. Chapter 1.2.3 is dedicated to "solar thermal and photovoltaic systems", where guidance is given on location and positioning criteria.

LANDSCAPE PROTECTION AND ENHANCEMENT: THE LANDSCAPE AUTHORIZATION

Landscape protection consists of a complex and structured management of the entire regional territory and, in particular, of the areas bound by the Code. It is aimed at safeguarding the landscape's “constitutive elements”, that is, the components of the physical-morphological and natural structure, the historical-cultural heritage and the relational structures that connect all these complex elements of aesthetic-cultural value.

Protection must therefore be expressed in terms of preserving both the elements of connotation and the conditions for using and understanding the landscapes, but also in terms of the quality of the landscape of the new projects, the assessment of their inclusion in the reference landscape context and their compatibility with the landscape values expressed by it.

In territories subject to specific landscape protection under articles 136 and 142 of the Code, any transformation project which changes the landscape property's external appearance must be approved in advance with the "**landscape authorization**" issued by the competent administration to which the protection functions were entrusted under the competences laid down in Regional Law 12/2005, after obtaining a binding opinion from the Superintendence. The assessment of projects shall be carried out by taking into account the rationale and management criteria (if any) of the specific safeguard act.

The landscape authorization is an administrative document independent and prior to the building permit and must in any case be obtained before the start of the work, even in the case of operations subject to simple communication (i.e. free building).

There are two separate procedures for the expression of landscape measures:

- **Ordinary procedure** as defined in art. 146 of Legislative decree 42/2004 and amendments and additions,
- **Simplified procedure**, covers minor works and interventions identified in Annex B of the D.P.R. 31/2017. However, the works and operations referred to in Annex A and those referred to in Art. 4 of D.P.R. are not subject to landscape authorization.

For areas not subject to specific landscape protection under the Code, the requirement of **landscape examination** for projects affecting the external appearance of places and buildings is reiterated, in accordance with D.G.R. No. 7/11045 of 2002.

THE PHOTOVOLTAIC SYSTEMS' INTEGRATION INTO THE BUILT ASSETS

The key factors identified to achieve the integration of photovoltaic systems, whether BIPV or BAPV, in existing buildings subject to specific landscape protection consist of:

1 – a sound methodological approach to ensure adequate protection of the built-up heritage;
2 – balancing the aesthetic, technological and energy integration aspects

1 - METHODOLOGICAL APPROACH

First, a check must be carried out to determine whether the property to be modify is subject to protection by means of a specific administrative act of the State or the Region within the meaning of Article 136 of the Code, or if it is automatically protected under Art. 142 of the same Code. In the first case, reference should be made to the management criteria of the protected property contained in the protection measure; if such a document is not available, reference should be made to the specific guidelines and criteria contained in the Regional Landscape Plan.

For the protection and management of the transformation of buildings falling within areas subject to protection pursuant to Art. 142 of the Code, it is necessary to refer to the provisions and criteria issued by the Region, as well as to the indications and prescriptions by Provincial PTCs (Provincial Territorial Plans of Coordination) and PGT (territorial Zoning Plan) with landscape content.

In general, the essential starting point for intervening in architectonic assets is to prepare a well-done project which requires:

- an historical analysis of the asset, of its building steps and the interventions;
- a building survey of the asset's current state and of its constitutive materials;
- a careful analysis of the territorial context's landscape values where the asset is included, a census and a classification of the landscape's constitutive elements;
- Knowledge of the reasons for the building/area's landscape protection as well as the contents and indications of the Regional Landscape Plan or of the more detailed Landscape Plans (Provincial and Park PTCs, PGTs);
- An analysis of the elements of landscape value present in it, as well as any presence of cultural protected assets by part II of the Code;
- An impact assessment on the landscape of the proposed changes;
- A proposal of any mitigation and compensation elements.

The project must also contain all the elements necessary to enable the work's compatibility verification with the landscape values set by the protection discipline, as well as consistency with the criteria for the protected asset management and the overall consistency with the landscape quality objectives contained in the urban and territorial planning tools.

It may be appropriate to enter into a preliminary dialogue with the territorially competent Superintendency and local authority's technical offices competent for landscape , in order to carry out the assets correct analysis and assessment and to find the most appropriate landscape-compatible solutions in the works.

2 – BALANCING AESTHETIC, TECHNOLOGICAL, AND ENERGY INTEGRATION ASPECTS

2.1 – CRITERIA AND METHODS FOR AESTHETIC INTEGRATION

Aesthetic integration means the photovoltaic (BAPV and BIPV) system's ability to respect the architectural composition, a building's stylistic, compositional and morphological language, integrating harmoniously into the building, so as to be the least possible visible.

When working in areas subject to landscape protection, of course **the aesthetic aspect is essential** to ensure that photovoltaic systems' integration preserves the architectural heritage's morphological, material, and colour features and cultural values - the concept of landscape itself is closely linked to the visual factor.

For this reason, we believed it was appropriate to go deeper into the criteria and methods that define the aesthetic integration, though these should not be considered valid and unambiguous for each intervention.

Indeed, the process of aesthetic integration must be seen as a specific procedure for each intervention where the different criteria must be assessed on a case-by-case basis, trying to comply with them as far as technically possible.

To achieve a module's aesthetic integration, several factors must be considered:

1. **Visual compatibility:**
   - colour;
   - reflection;
   - texture;
   - pattern;
   - transparency.

2. **Spatial compatibility:**
   - coplanarity;
   - geometry and distribution.

VISUAL COMPATIBILITY

AESTHETIC INTEGRATION

COLOUR

REFLECTION

TEXTURE

PATTERN

TRANSPARENCY

COPLANARITY

GEOMETRY AND DISTRIBUTION

The different modules' colour has a high visual impact on the building and on the reference built or naturalistic context.
Most standard photovoltaic modules are produced in the range of dark colours (black and blue), but the production of coloured photovoltaic panels, even in light colours, now allows for new and infinite possibilities of their colour integration

For example, photovoltaic cells can be hidden under a more or less opaque coloured layer, thus making them invisible and achieving a higher aesthetic integration.

It should be remembered, however, that the panels' energy efficiency is closely dependent on colouring and it decreases the more we depart from dark colours.

COLOUR INTEGRATION CRITERIA:

- choose colour ranges compatible with the traditional materials' colours and the original building on which the work is carried out;
- choose integrated colour ranges into the wider reference urban or natural environment;
- use the same colours for panels and frames;
- preference should be provided for frameless panels.

As a general rule, as regards to traditional roof coverings, typical of the Italian and Lombard context, the most common colours are those in the ranges of reds – terra-cotta colour roof tiles, and grey-green for stone coverings. The photovoltaic panels production can increasingly provide a wide choice of colours, even with customized solutions to produce the most similar products to existing roof covering surfaces.

However, the installation of photovoltaic systems on roof coverings with traditional antique materials remains difficult. (for example, the roof tiles). They have particular shapes and thicknesses linked to their handicraft origin and an uneven and not homogeneous colour caused by exposure to sunlight, atmospheric agents and the action of time.

At present, the photovoltaic roof tiles have critical aspects in terms of energy efficiency and aesthetic integration.

An object's colour commonly defines the visual sensation perceivable by the human eye in response to the different wavelengths of light radiation reflected by the object's body.

THE COLOURS OF HISTORICAL TRADITION

Terra-cotta: presence of tiles roof covering.

1

2

Photos 1 and 2: LA CERTOSA, PARCO URBANO – VENICE PHOTO CREDITS: Solmonte, Gruppo STG
The project was awarded the Special Prize for Solar Architecture in Prestigious Contexts, announced by In/Arch for the 2020 In/Arch Awards

1

2

GRAND HOTEL VICTORIA, Menaggio (Como), a project by Studio Architetto Pè (Carimate – Co)
Photo 1: photo credits Ilaria Alberti (EURAC Research)
Photo 2: photo credits: Studio Architetto Franco Pè (Carimate – Co)

THE COLOURS OF HISTORICAL TRADITION

Anthracite or grey-green: for roof coverings in slate or stone or as a replacement for metal coverings.

1

2

Photo 1: RESIDENTIAL BUILDING IN VAREN (CH) – photo credits: SUNAGE SA – Balerna (CH)
Photo 2: CHALET PEDEVILLA – Marebbe (Bolzano) – photo credits: Sudio Pedevilla Architects (Brunico – Bz)

VISUAL COMPATIBILITY

AESTHETIC INTEGRATION

COLOUR

REFLECTION

TEXTURE

PATTERN

TRANSPARENCY

COPLANARITY

GEOMETRY AND DISTRIBUTION

As with all the buildings glazed or reflective surfaces, when sunlight hits photovoltaic modules it can cause **glare and heating of the surrounding environment**. These **phenomena should be carefully avoided,** especially in view of the risk of creating so-called ' heat islands'.

These phenomena can be solved in advance thanks to a well integrated design, which simultaneously assess the aesthetic and the technical-energy factors.

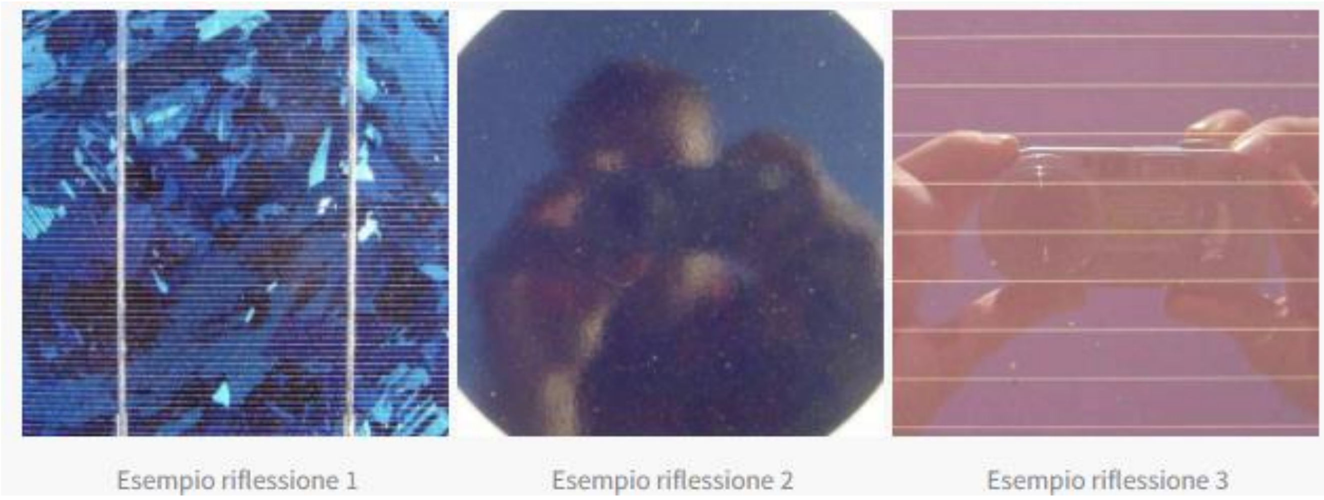
Thanks to the BIPV systems' versatility and the wide availability of heat production data from all photovoltaic components, it is possible to design systems where the risk of surrounding heating is zero (e.g. on a satin surface the reflection of sunlight is almost zero).

