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Collection of building typologies and identification of possibilities with optimal market share

BIPVBOOST

"Bringing down costs of BIPV multifunctional solutions and processes along the value chain, enabling widespread nZEBs implementation"

Start date: October 2018. Duration: 4 Years

Coordinator: TECNALIA Grant Agreement No: 817991 www.bipvboost.eu

Summary

This document reports on the definition, features, challenges and potentials linked to main archetypal BIPV scenarios, which result to have a high potential for the implementation in the European building stock. By taking into account the point of view and the support of three types of stakeholders (the architect, the product/system manufacturer and the construction company), the review and the analysis of the partners' large international portfolio, provided a census of best practices as the basis to define the archetypal building typologies, technological systems and building skin claddings. The BIPV "archetypes" and "clusters" analyses, have considered the component, the building skin and the building technological and typological levels, by permitting to set a multi-level and complete study in construction terms. Beyond the current literature, the integration of the architectural specifications allows to benefit of a more solid basis to provide barriers, challenges and key-topics. This guarantee to understand the BIPV market exploitability. Once defined such an archetypal scenario, specific topics affecting the success or failure of BIPV in the market have been analysed in order to recognize the main potentials (or gains) and challenges (or risks) for future technologies and market developments. Key-topics to boost BIPV implementation emerged with regard to technology and technical standards, cost effectiveness, process management and general acceptance issues. Thanks to the collected output, an outlook on the main aspects defining the market attractiveness and its evolving opportunities in the horizon 2020 to 2030 is provided, as a concrete reference framework for the general sector and for the following project stages, namely the product developments in WP3/WP4 and the demo cases in WP8 of BIPVBOOST project.

Document Information

Title	Collection of building typologies and identification of possibilities with optimal market share
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Disclaimer

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1 EXECUTIVE SUMMARY

1.1 Description of the deliverable content and purpose

This document is the output of the Task 1.3 of BIPVBOOST project. Within the scope of a massive utilization of PV in buildings from 2020 onwards, we performed an analysis of different archetypal buildings and building skin categories which have a potential for BIPV in the European market, referring to the sector trends, evolution and construction segments relevant for BIPV thanks also to the information and support provided by the project partners. The goal of this analysis is to determine the sector attractiveness and its evolving challenges and opportunities in the horizon 2020 to 2030. By taking into account the point of view of three types of stakeholders (architects, manufacturers and construction companies), a census of the best practices in the field of BIPV implementation founded the definition, the investigation and the analysis of the reference archetypal scenarios as well as the identification of the main trends describing barriers, challenges and key-topics for the future developments. The results, for each relevant archetypal segment (including both the building skin and building level), resulted in the definition of a reference outlook on the main aspects defining the market attractiveness and its evolving opportunities in the horizon 2020 to 2030 and a basis for the development of the following project stages.

1.2 Relation with other activities in the project

Task 1.3 was led by SUPSI, in coordination with the WP1 leader ICARES. It actively involved all the project partners participating in the task (VIRIDEN, SCHWEIZER, ONYX, PIZ, COMSA) as well as other stakeholders of the consortium (TULiPPS and FLISOM), who provided support with their experience in real case-studies, as the relevant basis to ground the main analysis and outlooks. The market analysis and the adopted segmentation were coordinated with other tasks' of WP1 managed by ICARES. Viriden+Partners supported the activities by providing information and feedback about pilot and pioneering projects of BIPV integration in architectural field. ONYX, PIZ, SCHWEIZER, FLISOM and TULiPPS provided a solid support by reporting their experiences and visions of the sector from a day-to-day activity on engineering, manufacturing, installing and realizing real projects worldwide. COMSA finally contributed, with the perspective of a general contractor and their experience in the installation and management of reference BIPV solutions.

Table 1.1 depicts the main links of this deliverable to other activities (work packages, tasks, deliverables, etc.) within BIPVBOOST project. The table should be considered along with the current document for further understanding of the deliverable contents and purpose.

Table 1.1 Relation between current deliverable and other activities in the project

Project activity	Relation with current deliverable
T1.1-T1.2	Definition of the main building segmentation, typologies and building skin elements
T9.1	Coordination on the market analysis.
WP4	The D.1.3 provides possible inputs for the modules/systems developments
WP5	The D.1.3 provides possible inputs for the testing procedures development
WP8	The D.1.3 provides possible inputs for demo sites

1.3 Reference material

The deliverable D9.1 has been used as input and have been partially consulted to coordinate the Market Analysis. For other references see the **Error! Reference source not found.** chapter at the end of the document.

1.4 Abbreviation list

VPC: value proposition canvas

nZEB: nearly Zero Energy Building,

I.G.U.: Insulated Glass Unit

c-Si: crystalline Silicon

a-Si: amorphous Silicon

MFH: multy family house

SFH: single family house

1.5 Main definitions

Technological system: it is meant as the technological unit and/or technical section that assemble a main part of the building skin (e.g. a façade or roof system) by satisfying all the technological requirements and features needed for such a building envelope part.

Building skin cladding: external part of the technological system layering (e.g. façade cladding or roof tiling) together with the associated technological requirements (e.g. building covering, weather protection, safety, etc.).

Building typology: it is a set of buildings with similarities in function, dimension and distribution.

Archetype: it is defined as the combination between technological system and building skin cladding. The archetype represents a reference category to apply at the building stock classification in order to schematize the BIPV implementation by taking into account the main features of the building envelope construction.

Cluster: it is defined as the combination of an archetype with a building typology. The cluster is used in order to identify the main scenarios of BIPV application which consider both the skin technology and building level.

Value proposition canvas (VPC): within the BIPV purpose, it is a method/tool used to determine reference factors and key-topics describing the main challenges, barriers and opportunities for the market implementation of BIPV and its evolution in the upcoming years

Nearly-Zero Energy Building (nZEB): it is a building that has a very high energy performance, as determined in accordance with Annex I[1]. The nearly zero or very low amount of energy required should be covered to a very significant extent by energy from renewable sources, including energy from renewable sources produced on-site or nearby (1).

[1] In Annex I items that should be considered in order to reach the expected energy performance (e.g. heating, cooling, ventilation, lighting, solar systems, natural lighting, building fabric, etc.)

2 OBJECTIVES

The aim of this deliverable is to set definitions, reference classes and scenarios, in order to provide a basis document for the project with an outlook on the BIPV sector attractiveness and its evolving opportunities in the horizon 2020 to 2030 by taking into account a perspective focused on building envelope technology, building typologies and building process.

After a look to the building stock and to the market perspectives, the case studies provided by the main stakeholders of the BIPVBOOST consortium, represent the basis to define the reference cornerstones for the following study, by permitting to determine some reference factors and key-topics describing challenges and potentials for the attractiveness of the BIPV sector and its evolving opportunities in the upcoming years.

An inclusive approach, mainly combining the construction word, the business sphere and the photovoltaic sector has been adopted. The archetypes are used to support the analysis: they represent reference categories to apply at the building stock classification in order to schematize the BIPV implementation fields. An archetype is defined on the basis of the cladding construction typology (opaque/transparent and glazed/no glazed), in order to schematize/represent classes of building skin and cladding types.

The analysis will follow the point of view of the three main stakeholders involved into the construction process: architects, BIPV manufacturers and construction companies. Each stakeholder was initially assigned to provide a complete initial overview and analysis of the BIPV market, concerning the main barriers and challenges of the current process, in order to avoid the influence from any pre-defined raster sketched out.

In Figure 1, the main workflow at the basis of the performed analysis is shown. The process is subdivided in three steps.

STEP I: The **building stock classification** is referred to the definition of specific building typologies, technological systems and building skin cladding systems. It permits to have, starting from the stakeholders' portfolio, a representative picture of the main sector categories and reference classes of analysis.

STEP II: Definition of the archetypal building cases, which are the landmarks representing the main BIPV application cases. The **archetypes**, defined according to the features of the building skin cladding, are combined with building typologies to generate **clusters** (the building typology represents a building type with a certain functionality and use with the related construction features).

STEP III: With the goal to describe the state of the art and the potentials of each defined cluster within the BIPV landscape, the **value proposition canvas** methodology, an adapted classification system used within the business sector, was used to support the understanding and the evaluations. The input provided by partners played an important role referred to the understanding of the entire BIPV process.

The results permitted to obtain an outlook on some features and key-topics to be faced in order to address a future development and implementation of cost-effective BIPV solutions. Results were organized and summarized through some key-topics and case histories (which can be also referred to the products and buildings development of the next project activities and demo cases), in order to specifically highlight the BIPV evolving opportunities and the possibilities for an optimal market share in clear construction categories.

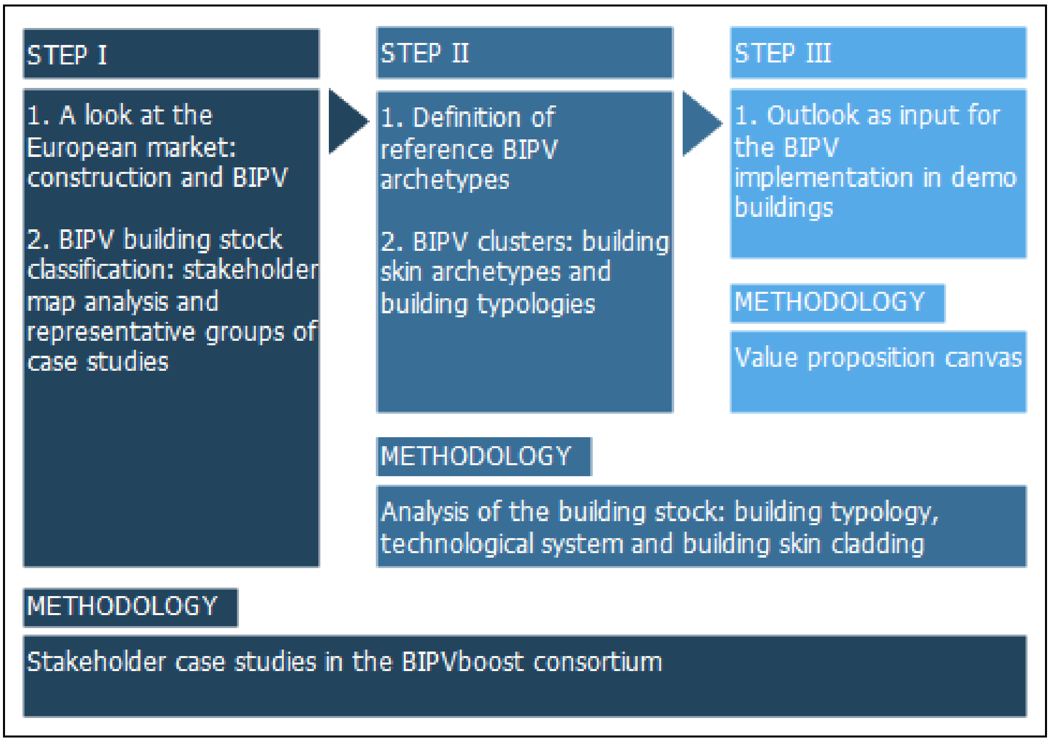
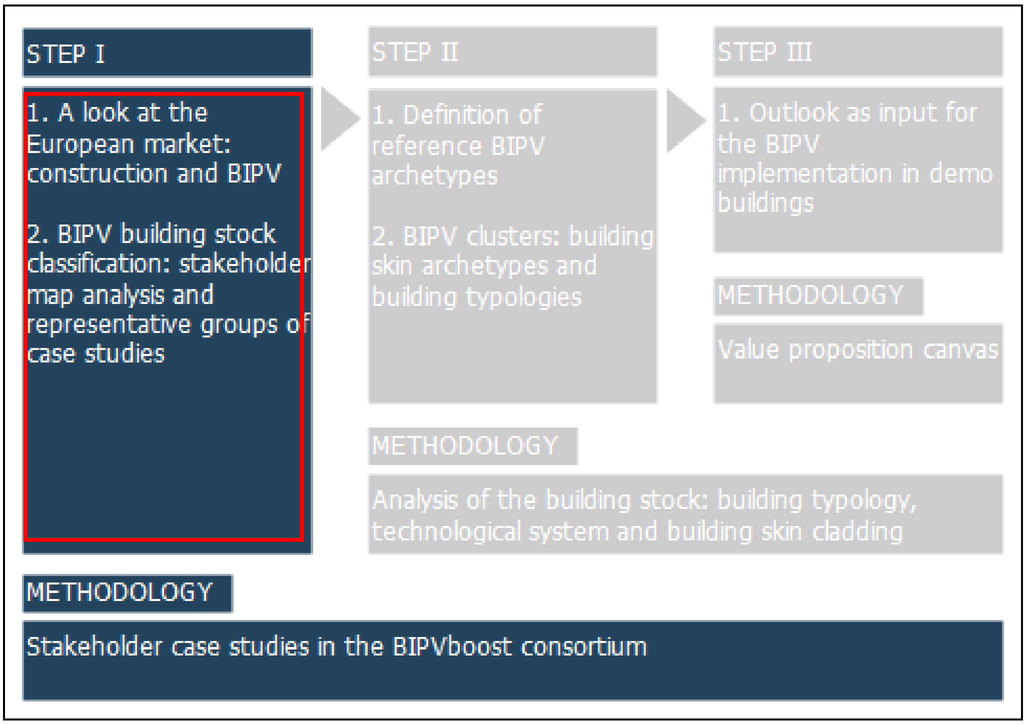


Figure 1 Workflow and methodology adopted for the analysis of the BIPV market attractiveness. The analysis is subdivided in three steps: (i) building stock classification, (ii) definition of archetypes and clusters, (iii) state of the art and potential of the clusters.

STEP I


STEP I
1. A look at the European market: construction and BIPV
2. BIPV building stock classification: stakeholder map analysis and representative groups of case studies
STEP II
1. Definition of reference BIPV archetypes
2. BIPV clusters: building skin archetypes and building typologies
STEP III
1. Outlook as input for the BIPV implementation in demo buildings
METHODOLOGY
Value proposition canvas
METHODOLOGY
Analysis of the building stock: building typology, technological system and building skin cladding
METHODOLOGY
Stakeholder case studies in the BIPVboost consortium

3 BIPV implementation perspectives: a look at the European market

The market perspective provides a global vision of what the BIPV sector is today and which main trends are expected for its evolving opportunities in the next years. The BIPV market is quite dynamic in the last years and a lot of products and systems entered this sector as reported in some previous analysis (2). The following summarized look at the EU market is based on information collected from some scientific studies, international research projects, market reports and forecasts at European and worldwide level, considering both the construction and the BIPV sectors, as mentioned below.

The document concerning the market analysis is object of the deliverable 9.1 “Update on BIPV market and stakeholder analysis” and the following sections only report some highlights as an introductory framework to the following parts.

3.1 Construction sector

The Western Europe’s major construction market will average grow only 1.6% per year and will not exceeded 2% in any year to 2030. One of the reasons for the construction market slowdown could be found in the demographic weakness. Strong public finances could help to increase it in Europe. But probably the European construction market will not reach the pre-crisis level of 2007 until 2025 (2). According to other sources (3) the growth of the European construction market will be 2.7% by 2018 and it will continue by 2019 and 2020 touching all of the main sectors: residential, non-residential and civil engineering, both new construction and renovation. Even though a little growth of the European (4) construction market is visible, it is low if compared with the global growth it is estimated that the global growth in the construction sector is up to 8 trillion $, with a foreseen 85% growth by 2030 reaching a total size of 17.5 trillion $. China, US and India will account for 57% of this global growth. The construction sector will account for 14.7% of global GDP (2).

The regulation pushing towards building renovation and particularly nZEBs is one of the main drivers for an optimistic forecast about the BIPV economy in Europe (4). Indeed, much of the European building stock needs to be renovated. More than 40% of buildings was built before 1960 and 90% before 1990. In Europe the new constructions represent about 1% of the building stock. Non-residential buildings account for about 25% of the total floor area of the European building stock. Considering that more than 35% of the European’s buildings are over 50 years old, the renovation potential market is huge. The Italian, French and German energy renovation markets account for about half of the total European market. Increasing the rate at which existing buildings are renovated to at least 2-3% per year until 2030 is a key objective of the European’s resources Efficiency agenda. The range of the building renovation rate in Europe is 0.5% to 2.5% a year (2012) with the rate varying as a result of time limited renovation programmes and other factors (5).