CRITERIA FOR REFLECTION INTEGRATION:

- analyse the panel building material and prefer reduced reflection photovoltaic systems to respect the materials aesthetic characteristics of the historical construction tradition and to avoid the warming of the surrounding environment. Reflection can be controlled by controlling the panels' colour, texture and pattern or by using panels with special anti-reflection coatings, which are generally applied on the glass surface. The latter does not fully solve the problem and cannot be regarded as the only feasible way to eliminate glare or other disturbing reactions, but it must be combined to other integration criteria;
- carefully assess the sun's relative position, which varies according to the location's latitude, season and time of day, in relation to the panel positioning to find the trajectory of reflected light;
- consider factors such as the building's morphology, visibility from the surrounding environment (especially from significant observation points, such as from public spaces or panoramic points or paths). For this purpose, we recommend the use of photomontages, virtual mock-ups and on-site analyses.

Reflection is a physical phenomenon whereby light radiation affects the separation surface between two transparent media is partly sent back (reflected) and partly penetrates into the medium.


1



2

Photo 1: Source www.seelectricalservicesltd.com
Photo 2: Example of highly reflective photovoltaic panels - source www.bipv.ch

VISUAL COMPATIBILITY

AESTHETIC INTEGRATION

COLOUR

REFLECTION

TEXTURE

PATTERN

TRANSPARENCY

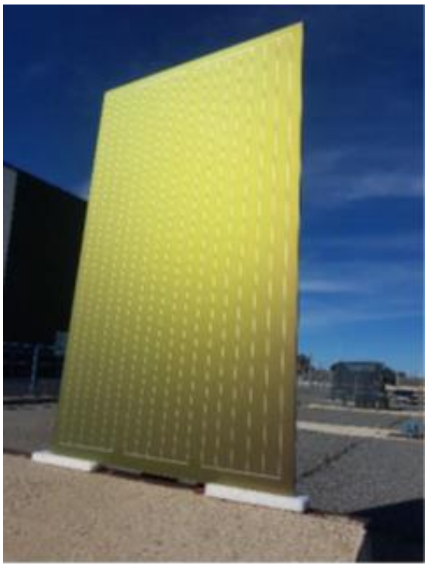
COPLANARITY

GEOMETRY AND DISTRIBUTION

In photovoltaic systems, texture is a glass' front layer feature that can be obtained by several techniques, including custom made ones.

CRITICAL FOR TEXTURE-LEVEL INTEGRATION:

- prefer photovoltaic panels with the module's front layer made of material with a coarse texture and thus an opaque appearance, for less reflection of light,
- select textures that help make the photovoltaic panel as similar and consistent as possible with the tactile and visual qualities that characterize the building's construction materials (different textures can define a smooth, rough surface, etc.).



Examples of photovoltaic panels with different textures:
Left: Amorphous silicon photovoltaic panel
Right: Crystalline silicon photovoltaic panel
Source: www.onyxsolar.com

The term is derived from the Latin *textura* , that is network, weaving. It designates an object visible and tactile quality that, depending on its texture, can be smooth, rough, soft, hard.

The pattern within a photovoltaic panel is the arrangement and size of the different photovoltaic cells that make up it and that form a texture composed of several pixels which influences the module's aesthetic appearance .

Thanks to the use of special coating materials and special glass moulding techniques, it is possible to obtain both monochromatic and homogeneous surfaces, where the photovoltaic cell is not visible, and surfaces characterized by different drawings, also created upon request.

By increasing or decreasing the photovoltaic cells' distance, it is also possible to affect the greater or lesser panel's transparency.

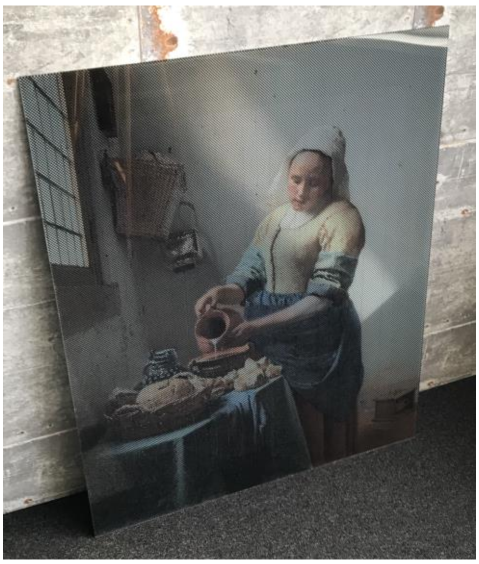
CRITERIA FOR PATTERN INTEGRATION:

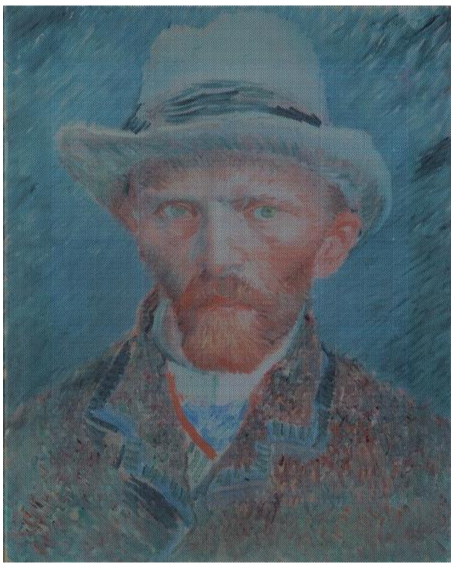
- choose patterns that make the photovoltaic cell invisible and have transparent or semi-transparent surfaces. This solution is suitable for workings on greenhouses, skylights, parapets, shelters;
- study patterns with accentuated textures, also tailored to experiment with contemporary creative and artistic solutions. This option is preferably applied in urban environments or on modern-day buildings and it represents an opportunity to redevelop obsolete, degraded or architectural buildings and structures, such as: energy infrastructure works (thermal and electrical power stations); noise barriers along road infrastructure (motorways, railways); shelters to cover parking spaces, bus stops, etc.; kiosks; protective parapets (balconies and terraces, walkways, etc.); partition fences and shields; lighting elements and advertising structures.

English term meaning disposition. It is commonly used to indicate a drawing or graphic motif that repeats in a symmetry or order.

1

2





3

Photo 1: Mock-up example made at the SUPSI CAMPUS in Trevano (CH)
Photo 2: "Foliated" photovoltaic panel - Energy Glass by GruppoSTG – photo credits: Elena Lucchi
Photo 3: Examples of customization - colourBlast® by SolarLab SA, EPFL Innovation Park, Lausanne, Switzerland, official partner of Kameleon Solar B.V.”

In glass BIPV systems, whether in the front (windows) or in coverings (skylights, shelters, etc.), transparency allows people to keep a visual contact with the outside and is an important factor for the thermal well-being of indoor environments: by modulating the degree of transparency, you can indeed control the amount of sunlight entering for more or less solar shielding.

The photovoltaic modules' transparency depends on the material from which they are made: for example, in glass-to-glass monocrystalline and multi-crystalline silicon modules, the degree of transparency is achieved by changing the distance between cells, which may have different shapes and sizes. In thin film modules, such as amorphous silicon modules, transparency is provided by the absence of the reflective layer under the cells or by a laser etching process that produces a coating with a homogenous transparency equivalent to that achievable with coloured glass.

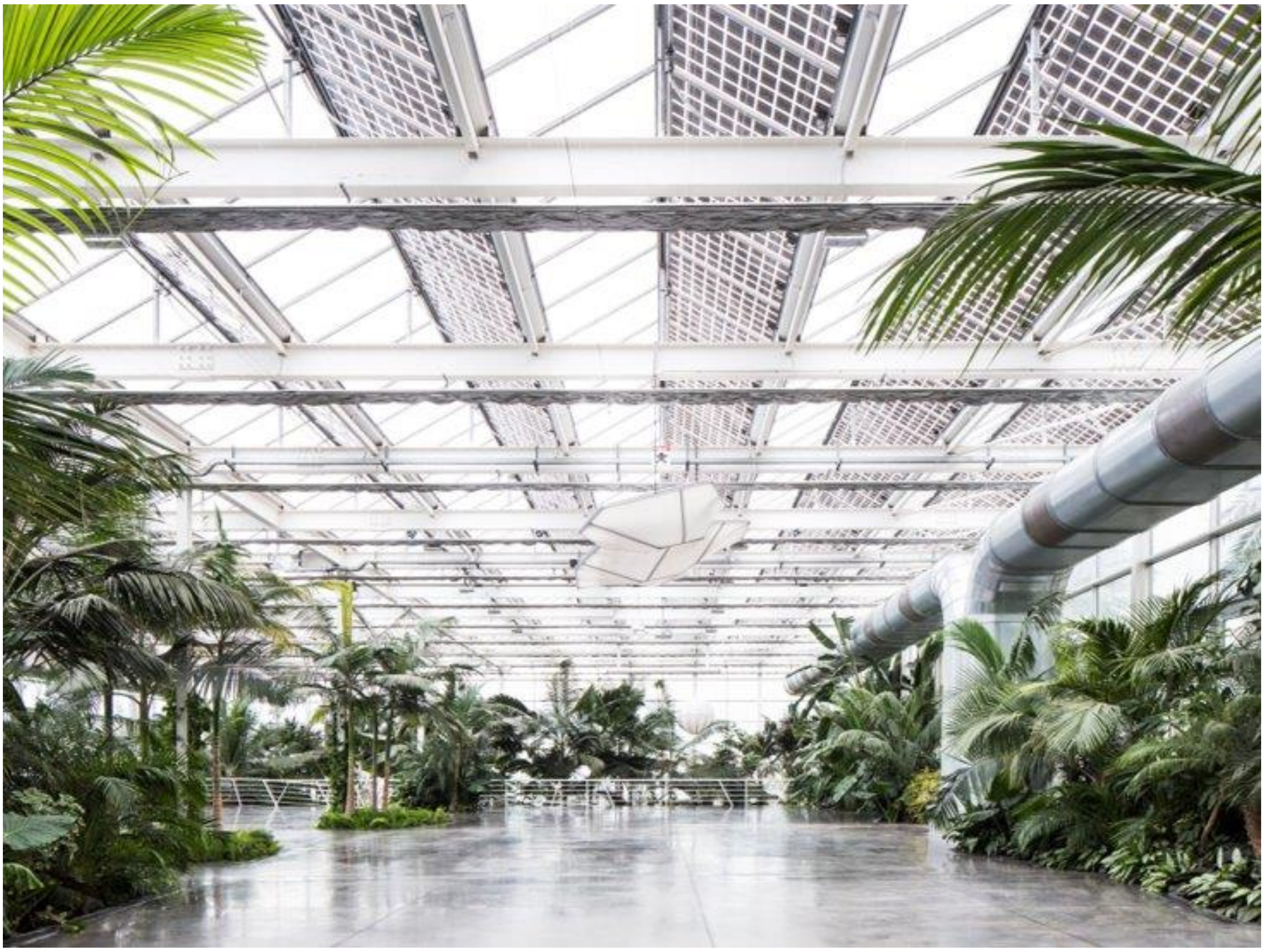
Thanks to the development of transparent photovoltaic technologies, it is now possible to make energy-related works on parts of buildings once closed (windows, skylights, etc.). **It should be remembered, however, that the higher the transparency level of the photovoltaic module, the lower the efficiency!**

CRITERIA FOR TRANSPARENCY INTEGRATION:

- choose the type of photovoltaic glass (amorphous silicon, crystalline silicon, etc.) according to the requirements to be met (shading, visual shielding, illuminance, etc.);
- prefer transparent modules for works on skylights, verandas, greenhouses and winter gardens in historic parks;
- opting for semi-transparent modules to create solar shields, pergolas, parking shelters, fences and dividers;
- provide for different transparency level depending on the location of photovoltaic elements in relation to the historical building (generally, greater transparency and therefore lightness is preferable at the points of contact with historical buildings).

Transparency is the ability of a body to allow light to pass through and at least to allow an object to be seen beyond its body by the observer.

PALAZZO LENORI, Rome – photo credits: Elena Lucchi



FONDAZIONE RADICEPURA, Giarre (Catania) – photo credits: Elena Lucchi (EURAC Research)

SERRA TORRIGGIANI, Florence– photo credits: Elena Lucchi

1

2

Photo 1: Glass camera with solar concentrator for electricity production – photo credits: Glass to Power Spa, Rovereto (TN)
Photo 2: Sample Case for Glass Camera with Solar Concentrator – photo credits: Glass to Power Spa, Rovereto (TN)

SPATIAL COMPATIBILITY

AESTHETIC INTEGRATION

- COLOUR
- REFLECTION
- TEXTURE
- PATTERN
- TRANSPARENCY
- **COPLANARITY**
- GEOMETRY AND DISTRIBUTION

The coplanarity refers to the application mode of the photovoltaic modules that are to be mounted while maintaining the same inclination as the surface on which they are placed.

In the case of coverings applications, compliance with the slope, orientation and general lines of the roof flaps is one of the crucial nodes for the installation of photovoltaic installations on existing buildings. Altering the perception of the building's volume is highly invasive and should be avoided in any case, especially when working on protected buildings.

When using BAPV technology, it would be appropriate to consider the installation of photovoltaic panels on the less visible parts of the building, in particular from public places (see examples pages 28 and 29).

BIPV technology enables systems to be built perfectly integrated into the building construction components by reducing, if not cancelling out, the portion of plant exceeding the existing surface (see examples p. 27).

CRITERIA FOR INTEGRATION AT THE COPLANARY LEVEL:

- avoid any arrangement of the panels that would alter the general lines of the building being serviced;
- maintain the technical reference element's inclination (e.g. roof flaps, skylights, greenhouses);
- preference shall be given to the panels installation on those parts of the building which are less visible from the main observation points;
- reduction of the photovoltaic panels' and support system's thickness ;
- preference should be given to the insertion of frameless photovoltaic panels.

In geometry, coplanarity refers to figures lying on the same plane. [Treccani]

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Photo 1: PINO PASCALI MUSEUM, Polignano a Mare (Bari) – photo credits: Angelo Margutti
Photo 2: photo credits: SUNAGE SA, Balerna (CH) www.sunage.ch

WINE CELLAR ALOIS LAGEDER, Magrè (Bolzano) – photo credits: Elena Lucchi

PODERE CASE LOVARA, Cinque Terre – Liguria – photo credits: The National Trust for Italy (FAI).

SPATIAL COMPATIBILITY

AESTHETIC INTEGRATION

COLOUR

REFLECTION

TEXTURE

PATTERN

TRANSPARENCY

COPLANARITY

GEOMETRY AND DISTRIBUTION

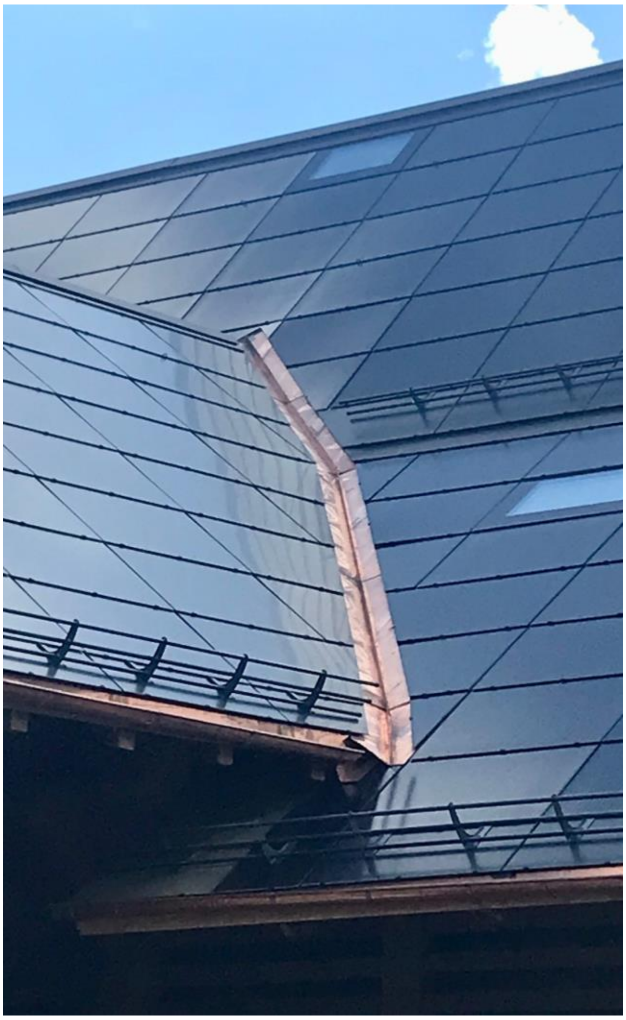
The shape, size and distribution pattern of photovoltaic panels on a covering or façade have a decisive impact on the aesthetic integration of these installations.

With regard to the pattern of photovoltaic modules on pitched roofs, it is common practice to place them in separate groups to avoid dormers, skylights, chimneys and other artifacts; the most common result is the typical "zig zag" distribution that does not respect the sloping lines of the flaps: these solutions result in visual fragmentation of the flakes, making immediately recognizable and invasive the presence of photovoltaic systems.

CRITERIA FOR INTEGRATION AT THE GEOMETRY AND DISTRIBUTION LEVEL:

- group the panels together in a continuous and regular design, creating a compact and orderly image, preferably placed on a single, full flake to obtain uniform geometry and to avoid the flake's visual fragmentation;
- respect the main compositional patterns of the architectural system, in particular the compositional coverage and façade lines;
- pay particular attention to the connection points between the different flakes, some eaves gutter elements, the ridge beam, the flashing, etc.

The term geometry is used to indicate an object geometric characteristics, such as its size and shape, but also the spatial arrangement of certain elements of an apparatus or an implant. Figuratively, the term has meaning linearity, proportion, regularity, symmetry of form or structure of things, or even the structure itself. [Treccani]



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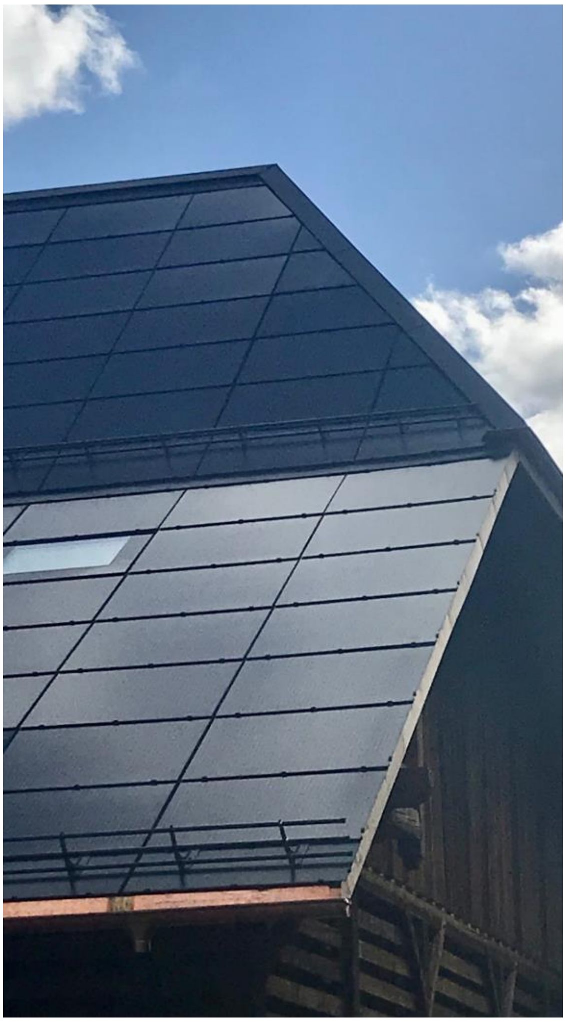