3.2 BIPV sector

According to some studies and analyses conducted by the Becquerel Institute, the share of BIPV over the global PV market is still a niche and it accounts for about 1% in 2017, while in Europe the BIPV market hold a share of about 2%. It is estimated that by 2022 BIPV will account for around 13% of the PV market (4). It is also important to remark that it is extremely difficult to forecast the development of BIPV given that, until now, it still depends on several uncertain parameters that could influence its development such as the lack of a clear regulatory framework or difficulties in the cooperation between different stakeholders. According to a study conducted by Fraunhofer ISE (6), the worldwide cumulative installation of PV at the end of 2018 was about 515 GW, while the worldwide PV market in 2018 was about 100 GW. The expected growth was of 7.7 billion € by 2016 considering both roof and façade and a CAGR of 19% in 2019 (7).

The estimated global BIPV cumulative capacity installed by the end of 2016, in GWp, calculated by the Becquerel Institute is shown in Figure 2 below. The highest capacity is installed in Europe, with Italy and France representing globally the second and third countries. Japan is the first country in terms of installed capacity, thanks to its favourable market conditions, such as limited space for ground-mounted systems, high urbanization, high turnover of housing construction, and privileged partnerships between (BI)PV manufacturers and construction companies active in the housing market. USA and China are now behind Europe but they have the potential to become a leading BIPV market in the medium-term [Becquerel Institute].

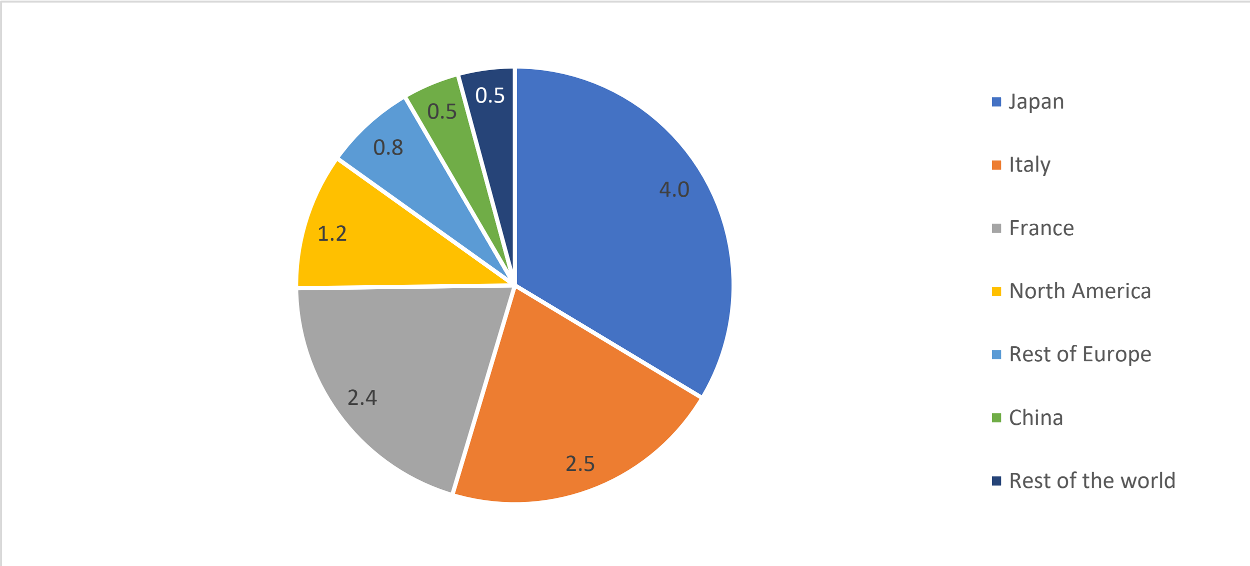


Figure 2 Estimated global BIPV cumulative capacity installed by the end of 2016, in GWp (Becquerel Institute)

In the past, the feed-in-tariffs policies and the price drop of regular PV led to an overestimation of the BIPV market growth (4). The drop in the price of standard PV made it more convenient than BIPV solutions in terms of ROI and business for many years. Additionally, policy mechanisms designed to boost the use of photovoltaics, such as feed in tariff programs, contributed to inflate the market of standard ground-mounted and rooftops installations.

The European leadership is based on the increasing stringent environmental regulations and rising pressures to minimize energy consumption from buildings: by 2020 the EU countries will adhere to the Net Zero Energy Buildings regulation (8). In the Figure 3 is shown the forecasted global BIPV market in terms of installed capacity [Becquerel Institute]. As reported within the Figure 3, north East and central Asia will represent the largest PV market in the world. This growth is foreseen to be limited between 2019 and 2020 before accelerating progressively. China, that owns part of the PV production capacity located in Europe, could adopt the strategy to continue its R&D activities in Europe, since Europe represents the major experiment and development area for new PV technologies and applications.

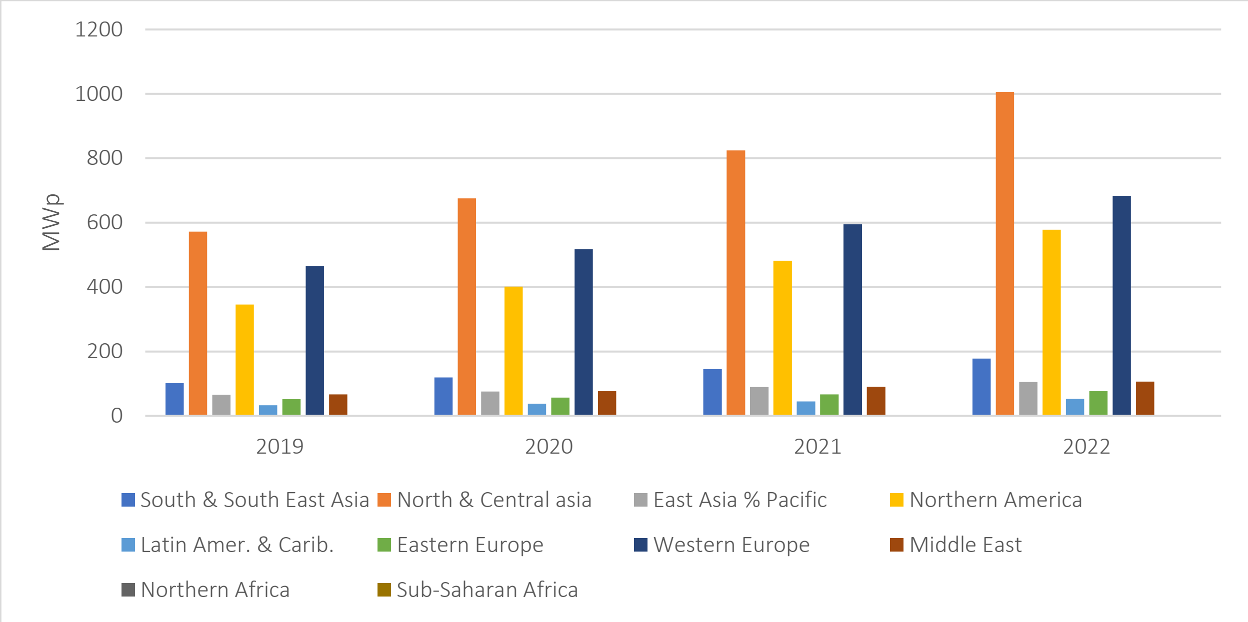


Figure 3 Forecasted global BIPV market in terms of installed capacity, under two scenarios (Becquerel Institute)

A focus on a high-quality BIPV at European level will represent a solid possible market strategy for companies and research institutes with a minor competition from the global market. By 2022 the BIPV systems installed in Europe will cover about 27% of the global BIPV installed (Becquerel Institute). By the same year the PV systems installed in Europe will cover just the 14% of the global PV capacity (9) even though the Asian BIPV market will increase its share in the next years. Nevertheless, the European BIPV market will preserve an important share of the global market as a peculiar quality-based asset. Thus the synergic combination of building and PV potentials in this field will represent a main key-challenge in which EU actors can bring innovation, new developments and a potential market development thanks to the added value of its high-quality construction and PV sectors.

HIGHLIGHTS

BIPV implementation perspectives: a look at the European market

Some main highlights about the market scenarios which are expected to create framework conditions for the EU BIPV sector in the upcoming years are:

a) The building stock in Europe is old and needs to be retrofitted.

b) Retrofit and renovation of buildings is one of the main drivers for the BIPV implementation in Europe even though with a moderate growth of the European construction market in all of the main sectors.

c) The residential building typology represents about 75% of the European building stock.

d) European BIPV market will preserve an important share of the global BIPV market.

e) Europe represents the major experiment and development area for new PV technologies and applications.

f) Synergic combination of building and PV/energy expertise will represent the main challenge for European BIPV development.

g) The EU construction market will grow slowly but strong public finances could help to revamp the market.

4 BIPV construction: building typology, technological system and building skin cladding.

The aim of this analysis is to investigate the characteristic of the building stock in a construction-based perspective by considering the technological aspects of the building skin and the architectural typologies as in the following:

- *Technological system*: it is meant as the technological unit and/or technical section that assemble a main part of the building skin (e.g. a façade or roof system) by satisfying all the technological requirements and features needed for such a building envelope part.
  - The technological system permits to define the building skin cladding type and the archetypes (Chapter 5 - ARCHETYPAL BUILDING).
- *Building skin cladding type*: external element of a technological system (cladding) together with the associated technological requirements (building covering, weather protection, safety, etc.).
  - The building skin cladding type permits to identify the archetypes (Chapter 5 - ARCHETYPAL BUILDING).
- *Building typology*: set of reference buildings classified on the base of specific functional, dimensional and distributive features.
  - The building typology permits to identify the clusters (Chapter 5 - ARCHETYPAL BUILDING).

The segmentation is used to analyse and classify in homogeneous groups the database of different BIPV case studies provided by the project partners and to identify the building skin cladding groups, the archetypes and the clusters. On this basis, the main challenges for the attractiveness of the BIPV market and its evolving opportunities in the upcoming years, emerged through the value proposition canvas method following presented.

4.1 Methodology for the stakeholders' BIPV building stock classification

The BIPV building stock provided by the project partners has been classified according to the technological system and building typology, as defined below.

The **technological system** includes the different construction possibilities related to the realization of a building envelope, subdivided in roof, façade and accessory systems. According to the building technology, we can list 11 main technological systems as the reference for this document. For each, several technical alternatives and technological solutions exist.

- <u>Rainscreen façade</u>: it consists in a load-bearing substructure, air gap and cladding. Usually PV modules are integrated as external coating similarly to non-active building elements. This façade uses the exterior layer breathing like a skin. There is no significant pressure differential between cavity and external environment. Evaporation and drainage in the cavity removes water eventually penetrating between panel joints. In summer heat from the sun is dissipated thanks to the cavity that is naturally ventilated through bottom and top openings. This is the reason why it is also called as "cold façade". The rainscreen façade is ideal for using solar modules made of crystalline solar cells, with system efficiency enhanced by rear ventilation. Many constructive models and technological solutions are available.
- <u>Curtain wall façade</u>: external not ventilated and continuous building skin system, totally or partially glazed, composed by panels supported by a substructure. A curtain wall system is an outer building envelope system in which the outer walls are non-structural. The curtain wall façade does not carry

any dead load weight from the building excluding its own dead load weight: moreover, it transfers horizontal loads (wind, seismic) to the main building structure through connections. A curtain wall is designed to resist air and water infiltration, dividing outdoor and indoor environments, and it is typically designed with extruded aluminium frames (but also steel, woods, etc.) filled with glass. The façade should satisfy all the main requirements such as load-bearing function, acoustic and thermal insulation, light transmission, waterproof, etc.

- Double skin façade: it is a façade building system consisting of two glazed skins separated by an intermediate air cavity. The ventilation of the cavity can be natural or mechanical. The functioning and the effectiveness depend mostly on the climatic conditions, the use, the location, the typology of the building and the HVAC strategy. The air cavity or the distance between the two skin layers can range from 20 cm up to 2 meters. The inner glass is insulated, while the external panes, where the PV modules are normally located, are usually laminated glasses since they should wide stand wind loads. The air gap between the two façades works as thermal and acoustic insulated area.
- Prefab/Multifunctional façade: it is a unique and preassembled multifunctional element installed on the façade, composed by PV cladding, protective layers and substructure.
- Accessory façade: transparent or opaque shading devices for façades or railings with the role of “fall protection“ that are necessary for the safety of the building (balconies, parapets or external screens).
- Cold roof: it consists in a load-bearing substructure, air gap and cladding. Pitched/sloped opaque roof is extremely common all over the world: it is known as “discontinuous” roof due to the presence of small element (tiles, slates, etc.) with the main function of water tightness. Of course, it is the part of the building envelope where the PV transfer has had the most success for many reasons such as the typical optimal orientation of pitches, the easiness of installing PV panels. Usually PV modules are integrated as external coating (tiles, shingles, standard modules, etc.) as similar non active building element.
- Skylight: it is a light-transmitting building element that cover all or a part of the roof. They are typically (semi)transparent. It has the thermal, acoustic, waterproof function.
- Canopy: it is an overhead building element with open sides. It has the function of weather protection. Often this solution is composed by a laminated glazing cladding since the thermal protection is not a requirement.
- Prefab/Multifunctional roof: it is a unique and preassembled multifunctional element installed on the roof, composed by PV cladding, protective layers and substructure. Polyvalent components are able to satisfy more than a single technological requirement in a unitized way.
- Walkable floor: PV paver installed on the roof of buildings, while preserving their habitability.
- Accessory roof: transparent or opaque shading devices for roofs mainly on a glazed support aimed to select the solar radiation.

The **building typology** is firstly subdivided on the base of architectural intervention accomplished on the building: new construction and retrofit. Secondly, 9 building typologies are defined:

- Commercial: shopping mall, trade show, shop, etc.
- Residential single-family house (SFH): detached, semi-detached house
- Residential multi-family house (MFH): apartment building, townhouse, hotel, etc.
- Industrial: firm, workshop, station, etc.
- Administrative: office, library, museum, etc.
- Educational: school, research centre, university, etc.
- Sportive: gym, covered tennis field, fitness centre, changing room, etc.
- Medical: hospital, clinic, senior centre, etc.
- Carport

The partners provided, as the reference database, 1’061 **case studies** subdivided according to the technological systems and building typologies. The following stakeholders, divided in three groups (manufacturers, architects and construction companies) provided the BIPV case studies for the analysis:

- 5 manufacturers: Onyx Solar, Piz Cladding System, Ernst Schweizer AG, TULiPPS Solar Systems, Flisom
- 1 architect: Viridén+Partner AG
- 1 construction company: COMSA Corporation

The BIPV buildings have been classified according to the technological system and building typology abovementioned. Beyond the analysis of the partners’ building stock, the database www.bipv.ch has been taken into account in order to check the completeness of the BIPV typologies at European level.

As second step of the BIPV building stock classification, 55 **representative BIPV case studies** of the partners’ building stock have been selected, in order to have groups of representative buildings which include a complete scenario of the technological systems. Below, the parameters used to classify the case studies related to the building skin cladding type are shown.

- PV technology: photovoltaic cell technology adopted (mono c-Si, poly c-Si, a-Si, etc.).
- Material used: material of the cladding (glass-glass, glass backsheet, etc.)
- Transparency of the module [%]: it is given by the formula below.

$$Transparency\ of\ the\ module = 1 - \frac{(\text{Total PV cells surface})}{(\text{Total module surface})}$$

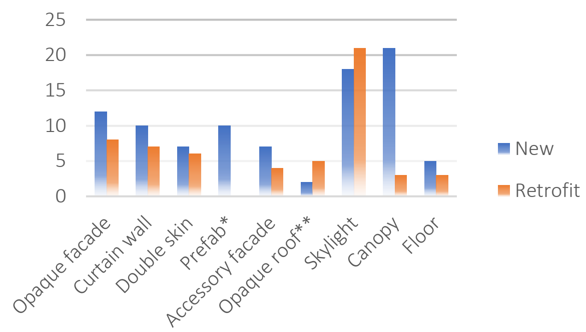
- PV surface [m^2]: surface of the envelope covered by photovoltaic.
- PV nominal power [kWp]: peak power of the photovoltaic system installed.
- Building skin covered by PV [%]: ratio between the active envelope (m^2) and the total envelope (m^2) of the building.