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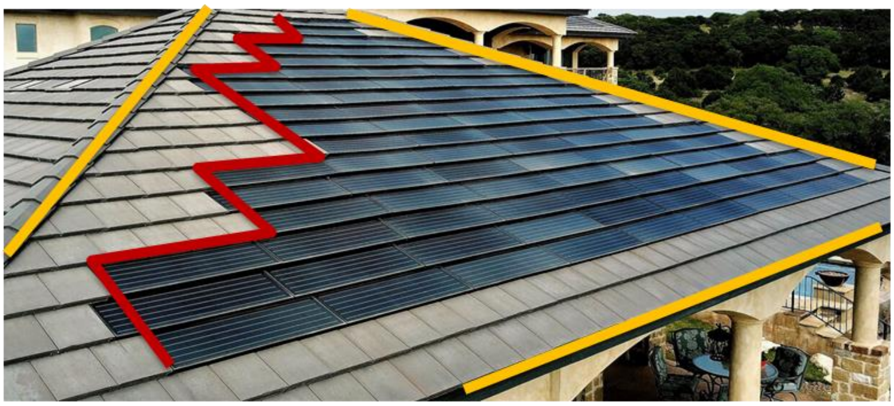

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Photo 1, 2: Photovoltaic panels of company 3S – Swiss Solar Solutions AG – photo credits: Elena Lucchi
Photo 3: Source www.bvisolar.com
Photo 4: Source www.wegalux.gruppostg.com
Photo 5: Panel "Custom Terracotta", GruppoSTG Srl. – photo credits: GruppoSTG Srl.

2.2. CRITERIA AND METHODS FOR TECHNOLOGICAL INTEGRATION

Technological integration refers to the integrated photovoltaic component's (BIPV) multifunctionality which, in addition to the task of generating energy, also acquires the role of building component, with structural and architectural functions, replacing traditional building materials.

As a fully constructive component, BIPV is subject to:

- **CPR - Regulation (EU) No 305/2011 on Construction Products**
- The DoP (Declaration of Performance), drawn up by the producer and containing information on the essential characteristics of the product attesting compliance with the seven basic requirements: energy efficiency and thermal insulation, safety and accessibility of use, mechanical resistance, noise reduction, environmental health and hygiene, fire prevention, sustainable use of natural resources;
- **CSN EN 50583-1 ''Photovoltaics in buildings'** ' (part I: BIPV modules).

As with all construction works, disposal and recycling/recovery possibilities, photovoltaic modules and other end-of-life components should also be taken into account.

Building functions attributable to BIPV may be as follows:

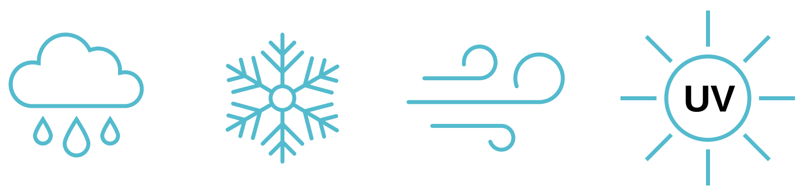
- weather protection;
- noise protection;
- thermal insulation;
- natural light shading and control;
- stiffness, mechanical strength and structural integrity;
- hygiene, health and the environment;
- safety and accessibility in use;
- installation;
- durability and reliability;
- quality.

Depending on the type of application, some integrated photovoltaic systems must provide protection from atmospheric elements such as rain, snow, wind, hail and UV rays during their useful life, preventing any damage to the housing and avoiding negative effects on the interior comfort.

The different systems must therefore be designed and tested to match the performance of the classic building components they replace.

CRITERIA FOR INTEGRATION IN TERMS OF PROTECTION AGAINST WEATHERING:

- water impermeability;
- air impermeability (air ingress has a direct impact on energy performance and internal acoustic comfort!)
- wind resistance;
- resistance to breaking from snow, hail, bumps in general;
- humidity protection systems against condensation.



TECHNOLOGY INTEGRATION

WEATHER PROTECTION

NOISE PROTECTION

THERMAL INSULATION

LIGHT AND SHADOW

RESISTANCE

HYGIENE AND HEALTH

SECURITY

INSTALLATION

DURABILITY

QUALITY

According to CPR 305/2011, "*The construction works must be designed and built in such a way that noise perceived by the occupants or people nearby is kept to a level that will not threaten their health and will allow them to sleep, rest and work in satisfactory conditions*."

CRITICAL FOR INTEGRATION AT NOISE PROTECTION LEVEL:

- study the correct photovoltaic module's integration in the building so that the photovoltaic module does not produce noise in windy conditions;
- design integration of photovoltaic modules with sound insulating materials to create an acoustic barrier and help to dampen or redirect unwanted background noise.

Like all construction works, integrated photovoltaic systems must also be efficient in terms of thermal insulation.

In addition to meeting the energy needs of the building on which they are installed, integrated photovoltaic systems can help reduce annual heating and cooling loads passively.

CRITERIA FOR INTEGRATION AT THERMAL INSULATION LEVEL:

- design photovoltaic overlay and facade coating systems in combination with insulating materials;
- design the panel' back ventilation to control the overheating of the system and the surrounding environment;
- consider the use of particular photovoltaic modules with rear-side heat recovery systems.

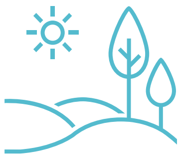
Photovoltaic systems integrated on glazed or semi-transparent elements must provide natural light to meet the needs of users for visual comfort.

As explained in the section on aesthetic integration, with reference to pattern and transparency, integrated photovoltaic modules in glass surfaces can help control shading in summer and natural lighting in indoor environments. This can reduce the energy consumption associated with the use of artificial lighting and summer cooling systems.

INTEGRATION CRITERIA AT THE LEVEL OF NATURAL LIGHT CONTROL:

the parameters to consider in the design of integrated photovoltaic systems are:

- eye contact with the outside;
- glare control;
- light contrast requirements;
- brightness and illuminance levels.



Depending on whether the photovoltaic panel is used as a covering element, as a façade cladding or as a solar shielding device, the mechanical and stability requirements that the photovoltaic panel must meet vary.

And they have special applications, such as photovoltaic flooring or photovoltaic glass coverings, that require greater load resistance and structural stiffness than standard photovoltaic modules and therefore require special attention in the design.

In particular, as required for all structural glass building components, post-break integrity of the system must be ensured, i.e., in the event of component collapse, the overall stability of the system must not be compromised and the risk of injury to persons or property reduced to a minimum (tempered, safety hardened glass).

CRITERIA FOR INTEGRATION IN TERMS OF STIFFNESS, MECHANICAL RESISTANCE AND STRUCTURAL INTEGRITY:

integrated photovoltaic systems applied on coverings generally must ensure:

- resistance to snow and wind loads;
- tolerance to loads imposed during construction and maintenance work;
- additional load and impact resistance requirements for walkable windows;
- properties of laminated glass in the case of glass-to-glass elements.

Photovoltaic systems applied vertically in front generally have to ensure:

- increased bending stiffness due to vertical panel installation;
- resistance to higher wind loads for high-altitude installations;
- increased resistance to point loads from shields;
- properties of laminated glass in the case of glass-to-glass elements.

The materials constituting the BIPV module, such as glass, frame, load-bearing structure, junction box and wiring, must be designed and manufactured in such a way that they do not pose a threat to hygiene throughout their life cycle, the health and safety of workers and end-users and cause an excessive impact on the environment and the climate.

CRITERIA FOR INTEGRATION IN TERMS OF HYGIENE, HEALTH AND THE ENVIRONMENT:

- avoid the use of toxic materials or significant quantities of rare materials where possible;
- design products so that can be easily separated to allow for disposal and recycling activities;
- selecting products of the highest quality from the human health and safety,and the environment point of view, through careful analysis of the life cycle information of panels provided by manufacturers;
- ensure adequate water tightness of the photovoltaic system and the technical element on which it is inserted.

The criteria for safety and accessibility in use refer to CPR 305/2011 which specifies *that "The construction works must be designed and built in such a way that they do not present unacceptable risks of accidents or damage in service or in operation such as slipping, falling, collision, burns, electrocution, injury from explosion and burglaries*".

Integrated photovoltaic systems must be designed to ensure electrical, construction, mechanical and fire safety in the same way as all traditional building components.

CRITERIA FOR SECURITY INTEGRATION:

- fire safety should be taken into account, including in the design of domestic photovoltaic systems or in areas not subject to fire prevention controls, as the installation of photovoltaic systems can lead to an increased fire risk, being comparable to actual power plants. In this respect, it may be useful to refer to the guidelines for the installation of PV plants issued by the Italian Ministry of the Interior – Department of Fire Corps, Public Relief and Civil Defence;
- carry out regular periodic system maintenance , checking the correct functionality and integrity of each component.

The photovoltaic panels' correct implementation is decisive for the final success of the project, both from the plant (performance and efficiency) and architectural (aesthetic integration) points of view.

The system installation "according to the rules of the trade" is the result of two factors: on the one hand, the proven technical and professional preparation of installers, and on the other hand, the role of the works director who must monitor and supervise the various stages of implementation in order to ensure compliance with the authorized project.

CRITERIA FOR INTEGRATION AT INSTALLATION LEVEL:

- Contact qualified operators (according to L.D. 28/2011) who meet the professional and technical requirements for the installation and extraordinary maintenance of renewable energy systems (compulsory training, FER license);
- entrust the management of the works to professionals of qualified experience, in order to ensure compliance with all the project's technical and architectural specifications, the safety measures, the obligations and the requirements laid down by the regulations in force;
- perform tests at the end of the work.

The replacement of a failed module is certainly more complex when the element is integrated into the building housing than when it is simply applied. The maintenance aspect must be assessed and analysed at the project stage.

However, modern BIPV technologies have made tremendous progress, making the replacement of individual PV panels easier.

However, it is important that integrated photovoltaic modules have the same level of durability and reliability as the other building components within which they are integrated.

CRITERIA FOR INTEGRATION AT THE LEVEL OF DURABILITY AND AFFIDABILITY:

- provide for regular periodic maintenance of the installation;
- ensuring the accessibility of the photovoltaic system for cleaning, maintenance and replacement of individual modules or panels;
- follow and respect the panel cleaning and maintenance instructions provided by the manufacturers.

The existence of guarantees on photovoltaic modules provided by the producers can help to guide the choice toward reliable and quality products.

CRITERIA FOR QUALITY AND FINANCIAL INTEGRATION:

- verify that the manufacturing defect warranty is present;
- verify the presence of the pv performance guarantee or the performance guarantee: with this the manufacturer guarantees a minimum performance threshold over a period of 25-30 years. Photovoltaic panels experience a physiological decline in performance over 20-30 years, estimated at typically around 1% per year (about 20% over 25 years). However, these parameters are generally fairly standardised across manufacturers, but can still be a useful comparison.
- analyse the data sheet provided by the producer, which shows all the characteristics of the pv panel, therefore, together with the reliability of the producer, it is the main reference tool for product comparison.

2.3 CRITERIA AND METHODS FOR ENERGY INTEGRATION

Energy integration expresses the photovoltaic (BAPV and BIPV) ability to produce energy. This is influenced by several factors that can be considered as guiding criteria for assessing the level of energy integration:

- exposure (orientation and inclination);
- shading;
- materials;
- ventilation.

For proper energy integration, it would be sufficient to install as many photovoltaic panels as possible, choosing the panel type only on the basis of its efficiency and positioning it to capture as much solar radiation as possible.

However, in order to ensure that a photovoltaic system is well integrated, especially in historical, architectural and landscape settings, it is not possible to reduce the analysis to energy assessment alone, but the right balance needs to be struck between maintaining aesthetic criteria and reducing energy consumption in buildings through careful integrated design.

In traditional systems, to achieve a truly efficient photovoltaic system, it is necessary to evaluate the proper **orientation** (azimuth angle to Cardinal points) of photovoltaic panels and calculate the correct degree of **tilt** (tilt angle to horizontal plane) during the design phase.

In the case of integrated photovoltaic technology BIPV, the calculation of tilt values is almost irrelevant, since the photovoltaic panel is also integrated into the cover as horizontal.

And so that the correct assessment of the building's orientation is essential for the application of BIPV in order to identify the parts on which to operate.

CRITERIA FOR EXPOSURE INTEGRATION:

- identify the side of the building most exposed to sunlight throughout the day. As a general rule, panels are more productive when the rays of the sun are perpendicular to their surface, so the best exposure is to the South; if this is not a viable solution, it is advisable to maintain a South-East to South-West orientation, with a maximum deviation of 45° from the South. However, it is always necessary to assess the specific area or of the individual building solar potential;
- preference shall be given to the panels installation on those parts of the building which are less visible from major observation points, in particular from public places, if its technically feasible from the point of view of the panels energy performance viewpoint;
- calculate the photovoltaic panels' performance reduction as the orientation of the modules changes from the optimal conditions to assess the cost-effectiveness of the system installation.

The presence of cast shadows on photovoltaic modules adversely affects the energy performance of the photovoltaic system, decreasing its efficiency and causing power losses. It is sufficient for even one panel to be subject to shading to penalize the performance of all other panels connected to it (string).

There are many obstacles that can cause shading and affect energy production: tall trees, adjacent buildings, chimnstones, spindles, or other objects on the cover of the building.

CRITERIA FOR INTEGRATION AT SHADING LEVEL:

- select the appropriate portion, as free as possible from obstacles such as prominences, chimnstones, trees, etc.;
- a shadow calculation may be carried out; simulation software may be used to study cast shadows at any time of the day and at any season of the year;
- use bypass diodes, optimizers, or microinverters that improve module performance even in shaded conditions;
- keep the modules clean to remove dirt, dust, and biological material.

ENERGY INTEGRATION

EXPOSURE

SHADOWS

MATERIALS

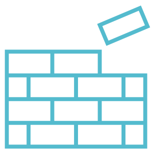
VENTILATION

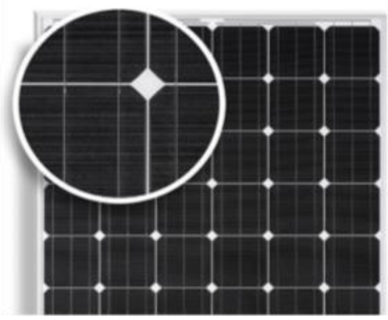
Research and experimentation have taken photovoltaic panel technology to ever higher and more energy-efficient levels.

The amount of energy produced, from a technological point of view, depends on several factors: building materials, colouring, transparency, etc.

MATERIAL LEVEL INTEGRATION CRITERIA:

- choice of material: there are different photovoltaic technologies, each with different characteristics depending on the type of cell or technology used. The most common are: monocrystalline silicon, polycrystalline silicon, thin film, amorphous silicon, CIS, CIGS etc. Depending on the type of material used and the type of chemical technology and structure used, three different photovoltaic systems can be defined: First, second and third generation. First-generation photovoltaic is traditional photovoltaic, with polycrystalline and monocrystalline silicon panels. Second generation photovoltaics are thin film modules, which have been widely applied in recent years and offer a significant reduction in material cost compared to the previous generation, although it has lower efficiency values. Finally, third generation photovoltaics is the most innovative category, still under development, to which the multi-function cells and organic Photovoltaics (OPV) devices belong;
- colouring and transparency of the module: on the market there are rich colour ranges that enable an optimal visual integration of photovoltaic modules in different contexts, as well as providing customized solutions. However, the loss of energy performance due to increased or decreased transparency and use of light colours should be considered.





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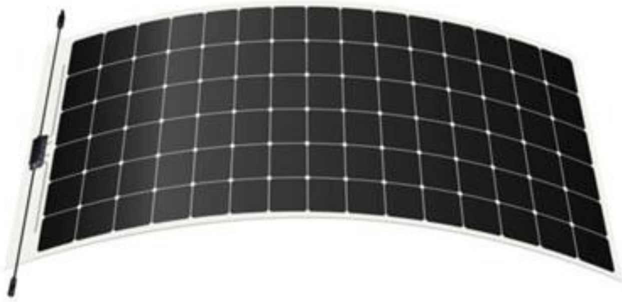

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Photo 1: Monocrystalline silicon panel - source: *www.solarinnova.net*
Photo 2: Polycrystalline silicon panel – source: *www.solarinnova.net*
Photo 3: Thin Film Panel – Source *https://maxeon.com*
Photo 4: Panel in CIS – source: *https://sunisyou.wordpress.com*
Photo 5: Types of photovoltaic panels – source *www.energysage.com*

Control of the panel temperature is important to avoid loss of efficiency caused by overheating of the panels, as the transmission of heat to the surrounding environment.

Good ventilation, preferably natural ventilation, is essential in order to lower the temperature and maintain high production efficiency of photovoltaic modules.

The type of ventilation depends on the placement of the modules and their integration into the enclosure. Three main categories can be distinguished: non-ventilated, moderately ventilated and ventilated panels.

CRITERIA FOR INTEGRATION AT VENTILATION LEVEL:

- Envisage the integration between ventilated roof and photovoltaic panels: in the implementation of modern integration systems of these two technologies, photovoltaic panels can be considered as roof tiles, making them an integral part of the ventilated roof structure;
- check the temperature coefficient: indicates the loss of efficiency for each degree over temperature. This figure, which can be found in the manufacturer's datasheets, varies depending on the quality of the modules: poor quality modules the coefficient is about 0.5% per degree centigrade, this value can improve up to 0.25% per degree centigrade, for panels of good quality.

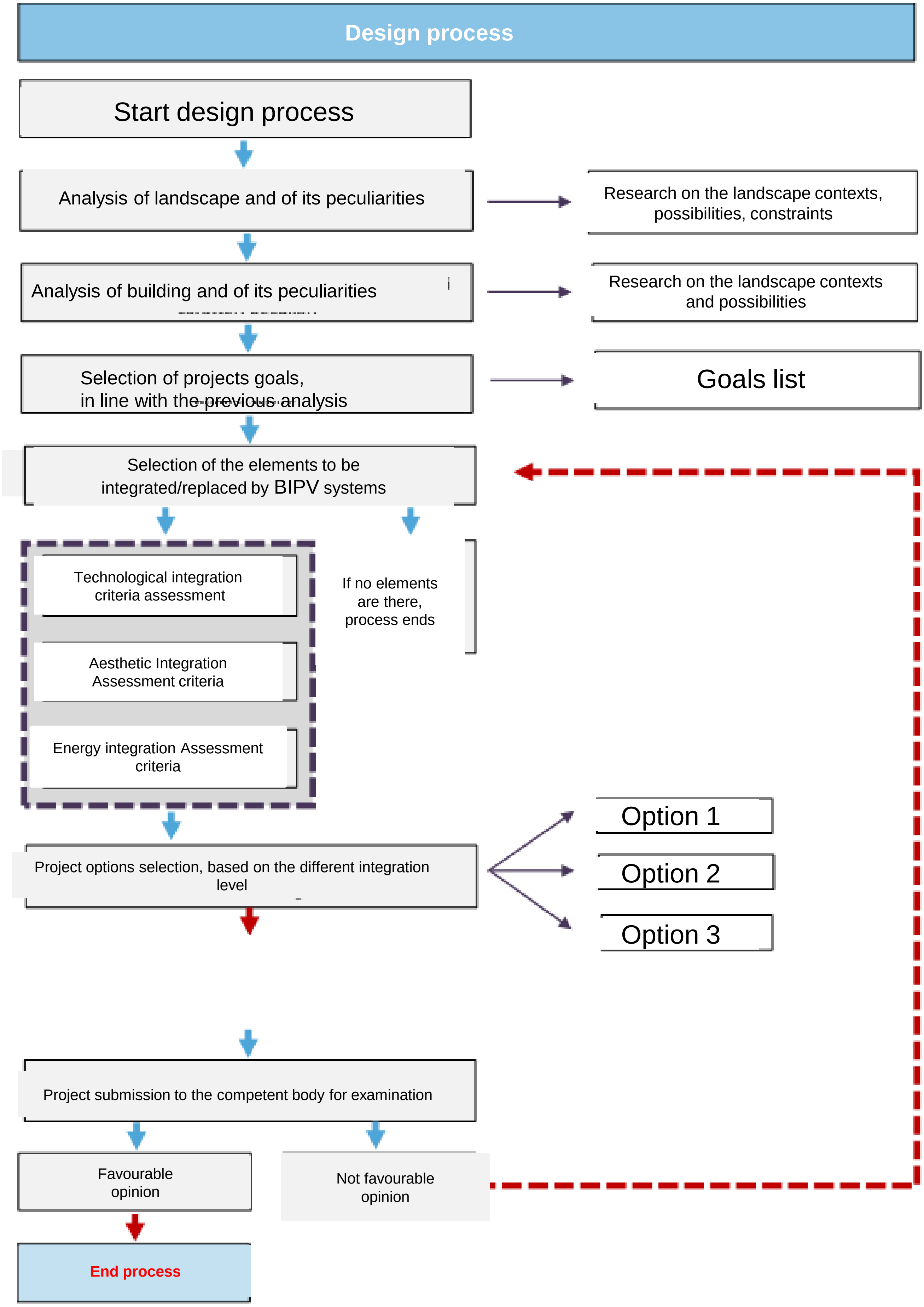
THE PROCESS OF INTEGRATING PHOTOVOLTAIC SYSTEMS

The process of integrating photovoltaic systems into the built assets is a very complex task, involving the analysis and combination of multiple factors, which could lead to the exclusion of each other: on the one hand, the requirements dictated by the preservation of the historical, architectural and landscape heritage, and on the other hand the desire to achieve the energy objectives set at European and national level, while minimizing the consumption of buildings as much as possible.