Each of these case studies is then analysed on the base of the parameters related to the **building skin cladding type**. Each technological system previously identified is represented by at least one group identified by the building skin cladding type. Furthermore, it has been also considered the thermal property (laminated or insulated glass) of the cladding.

4.2 Stakeholders portfolio analysis

The collection of the case studies allowed to determine a significant reference database within the European landscape, classifying BIPV buildings on the base of their technological system and building typology. The global result of such a reference building stock is reported in the table below.

STAKEHOLDER: Architect, manufacturers, construction company



MAIN ACTIVITY:

-

BIPV TECHNOLOGICAL SYSTEM:

Opaque cold roof

Skylight

Canopies

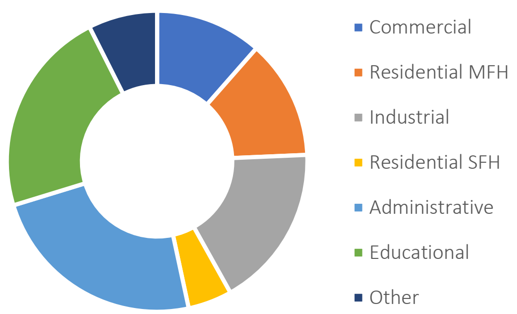
Opaque rainscreen façade

Insulated glazing

*Building not realized
**The additional 913 roof solutions are not represented, as building typologies are unknown

BUILDING TYPOLOGY:

Administrative, educational and industrial buildings

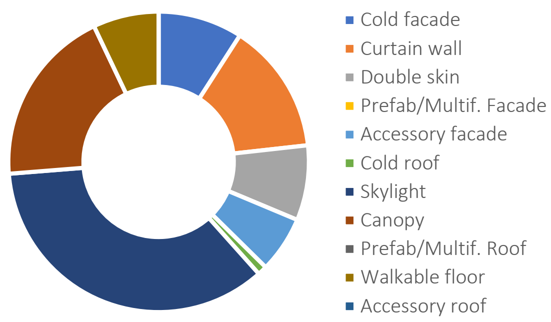


The BIPV systems analysed add up to 1’061, of which 72 are façades and 989 are roofs. 913 roofs, for which the building typology is unknown, are realized by the manufacturer Schweizer by providing the final user with the kit and material to realize the substructure system. These solutions are intentionally included into the analysis in order to underline their importance within the BIPV landscape. Beyond the opaque cold roofs, skylights and canopies are the most important roof BIPV technological systems considered. Opaque rainscreen façade and curtain wall are the most exploited BIPV façade solutions. It is interesting to notice that the total amount of buildings that adopted an insulated glazing solution are 56, a considerable number within this analysis.

Administrative (about 23% of the 148-buildings analysed) and educational (22%) buildings are the typologies most exploited by the partners participating in this analysis. These building typologies are often transparent solutions. Industrial buildings are about the 17%. Opaque roofs and façades are solutions that are suitable often for MFH and SFH residential building typologies.

The new constructions are 92, the retrofitted 56 which is the 38%. Accessory solutions are frequently new realizations. Single analysis for each stakeholder are reported on the tables below.

STAKEHOLDER: Onyx Solar, manufacturer



MAIN ACTIVITY:

Photovoltaic glass producer

BIPV TECHNOLOGICAL SYSTEM:

Transparent glazed solutions

Insulated and laminated glazing

Canopies

Curtain wall

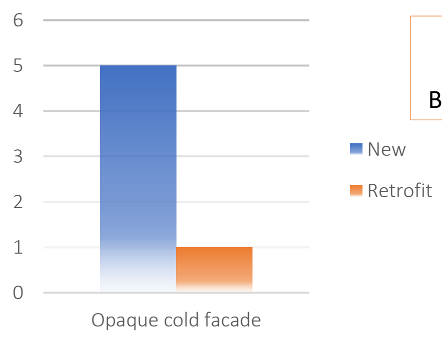
BUILDING TYPOLOGY:

Administrative, educational, industrial and commercial buildings

According with the matrix provided by Onyx Solar the total amount of buildings realized is 106, in Europe and worldwide. The effort of Onyx Solar is focused mainly on transparent and semi-transparent solutions both for roofs and façades (curtain wall, double skin and roof/skylights solutions), with both insulated and laminated glazings. Accessories for façade (louvres and fins) are few. Furthermore, a BIPV floor solution is produced to be installed on building flat roofs, typically considered as a part of the rooftop solution.

The building typologies most exploited are administrative (about 24% of the building analysed), educational (22%) and industrial (19%). Unlike other stakeholder involved within this analysis, the residential building segment is not fully exploited. The residential solutions developed for multifamily houses, including 3 canopies, amount to only 7%. Three BIPV installations are made on boats. It underlines the aptitude of the manufacturer to go through new solutions and technologies. The ratio between new and retrofitted buildings is 3:2.

STAKEHOLDER: Ernst Schweizer AG, manufacturer



+913

BIPV cold roofs

MAIN ACTIVITY:

Mounting system producer

BIPV TECHNOLOGICAL SYSTEM:

Cold roof

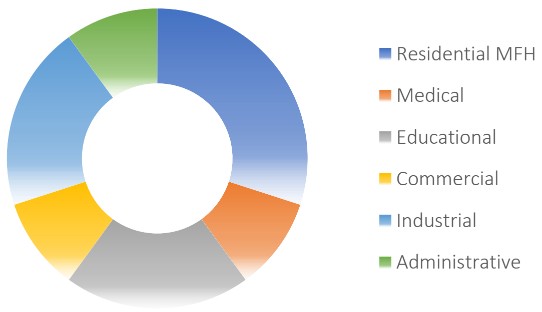
Pitched roof

BUILDING TYPOLOGY:

Residential MFH and SFH

The main activity of Schweizer within the BIPV field consists of the realization of active cold roofs. The product is delivered to distributors and installers mainly in Switzerland. The manufacturer patented a BIPV roof solution called Solrif. During the last years the average number of BIPV roof solutions delivered is about 90 pieces per year. The building typology are various but typically the ventilated roof is used in such an installation. BIPV façades are opaque rainscreen façades (as used in 5 buildings) and they are often residential MFH. New solutions are more than the retrofits.

STAKEHOLDER: Piz Cladding System, manufacturer



MAIN ACTIVITY:

Prefab cladding system producer

BIPV TECHNOLOGICAL SYSTEM:

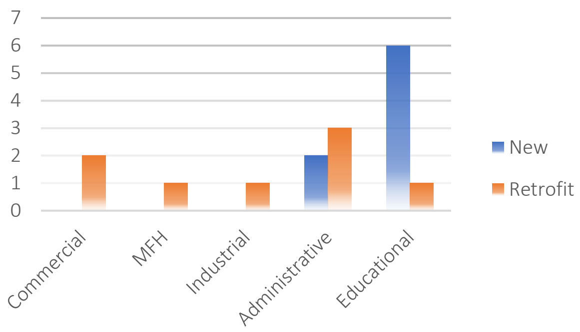
Prefab/Multifunctional systems

BUILDING TYPOLOGY:

Different building typologies

Piz Cladding produces a cement-based insulated cladding system for opaque façade. It's an easy mounting and lightweight pre-assembled system. Piz experimented PV in a prototype of a prefab BIPV solution developed, called "e-PIZ" by integrating silicon solar cells in the pre-assembled element. Since real buildings were not yet realized, the company provided an analysis on case studies realized during the last years with a theoretical potential for e-PIZ BIPV system. As output of the analysis building different typologies emerged.

STAKEHOLDER: Comsa Corporacion, construction company



MAIN ACTIVITY:

PV and BIPV installation

BIPV TECHNOLOGICAL SYSTEM:

Transparent glazed solution

Opaque solution

Accessories for façade

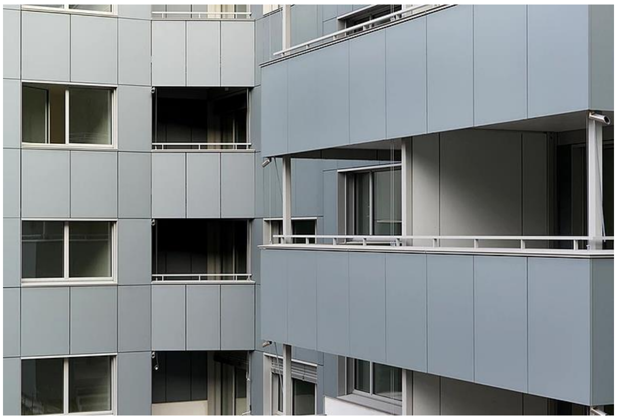
BUILDING TYPOLOGY:

Educational and administrative

According with the matrix provided by Comsa Corporation (active with TFM), 16 BIPV buildings were realized. Many educational buildings that include also 3 opaque canopies were realized with glass/glass modules. Almost half of the solutions are semi-transparent glazed façades. 4 technological systems are semi-transparent double skins.

Comsa Corporation realized different shading accessories for façade systems (5), mainly opaque elements for educative and administrative constructions. The first intervention dates back to one of the first BIPV reference in 1998 (the new library of Matarò, near Barcelona in Spain), realized with a double skin integrating solar semi-transparent glasses with a nominal power of 52 kWp.

STAKEHOLDER: Viridén + Partner AG, architect



Courtesy: Viriden+Partners

MAIN ACTIVITY:

Architecture and planning

BIPV TECHNOLOGICAL SYSTEM:

Opaque ventilated façade

BUILDING TYPOLOGY:

Residential MFH and administrative

The main building typology evaluated by Viridén+Partner is the residential MFH. The number of building realized by the architect's office is limited but each building had an important media output and faces with the resolution of specific issues (acceptance and costs particularly). Viridén is working together with research centres and experts of the field to optimize the BIPV solutions adopted. The architect realized BIPV pilot buildings in Switzerland, with an important focus on retrofit (Solarchitecture).

STAKEHOLDER: Tulipps Solar Systems, manufacturer

Courtesy: Tulipps

MAIN ACTIVITY:

Frameless BIPV system producer

BIPV TECHNOLOGICAL SYSTEM:

Opaque cold roof

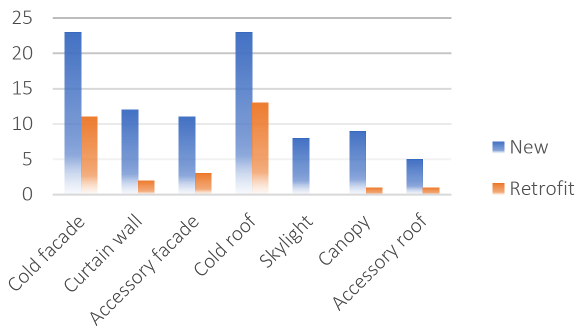
BUILDING TYPOLOGY:

Residential

The installation target of TULiPPS are opaque cold roofs. Five solutions out of six are new interventions: industrial (1), residential SFH (3) and demo offices (2). Within the BIPVBOOST project TULiPPS and other partners will upgrade their previous COSMOS module and the mounting design for roofs and façades

Beyond the analysis of the partners' case-studies, the examples database of the SUPSI platform, www.bipv.ch, was also analyzed.

Other case-studies (database www.bipv.ch)



MAIN ACTIVITY:

-

BIPV TECHNOLOGICAL SYSTEM:

Opaque solutions

BUILDING TYPOLOGY:

Residential (MFH and SFH) building typology

SUPSI collected 122 case studies of BIPV solutions into the database www.bipv.ch. From the analysis emerged that the residential building typology, both MFH and SFH, is the most exploited with 42 buildings (34%). Administrative and industrial buildings are respectively about 22% and 11%. The transparent solutions are used for 26% BIPV buildings, considering as transparent solutions curtain walls, skylights and canopies. No double skin façades have been found. A considerable number of accessory BIPV solutions (about 16%) are installed, both in façade and roof. New BIPV buildings are more if compared with the retrofitted one. The analysis was conducted at global level. Other details on the European Market can be found in the Report SUPSI-SEAC 2017. The residential solution is the most exploited according to the results of the database of SUPSI, followed by administrative and industrial. Educational, administrative and industrial are the main building typologies of the stakeholder analysis, residential solutions are not mentioned because for 913 opaque roof solutions the building typology is unknown and probably it would be residential.

4.3 Cladding typology

In this section five groups based on the building skin cladding type are defined by taking into account the material used and the thermal insulation property to describe if the system represents or not the main skin between indoor and outdoor (at this stage the specific glass layering has not been considered for the group definition):

- Group 1 - Glazed transparent solution with thermal properties. This solution is typical for skylights and curtain walls.
- Group 2 - Glazed transparent solution without specific thermal protection performances. This solution is typical for canopies, external pane of double skins facades and walkable floors.
- Group 3 - Opaque glazed solution without thermal protection. This solution is typical for cold roofs and façades and accessories.
- Group 4 - Opaque no glazed solution without thermal protection. This solution is typical for cold roofs and façades and accessories.
- Group 5 - Opaque prefab/multifunctional solution. It may have or not the thermal properties. This solution is typical for multifunctional façades and roofs.

Below each group is analysed with the related case studies.

Group 1: glazed transparent solutions with thermal properties			
TECHNOLOGICAL SYSTEM:	**CLADDING FEATURES:**	PV TECHNOLOGY	N° OF ANALYSED CASE STUDY: 11
Skylight	**Glass-glass**	a-Si	
Curtain wall	**Transparent**	c-Si	
	Thermal protection		

Main highlights: Retrofitted solutions, lower efficiency of the module due to the transparency rate, different technology used (amorphous silicon, c-Si), in order to maximize the energy production, the PV system is often installed towards south.

Figure 4 Balenciaga, Onyx, Curtain wall, 2018, USA

Figure 5 BellWorks, Onyx, Skylight, USA

Within this group, case studies of Onyx and Comsa are included. Most of the case studies are semi-transparent glazed solutions that are not usually used for the residential building typology but rather for administrative and other building typologies. However, there is not a building typology that is predominant within the sample analysed. The two technological systems exploited within this group are **skylights** and **curtain walls**, a roof and a façade application. Within this analysis almost the total amount of solutions is retrofitted. The **transparency rate** is consistent with a low energy density (W/m^2) of the module compared with the same opaque solution. Indeed, within this group, the nominal power per square meter of building skin is lower than opaque solution that results in low active (PV) surface every square meter. The cell coverage ratio (active area divided by the total cladding surface), averagely calculated for crystalline claddings, is about 35%. The light transmission combined with cells, averagely calculated for a-Si solutions, is about 20%. Two laminated glass and a I.G.U chamber are usually required to satisfy the thermal properties.

The percentage of the building skin covered by photovoltaic is typically low, in average less than 25%, also in case of roofs. The average height of the buildings where a skylight is installed was lower than 20 m

Below an informative specification that permits to understand an example of the configuration of the insulated glazing unit used by Onyx. For c-Si cladding solutions, double laminated PV glass is used as external pane of an insulated glazing as shown in the Figure 6 and Figure 7.

PV GLASS CONFIGURATION

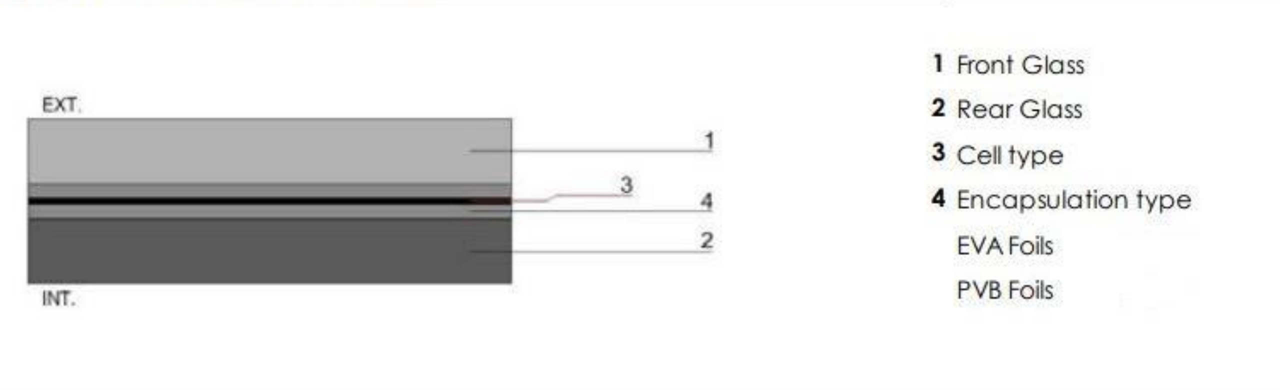


Figure 6 Double laminated PV glass configuration for crystalline technology as external pane of an insulated glazing (source: Onyx Solar)

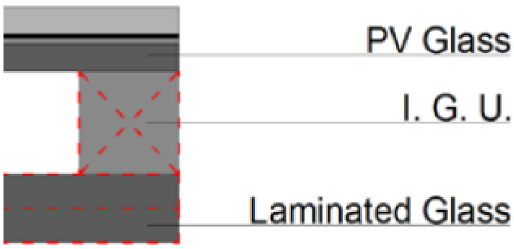


Figure 7 Double glazing unit (source: Onyx Solar)

Group 2: glazed transparent solution without thermal protection			
TECHNOLOGICAL SYSTEM: Double skin Canopy Walkable floor	**CLADDING FEATURES:** **Glass-glass** **Transparent** **No thermal protection**	PV TECHNOLOGY a-Si c-Si	N° OF ANALYSED CASE STUDY: 11

<u>Main highlights</u>: New construction, low efficiency of the module due to the transparency rate or the a-Si, canopies represent a solution mainly suitable for the tertiary sector (both public and private).

Figure 8 FEMSA, Onyx, Double skin, 2013, Mexico

Figure 9 Forum Barcelona, Comsa, Canopy, 2008 Spain

The analysed case studies, that adopted a transparent laminated glazing solution, are mainly realized by Onyx and Comsa. The thermal protection is not guaranteed by the laminated glass, for this reason this solution is suitable for external applications such as canopies or façade solutions like double skin which don't require the thermal protection. The canopies are not usually installed for small properties, or they cover common spaces and areas of public buildings and areas. The building typologies that exploit canopies are industrial, educational and administrative. The majority of solutions are new constructions.

The low efficiency of the module is a consequence of the photovoltaic technology adopted and the transparency rate of the cladding solution. For canopies the surface covered by photovoltaic is normally the total surface. For double skin solutions, the photovoltaic surface represents a minor part of the total envelope.

Considering the data provided by Onyx, the photovoltaic technologies exploited are a-Si and c-Si. Both the transparency of the module, calculated for crystalline claddings, and the light transmission, calculated for a-Si solutions, are about 20%. Beyond the two configurations of laminated glass used in the previous group, a new type of laminated PV glass is used for a-Si, as it is shown in Figure 10.

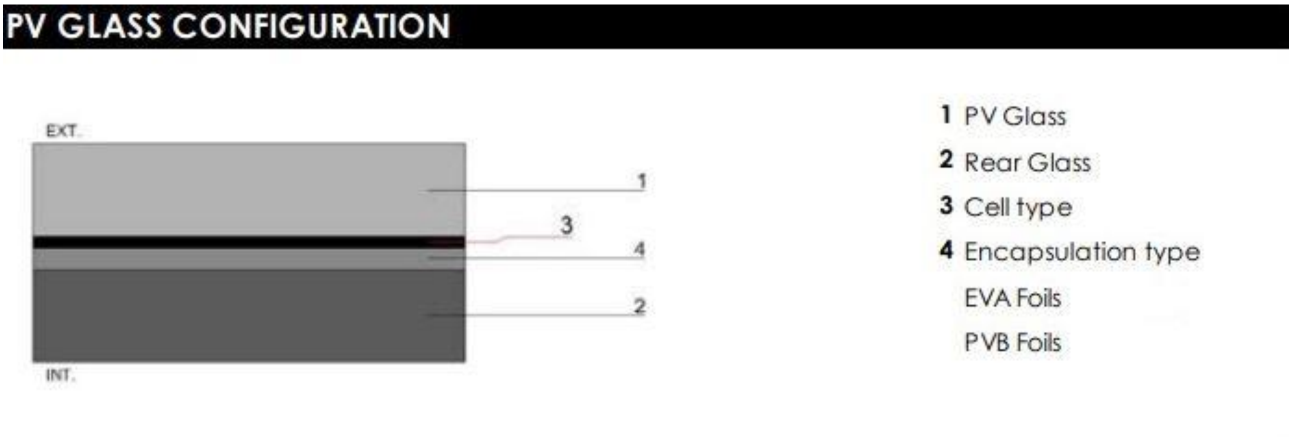


Figure 10 laminated PV glass configuration for amorphous technology (source: Onyx Solar)

Group 3: glazed opaque solution without thermal protection			
TECHNOLOGICAL SYSTEM: Rainscreen façade Cold roof Accessory façade	**CLADDING FEATURES:** **Glass-glass** **Opaque**	PV TECHNOLOGY c-Si	N° OF ANALYSED CASE STUDY: 16

Main highlights: Residential buildings (façade/roof), high efficiency modules, full roof coverage to maximize the energy production.

Figure 11 MFH, Schweizer, Rainscreen façade, 2016, CH

Figure 12 Residential, Tulipps, Cold roof

This solution represents the most exploited by the partners. The module here considered is fully opaque and the efficiency of the module is high in comparison with conventional transparent solutions. Several solutions adopted a photovoltaic crystalline technology. However, in some cases, CIS technology and a-Si are used. The BIPV technological systems are rainscreen façades and cold roofs. However, within this analysis, also accessory surfaces and an opaque curtain wall are included.

The difference between new and retrofitted solutions does not characterize the group.

The building skin covered by photovoltaic shows a high value for roof solutions since in average they are fully covered. Some residential buildings are fully covered by an active cladding.

The residential sector, both MFH and SFH, is the most exploited building typology.

In most of cases, the cladding solutions are laminated glass-glass or tempered glass-glass.

Group 4: opaque no glazed solution without thermal protection			
TECHNOLOGICAL SYSTEM: Rainscreen façade Cold roof Accessory façade	**CLADDING FEATURES:** **No glazed backsheet (e.g. membrane)** **Opaque**	PV TECHNOLOGY c-Si CIGS HIT	N° OF ANALYSED CASE STUDY: 7

Main highlights: Residential buildings, standard modules, high potential of development of lightweight systems

Figure 13 MFH, Viridén, Rainscreen façade, 2012, CH

Figure 14 Carport, Flisom, roof, CH

The number of the case studies here analyzed is limited. Most of the cases are realized in Switzerland by Schweizer. They consist in BIPV solutions realized with standard modules on cold roofs. Both new and retrofitted interventions are considered. The majority of case studies analyzed are residential buildings, industrial, commercial and carports. For roof solutions analyzed, the building envelope surface covered by photovoltaic is considerable. The lightweight systems have a high potential for retrofit.

The photovoltaic technology of the analyzed case studies is both crystalline (c-Si), thin film (CIGS) and Heterojunction cell technology (HIT).

Group 5: opaque prefab/multifunctional solution			
TECHNOLOGICAL SYSTEM: Multifunctional	**CLADDING FEATURES:** **Pre-assembled**	PV TECHNOLOGY -	N° OF ANALYSED CASE STUDY: 10

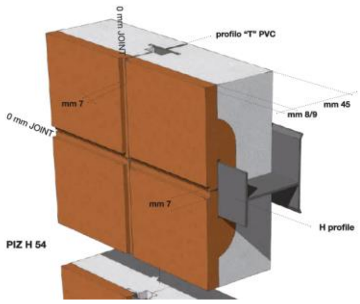


Figure 15 Prefab element, Piz, Prefab façade

Figure 16 College, Piz, Prefab façade, 2009 France

Even though BIPV solutions have not yet been implemented, the prefab façade cladding has been used and demonstrated in several case studies by PIZ. The solution put together the insulation with the active cladding in a unitized element.

HIGHLIGHTS

BIPV building stock classification: building typology, technological system and building skin cladding. Stakeholder case studies in the BIPVBOOST consortium

The building typology, the technological system and the building skin cladding are the main aspects considered to analyze the BIPV building stock provided by the BIPVBOOST partners.

BIPV case studies provided by partners represents a significant portfolio of the technical alternatives available, building types and cladding systems.

a) The building skin cladding is mainly characterized by the transparence rate and the kind of material. According to this definition 5 groups of building skin cladding types are identified:

Group 1 - Glazed transparent solutions with thermal properties.

Group 2 - Glazed transparent solution without thermal protection.

Group 3 - Opaque glazed solution without thermal protection.

Group 4 - Opaque no glazed solution without thermal protection.

Group 5 - Opaque prefab/multifunctional solution.

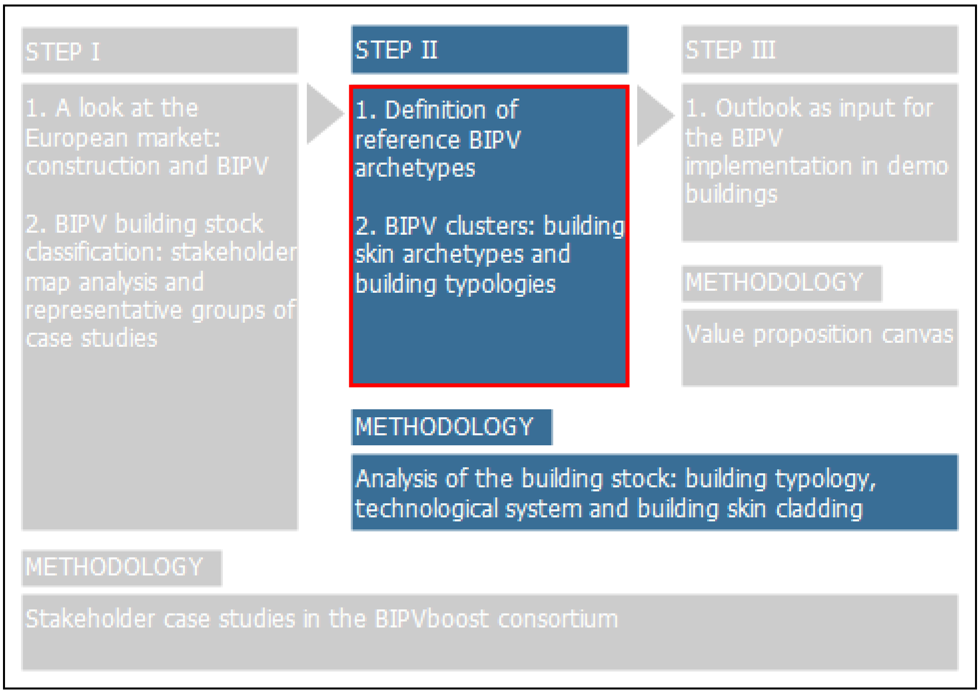
b) Both crystalline and thin film based photovoltaic solutions are exploited. a-Si is mainly used to reach a homogeneous effect on semitransparent solutions; while c-Si is mostly exploited for opaque applications with higher power need.

c) The priority markets for BIPVBOOST partners are residential buildings (MFH and SFH) and the tertiary segment (administrative, educative and commercial) or industrial buildings.

d) The opaque solutions, both roof and façade, are mostly suitable for residential building typologies and are the most exploited solution by architects and manufacturer of substructures. Transparent solutions such as curtain wall, double skin, canopies and skylight are often related to the tertiary segment; the solution could be both laminated or insulated glazing unit.

e) BIPV prefabricated solutions are completely developed until now, thus representing a promising segment for the retrofit market.

STEP II



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5 ARCHETYPAL BUILDING ANALYSIS

The archetypes can be considered the landmarks for any kind of BIPV process. They are, in principle, the original shape of a BIPV system based on their basic technical and building function.

The **archetypes**, in the framework of this report, are identified thanks to the previous building stock classification analysis and they are defined on the basis of the base five groups previously identified (namely as combination between the building skin cladding type and the technological system).

The archetypes, combined with different building typologies, define another entity named as **cluster** which will permit to apply a following assessment (through the method of the value proposition canvas) by taking into account both the building skin and whole building level in the analysis. Such a definition can also be a reference on which more detailed analysis, planned within the next work packages, could be also undertaken.

5.1 Methodology for the definition of archetypes

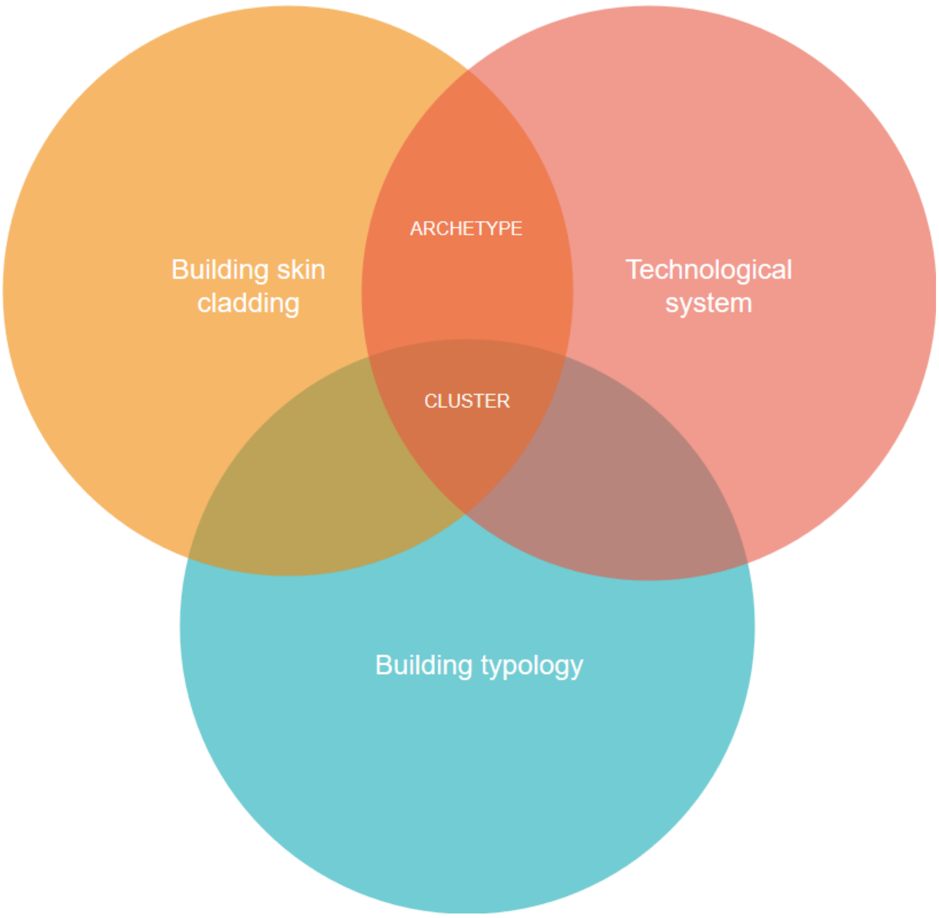


Figure 17 The combination between building skin cladding and technological system permits to define the archetype. The combination between the archetype and the building typology permits to define the clusters

Considering the previous analysis and the outcomes so far, the definition of archetypes can be based on the previous defined groups, specifying as added parameter the features regarding the **building skin cladding technology**: transparency/opacity and construction materials used. In this way an archetype reflects the construction identity of the building skin by considering both the material level and the technology of the building envelope.

The *transparency rate* permits to distinguish semi-transparent and opaque solutions. Semi-transparent solutions could be: curtain walls, double skin façades, warm façades, skylights or canopies. Examples of opaque solutions are: rainscreen and prefab façades/roofs, railings, louvres, curtain wall, flat or pitched roof solutions.