The role of the designer is precisely to find the right harmony between aesthetic, technological and energy integration, assessing the applicability of the different criteria on a case-by-case basis.

The following is a schematic procedure, which summarizes the process that should be undertaken by the designer. The procedure does not define prescriptions, but can be used as a useful reference to guide the designer in identifying the most appropriate design solutions.

A **list of the minimum design documents** to accompany the landscape authorization application is also provided , together with a brief explanation of the contents that they must contain. This list is not exhaustive, but must be assessed and calibrated on a case-by-case basis, in relation to the type of intervention, by agreeing on the scope of the documents from time to time with the competent Superintendence. This list may be a guide to be considered for operations involving areas not subject to specific protection, in order to design projects with a view to the correct integration of the landscape.


Design process
Start design process
Analysis of landscape and of its peculiarities
Research on the landscape contexts, possibilities, constraints
Analysis of building and of its peculiarities
Research on the landscape contexts and possibilities
Selection of projects goals, in line with the previous analysis
Goals list
Selection of the elements to be integrated/replaced by BIPV systems
Technological integration criteria assessment
Aesthetic Integration Assessment criteria
Energy integration Assessment criteria
If no elements are there, process ends
Project options selection, based on the different integration level
Option 1
Option 2
Option 3
Project submission to the competent body for examination
Favourable opinion
Not favourable opinion
End process

MINIMUM DESIGN DOCUMENTATION (ACCORDING TO THE AGREEMENT UNDER ART. 3 OF DPCM 12/12/2005 ON THE DOCUMENTATION TO ACCOMPANY THE APPLICATIONS FOR LANDSCAPE AUTHORIZATION BETWEEN THE REGION OF LOMBARDY AND THE REGIONAL DIRECTORATE FOR CULTURAL AND LANDSCAPE HERITAGE OF LOMBARDY OF THE MINISTRY FOR CULTURAL HERITAGE AND ACTIVITIES)

Applications for landscape authorization relating to operations to transform the Lombard territory must be accompanied by documentation, at the appropriate scale and in relation to the type of operations, consisting of the landscape report, the current state documents and the project documents.

Landscape report: *it contains all the elements necessary to verify the compatibility of the intervention, with specific reference to the reasons for the landscape constraint on the area as well as the contents and indications of the Regional Landscape Plan (PPR) or of the more detailed landscape plans (PTC Provinciali e di Parco, municipal urban development tools). The report must state the reasons for and highlight the quality of the intervention, including the architectural and formal language adopted in relation to the intervention context; it must take account of the current situation of the places, in particular the reference landscape context (natural, traditional agricultural, industrialized agricultural and urban, peri-urban and widespread and/or scattered settlement) and the morphology of the area (coastal/riviera, lowland, mountain hills) and indicate the features of landscape value in the area as well as any presence of cultural assets protected by part II of the Code; describe the design of the intervention and the landscape effect resulting from the implementation of the proposed intervention and any proposed mitigation and compensation elements.*

Documents for the current status representation

1. Territorial planning (chorography, aerial photography, excerpt of the PTC Provinciale o di Parco if applicable, of the municipal urban planning instrument, and photo plan if existing);

2. General plan with identification of the constituent and representative elements of the landscape;

3. A listed plan, including plant species related to the nearest road office; in the case of territory in decline, the project will be accompanied by one or more listed sections extended to the whole territory covered by the intervention, with an indication of the ground movements planned to be excavated and carried over and the land containment works.

4. An overview of the current state of the building or of other objects (plants and coverings, façades and meaningful sections in 1:100 scale), describing the original fittings (e.g. type of plaster, painting of surfaces, covering materials, etc.);

5. Photographic documentation representing from several points of view, on a panoramic basis, the building or area affected by the intervention.

For a full discussion of the subject, see the AGREEMENT PURSUANT to Article 3 of the Treaty. OF DPCM 12/12/2005 ON THE DOCUMENTATION TO ACCOMPANY THE APPLICATIONS FOR LANDSCAPE AUTHORISATION BETWEEN LOMBARDY REGION AND THE REGIONAL DIRECTORATE FOR CULTURAL AND LANDSCAPE HERITAGE OF LOMBARDY OF THE MINISTRY FOR CULTURAL HERITAGE AND ACTIVITIES (ANNEX TO THE D.G.R. OF 22 DECEMBER 2011 – N. IX/2727).

Project deliverables

1. Plan with the environmental inclusion of the project (1:500, 1:5000) identifying the aesthetic and perceptual characteristics of the intervention in relation to the context;

2. Meaningful plants, façades and sections;

3. An indication of the materials of use, their colours (sampled) and of the construction systems, with a representation of any details if necessary;

4. Schematic environmental sections (1:500, 1:1000) showing the relationship between the intervention and the landscape subject to protection;

5. A photographic representation of the on-site simulation of the planned work (by means of padding or other method of real-life representation of the footprint) or a photomontage showing its inclusion in the landscape context, in relation to the type of intervention proposed;

6. Indication, if any, of the elements of mitigation and compensation.

BIPV SYSTEMS' MINIMUM ENVIRONMENTAL CRITERIA, LIFE CYCLE, COSTS, AND BENEFITS

MINIMUM ENVIRONMENTAL CRITERIA (MEC)

Adopted by decree of the Italian Ministry of Ecological Transition, Mec [1, 2] are *the environmental requirements defined for the various stages of the purchasing process, aimed at identifying the best design solution, product or service from an environmental point of view over the life cycle, taking into account market availability*. MECs refers to a wide range of product, manufacturing, and services for the environmental sustainability of government consumption. In the construction sector, the MECs is aimed at new construction or renovation/maintenance of buildings, with the aim of increasing the number of ''green'' tenders.

Legislative decree 18 April 2016, no 50 "Procurement Code" made it compulsory for all clients to apply the MECs, both as award criteria for participation in tenders and as 'initial'' requirements, setting out the requirements on products and processing, thereby encouraging businesses to adapt and make themselves more sustainable.

Technical specifications (paragraphs 2.2.5 and 2.3.3) are devoted to the subject of '**Energy supply**' to ensure that a system of energy supply from renewable energy installations is provided for in new construction or, renovation work including demolition and reconstruction work or energy upgrading work, able to cover part or all of the total energy needs of the building within the building site itself.

Another innovative and interesting aspect introduced by the MECs is the requirement for each project to have a **maintenance plan for the work,** which describes the program of tests relating to the environmental performance of the building, **and a plan for the disassembly and selective demolition of the work** at the end of its life, allowing the reuse or recycling of the materials, building components and prefabricated elements used, with the aim of reducing the environmental impact on natural resources. Photovoltaic installations, if designed to be disassembled, must also be included in the plan.

The incorporation of BIPV into the MECs is not yet fully implemented; the reasons for this can be found in the fact that they are newly-released products on the market and in their highly tailored nature, which still makes them niche products at the moment.

In particular, the issues of the life-cycle, disassembly, recovery and reuse of BIPV systems are areas that have yet to be explored and that research and producers will certainly have to face and deal with if they want to open up to a wider market, especially in the public works sector. As things stand, there is little data in the making (applications are recently installed), but for first point, it may be interesting to make an initial comparison with traditional plants, which are a mature technology.

[1]: Entrustment of the services of design and construction work (approved by M.D. 23 June 2022, no. 256, GURI No. 183 dated 6 August 2022 – effective 4 December 2022;

[2]: Entrustment of design and works services for the new construction, renovation and maintenance of public buildings (approved by M.D. 11 October 2017, GURI No. 259 of 6 November 2017)

LIFECYCLE: DIFFERENCES BETWEEN A CONVENTIONAL AND A BIPV TYPE INSTALLATION

The general line, a BIPV installation's useful life can be estimated at around 20-25 years, but it should be remembered that, at the end of this period, the plant continues to produce energy, albeit with a lower yield, while maintaining its function as a building component (covering, façade coating, etc.). On the other hand, the traditional photovoltaic installations life cycle is only linked to the photovoltaic module's energy production capacity and only to a marginal extent to the support structure.

As far as disposal is concerned, since in BIPV systems the photovoltaic component is secondary to the architectural structure in which it is integrated, which is the main part, the possibility disposing the different components with the most appropriate treatment and, therefore, recovery is strongly dependent on recycling and/or regeneration techniques of the architectural element in which it is included. However, it is important that the photovoltaic component is properly disposed of in order to avoid any risk of environmental pollution: currently the IEC 61730 standard, for BIPV, provides for manufacturers to join a consortium for the disposal of the photovoltaic module at a cost calculated at €/piece.

Inevitably, the world of BIPV research and production will have to face the challenge of making the disassembly, recovery and recycling of these products increasingly more stringent, in order to maximise the division of the different components to decrease the percentage to be disposed of. This issue is by no means marginal in view of the widespread use of photovoltaic installations in response to the energy crisis and the demands for European and national legislations.