The *material* of a BIPV cladding, in this analysis, represents the main material/s in which the solar cells are integrated or encapsulated in order to form the end BIPV product. Two families are identified: *glazed* and *non-glazed materials*. A glazed cladding element is typically a glass-glass solution, where the glass has the function of both front-sheet and back-sheet of the cladding. A non-glazed cladding is composed by a non-glazed back-sheet (e.g. a support polymer-based, metallic, cement-based, etc.) and a front-sheet that could be indifferently glazed or non-glazed.

A further specification can be done. The cladding type can be distinguished from *insulated* from *laminated* glazing solutions. An insulated glazing solution indeed is used normally when the thermal protection between two spaces is required, e.g. insulated glass unit, curtain walls or skylights. The thermal protection is given by the air gap between two glass panes. The panes could be either by laminated glazing if they need to satisfy some specific requirements, such as mechanical safety. A laminated glazing solution without thermal protection are foreseen only to satisfy the safety requirement, e.g. canopies and the external pane of double skin façades.

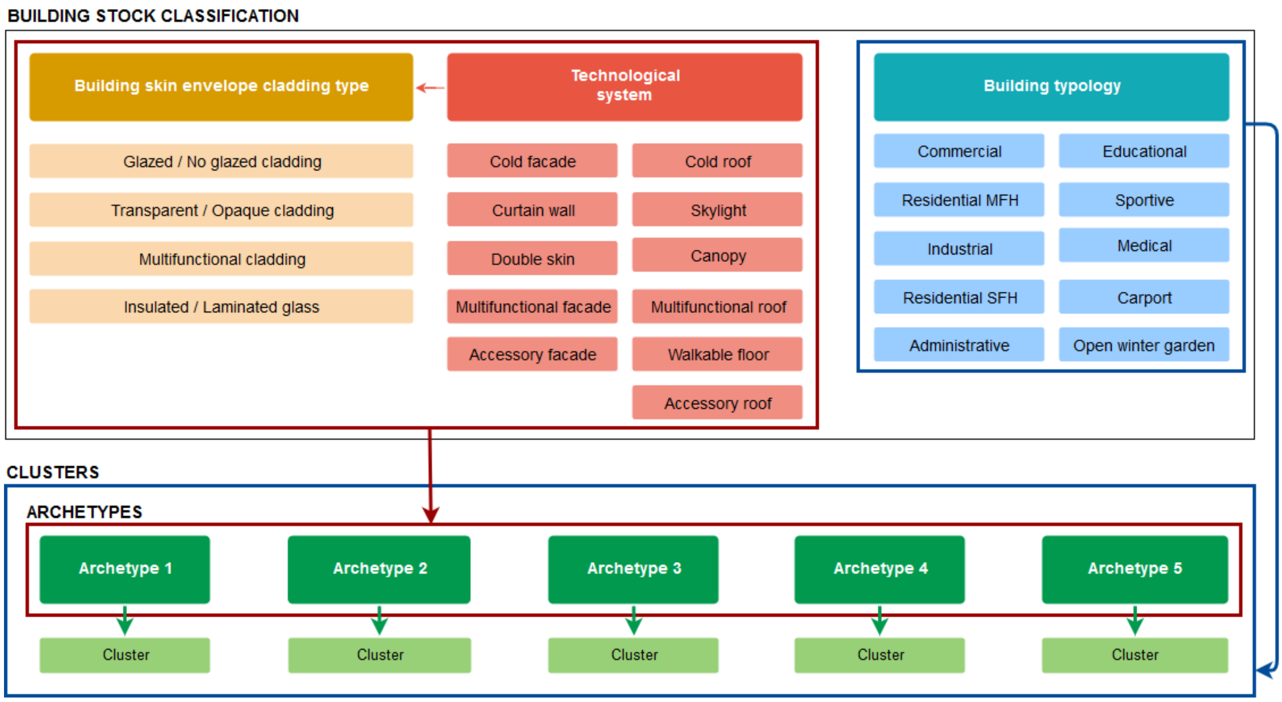


Figure 18 Archetypes and clusters: the building skin cladding type and the technological system define the archetypes. The archetypes combined with the building typologies define clusters.

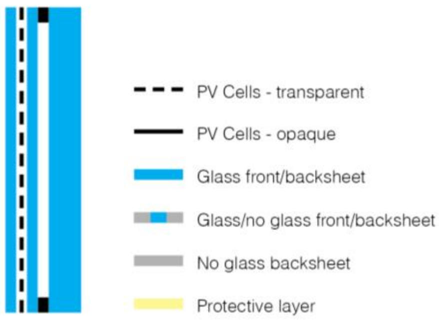
5.2 Archetypes

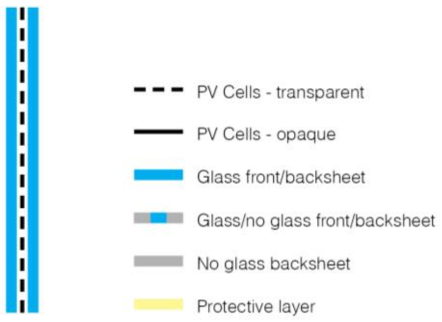
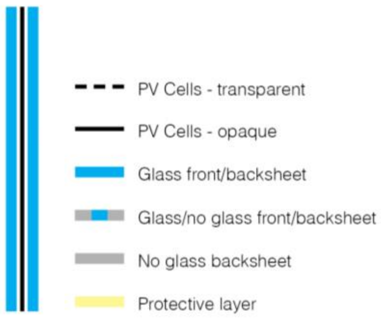
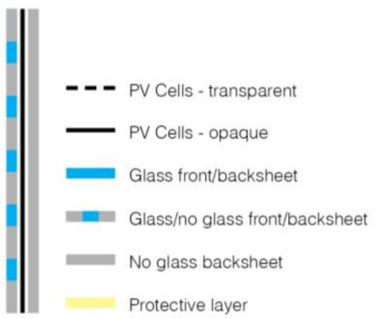
Five archetypes have been defined considering the main features of the building skin cladding type, the technological system and the groups identified within the building stock classification:

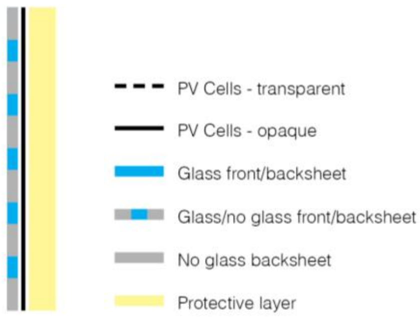
- Semi-Transparent insulated glazing
- Semi-Transparent laminated glazing
- Opaque glazed element
- Opaque no glazed element
- Opaque prefab element

In the Table 5.1 the archetypes combined with the reference technological systems are shown together with a brief description.

Table 5.1 Archetypes description

ARCHETYPE	TECH. SYSTEM	DESCRIPTION
1. Semi-Transparent insulated glazing  	Curtain wall Skylight * **CLADDING** Glazed Transparent Insulated	This archetype represents a traditional double (or triple) glaze unit with thermal insulating properties. The curtain wall/skylight is realized with at least two panes of glass with an air gap between. The transparency is a requirement and it is guaranteed thanks to the special disposition of the photovoltaic cells. This solution could be suitable for both façade and roof. The transparency of the material permits to place the system alongside spaces that need also daylighting and solar gains. Reference manufacturer BIPVBOOST: ONYX Solar Demo site: -
2. Semi-Transparent laminated glazing	Double skin Canopy Railing Louvre * **CLADDING**	This archetype is represented by a traditional laminated glazing. The thermal property is not a requirement. The laminated glazing is used for double skin façades, canopies or special façade/roof accessories.

	Glazed Transparent Laminated	Reference manufacturer BIPVBOOST: ONYX Solar Demo site: Balustrades based on glass-glass bifacial modules and walkable floors based on back-contact solar cells in ISFOC office building (Puertollano, Spain)
3. Opaque glazed element 	Rainscreen façade Spandrel Cold roof Railing Louvre * **CLADDING** Glazed Opaque Laminated	The archetype is composed by a laminated photovoltaic module glass-glass, opaque to the light. The photovoltaic cells cover the full glazed surface, there is no transparency. The thermal property is not a requirement. This is a traditional solution used for ventilated façades or roofs. It could be also used for accessory BIPV solutions. Reference manufacturer BIPVBOOST: ONYX Solar TULiPPS Demo site: Building-integration of glass façade with c-Si technology and different configurations (Aretxabaleta, Spain)
4. Opaque no glazed element 	Rainscreen façade Cold roof Railing Louvre * **CLADDING** No glazed Opaque	This archetypal solution is an opaque component. No thermal requirements are necessary. The back-sheet of the cladding is made by a non-glazed material (e.g. metal, polymer). The front-sheet could be made of glass or any other material (e.g. polymer). The solution is suitable both for façades, roofs and accessories. Lightweight and flexibility are features that make this archetype different from the "opaque glazed element" solution. Reference manufacturer BIPVBOOST: Schweizer Flisom Demo site:

		Building integration of metal based roofing shingles in OPTIMAL residential single-dwelling building (Saint-Dennis, Belgium)
5. Opaque prefab element 	Prefab * **CLADDING** Multifunctional Opaque	This archetype represents a prefabricated and pre-assembled composite solution where the cladding is one single element composed by a front-sheet, photovoltaic layer and a substrate. The front-sheet could be both glazed or not glazed. The system transparency is not a requirement. The substrate could be composed by different materials such as thermal/acoustic or fire protective layer. Considering the different layers that compose the element, the solution is typically opaque. Reference manufacturer BIPVBOOST: Piz ONYX Solar Flisom Demo site: Prefab/Multifunctional BIPV opaque façade cladding systems in PIZ residential multi-family dwelling with a twin building (Morbegno, Italy)

* Other solutions could be suitable if satisfy the requirements of the archetype.

5.3 Clusters

On the base of the experience and the realized buildings, each stakeholder identified one or more clusters as the combination between the archetype and the building typology. In this chapter the clusters will be used in order to include the building level within the analysis. In such a multi-level approach, different drivers of the BIPV development can be identified in an inclusive perspective of all the main building dimensions (typological and technological). The clusters here mentioned are mainly addressed to describe the project stakeholders' scenario, but also other clusters could be in principle defined.

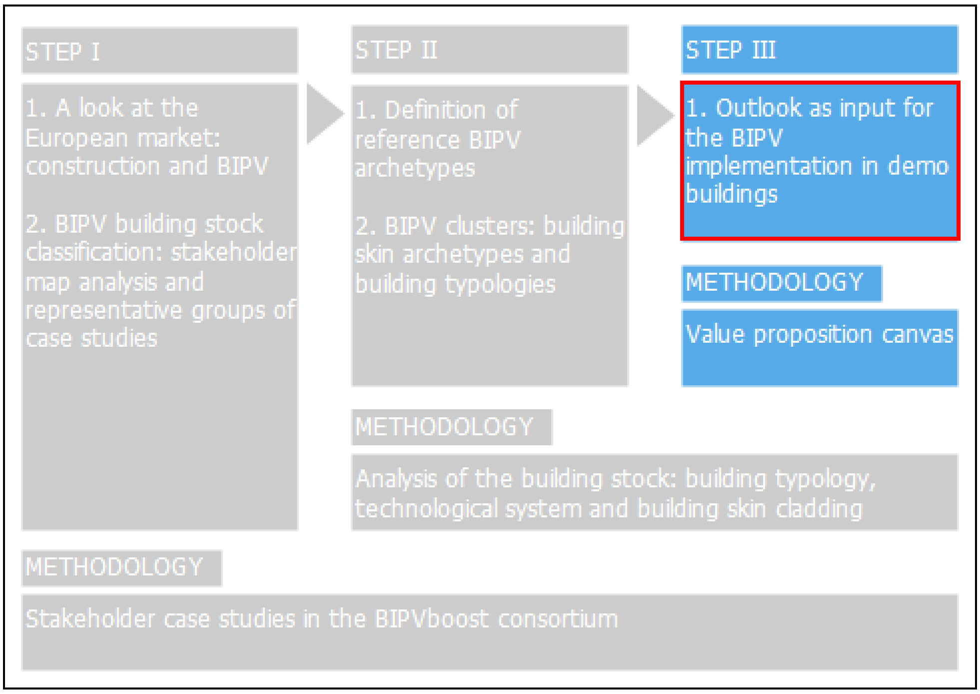
The 10 clusters, emerged by analyzing the reference building stock of the case-studies, are:

- C1 Opaque glazed element in SFH and MFH as pitched roof; metal construction manufacturer.
- C2 Opaque glazed element in MFH as façade; metal construction manufacturer.
- C3 Opaque glazed element in commercial as pitched roof; metal construction manufacturer.
- C4 Opaque no glazed element in industrial as façade; metal construction manufacturer.

- C5a Transparent insulated glazing in commercial as façade and roof; manufacturer of transparent photovoltaic.
- C5b Opaque glazed element in administrative and educational as façade; manufacturer of transparent photovoltaic.
- C6 Transparent laminated glazing in educational as accessory; manufacturer of transparent photovoltaic.
- C7a Transparent insulated glazing in administrative and educational as façade; construction company.
- C7b Opaque no glazed element in administrative and educational as accessory; construction company.
- C8 Opaque glazed element in MFH as façade; architect.
- C9 Opaque prefab element in educational, commercial and industrial as façade; cladding system manufacturer.
- C10 Opaque glazed element as façade and roof; solar systems manufacturer.

The value proposition canvas C5a and C5b / C7a and C7b do not show many differences. Within the following analysis they are analyzed together highlighting possible differences.

STEP III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6 STATE OF THE ART AND POTENTIALS FOR THE BIPV MARKET EXPLOITATION (3)

With the aim to determine the main factor of attractiveness for the BIPV market implementation and its evolving opportunities in the horizon 2020 to 2030, the integrated vision of all the main stakeholders involved in the project has been taken into account to determine the limits and the opportunities for the next years. In order to satisfy these requirements, we used and adapted an assessment methodology used on the business field: the **value proposition canvas**.

The aim of this method, adapted to the needs of this task, is to analyse the identified archetypes through **clusters**. A cluster is defined as the combination of an archetype with one or more building typologies. This allows to explore the main parameters that influence the BIPV process, considering gains, pain points and also trying to identify related solutions. This is the starting point to indicate a value proposition of aspects that can be provided as input for the following project work packages (product development and demo cases). The analysis was conducted thanks to the input of the project partners that represent the main stakeholders involved within the BIPV process: architects, manufacturers and construction companies.

6.1 Methodology: a business method to evaluate the market exploitability

The value proposition canvas is used by companies, start-ups and any kind of commercial activities to better understand the customers into a business process. It has been developed by Alexander Ostenwalder within the book "Value Proposition Design". The value proposition canvas is a simple way to understand customer needs, design products and services they want. The version of the value proposition canvas followed within this task is inspired by the canvas of Alexander Ostenwalder but it is different in contents and methodology in order to be better adapted to the BIPV process here analysed.

The **cluster** is the input data of the value proposition canvas. The cluster is identified by the archetypes and the building typologies. Each stakeholder (BIPV manufacturer, architect and construction company) has identified and described one or more clusters referred to its activities and experience. The value proposition canvas (Figure 19) exploits the strength of the visual thinking and techniques of the brainstorming to assess the situation in a structured path the profile of each cluster. The methodology of the value proposition canvas, adapted to the purpose to define the main challenges for the attractiveness of the BIPV market and its evolving opportunities in the upcoming years, is referred to experience and the thought of the stakeholders (manufacturers, architects and construction companies) of the BIPVBOOST consortium. It has been possible to cover the full BIPV process, from the design/production of the BIPV products (manufacturer), through the planning phase of BIPV buildings and the interaction with final users/tenants (architect), to the construction stage (construction company).
The "value proposition canvas" is subdivided in two parts. First in the "**cluster profile**", represented by the circle, permits to analyse in detail the cluster selected from the point of view of the stakeholders: segment description (1), aimed gains (2^1) and pain points (2^2).

- 1. Definition of the cluster: it is shown an overview of the cluster. In particular, the building typology, the archetype, the application of the BIPV system selected and the typology of the intervention (new/retrofit) are explained.
- 2^1. Aimed gains: results, benefits and anticipations that the stakeholder expects from the cluster selected.
- 2^2. Pain points: difficulties, obstacles and risks that the stakeholders could relate to the cluster for development, market implementation, cost reduction, etc.

Second is the "**value map**", represented by the square, which shows the value and benefits related to the specific cluster through the gain creators (3^1), the pain relievers (3^2) and the product & services (4). The aim of this section is to describe which are the inputs for a possible development of BIPV products and buildings. Gains creators and pain relievers main outputs will be used within the next paragraphs in order to define the potentials, barriers and routes of development of the BIPV market to ensure cost effectiveness, quality and a good market exploitation and replicability through real BIPV demo-cases.

- 3^1. Gain creators: they represent the solutions or the supposed solutions that aim to bring benefits to the cluster development.
- 3^2. Pain relievers: this section has the aim to find possible solutions to reduce difficulties that stakeholders have identified for the pains defined before
- 4. Product & Services: it includes the main inputs for the BIPV products and buildings development that will be faced within the next work packages of the BIPVBOOST project. Products and services will be matched to BIPV demo cases within the last analysis of this deliverable.

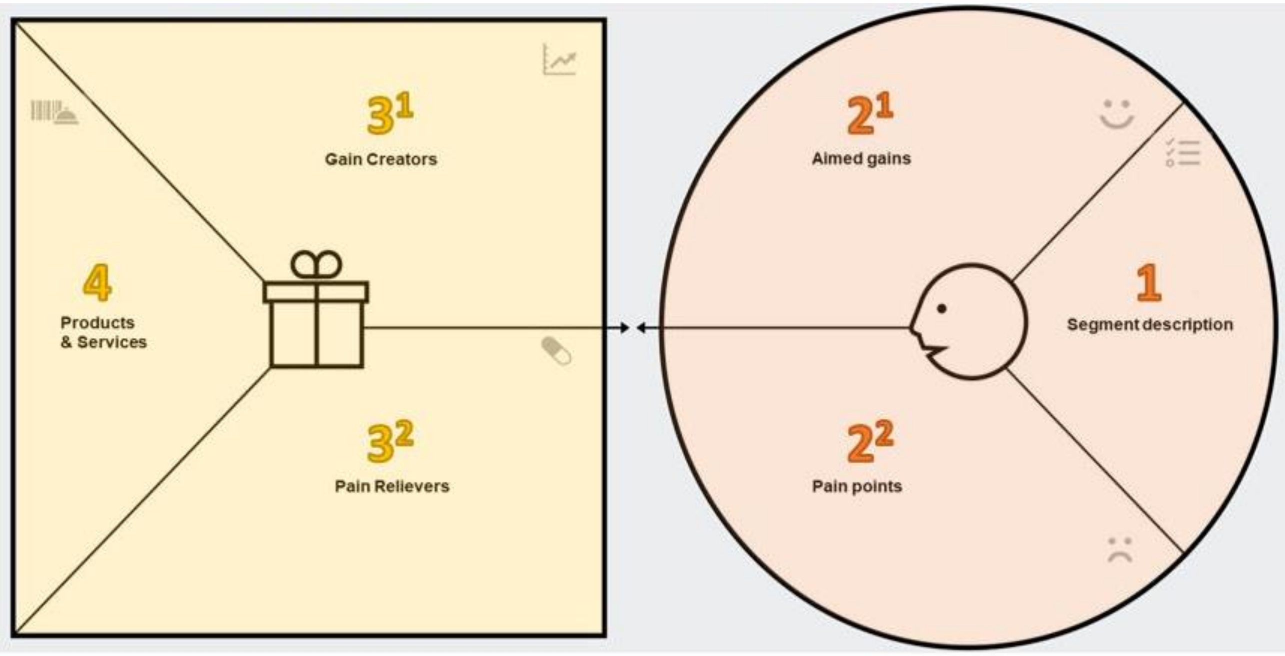


Figure 19 Schema of the value proposition canvas

The analysis should be conducted considering the canvas as a table where ideas are glued and the expected results can be referred to different situations of the whole process (business cases, normative framework, technology, social aspects, etc.).

The next section is subdivided in two different parts. The first and the second one show, respectively, the results of the value proposition canvas for the clusters and the specific parameters of assessment.

6.2 BIPV Clusters: from the current market towards potential developments

For each cluster the main gains and pains emerging from the "cluster profile" and "value map" of the value proposition canvas are listed. In the tables below, the clusters of each stakeholder are separated in order to distinguish the point of view of architects, manufacturers and construction companies. Some archetypes are considered together by stakeholders due to the same features found within the canvas. At the end of each section some requirements are highlighted to summarize the emerging aspects.

The clusters selected are not exhaustive since they are limited to the choice of the partner involved within the BIPVBOOST consortium.

ARCHETYPE: Opaque glazed element			**C1**
BUILDING TYPOLOGY: SFH/MFH			
NEW	RETROFIT	STAKEHOLDER: Construction manufacturer	
✓	✓	APPLICATION: Pitched roof	

Aimed gains:

1. BIPV solutions for residential roofs should be simple and cost effective for planning and installation.
2. This cluster requires an optimization of the system towards the self-consumption since the feed-in tariff remuneration is not available anymore.

Gain creators:

1. The installer has access to tutorials, handbooks and technical information for all the onsite installation details. The supplier provides a library of proven, documented products and solutions. Furthermore, it is required by manufacturer the use of specific tools along the value chain that permit to simplify the BIPV process, operate under non-standard conditions of elements, reduce the manual interaction and verify if a standard is complied. Beside the standard 60 cells PV modules, suppliers should offer a family of module sizes to accommodate the maximum active full roof installation. The tool should offer an automatic layout algorithm with "architectural intelligence" thus reducing the amount of manual interaction.
2. In-depth and hourly analysis of the energy demand of the building and simulations of the energy production considering the environment, location, shadows and other barriers that could compromise the BIPV system. Furthermore, the cost of a BIPV solution should not exceed a certain surcharge compared to a BAPV solution.

Pain points:

a) Nowadays not all BIPV products included within this cluster can fit the requests of the customers. Roof BIPV solutions could have technical problems of installation in particular conditions of slope (below the 22° the installation requires a sub roof to be protected against the torrential rains and condensation with sarking that can resist temperatures up to 80°C) or they need additional elements, while the available roof surfaces for PV cannot be fully covered because of the low flexibility in size of the modules.

b) The final aesthetic effect and the cost effectiveness of a BIPV roof solution influence the choice of the tenants of the SFH/MFH.

c) Within the planning phase of new buildings, it is very often unclear if the aim of the nZEB standard will be reached.

Pain relievers:

a) New and specific roofing systems should be implemented to facilitate the installation in different conditions and customizable special modules should be available to fully cover the irregular building roof surfaces. One of the aims of the manufacturer is to improve BIPV roof systems for rain tightness down to 15° roof pitch.
b) Nowadays there are not a lot of BIPV roof solutions that are similar to tiles in order to keep a more traditional effect.
c) The nZEB standard could be verified easily by electricity demand algorithm for the building and solar gain simulations with the same planning tool.

Highlights: enhancement of the technical solutions, tutorial and handbooks to facilitate the BIPV planning, increase self-consumption instead of the general PV electricity production.

ARCHETYPE: Opaque glazed element			**C2**
BUILDING TYPOLOGY: MFH			
NEW	RETROFIT	STAKEHOLDER: Construction manufacturer	
✓		APPLICATION: Façade	

1. Aimed gains: BIPV solutions for residential façades should be simple and cost effective for planning and installation.

Gain creators:

1. The installer has access to tutorials, handbooks and technical information for all the onsite installation details. The supplier provides a library of proven, documented products and solutions. Furthermore, it is required by manufacturer the use of specific tools along the value chain that permit to simplify the BIPV process, operate under non-standard conditions of elements, reduce the manual interaction and verify if a standard is complied. Furthermore, in order to simplify the process of installation could be helpful to create products preassembled that do not need further manufacturing in the construction site. Flexible back-rail mounting systems could allow to compensate the construction tolerance in the three dimensions and back-rails are delivered preassembled by the module factory.

Pain points:

a) For façade BIPV solution the workmanship has a higher cost of about 2 times more due to the lack of experience of all parties involved and the massive increase of complexity.
b) Planning errors and construction tolerances are adding up on site, exceeding the flexibility of today's façade mounting systems.
c) Within the planning phase of new buildings, it is very often unclear if the aim of the nZEB standard will be reached.

Pain relievers:

a) Special trainings and the dissemination of tutorial and handbooks could help to reduce the workmanship costs.
b) The use of specific tools to simplify the BIPV process is required and, considering the high impact of the façades, the integration of software regarding the virtual reality (VR) permits to better interact with investors and architects (rendering, modules color and texture information). By the manufacturer emerged the need to have exchangeable PV module library that is used in the

architectural CAD tool for layout/design, as well as for shading evaluation and yield calculation in the software BIMsolar.

c) The nZEB standard could be verified easily by electricity demand algorithm for the building and solar gain simulations with the same planning tool.

Highlights: preassembled product to avoid manufacturing process in situ, specific tools that simplify the process, Virtual Reality to interact investors and architects, exchangeable PV module libraries compatible with BIM tools, achievement of the nZEB standard.

ARCHETYPE: Opaque glazed element			C3
BUILDING TYPOLOGY: Commercial (agricultural)			
NEW	RETROFIT	STAKEHOLDER: Construction manufacturer	
	✓	APPLICATION: Pitched roof	

Aimed gains:

1. The aim of the tenants remains to maximize the electricity production since they are able to self-consume a large amount of energy during the day.

Gain creators:

1. An optimization of the tilt angle and the azimuth, beyond an accurate analysis of the shadows, is required.

Pain points:

a) Often the BIPV is installed on the roof especially when the site protection requirements do not allow standard BAPV solutions.

Pain relievers:

a) Cost effective BIPV roof products that match the appearance of (old) clay tile roofs.

Requirements by the manufacturer: maximization of the electricity production and normative compliance.

ARCHETYPE: Opaque no glazed element			C4
BUILDING TYPOLOGY: Industrial			
NEW	RETROFIT	STAKEHOLDER: Construction manufacturer	
	✓	APPLICATION: Façade	

Aimed gains: n.a.

Gain creators: n.a.

Pain points:

a) For industrial buildings, often realized with a lightweight structure, the integration of BIPV roof systems compatible that do not overcome the maximum load permitted is often challenging. Moreover, well established glass-glass PV façade modules are too heavy and require expensive substructures.

Pain relievers:

a) It should be considered the possibility to integrate a lighter and more flexible system to be adapted to the non-regular shapes of roof as well as for façade as a possible driver.

Highlights: to verify the compatibility with lightweight constructions, to exploit lightweight system and adaptable to non-regular shape of the roofs (e.g. curved, saw-tooth), industrial buildings have often large opaque area and the standard construction could be a prefab system easy and fast to install.

ARCHETYPE A: Transparent insulated glazing			**C5a**
BUILDING TYPOLOGY A: Commercial			
NEW	RETROFIT	STAKEHOLDER: Manufacturer of photovoltaic glasses	
	✓	APPLICATION: Façade and roof (skylight)	
ARCHETYPE B: Opaque glazed element			**C5b**
BUILDING TYPOLOGY B: Administrative/Educational			
NEW	RETROFIT	STAKEHOLDER: Manufacturer of photovoltaic glasses	
✓		APPLICATION: Façade	

Aimed gains:

1. The BIPV systems, often installed as trademark in buildings that occur for environmental actions, need a strong aesthetic and architectonic impact.
2. Reduce the payback time period of the BIPV system in order to make it accessible to a large number of potential users.
3. In order to reduce direct costs of the system a reduction of the raw materials (e.g. wood) is required.

Gain creators:

1. The participation and the involvement of competent architects that are familiar with BIPV processes and the application of BIPV products could be a solution to create best practices with a high environmental impact.
2. Since the feed-in tariff is not anymore a solution in most of the European countries, an extra benefit is generated increasing the self-consumption shifting, for example, the loads during the time when the PV system produces energy. The cost of a BIPV installation could be reduced beneficiating from the environmental policies and economic benefits specific for the place where it is located (national or regional incentives).
3. Possible solutions are: reduction of the wooden crater thickness at top and lateral openings, racking and cell/net crating development, double stacked crating level.

Pain points:

a) The operations and the planning of BIPV systems encounter difficulties due to several missing gaps within the normative framework.
b) The need of a high customizability of the modules in a BIPV process plays a key role that nowadays is limiting the diffusion of BIPV systems and their fully acceptance. Especially when the semitransparency and the high aesthetic value are required, regular BIPV solutions are a barrier for the user needs, design and integration.
c) The lack of experience/knowledge of architects and installers and the lack of coordination among the key partner make difficult to plan and install these kinds of solutions.

d) For the transparent insulated solutions (**C5a**) increasing performance for comfort are required within the building segment.
e) Low knowledge of the already commercial and certified BIPV solutions available on the market

Pain relievers:

a) Nowadays the regulations come from the field of photovoltaic or conventional material. Within the BIPV framework is missing a normative that standardize the entire process and specific BIPV requirements. According to the experience of the manufacturer, the wind protection for the transparent insulated glazing (**C5a**) and UV radiation as well as the humid environment for the opaque glazed element (**C5b**) is a requirement. PV glass and products tested and certified meet international standards, codes and safety guidelines (UL-1703, ULC/ORD-C1703, IEC 61215:2005 & IEC 61730:2004, MCS product certification, UNE-EN 14449:2006, among others).
b) The customer expects a complete customized module regarding dimensions, power, transparency, color, aesthetic, passive treatments, mechanical, thermal and acoustic properties fully integrated with building structure and retrofitting projects.
c) The manufacturer suggests to introduce BIPV consulting services at every project's step. A global network of distributors, electrical and mechanical installers to provide clients with concrete and up-to-date information on the different installation solutions.
d) The required comfort is reachable just increasing the performance and the properties of materials and enhancing the integration between envelope material, structures and photovoltaic.
e) A strong business plan and marketing strategy to communicate and disseminate the project carried out and the new products developed is required.

Highlights: customization of the module as mean of acceptance, improve standardization for BIPV, crating cost reduction through strategies of optimization, a strong aesthetic and architectonic impact is an aim to increase the image of the building, BIPV consulting services to facilitate the process and information of the products.

ARCHETYPE: Transparent laminated glazing			**C6**
BUILDING TYPOLOGY: Educational			
NEW	RETROFIT	STAKEHOLDER: Manufacturer of photovoltaic glasses	
✓		APPLICATION: Accessory	

Aimed gains:

1. The accessory solutions should be integrated in the building keeping a high aesthetically value of the façade without modify the original aspects of the façade. If installed in public or administrative buildings these systems play an important role of trademark.

Gain creators: n.a.

Pain points:

a) The lack of experience of architects and installers is a weak point.
b) The operations and the planning of BIPV systems are made more difficult due to several missing gaps within the normative framework, especially in extreme conditions.
c) Often accessories, both for façades and roofs, are products for specific installations such as balconies, railings, parapets, partitions, etc. The uniqueness requires even more efforts due to the lack of experience and specific regulations.

Pain relievers:

a) The manufacturer suggests to introduce BIPV consulting services at every project's step. A global network of distributors, electrical and mechanical installers to provide clients with concrete and up-to-date information on the different installation solutions.
b) According to the experience of the manufacturer, PV glass and products tested and certified meet international standards, codes and safety guidelines (UL-1703, ULC/ORD-C1703, IEC 61215:2005 & IEC 61730:2004, MCS product certification, UNE-EN 14449:2006, among others).

Highlights: BIPV consulting services to facilitate the process and information, technical specific solutions that often are not replicable for other buildings, lack of standardization, a strong aesthetic and architectonic impact is required to increase the image of the building.