THE COSTS AND BENEFITS OF BIPV SYSTEMS

When compared directly to traditional photovoltaic panels, the costs of BIPV solutions are certainly higher, although this comparison is not entirely correct indeed.

It should be stressed that integrated photovoltaic systems are real building components that, in addition to producing electricity from renewable sources, also perform architectural and structural functions, and it would therefore be more appropriate to talk **about extra-cost** than the traditional building systems that BIPV replace in the building envelope. An example is the BIPV systems for roofing, where PV modules are used to replace traditional roof tiles, to make a discontinuous covering that is waterproof, has resistance to chemical, physical, and mechanical stresses. The assessment of the initial investment should therefore take into account the expenditure not incurred for the installation of the original functional layer.

When it comes to costs, one cannot fail to address the issue of Return of Investment (ROI), the time it takes to recoup the economic investment incurred in purchasing the plant. In this respect, an interesting study was carried out under the ''BIPV meets History' project to develop a methodology for quantifying the economic impact of the aesthetic integration of BIPV, applied to a pilot case in the city of Como. [1]

[1]: Definition taken from the website of the Italian Ministry of Ecological Transition – www.mite.gov/pagina/i-criteri-environmental-minimum#2

Here are some of the conclusions of the study: '*The methodology developed makes it possible to calculate a synthetic economic parameter based on building parameters, in order to assess the extra cost attributable to innovative BIPV installations… surely the current high purchase costs of this technology on the Italian market are such as to make this design solution uncompetitive on the market. However, assessing the profitability of the intervention on the basis of economic parameters relative to the installation surface, as is normally done for traditional photovoltaic installations, does not take into account the specificity of the intervention using photovoltaic as a building element, thus becoming an integral part of the building structure. It is therefore necessary to provide a synthetic economic parameter that can be compared with other economic parameters in the construction sector. In this report, the extra cost attributable to an advanced level of architectural integration, through the use of innovative BIPV, was referred to the useful surface area of the building on which the photovoltaic is installed. This cost can be easily absorbed by a higher property estimate on the market, as a building with a higher level of energy self-sufficiency, using a higher percentage of energy from renewable sources.*''

It can therefore be said that the assessment of the BIPV system's costs/benefits of cannot only be based on ROI, as is common practice, but that environmental and social benefits, which are difficult to derive from a standard price recognized by the market, must also be taken into account.

These include:

- aesthetic value;
- the possibility of intervening in the built heritage in protected areas otherwise excluded from energy redevelopment operations;
- the possibility of application to parts of the building envelope such as windows, skylights, greenhouses, solar lastres, etc... which would otherwise be precluded by traditional photovoltaic systems ;
- the high customization enables the design of tailor-made solutions for each intervention, thanks to a multitude of colours, dimensional, finishing proposals (opaque, transparent, semi-transparent, with printed drawings, etc.);
- the (unique) possibility to make energy-active some building envelope elements that are usually passive (non-energy-productive);
- a higher diffuse quality of the landscape.

The landscape as well as the architectural assets are a collective heritage that has made our territory unique, and whose value must be preserved. The undoubtedly higher costs of BIPV technologies must therefore be assessed not only on the basis of the price of materials, but also on the basis of the benefit from the aesthetic FER integration on assets with high social, cultural and environmental value.

[1]: ''Evaluation of Business Models and Economic Impact of Aesthetic Integration'', edited by Martina Pelle and Davide Moser – EURAC Research - https://www.bipvmeetshistory.eu/wp-content/uploads/2022/07/BIPV-REPORT-WP5_P32.pdf

DIGITAL PLATFORMS FOR THE PROMOTION OF BIPV

Most professionals are unaware of the new technological possibilities for integrating solar energy into architecture and therefore do not apply them in design practice. The potential for a multidisciplinary approach that combines energy and architecture is enormous.

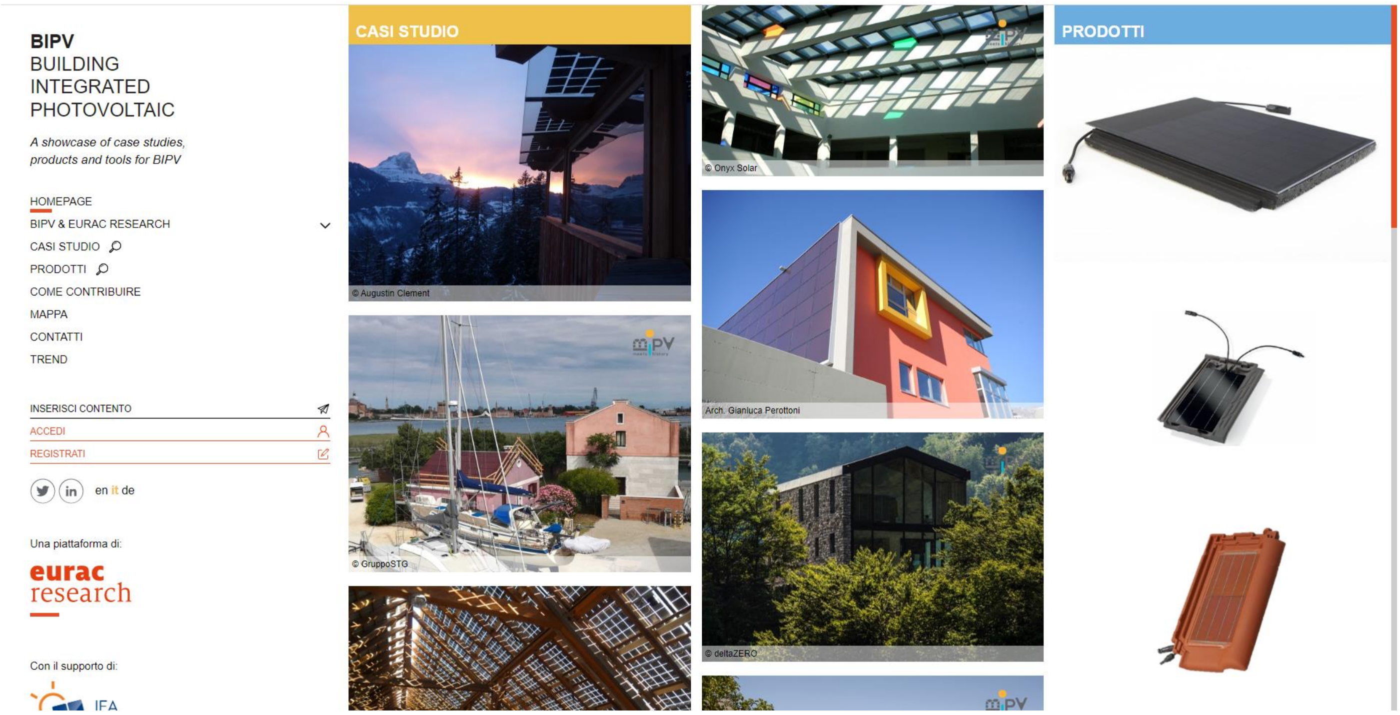
As mentioned above, one of the strongest barriers to the spread of integrated-type photovoltaic solutions is undoubtedly knowledge. At a time of rapid information and rapid technological change, digital platforms are the most appropriate means of communication because they are constantly updated with the latest news.

Here are two platforms developed as part of the project that serve as a benchmark for all players in the industry.

https://integratedpv.eurac.edu/it

The objectives of the Italian platform are to describe in detail the most significant case studies of solar architecture in valuable contexts, to provide design support early in the design phase, to facilitate communication among stakeholders, to establish a network of contacts and to keep the state of the art of BIPV up-to-date, with an overview of the market and innovative (customizable) products. Among the most interesting contents of the platform are: the case studies analysed and the section 'Trend' where a focus is placed on how integrated photovoltaic systems are integrated into areas subject to protection under the Code.

The platform places great importance on images from both case studies and BIPV products that are compatible with protected contexts.



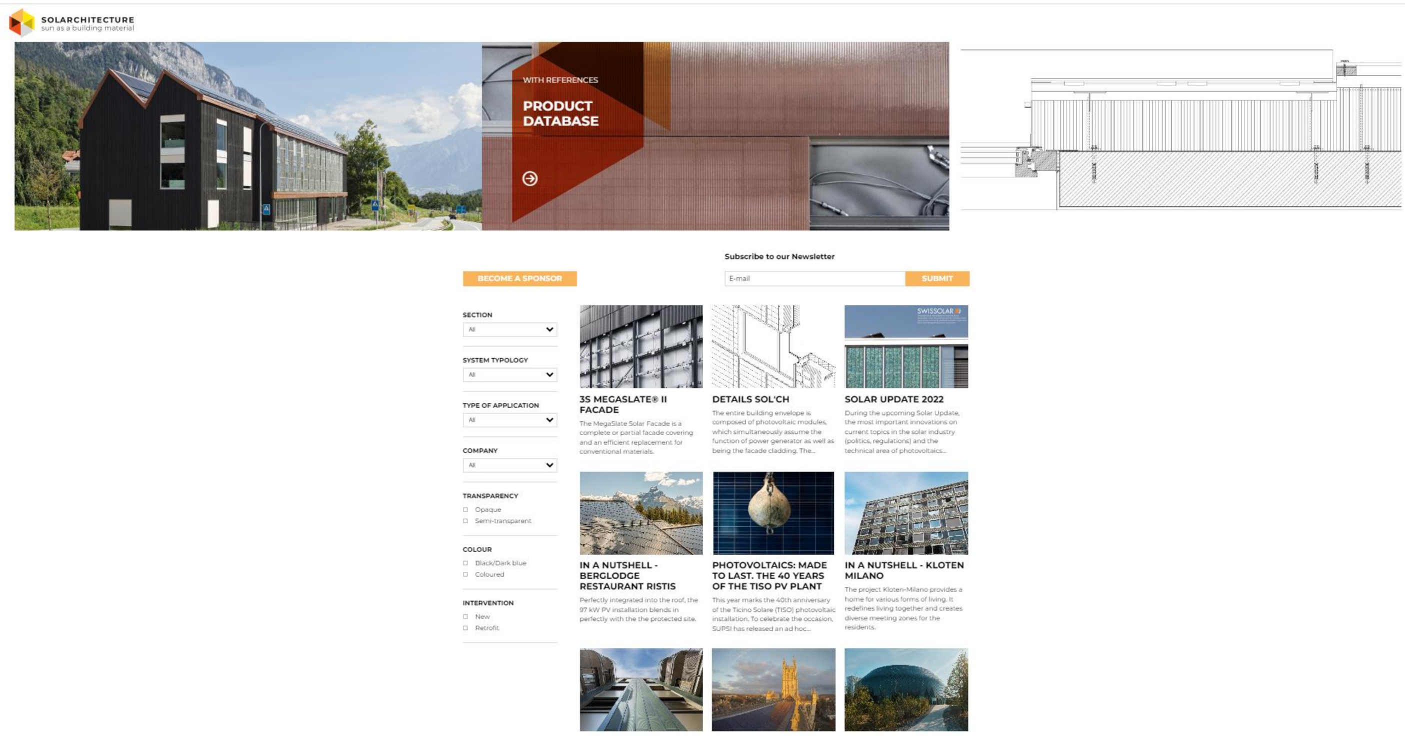
www.solararchitecture.ch

The new Swiss platform on solar architecture focuses not only on BIPV technology systems but also on architectural quality. The main goal is to promote the construction of solar buildings by shifting the focus from technology to architecture, by encouraging both architects and customers to adopt new building concepts, by innovatively communicating the solutions to be adopted, and using a more complex approach where energy, architecture and construction are part of a single design concept. This website is managed and developed through the collaboration of four main partners: SUPSI - University of applied Sciences of Switzerland Italy; the Swiss Federal Institute of Technology Zurich (ETHZ); Swissolar, the Swiss Solar Professional Association representing Swiss solar professionals; and SvizzeraEnergia, a body set up by the Swiss Federal Council to promote energy efficiency and renewable energy.