ARCHETYPE A: Transparent insulated glazing			**C7a**
BUILDING TYPOLOGY A: Administrative/Educational			
NEW	RETROFIT	STAKEHOLDER: Construction company	
✓	✓	APPLICATION: Façade	
ARCHETYPE B: Opaque no glazed element			**C7b**
BUILDING TYPOLOGY B: Administrative/Educational			
NEW	RETROFIT	STAKEHOLDER: Construction company	
✓	✓	APPLICATION: Accessory	

Aimed gains:

1. The BIPV product should be considered as a traditional building element.
2. The value of the building could increase thanks to the BIPV installation. The aesthetics is relevant, customers or public can perceive the building as green or sustainable image.
3. PV is considered mainly as an electricity generating product, but BIPV is a constructive element generating electricity, therefore combining both functions of constructive element and energy harvesting technology.
4. Since the BIPV product is a part of a system it should be sold together with the entire system (substructure, fixings, etc.) in order to facilitate installers. The planning of a BIPV façade should be understood as an element which interact with the external environment.

Gain creators:

1. The BIPV product should be able to generate electricity, combining both the function of constructive element and energy harvesting technology, exploiting the solar gains (shading, daylighting, thermal insulation), primary weather protection (rain, snow, wind, hail, etc.), mechanical rigidity, structural integrity and noise protection. It is necessary not only to produce a traditional material, but also to offer associated product solutions for the professional assembly (e.g. connections and ends parts of the roof, such as ridge, valley and hip).
2. An accurate design and the possibility to integrate the active modules in a multitude of innovative ways is necessary. However, it is necessary to obtain new permits in case of refurbishment and retrofit of the building envelope (also with an accessory installation).
3. The integration of transparent insulating glazing and accessory façade should begin from the preliminary studies, where the pros and cons of all the possible solutions are reveal, without forgetting the climate, location and issues like solar gains, lighting comfort, thermal comfort, gleam,

and natural light factor. The building and the BIPV installation should be understood as an element which interact in their external environment.

Pain points:

a) The difficulty with standards for BIPV is that the integration of PV into the building fabric can be very varied. Not all the BIPV products can be certified according to one standard, even if they might contain the same type of PV technology.
b) Some sectors like construction, require changes in the building conception, construction and costs and some energy renewable energy regulation barriers for them.
c) In retrofit buildings the installation of an accessory façade (**C7b**) could require new permit obtaining.
d) In retrofit buildings, it is not always possible to ensure an optimal arrangement of the BIPV system (building orientation, shadow, etc.)
e) The surcharged of the cost represented by the installation of the BIPV is a particular factor which make investors hesitate. The payback period of the BIPV marginal costs, should be competitive regarding the economic benefits of BIPV electric generation.
f) According to the local regulation there are several problems with large amount of documentation required in the legal and administrative process. Within the obstacles are found: long waiting list for the granting of permits and authorizations, unclear regulations for BIPV systems, etc.

Pain relievers:

a) A request of the constructor is to have a more complete catalogues with enough information for the correct use of the BIPV systems, together with construction details that reflect how to integrate products with the rest of the building construction elements and a detailed technical information regarding all the electrical and physical parameters.
b) It is important to give the construction sector enough time to get adapted to the demand of such ambitious energy standards, since they required radical changes in the way how buildings are conceived and built.
c) It should be necessary to manage permit obtaining even in the case of new BIPV façade systems that transform the old building skin into a modern and attractive one.
d) Accessory façade (**C7b**) could improve the energy production of the BIPV system, because they might allow to modify the inclination and the orientation of the solar panels.
e) Related to the payback period, each building needs a personalized design with an accurate study of the production, context, shading and shape of the façades. The use of specific PV technology and materials, together with an accurate design, could help to reduce the payback period and improving acceptance.
f) Transparent insulated glazing and accessory façade, represent an expanding market supported by many aspects or drivers. One of them is the legislation required to building energy performance (nZEB).

Requirements by the manufacturer: BIPV products should be considered as building elements, catalogues and construction details/technical information to facilitate the installation (the building sector needs time to adapt to technological changes), BIPV to increase the green and sustainable image of the building owner, a simplification of legal and administrative process is required, BIPV payback period should be anyway competitive.

ARCHETYPE: Opaque glazed element			C8
BUILDING TYPOLOGY: MFH			
NEW	RETROFIT	STAKEHOLDER: Architect	
	✓	APPLICATION: Façade	

Aimed gains:

1. Increase the value of acceptance of BIPV considering the point of view of the final user, the society and the architects.
2. Within the BIPV project development, the architect identifies the aim and then reaches it proceeding step by step.
3. Realise plus energy buildings with a high value of energy produced on site and consumed outright, increasing the value of self-consumption.

Gain creators:

1. Final user, society and BIPV products are the 3 different levels identified by the architect that could permit to increase the acceptance of BIPV solutions: (i) the final user is recognising the potential of aesthetically nice BIPV buildings since different best practices are by now visible on the market. The final user commissions to architects BIPV projects; (ii) political movements, influenced often by young people, are trying to address the efforts towards a more sustainable life style of citizens, promoting renewable energies and "green" strategies; (iii) the architects are realizing that BIPV products and BIPV materials are nowadays aesthetically nice and customizable. The constraints that could limit the design of the building are few. The BIPV material should be by now considered as a traditional non active material.
2. The process is an interaction between the architect, the client, tenants and manufacturers. This interaction, constantly and long, permits to receive feedbacks necessary to upgrade the value of the project.
3. Benefit from a building renovation to make the building more efficient with a low energy demand and size the BIPV system on the base of the new energy demand. The renovation and accordingly the realization of the BIPV façade should be previously optimized in order to limit troubles for the tenants.

Pain points:

a) Different problems at different stage of the BIPV process are emerged.
b) Difficulties to define a valid working group/partners. The choice of the right partner/BIPV products takes time and also financial resources especially when the processor the technology is new.
c) Feedbacks of other architects and journalists concerning the BIPV façade realization are important since an aesthetically nice BIPV installation is necessary to increase the acceptance.
d) Time of delivery and development of BIPV material not respected by the manufacturers.

Pain relievers:

a) More than the use of specific software that could simplify the process, the architect suggests to face the different problems finding right experts operating within the BIPV sector (manufacturers, research institutes, planning companies, etc.). One of the main challenges is to identify a pool of experts, work together with them and build up a process where a mutual trust is essential. Differently to other stakeholder' thought the regulations/permissions required are not considered as a particular issue. A glazed opaque BIPV solution needs the same permissions as a similar non active glazing façade.

b) If the partners are not competent the project has high chance to fail. An accurate research of the right partner is necessary. Furthermore, it is important that public funds are addressed to these research processes.
c) Showing the developed BIPV products to other architects and experts of the sector and receive feedbacks during the planning phase is important. In Switzerland architects do not like to see through the PV modules the PV cells, it is necessary to find other solutions to hide the cells. One of this solution is to use active modules where the PV cells are not visible thanks to specific coatings. The low efficiency of PV module is however accepted if the module is aesthetically pleasant.
d) When BIPV manufacturers are not able to observe the agreement established with the architect the time plan suffers remarkable delay. A manufacturer should be honest with the architect/customer recognising when a BIPV solution is not feasible at the current technology development rate.

Highlights: identify a pool of experts of the BIPV sector with whom it is possible to work together on the development of BIPV products/projects, define carefully a valid working team, in Switzerland a PV module on which cells are visible is categorically not accepted as architectonic material, the acceptance of BIPV buildings will be reached considering three different levels: final user, society and architects

ARCHETYPE: Opaque prefab element			**C9**
BUILDING TYPOLOGY: Educational/Commercial/Industrial			
NEW	RETROFIT	STAKEHOLDER: Façade cladding system manufacturer	
✓	✓	APPLICATION: Façade	

Aimed gains:

1) The BIPV envelope solution should be considered as a unique element. The cladding and the protective skin layer offered is a preassembled element ready to be installed (prefab/multifunctional BIPV solution).
2) For a massive use of the BIPV prefab solution, it should be easy to install.
3) The building is expected to be nZEB with an optimization of the self-consumption and self-sufficiency, often an eco-friendly and technological image is required on the façade.

Gain creators:

1) In order to create an effective product able to convince architects and public administrations in choosing it, just a unique reference producer should be the responsible of the entire process. The multifunctional product should be highly customizable in dimensions, colour, distribution of PV cells with the possibility to integrate the BIPV system with the conventional cladding system using the same installation process and technology.
2) The low cost, the flexibility (colours, finishes and dimensions) and ease of installation for the light weight (without the need to mount fixed scaffolding that are not well seen by the tenants) are the fundamental aspects.
3) Each building need a personalized design with an accurate study of production, the aesthetic effect, context, shading and shape of the façades. The BIPV on the façade helps to make the business of a virtuous company from an energetic point of view, with a very positive image return.

Pain points:

a) A normative framework that regulate the technical BIPV specifications (thermal and acoustic insulation, fire safety and PV) of the product is necessary.

Pain relievers: n.a.

Highlights: lack of standardization for multifunctional BIPV products, customization of the multifunctional component to satisfy acceptance requirements, easy-mounting installation process for a massive market implementation, achievement of nZEB standard (multifunctionality of the building skin).

ARCHETYPE: Opaque glazed element			C10
BUILDING TYPOLOGY: -			
NEW	RETROFIT	STAKEHOLDER: Solar roof/façade systems manufacturer	
-	-	APPLICATION: Façade and roof	

Aimed gains:

1) The aim of the manufacturer is to realize a lightweight solution. This kind of solution has different benefits:
   - less permanent loads on the mounting construction, in particular less shear stress on adhesive bond between the rear frame and PV laminated, less bonding surface and longer lifetime;
   - less transport cost of PV modules;
   - Easier and more ergonomic handling and mounting during the installation;
   - faster installation on building site due to the lightweight solution.
2) Easy mounting and de-mounting of PV modules.

Gain creators:

1) The reduction of the glass thickness could be a solution to create the lightness because of the possibility to use less row materials, less energy and less cost of transportation. Some building standards (e.g. EN14449) requires a minimum glass thickness for the curtain wall application. In the case of rainscreen façade or roofs in order to fulfill the primary requirements related to the mechanical durability (e.g. wind load, fire safety and static load) this optimization could be undertaken.
2) In Netherland, where the manufacturer is operating, the building sector has a shortage of qualified workmen. The objective is to develop a new mounting system that requires less time for installation and reduce the need of experienced workmanship.

Pain points:

a) When PV modules are installed as cold face panels on a wall façade, they do not look nice and have a non-aesthetic appearance.

Pain relievers:

a) To achieve an aesthetic appearance, a mounting system with the following options could support the market spread: possibility to exchange in all sizes for PV laminated using the same glued rear frame concept with equal connection system and include the realization of an aesthetic panels made of aluminum sandwich with bedhook connection that can be mounted to the same mounting rail system as the click&go BIPV mounting system.

Highlights: lightweight system to reduce the cost of the BIPV process and the environmental impact, achievement of aesthetically nice solutions developing a special mounting system, reduce the time and the complexity of the installation with a special easy-mounting system.

6.3 Key-topics to boost the BIPV sector

The information collected from the results above reported, has been analysed in this chapter by focusing on some emerging key topics. Several considerations were pointed out from the partners' value proposition, so that in the following part a recap and grouping according to the main thematic aspects is reported. Below stakeholder synthetic recap of the main issues defined by the project partners for these topics.

KEY TOPIC: Technology and technical standards

- The BIPV technology should be optimized for the specific building skin system and building typology (each solution needs to satisfy the specific standard families imposed for the static calculation, the fire safety, the thermal and acoustic protection, etc.). Well established glass-glass PV façade modules are nowadays reliable but too heavy requiring expensive substructures, transportation, difficult and long installation in some cases. Alternative solutions to reduce the weight adopting different PV/building materials (CIGS, polymer, etc.) or different layering of the cladding for some market segments (retrofit, lightweight constructions, etc.) should be developed.
- Lack of long-term guarantees of available solutions and impossibility to certify/mark a BIPV products according to one clear approach/standard.
- Each BIPV product/system would need a specific normative to combine the photovoltaic and building qualification schemes and also to cover the missing gaps in some technical requirements. The identification of reference standards is essential to develop easy processes of planning and installation.
- High time and costs to qualify a BIPV module in the current process with the conflicting aspect of customization and need to re-test different families of products (barrier for customers, manufacturers and market growing). International standards in PV sector vs local-based normative in building field is another barrier.

KEY TOPIC: Acceptance

- A BIPV system/product is accepted by the society if it satisfies both the aesthetical aspects and functional/energy requirements.
- In Switzerland a PV module on which cells are visible is categorically not accepted as architectonic material, the acceptance of BIPV buildings will be reached considering three different levels: final user, society and architects. It is nowadays recognised the potential of BIPV products and the validity of architectonic projects. Furthermore, these processes are supported by social/political movements.
- A BIPV system/product, in order to be accepted, combine the high flexibility in module dimensions, colors, distribution of the PV cells, with high energy production and cost effective, the possibility to integrate the BIPV in the conventional cladding system, using the same installation solution.
- The flexibility of manufacturing is an important aspect of acceptance as a building element.
- The active cladding is expected to be comparable to a traditional non-active material. It has to be flexible and versatile. Sometimes the electric production should be considered as a plus. All the features of a standard material (e.g. colour, transparency, aesthetic, thermal and noise protection) cannot be compromised or substituted with the energy production.
- The adapting time to technological changes of the building construction sector are usually long. New functional aspects and right business plans would permit to attract new potential users and investors.
- A BIPV solution can increase the value of the building. It can be associated to a trademark thanks to the ecofriendly and technological image.

KEY TOPIC: BIPV process

- Handbooks for certifications, installation details and as tutorials could simplify the planning activities and the installation on site.
- Flexible product concepts (such as backrail mounting systems, allowing to compensate construction tolerance), could accelerate the time of installation and the costs, simplifying the BIPV process.
- Mounting systems or preassembled products that require less time for installation and reduces the need of experienced workmanship, are required by the stakeholders.
- The lack of experience and knowledge of architects and installers and the lack of coordination among the key partners (building owners, material suppliers and installers) should be solved (a BIPV consulting service a global network, a digital process).
- The software nowadays available on the market related to BIPV do not satisfy manufacturer or planners. More specific tools, that permits to solve non-standard situations such as non-regular shapes and customized modules, are required.

KEY TOPIC: Cost effectiveness

- Each business plan related to the BIPV system should be referred to specific case studies by choosing optimal scenarios in term of cost/benefits.
- The business plan changes also according to the building typology considered. E.g. for industrial buildings or for the residential MFH or SFH, in case of feed-in tariff or self-consumption, etc.
- The extra cost of a BIPV solution should have a short payback time, not exceeding a certain surcharge compared with a similar BAPV solution or conventional materials. a BIPV system could help to increase the business of the with a positive image.
- The legal and administrative processes should be simplified in order to reduce long waiting list for the granting of permits and authorizations.

HIGHLIGHTS

BIPV Clusters: building skin archetypes and building typologies. From the current market towards potential developments

a) Nowadays the reference normative come from the PV field or conventional building material. Within the BIPV sector a normative that standardize the entire process by specifying BIPV requirements is missing.

b) Facilitation of the BIPV planning with tutorials, handbooks, catalogues, consulting service and development of specific tools that are able to operate in non-standard situations.

c) Preassembled, multifunctional, lightweight and easy-mounting systems to reduce the manufacturing process in situ could be a driver.

d) The BIPV products should be similar to other traditional buildings materials combining both the function of constructive elements and energy harvesting technology with a high value of customization. The customization of a BIPV product could also facilitate the acceptance (aesthetic), the BIPV process (flexibility in design and planning) and solving of technological issues.

e) A strong business plan is important to maximize the benefits and the cost effectiveness of the BIPV systems, as well as it is important to have a deep knowledge of the main directives and subsidies offered at local or national level. The knowledge of the principles of BIPV, the integration of BIPV processes with planning tools and the simplification of legal and administrative process is required.

Key-topics to boost the BIPV market

a) Technology and technical standards: the technology of the BIPV building skin system and its engineering process is considered a main issue to address the market needs. The normative and standardization aspects are closely related to a growing market implementation. The main link is with WP4 and WP5 of the project.

b) Acceptance: acceptance of the BIPV systems/products will have to consider more and more the user needs, the point of view of the tenants, owners and users. Also the sensitization of architects is still considered a topic. The main link is with WP9 of the project.

c) BIPV process: the BIPV process is described as complex, fragmented and with the need to be optimized. Within this topic are faced themes regarding: planning, installation and digitalization. The main link is with WP4 and WP6 and WP7 of the project.

d) Cost effectiveness: Strategies for reducing the final cost are considered the key-strategy from each stakeholder, as they perceived from the market and their customers. This aspect is impacting all the product and process chain, including also the strategy to improve benefits of BIPV through design strategies optimizing the self-consumption and self-sufficiency and the achievement of the nZEB standard and the alignment with local regulations. The main link is with WP4, WP6 and WP7 of the project.

6.4 Outlook for the BIPV implementation

The analysis carried out in the previous chapters and the main results, besides providing an input for the product development, can be also used as input for real project scenarios. Each demo site developed within this project, could be related to an archetype as well as to one cluster. Accordingly, the output emerged from the previous considerations, can be used to define the potentials, barriers and routes of development to ensure cost effectiveness, quality and a good market exploitation and replicability. Below the aspects used to report some main key-drivers for the different considered building scenarios:

- Aimed gains and means of development: What does the market require and which actions could help to support the development in the perspective to be replicable for the market?
- Pains and obstacles: What factors could slow down the development, implementation or acceptance?
- Challenges: which main challenges are faced in such real applications? Considering the potentials and obstacles, which are the main routes of developments to ensure cost effectiveness, quality and a good market exploitation and replicability?

6.5 Challenges in building scenarios

SCENARIO 1: Balustrade based on glass-glass bifacial modules		
IMPLEMENTATION SEGMENT: Balustrades REFERENCE PROJECT DEMO CASE: ISFOC office building (Puertollano, Spain) REFERENCE PROJECT PRODUCT: Glass-glass bifacial modules	TECHNOLOGICAL SYSTEM: Accessory façade CLADDING TYPOLOGY: Semi-transparent Glazed Laminated REFERENCE ARCHETYPE: Semi-Transparent laminated glazing	
1. AIMED GAINS AND MEANS OF DEVELOPMENT: TECHNOLOGY/STANDARDS: Existing building standards for balconies, safety rules in parapets, can support the certification scheme as a reference ACCEPTANCE: Local elements can be also perceived as a minor impacting element so easing the PV integration PROCESS: - COSTS: - In new buildings, the extra-cost to make it active is not relevant If accessories are in addition to other skin surfaces their contribution can be seen as a plus	2. PAINS/OBSTACLES: TECHNOLOGY/STANDARDS: Technological complexity in some construction details (e.g. cabling integration in external elements, glass anchoring, etc.) Possible interferences/clashes with façades/floors Lack of regulatory framework (e.g. BIPV glass safety for balconies) ACCEPTANCE: Local element, not integrated as building skin can be seen as not fully aesthetically integrated PROCESS: If a partial intervention is planned (e.g. only in accessory and not in the full building skin) it’s more difficult to set a digital process (e.g. missing a global building 3d model, data) COSTS:	

<table>
<tr><td></td><td>In some building typology the energy potential is low. Local elements with low energy production for the global building energy demand
High cost of glass and structures in balconies (structural laminated glasses, with high mechanical requirements)</td></tr>
<tr><td colspan="2">CHALLENGES
- Define effective construction details to ensure an optimal construction integrability of accessory elements and the correlation/interferences with other building skin parts (e.g. cabling integration, fixings, etc.)
- Define the correct reference framework from existing norms and codes to ensure a proper performance assessment and quality of the installation. PV qualification is not sufficient and mainly the building requirements are predominant (e.g. for balconies and parapets)
- Develop specific testing/performance assessment for BIPV (mechanical safety of BIPV glass under certain temperatures, loads, stresses, etc.)
- Define an aesthetic concept according to the context (e.g. if PV is accepted the elements can become a key-aspects of the language; if not the accessory should be camouflaged)
- Define a proper business model in order to overcome the typical high final cost of such a system
- Define new typologies/strategies of BIPV modules crating to ensure a cost reduction of the process</td></tr>
</table>

<table>
<tr><th colspan="3">SCENARIO 2: Walkable floors based on back contact solar cells</th></tr>
<tr><td>IMPLEMENTATION SEGMENT:
Walkable floor

REFERENCE PROJECT DEMO CASE:
ISFOC office building (Puertollano, Spain)

REFERENCE PROJECT PRODUCT:
Glass-glass back contact modules from automated tabber</td><td>TECHNOLOGICAL SYSTEM:
Floor

CLADDING TYPOLOGY:
Semi-transparent
Glazed
Laminated

REFERENCE ARCHETYPE:
Semi-Transparent laminated glazing</td><td></td></tr>
<tr><td>1. POTENTIAL AND MEANS OF DEVELOPMENT:
TECHNOLOGY/STANDARDS:
Existing building standards and safety rules for walkable floors can support the certification scheme as a reference
ACCEPTANCE:
The surface interacts with users and public spaces (e.g. rear lighting, interactive, etc.)
PV pavers allow building owners to install solar energy in rooftops, while preserving their habitability
PROCESS: -
COSTS:
If the energy production is not the unique goal, the extra-cost of the solution is not relevant</td><td colspan="2">2. PAINS/OBSTACLES:
TECHNOLOGY/STANDARDS:
Possible technological complexity both at macro and micro level (e.g. cabling integration in external elements, wear, slippery hazard, etc.)
Lack of regulatory framework (e.g. BIPV glass safety for walkable floor)
ACCEPTANCE:
Lack of confidence on such a new solution
PROCESS: -
COSTS:
A massive flow of people could increase the shadowing on the walkable floor and reduce the cost-effectiveness of the solution</td></tr>
</table>

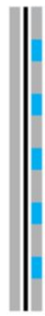
CHALLENGES
- Define a multiple function of the walkable floor (e.g. the energy production can be used to light up the path) - Define the correct reference framework from existing norms and codes to ensure a proper performance assessment and quality of the installation - Realize and promote new walkable floor to ensure the confidence with this solution - Define a proper business model in order to overcome the typical high final cost of such a system - Define new typologies/strategies of BIPV modules crating to ensure a cost reduction of the process

SCENARIO 3: Building integration of glass façade with c-Si technology		
IMPLEMENTATION SEGMENT: Ventilated façade REFERENCE PROJECT DEMO CASE: Industrial building (Aretxabaleta, Spain) REFERENCE PROJECT PRODUCT: Glass-glass c-Si opaque modules with different configurations and opaque façade structure	TECHNOLOGICAL SYSTEM: Rainscreen façade CLADDING TYPOLOGY: Opaque Glazed Laminated REFERENCE ARCHETYPE: Opaque glazed element	
1. POTENTIAL AND MEANS OF DEVELOPMENT: TECHNOLOGY/STANDARDS: Existing building standards for glass and building elements can support the certification scheme as a reference ACCEPTANCE: A customized product in size and color to ease the acceptance by architects Well established glass-glass PV façade modules are nowadays reliable PROCESS: BIPV solutions for residential façades should be simple and cost effective for planning and installation. The design of the system can be optimized for an easy mounting and de-mounting A customized product in size to ease the installation COSTS: The payback time can be calculated considering only the extra cost needed to make active the building envelope	2. PAINS/OBSTACLES: TECHNOLOGY/STANDARDS: Complex technological systems (curtain walls, SSG, double skins) with a high engineering ACCEPTANCE: No differences must be visible between PV modules and similar non active modules PROCESS: Lack of experience of PV installers COSTS: Expensive technological systems (curtain walls, SSG, double skins) The total cost is higher than a traditional BAPV installation	

CHALLENGES

- PV qualification is not sufficient and mainly the building requirements are predominant. Define the correct reference framework from existing norms and codes to ensure a proper performance assessment and quality of the installation
- Define a new mounting system that requires less time for installation and reduce the need of experienced workmanship
- Organize a BIPV consulting service at every project's step in order to provide architects and installers with concrete and up-to-date information on the different installation solutions
- Define a tool that permits to solve non-standard situation to ensure a simple planning and installing process
- Define a proper business model in order to ensure a maximization of self-consumption and self-sufficiency ratio (e.g. optimization of the hourly profile of the energy demand with those of the energy production)

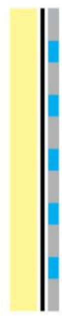
SCENARIO 4: Building integration of metal based roofing shingles

IMPLEMENTATION SEGMENT: Roof new construction or retrofitting REFERENCE PROJECT DEMO CASE: Single-dwelling (Saint-Dennis, Belgium) REFERENCE PROJECT PRODUCT: CIGS module with mounting roof structure	TECHNOLOGICAL SYSTEM: Cold roof CLADDING TYPOLOGY: Opaque No glazed REFERENCE ARCHETYPE: Opaque no glazed element	
1. POTENTIAL AND MEANS OF DEVELOPMENT: TECHNOLOGY/STANDARDS: Lightweight, flexible modules The PV laminate can be bounded with already existing building components (e.g. metal sheets for roof tiling, watertight membranes, etc.) ACCEPTANCE: The PV system is low impacting and lightweight Curved surfaces can be cladded with flexible modules PROCESS: BIPV solutions is usually cost effective for transport and installation Ease of handling and mounting (possible extra-sized modules) Optimization of the packaging and reduction of the handling risks due to the lower fragility COSTS: Improvements in the basic frame structure are possible for cost saving Cost effectiveness and environmentally benefits of lightweight solutions can be a driver	2. PAINS/OBSTACLES: TECHNOLOGY/STANDARDS: Reference standards as construction non glazed components are missing for some material typologies Production flexibility (e.g. fixed sizes/dimensions) can limit compatibility with existing building surfaces ACCEPTANCE: Mimicry is still difficult and the mainly black color can be perceived as a limit of customization and aesthetics A partially covered BIPV roof system could be seen as a not aesthetically pleasant architectonic component if dummy modules are difficult to produce PROCESS: - COSTS: -	

CHALLENGES

- Develop a lightweight and flexible system to ensure a cost reduction of the upstream and downstream process, a reduction of time and complexity of site preparation and installation with an easy-mounting system (e.g. a CIGS solution guaranties flexibility and lightness)
- Define optimal design of roofing kit systems to facilitate the installation and fixing in different conditions, customizability special modules (dummies) to fully cover the irregular surfaces and to ease the flashing of roof parts.
- Develop specific testing/performance assessment for BIPV roof solutions
- Define tools that permits to solve non-standard situations to ensure a simple planning and installing process and an effective interoperability between work stages

SCENARIO 5: Building integration of multifunctional BIPV opaque façade cladding systems

IMPLEMENTATION SEGMENT: Opaque cladding REFERENCE PROJECT DEMO CASE: Residential multi-family dwelling (Morbegno, Italy) REFERENCE PROJECT PRODUCT: Multifunctional BIPV element with integrated insulation	TECHNOLOGICAL SYSTEM: Prefab façade CLADDING TYPOLOGY: Opaque Multifunctional REFERENCE ARCHETYPE: Opaque prefab element	
1. POTENTIAL AND MEANS OF DEVELOPMENT: TECHNOLOGY/STANDARDS: Pre-assemblage of the product and the prefabricated manufacturing process can reduce time and costs Multifunctionality of the façade kit can add a high value for retrofit Existing building standards (EADs, hEN) for such a building elements can support the certification scheme ACCEPTANCE: BIPV solution similar to a standard non-active façade cladding solution PROCESS: A multifunctional system can ease and simplify the installation process A digital process is easily compatible with prefabrication COSTS: Low cost of multifunctional solutions that combine in a unique element more features of the building skin envelope	2. PAINS/OBSTACLES: TECHNOLOGY/STANDARDS: Absence of ventilation can represent a limit for operating conditions and energy yield Different technological elements integrated together need a mutual combination and a compatibility analysis of technological and manufacturing aspects (lamination methodology, production process, electrical connection, bonding of photovoltaic component and the building component) ACCEPTANCE: As new solution the final users could be diffident regarding the reliability/durability of such a system PROCESS: Lack of knowledge concerning the installation/electrical connection/disposition of PV products in prefab building components COSTS: -	

CHALLENGES

- Develop unique prefabricated product systems through the optimal combination and compatibility in technology and manufacturing process
- Define the correct reference framework from existing norms and codes to ensure a proper performance assessment and quality of the installation. PV qualification is not sufficient and mainly the building requirements are predominant
- Develop specific testing/performance assessment for such a product typology
- Define a proper business model of the prefab system, assessing properly its extra cost in comparison with other standard solutions, considering also the multifunctionality of this solution
- Increase the customizability of the solutions
- Define a large portfolio of best practices and certified demo buildings as mean to increase the acceptance and demonstrate the reliability of the system

7 CONCLUSIONS

This document, as the output of the Task 1.3 of BIPVBOOST project, was aimed at determining the BIPV s attractiveness and its evolving opportunities in the horizon 2020 to 2030, in relation to a building envelope and building construction approach. Within the scope of a massive utilization of PV in buildings from 2020 onwards, we performed an analysis of different archetypal buildings and building skin categories with BIPV potential for the European market, referring to the sector trends, evolution and construction segments relevant for BIPV thanks also to the information and support provided by the project partners. By taking into account the point of view of three stakeholders types (architects, manufacturers and construction companies), a census of the best practices in the field of BIPV implementation originated the definition of the reference archetypal scenarios and the identification of the main trends describing barriers, challenges and key-topics for future developments. This deliverable represents a starting point for the next activities of the BIPVBOOST project by tracing the basic definitions and a fil rouge of a construction-based approach, by defining the key-aspects related to the market deployment in terms of cost reduction, flexibility in design, performance, reliability, aesthetics, standardization and compliance with regulations.

The European BIPV segment has a huge potential for development. Considering also that the European building stock needs a deep renovation, the application of BIPV solutions in retrofitted buildings is one of the main drivers. Through the analysis of BIPV case studies, a catalogue of reference **building typologies**, **technological systems** and **building skin claddings** has been provided and used as a key-element to identify archetypes with a promising market share. Five **archetypes**, on which each BIPV solution can be grouped, are identified by taking into account the construction features of the building skin cladding and the main BIPV technological solutions nowadays available on the market.

Based on these segmentation, preliminary indicators that permit to identify some strategies of BIPV development, underlining gain creators and pain relievers on specific building situations (building typologies, technological systems and building skin claddings) emerged according to the vision of the partners. The key topics were identified in relation with the technology and technical standards, the BIPV acceptance, the process and its cost effectiveness. The **technology** of the BIPV building skin system and its optimal engineering is considered a main issue to address the market needs with reliable, easy mounting and fully integrated active skin systems where PV and construction parts are a unique concept. The **technical standards** are closely related to the technological aspects as the performance assessment and validation before the market introduction are considered crucial for a successful BIPV implementation. A more explicit qualification approach and process in expected. The **acceptance** of BIPV is then considered more and more also linked to the user needs, the point of view of the tenants, owners and users: aesthetical quality is part of BIPV definition without any doubt so that flexibility and customization are indisputable market creators. The **BIPV process** is described as complex, fragmented and with the need to be optimized and coordinated more efficiently. **Cost effectiveness** is finally considered strategic from each stakeholder, in the perspective of a nZEB target, since this aspect is impacting all the product and process chain and is the key performance indicator of each innovation action.

Nowadays, the most evident BIPV barriers are clear. Many issues have been solved during the last years and many strategies of implementation developed. However, the main challenge remains now to demonstrate BIPV in real and reliable systems, installing them on real buildings and with a synergic product and process innovation. This deliverable, according to the aim of the BIPVBOOST project, represents a first step in this direction by offering an overview of the main strategies emerged from a breakdown analysis of the entire BIPV sector and its main stakeholders. We have focused on the building typological, construction and technological aspects, identifying some of the main routes and challenges of development, as emerging from the multi-disciplinary experience of the project consortium.

The outlook identified traces a methodological and reference basis, on a construction-based approach, to ground the further activities of BIPVBOOST project, namely the actions for product and process innovation.

Indeed, within the next work packages, further studies will be conducted with the aim to “implement the cost reduction roadmap in the building skin solution” (WP4), “reduce the cost based on the performance levels and advanced standardization schemes for BIPV” (WP5), “Digital and data-driven process for BIPV cost reduction along the value chain (WP6, 7) and “demonstration in real buildings” (WP8).

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