The site is divided in:

- case studies;
- products;
- technical details;
- knowledge;
- stories.

The section on BIPV products and technologies explains the technical solutions availableon the market and in continuous development; it also provides technical and building details, technical insights related to technological innovation and news of events related to the photovoltaic sector.



CONCLUSIONS

These guidelines summarise the main results of the research and analysis work developed under the INTERREG IT-CH "BIPV MEETS HISTORY" project, which took into account the different technologies available to date on the market, some exemplary Italian and international case studies, the national Italian and regional regulatory and authorisation system (derived from European one).

The work carried out within the project has revealed the most important challenges and barriers in the use of integrated photovoltaic technology in Italian national and regional territories, in particular, in landscape-protected environments.

Thanks to the work briefing sessions with the Territorial Superintendencies of Lombardy, the sector leading manufacturing companies and the main stakeholders (professional orders, technicians of the local authorities, ANCI, ANCE …) it has been possible to identify some of the issues considered to be substantial in order to overcome the obstacles that hamper the spread of photovoltaic technology on the assets built, which can be summarised as follows:

1° INTEGRATED DESIGN AND BALANCING AESTHETIC, TECHNOLOGICAL AND ENERGY ASPECTS

Usually in the installation of photovoltaic systems, the plant project is developed by the engineers solely from the point of view of energy performance, in a way that is disconnected from the architectural project. Photovoltaic installations, on the other hand, can and must be given architectural relevance so that their integration, especially on the historical-architectural and landscape heritage, is designed in an integrated way, including from the point of view of compositional design. BIPV systems are now the solution that enables the aesthetic integration of photovoltaic technologies in the buildings, thanks to the endless customisation possibilities they provide.

2° STUDY OF SITE-SPECIFIC SOLUTIONS

There are no a priori right or wrong solutions or valid technologies in any context. In view of the vast and heterogeneous nature of the built heritage, a site-specific assessment for each operation is indispensable; it must take into account and classify the building's material, colours, and compositional characteristics, the wider landscape in which it fits, and the technological and plant aspects of photovoltaic.

Through a collaborative dialog with the Superintendence, the technical offices of the Public Administrations and the municipal, provincial and regional Landscape Commissions, it is possible to arrive at a shared project which simultaneously meets the demands for electricity generation from renewable sources and for the aesthetic integration of photovoltaic technology on buildings subject to protection.

3° DISSEMINATION OF A GREATER CULTURE AND KNOWLEDGE OF INTEGRATED PHOTOVOLTAIC SYSTEMS

The Interreg "BIPV meets History" project aims to spread an integrated photovoltaic system culture with the aim of triggering new virtuous processes of collaboration and cooperation between the world of research and industry, institutions and culture, so that there is an increase in the competitiveness and quality of the integrated photovoltaic market, making it accessible to an increasing number of end-users.

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REGULATORY REFERENCES ON LANDSCAPE, PLANNING, ENERGY AND ENVIRONMENT

NATIONAL LEGISLATION

LANDSCAPE AND PLANNING [1]

- DPR June 6, 2001, No. 380 – *Consolidated text of the building laws and regulations.*
- Q. Lgs 22 January 2004, n. 42 – *Code of Cultural Heritage and Landscape.*
- DPR February 13, 2017, No. 31 – *Regulation identifying operations excluded from the landscape authorization or subject to a simplified authorization procedure.*
- MIBACT – *Guidelines for the energy improvement of cultural heritage.*

ENERGY AND ENVIRONMENT [1]

- National Action Plan – (pan)
- National Energy Strategy 2017 – (SEN)
- Integrated National Energy and Climate Plan (PNIEC) – December 2019
- Q. Lgs 19 August 2005, n. 192 – *implementation of Directive (EU) 2018/844, amending Directive 2010/31/EU on the energy performance of buildings and Directive 2012/27/EU on energy efficiency, and Directive 2002/91/EC on the energy performance of buildings.*
- Q. Lgs 3 March 2011, n. 28 – *implementation of Directive 2009/28/EC on the promotion of the use of energy from renewable sources, amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC.*
- DM 15 March 2012 – *Definition and qualification of regional renewable energy targets and definition of how to deal with cases of non-achievement by regions and autonomous provinces.*
- Q. Lgs July 4, 2014, n. 102 – *implementation of Directive 2012/27/EU on energy efficiency, amending Directives 2009/125/EC and 2010/30/EU and repealing Directives 2004/8/EC and 2006/32/EC.*
- DM Economic development 11 May 2015 - *methodology to be applied to collect the data needed to measure the achievement of regional targets for renewable energy sources.*
- Interministerial Decree 26 June 2015 – *Application of the methodologies for calculating energy performance and definition of minimum requirements and requirements for buildings.*
- Q. Lgs July 18, 2016, n. 141 - *Supplementary provisions to the Legislative Decree of 4 July 2014, n. 102, implementing Directive 2012/27/EU on energy efficiency, amending Directives 2009/125/EC and 2010/30/EU and repealing Directives 2004/8/EC and 2006/32/EC.*
- D.Lgs November 8, 2021, n. 199 - *implementation of Directive (EU) 2018/2001 of the European Parliament and of the Council of 11 December 2018 on the promotion of the use of energy from renewable sources*.
- D.L. march 1, 2022, no. 17 - *urgent measures to reduce the costs of electricity and natural gas, to develop renewable energies and to relaunch industrial policies*.
- D.L. april 30, 2022, no. 36 - *further urgent measures for the implementation of the National Recovery and Resilience Plan (NRPs).*

- Law No. 34 of 27 April 2022 - *Conversion into law, with amendments, of Decree-Law 1 March 2022, n. 17 on urgent measures to reduce the costs of electricity and natural gas, the development of renewable energies and the relaunch of industrial policies.*
- D.L. No. 50 of 17 may 2022 - *coordinated with the conversion law of 15 july 2022, n. 91 containing: Urgent measures on national energy policies, business productivity and investment attraction, as well as on social policies and the Ukrainian crisis.*
- D.L. No. 144 of 23 September 2022 - *further urgent measures on national energy policy, business productivity, social policies and the implementation of the National Recovery and Resilience Plan (NRPs).*

LEGISLATION LOMBARDY REGION

LANDSCAPE AND PLANNING

- DGR n. VII/11045 of 8 November 2002 – *Guidelines for the Pasistic Review of Projects.*
- Regional Law of 11 March 2005, No. 12 - *Law for the Government of the Territory.*
- DGR 10974/2009 - *Guidelines for the Landscape Design of Technology Networks and Power plants*
- DCR 19 January 2010 - *Regional Territorial Plan (PTR) and Regional Landscape Plan (PPR)*
- DGR n. IX/2727 of 22 December 2011 - *criteria and procedures for the exercise of administrative functions in the field of landscape property in implementation of the l.r. of 11 March 2005, n. 12.*
- Regional Law 28 November 2014, n. 31 - *provisions for the reduction of soil consumption and the redevelopment of degraded soil*
- DGR n. XI/207 of 11 June 2018 - *Simplification and incentive measures for building stock recovery*
- Regional Law of 26 November 2019, No. 18 – *simplification and incentive measures for urban and territorial regeneration, as well as for the recovery of existing housing stock. Amendments and additions tothe Regional Law No 11 March 200512 (Law for the Government of the Territory) and other regional laws.*

ENERGY AND ENVIRONMENT

- Regional Energy, Environment and Climate Program (PREAC)
- Regional Law 18 April 2012 No. 7 – *measures for growth, development and employment.*
- Decree No. 8711 of 21 October 2015 — *Regulation of training and upgrading courses for the extraordinary installer and maintainer of energy installations powered by renewable sources, pursuant to Article 15(2) of Legislative Decree No "3 March 2011 " 28.*
- DGR n. XI/4803 of 31 May 2021-*in support of the new regional guidelines for the authorization of plants producing electricity from renewable energy sources (FER) as a result of the relevant national legislation being updated.*

GLOSSARY

BIPV: Building Integrated Photovoltaic

A-SI: Amorphous silicon

BAPV: Building attached Photovoltaics

BIPVT: Building-integrated photovoltaic-thermal

CdTe: Cadmium telluride photovoltaics

CIGS Copper: indium gallium selenide

CIS: Copper indium selenide

EED: Energy efficiency Directive

EPBD: Energy Performance Buildinig Directive

FER: Renewable Energy Resources (RES)

mc-SI: Multicystalline Silicon

NZEB: Near Zero Emerhy buildings

OPV: Organic Photovoltaics

DP: Photovoltaic

RED: Renewable Energy Directive

sc-SI: Singlecrystalline Silicon

EU: European Union

VOC: Volatile organic compounds

The world of integrated photovoltaics is constantly developing and expanding, to stay up-to-date we invite you to sign up for the newsletter by visiting:

www.bipvmeetshhistory.eu

Also follow us on: