IEA INTERNATIONAL ENERGY AGENCY

Transition towards Sound BIPV Business Models

PHOTOVOLTAIC
POWER SYSTEMS
PROGRAMME

Report IEA-PVPS T15-03: 2018

INTERNATIONAL ENERGY AGENCY
PHOTOVOLTAIC POWER SYSTEMS PROGRAMME

Inventory on Existing Business Models, Opportunities and Issues for BIPV

IEA PVPS Task 15
Subtask B – Transition towards sound BIPV business models
Report IEA-PVPS T15-03: 2018
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Foreword

The International Energy Agency (IEA), founded in November 1974, is an autonomous body within the framework of the Organization for Economic Co-operation and Development (OECD) which carries out a comprehensive programme of energy co-operation among its member countries.

The IEA Photovoltaic Power Systems Programme (PVPS) is one of the technological collaboration programmes (TCP's) on research and development within the International Energy Agency (IEA). IEA PVPS has been established in 1993, and participants in the programme have been conducting a variety of joint projects regarding applications of photovoltaic (PV) conversion of solar energy into electricity.

The mission of the PVPS is *"…to enhance the international collaboration efforts which accelerate the development and deployment of photovoltaic solar energy as a significant and sustainable renewable energy option…"*. The underlying assumption is that the market for PV systems is gradually expanding from the niche-markets of remote applications and consumer products to rapidly growing ones for building-integrated and centralised PV generation systems.

Building Integrated PV (BIPV) is seen as one of the five major tracks for large market penetration of PV, besides price decrease, efficiency improvement, lifespan, and electricity storage, and IEA PVPS Task 15 focuses on the international collaboration to create an enabling framework to accelerate the penetration of BIPV products in the global market of renewables, resulting in an equal playing field for BIPV products, BAPV products and regular building envelope components, respecting mandatory issues, aesthetic issues, reliability and financial issues.

To reach this objective, an approach based on 6 key developments has been developed, focussed on growth from prototypes to large-scale producible and applicable products. The key developments are a dissemination, business modelling, regulatory issues, environmental aspects, and demonstration sites.

This Task contributes to the ambition of realizing zero energy buildings and built environments. The scope of this Task covers new and existing buildings, different PV technologies, different applications, as well as scale difference from 1-family dwellings to large-scale BIPV application in offices and utility buildings.

The current members of IEA PVPS Task 15 include: Austria, Belgium, Canada, Denmark, France, Italy, Japan, Korea, Norway, The Netherlands, Spain, Sweden and Switzerland.

This report concentrates on the business models for BIPV. The main authors of this document are Philippe Macé (Becquerel Institute, Belgium), David Larsson (Solkompaniet, Sweden) and Jessica Benson (RISE, Sweden).

Further information on the activities and results of the Task can be found at www.iea-pvps.org.

Michiel Ritzen, operating agent IEA PVPS Task 15

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Executive Summary

Building integrated photovoltaics (BIPV) can have a vastly different business model than other PV installations; applied on buildings or ground mounted. Business models for ordinary PV installations generally focus only on revenues from the electricity generated, whereas BIPV has the potential to also reduce costs through the replacement of other building materials.

A basic BIPV business model includes both electricity revenues and material cost savings.

This report includes examples of various BIPV installations ranging from simple in-roof installations to innovative facade designs. The timing of introducing BIPV in the design process affects the complexity of the façade. The façade examples cover the use of standard modules to custom-made modules adapted to the design. The BIPV roof examples cover both small, simple in-roof installations and a full roof BIPV solution. Results from the studied cases, show that only one of the involved companies have a BIPV-specific business model in place.

A basic BIPV-specific business model could be based solely on cost savings from replacing other building materials and revenues from electricity generation. This is viable if the BIPV installation has sufficiently low cost, or if the value of the replaced materials and electricity generated is sufficiently high. A BIPV specific business model is found in the case with a full BIPV roof, an installation that arose from the need for a roof renovation. The other examples are also based on material savings and electricity revenues but many were made with publicly funded incentives like investment subsidies.

The green value of PV can be significantly higher with BIPV.

The purpose of the case study is to identify the main drives for choosing BIPV in each example. These drives and values can be used as a basis in the development of new business models. For example, there is a green value, i.e. value of being environmentally friendly and sustainable, attached to PV, which could be significantly higher for a good looking, architecturally integrated BIPV installation than for the average PV system. For example, the green identity attracts high paying customers as tenants in two of the cases, which allows for higher rental fees. Future work is needed to explore ways to fully capture and monetize the green value of a building with BIPV.

Another business model, shown in one example, could be to build and sell the building at a premium. So far, there is no clear evaluation of the price premium of a building with BIPV. On the other hand, compared to the total cost of a new building, the cost of a BIPV installation is seemingly moderate. In two of the examples with large BIPV facades, the added cost was only 1-2 % of the building cost. A leasing arrangement with the utilty is also described in one example.

In the future, it is likely that BIPV must cope without investment subsidies and that electricity revenues will be high from self-consumption, but low from excess production. Highlighted in the analysis of regulatory environment is the need for collective self-consumption to be allowed. BIPV can also benefit from regulatory measures imposing a reduced purchased energy demand of new or retrofitted buildings.

The cost of a large BIPV facade is seemingly low, compared to the total cost of a building.

1. Introduction

The main objective of IEA PVPS Task 15 is to facilitate the acceleration of building integrated photovoltaic (BIPV) application in the built environment, by identifying and breaching the most important process and policy thresholds, in combination with the development of business and marketing strategies for BIPV application worldwide.

This report is part of the work of subtask B “Transition towards sound business models” that aims at identification and development of sound business models in line with the main objective of Task 15, and with these results assist decision makers in development of BIPV projects.
In this first report from subtask B, ten BIPV installations are used as examples to analyze the status quo of BIPV business models. The design of a business model for BIPV is depending on the regulatory framework in each region and an overview of regulatory environment in different countries shows incentives or barriers for BIPV implementation. Finally, policy recommendations based on analysis of regulatory framework and case studies are given to overcome barriers for BIPV implementation.

The second report of subtask B will include a more detailed analysis of how new business models for BIPV realization can evolve, along with policy recommendations, resulting in a supportive toolbox for stakeholders to design their BIPV business model.

1.1 Objective

The first objective of this report is to give examples of the story behind BIPV installations completed in recent years. Why were they built, and can they be replicated? What value streams are associated with the installations shown in the examples, and how they can be utilized even better in future projects? These are some of the questions to be answered for every case study. The described values and drives for BIPV installations can then form the foundation for new viable business models.

The second objective is to present regulatory framework to highlight incentives and barriers for BIPV and to discuss possible future scenarios and recommendations in this regard as well as to analyse their impact on the business models.

1.2 Method and delimitations

The analysis of status quo of BIPV business models today have been done based on findings from selected case studies. The case studies and regulatory framework have been provided mainly by the participants in subtask B.

To reach mass-scale BIPV deployment, feasible business models should be based on systems with high potential for replication and economies of scale. Criteria for case study selection were therefore set to include the following BIPV applications, for both new construction and refurbishment projects:

- Residential building rooftop
- Residential building facade
- Commercial building rooftop
- Commercial building facade

Rooftops are not always available for BIPV, as there is a competition about the space with other applications, green roofs being one example. Still, rooftops are often the most cost-efficient location for a BIPV installation, whereas the facade sometimes holds a larger available area. Here the focus was set on cold facades, i.e. solutions where the BIPV product is added as an outer layer, but a few examples where PV is embedded in glazed surfaces have been included as well.

2. Case studies

The following chapter contains a description of the cases that form the basis for the analysis of BIPV business models. The presentations of the cases are based on the questionnaire found in Appendix 1 and highlights information about business models including stakeholders, values and lessons learned for the various BIPV projects. The business model summary highlights the drives behind the installation. In the fact box, approximate figures for each BIPV installation are presented including building type and year of installation and cost comparisons. Figures of self-sufficiency shows the percentage of total electricity consumption covered by the BIPV production and the level of self-consumption shows the direct use of produced electricity. More detailed information about BIPV cases, including most of the following cases, will be found in the results from Task 15 subtask A.

The case studies have been provided by the participating countries in subtask B and are all from Europe. The aesthetic aspect of BIPV is considered to be higher than BAPV and the aesthetics is important to reach a mass market. Therefor there is a note for cases with early BIPV installations and aesthetics similar to BAPV. These cases still provide valuable information about BIPV business models. Also note that as BIPV is a building component with PV used to replace other materials, it should not always be compared to BAPV. A comparison might as well be with the other building materials being replaced, and this cost comparison is presented in the fact box.

Facts and figures

Type of installation
BIPV as facade cladding

Building type
New building, school

Year of installation
2016

Size
Area: 6 000 m^2
Installed power: 700 kWp

Incentives for PV or BIPV
No

Investment cost
N/A

Cost comparison
Cost of BIPV was comparable to alternative facade cladding

Electricity production
500 000 kWh/year

Level of self-sufficiency
50 % of total electricity consumption

Level of self-consumption
N/A

Electricity revenues
Self-consumption: 0.29 €/kWh
Feed-in electricity: 0.29 €/kWh

2.1 Copenhagen International School, Denmark

Copenhagen International School (CIS) is located at *the harbour in the new sustainable district Nordhavn. The green colour-changing facade is made by 6 000 m^2 individually angled PV modules with Kromatix glass. One colour can appear in many different shades as the light changes through the day or by different angles of the modules. In that way the facade becomes multi-coloured even though all the modules have the same colour.*

The private school was built in 2016 and the choice of BIPV was made in the early design phase, primarily for the green value and aesthetic reasons. The building is listed according to Energy Class 2020 and it is so airtight that there is a need for cooling even in winter. The expected energy consumption for cooling and a reduction of daily operation costs was also a reason for choosing PV.

The energy production from the 700 kWp BIPV system is estimated to cover 50% of the total annual electricity consumption at the school.

Business model summary:
BIPV is an essential part of the building's profile and green identity. A property company rents out the building to the school. The cost of the BIPV component was comparable to alternative facade cladding materials. The system is profitable as an electricity provider. The value of massive public attention has not been quantified; this might attract more students to the private school.

Business model

The school established a property fund (ECIS) with the purpose of building a new school including the BIPV-system. The school is the tenant at ECIS.

The BIPV system was tendered in a total system delivery where the PV manufacturer acted as main EPC (Engineering, Procurement and Construction) contractor for negotiation and installation. All the workers needed for the installation of the system e.g. electrician, module installer, were subcontracted to the project by the main contractor. The project was completed in due time and within the budget, as part of building the new school. Both plans and problems were solved in a close cooperation between EPC contractor, developer and developer's advisors (architects and engineers).

The size of the installation was mostly affected by aesthetics and aiming at highest possible self-sufficiency to lower the operation costs as tenant. There were no economic restrictions or any kind of subsidies involved regarding the BIPV installation.
An alternative facade cladding, anodized aluminium metal, turned out to have the same price as BIPV and that became an argument for choosing BIPV. BAPV on the roof was never an option since the roof is used as a playground. The building is listed according to Energy Class 2020. This is possible to achieve as school when the total energy requirement for heating, ventilation, cooling, hot water and lighting per. m² of heated floor space does not exceed 25 kWh per year. In the Danish Building Regulations (BR) there are no specific requirements for PV. But indirectly PV can be necessary to comply with the so-called 'Energy Frame' where all elements may be combined freely as long as the framework is respected.

The use of 1200 micro inverters was necessary as there is internal shading on the BIPV facade. The micro inverters were placed under the ceiling plates inside the building to allow easy serviceability of the PV plant by the school´s technical staff, and to minimise the operational cost.

For Copenhagen International School, the overall intention and background for the BIPV-facade was to build a sustainable school, reduce operational costs, and demonstrate the walk-the-talk in teaching. The 900 students in the school are all aged between 6 and 16, and the BIPV-facade will provide them with knowledge and awareness of sustainability. For the installer/manufacturer the building is a showcase of innovative BIPV that gains a lot of publicity. Information and measurements from the BIPV system is included in teaching and a part of the school´s sustainable profile. The students also benefit from the unexpected attention by media and professionals that the BIPV facade has gotten. Scholarships for the students are supported by the fee from the many visitors both from Denmark and abroad. The school gains a lot of publicity, a value that was not first thought of.

The BIPV plant is under net measurements where excess electricity from the BIPV plant is delivered to the grid without any payment for the delivered energy. Most of the produced solar power is self-consumed in the school. It is possible to choose another net metering scheme with payment for excess electricity to the grid. That requires a balance responsible aggregator willing to receive and sell the electricity into the market and typically, that setup is expensive.

Lessons learned

BIPV was introduced in an early design stage. It is important to keep BIPV in the discussion through the whole process. In general, stakeholders had bias against PV. As a result, BIPV was about to disappear from the project a couple of times but ECIS had a very insisting board member who kept BIPV in the discussion, and also was the driving person behind the design of the facade.

2.2 Frodeparken, Sweden

Facts and figures

Type of installation
Facade
Building type
New building, residential
Year of installation
2014
Size
Area: 900 m^2
Installed power: 100 kWp
Product dimensions: 1200x636 mm
Incentives for PV or BIPV
30% PV investment subsidy
Investment cost
Approx. 390 000 € (430 €/m²).
After subsidy 260 000 € (290 €/m²).
1% of the total building cost.
Cost comparison
150 000 € higher cost than plastered concrete (after subsidy).
The same or lower cost than a curtain wall glass facade.
Electricity production
70 000 kWh/year
Level of self-sufficiency
28 % of total electricity consumption (households not included)
Level of self-consumption
43 % of produced PV electricity is self-consumed
Electricity revenues
Self-consumption: 0.10 €/kWh
Feed-in electricity: 0.04 €/kWh

Frodeparken is a multi-family house in the city centre, right next to the railway station in the city of Uppsala. The curved facade is covered with standard sized thin-film PV modules (CIGS). To achieve this, the architect had to adjust the measurements on the facade according to the fixed size of the module. In turn, the PV installation was significantly cheaper than it would have been with customized modules. Only a few tailor-made dummies were used in some areas. Behind the PV modules, there is a concrete surface.

Using BIPV on the facade of this particular building was suggested very early, in the design phase of the whole area. The main idea was to present the city as a high-tech and sustainable city, as the building is part of the entrance to Uppsala from Stockholm, for people arriving by train.

Originally, the architect's proposal was a polycrystalline silicon blue facade, with a complex design that would have required tailor-made modules. Later, this was changed to CIGS thin-film PV based on research from Uppsala University.

Business model summary:
BIPV for this building was considered already in the city planning. The cost of the BIPV installation was the same or lower compared to a glass facade. This type of owner cannot use the opportunity to fully monetize on marketing value, since rental fees are regulated. The cost was reduced through the use of standard sized modules.

Business model

The building is owned by the municipal housing company, Uppsalahem, which has a politically designated board and thus, at least to a reasonable extent, aims to strengthen the positive impression of Uppsala as a city. Today, the city also has high goals set for local solar electricity generation – 30 MWp by 2020 and 100 MWp by 2030. The investment in a BIPV facade was made by the housing company as an environmental and profile measure where the BIPV facade contributes to the presentation of the area and the city as environmentally friendly and high-tech.

The installation also received 30% investment subsidy from the government, but this was not taken into account when the investment decision was made. The only direct monetary surplus is from the electricity produced, including electricity certificates. The building has received a lot of attention from people interested in BIPV, which can be said to strengthen the brand of Uppsalahem and the city of Uppsala, although it is difficult to quantify the value of this.

White arkitekter was the architecture company originally proposing BIPV in the design phase of the city block, and the same company also made the final design of the building. Direct Energy (now Solkompaniet) was involved as PV consultants in the design phase of the building, and later also installed the BIPV system. The PV modules were delivered by Q-Cells (now Solibro) and the mounting system was delivered by the German company U-kon.

Lessons learned

At the time the investment was made, net-metering was still being discussed in Sweden and monthly net-metering was seen as the most probable future regulation. As it turned out, the outcome was instead a tax deduction scheme for excess electricity fed into the grid, similar to annual net-metering but restricted to maximum 30 000 kWh/year per company. This had a strong negative affect on the direct economic outcome of the installation, since more than half of the electricity generated is fed to the grid.

As described above, the vast interest gained by the PV facade can be said to have strengthened the brand of Uppsalahem. As a municipal housing company, with restricted rental fees, it is however difficult to evaluate this added value in monetary terms. If the building had been for example a commercial office building, the business model could have been very different.

Facts and figures

Type of installation
BIPV facade (with BAPV on flat roof)

Building type
New commercial office building

Year of installation
2015

Size (BIPV)
Area: 1242 m^2
(1011 modules, 22 sizes)
Installed power: 115 kWp
Product dimensions: 0.7 – 1.6 m^2

Incentives for PV or BIPV
No general incentives, this project got special financial support.

Investment cost
N/A

Cost comparison
370 000 € higher than ordinary facade
200 000 € higher after subsidy.
1.4% of total building cost

Electricity production
55 000 kWh/year (BIPV)
50 000 kWh/year (BAPV)

Level of self-sufficiency
23 % of total electricity consumption

Level of self-consumption
100 % of produced PV electricity is assumed self-consumed

Electricity revenues
Self-consumption: 0.10 €/kWh
Feed-in electricity: 0.03 €/kWh
(0.10 €/kWh paid by some electricity companies <5000 kWh/year)

2.3 The Solar Emerald, Norway

The Solar Emerald ("Solsmaragden")" is a seven-storey commercial building located in Drammen in Eastern Norway, holding office space for around 450 people (BRA 8650 m^2). The building has a traditional BAPV system on the flat rooftop that also provided power during the building phase, and a 115 kWp BIPV system on the east, south and west facades operational since January 2016.

The main drive of the project was the vision of the building owner and property developer, Union Eiendomsutvikling AS. The idea was to realize outstanding environmentally friendly architecture and to achieve the highest energy label (Energy class A and Norwegian passive house standard NS3701), and thereby to stand out as an attractive office space for tenants.

The modules were tailor-made for the project by the Belgian company Issol. The front glass is printed with a pattern of green coloration. The printing method provided the architect with high flexibility in the choice of colour and pattern (figure). The green print introduces a 17 % loss relative to a standard module.

Printed glass offering a wide choice of patterns and colours.

Although PV production is not optimal due to unavoidable shading from the surrounding buildings of the city, the various facade orientations distribute the power production over the day and provide a good match with the energy consumption profile in the building.

Business model summary:
An early installation on the Norwegian market, built with subsidies. Custom design and many component sizes increased the cost. The environmental identity is highly valued. The owner would do it again, even without subsidies.

Business model

The building development company *Union Eiendomsutvikling* owns the building and made the decision to install BIPV. The project was a result of a vision from the general manager of the building owner/developer, who wanted a green building with an aesthetically pleasing facade. After discussions with a local PV installation company, the decision was made to use BIPV as facade material. The building was expected to:

- Realize outstanding environmentally friendly architecture;
- Produce significant amount of renewable solar electricity;
- Create an environmental identity.

The total cost for the new office building was around 27 M € where the added costs for the BIPV system accounted for 1.4 %. The calculation was based on the integration of PV as a facade material, where the cost associated with a typical traditional facade material was subtracted. The building's design had already been defined at an earlier stage. This resulted in the need for adapted PV modules, with 22 different sizes and a higher complexity in the string's design. In the end, a new technology was developed that satisfied all requirements for cost, appearance and installation method.

The size of the installation was not influenced by the financial analysis, but rather by the project requirement for a uniform and outstanding architectural appearance. The financial business model was based on achieving high building standards and creating a positive attention that would attract new companies as tenants. Today, an increasing number of companies are willing to pay a higher rental in return for high energy standard and sustainable building certification. The building developer stated that the investment was good value for several reasons, particularly to successfully attract important tenants based on the green profile.

No specific legal incentives for PV or BIPV were applicable. However, the project received financial support around 0.16 M € for demonstration of a new system. The support came from Enova, a public enterprise owned by the Norwegian Ministry of Petroleum and Energy, as part of their program "New technology for future buildings". General support schemes for PV installations on commercial buildings in Norway are not available, except for renewable electricity certificates.

The public support was a triggering factor for the BIPV installation. However, the building developer claims that they would do it again, also without financial support, and that the professional guidance received from the supporting partners was of equally high value to them. Environmentally friendly solutions and local products/services were considered an added value to their business case. For future BIPV facade projects, cost reduction is expected based on competency gained by all companies involved.

The stakeholders in the project focused on technical challenges and how to find good solutions with new systems. A new facade-adapted module was developed by the module producer *Issol* (Belgium) in collaboration with the building owner, the project architect from *LOF Arkitekter*, and the PV system supply company *FUSen*. The module basis is made from standard 125 mm mono-crystalline silicon solar cells in a frameless glass-glass configuration using 4 mm safety glass. Mounting details were designed by local sub-contractors under the responsibility of the main contractor *Strøm Gundersen AS*, using their own solution for the BIPV module suspension on the facade.

The BIPV modules are mounted as ventilated cladding, replacing other exterior cladding on the facade. Walls were reinforced to carry the added weight of a BIPV system.

Lessons learned

This type of tailor-made BIPV facade is still rather costly. Hence, other criteria than economic profit will be the main drives. In this case, the drive was a facade appearance that created an environmental identity. Despite added costs, the building owner is satisfied with the end-product and would do it again, also without public support. The project has created significant positive media attention and sees a return of interest from potential tenants and companies interested in the innovative green building.

One challenge was the lack of suppliers of coloured BIPV. Hence, own resources were used to develop a suitable solution. Using local installation solutions ensured building code compliance and lowered the costs. The lack of clear guidelines for BIPV facade installation was viewed as an obstacle for the project, requiring own interpretation in terms of material requirements and safety. Other challenges included logistics and small error tolerances in dimensional measurements (multi-storey building). The installation sequence and string design was complex. Hence, an important lesson learned is the need for focus on details, as doing things right the first time avoids costly error correction.

The complexity called for close collaboration between all parties during the whole building process (architect, building owner, consultants, engineers, contractors, and funding bodies). Solutions had to be found during the construction process. Good interaction and teamwork between business partners made the project possible, and each partner gained new competence as valuable input for future BIPV projects.

Facts and figures

Type of installation
BIPV facade (with BAPV on roof)

Building type
New commercial office building

Year of installation
2015

Size (BIPV)
Area: 667 m^2
Installed power: 122 kWp

Incentives for PV or BIPV
No specific incentives.

Investment cost
N/A

Cost comparison
400 k€ relative to original budget

Electricity production
51 MWh/year (BIPV)
51 MWh/year (BAPV)

Level of self-sufficiency
100 % of total electricity consumption

Level of self-consumption
N/A

Electricity revenues
N/A

2.4 The Treurenberg building, Belgium

The Treurenberg building, located in Brussels-City downtown, is the first Net-Zero Energy office building (NZEB) to be completed in Brussels. The original building constructed in 1960's has been demolished and the new building with nine levels offers 9 800 m^2 of office space that can accommodate up to 750 persons.

The construction required the most advanced techniques to become a Net-Zero Energy Building certified with BREEAM Excellent. The building benefits from three facades ideally exposed to the East, South and the West and it was therefore decided to cover these facades with monocrystalline PV modules on the three upper levels of the building. Monocrystalline solar modules are also placed on the roof with a very low inclination of 5°, to maximize the available roof surfaces. The PV modules are integrated in the dark facades of the upper levels and in the roof so that the technical elements are not noticed.

The energy produced from the BIPV on the facades and the solar modules on the top was calculated to be 102 MWh/year and it corresponds to 100 % of the annual electricity consumption of the building. The building and PV systems are owned by the building developer firm AXA Belgium. Since 2016, and for a period of 15 years, the building is rented by an EU agency.

Business model summary:
PV was needed to achieve BREEAM certification as well as to fulfill NZEB standard. BIPV was used to fulfill the aesthetic requirements of the facade part.

Business model

The overall intention and the background for the BIPV plant was to build a Net Zero Energy Building whose envelope, equipment's and finishing respect the criteria of a green building i.e. energy saving in the long run, with an "Excellent" BREEAM certification. The owner can, with this kind of building, attract a very high paying tenant.

The building developer and owner AXA Belgium, established a property fund with the purpose to build the very high quality building. The first idea was to build a passive building and then the contractor suggested to convert it to NZEB with BIPV, the project was realized with 6 months later than scheduled due to additional work studying the technical feasibility of NZEB and the additional costs. The added cost for BIPV was 400 k€ relatively to the original approved budget. No specific incentives for BIPV were used. The size of the installation was not determined by aesthetics or by the financial analysis.

ISSOL installed and designed the BIPV system with ASSAR architects. For ISSOL and ASSAR architects, the building project is a showcase that contributes to a greater acceptance for BIPV technology and attracts new customers. In addition, the project offered learning opportunities for the stakeholders involved.

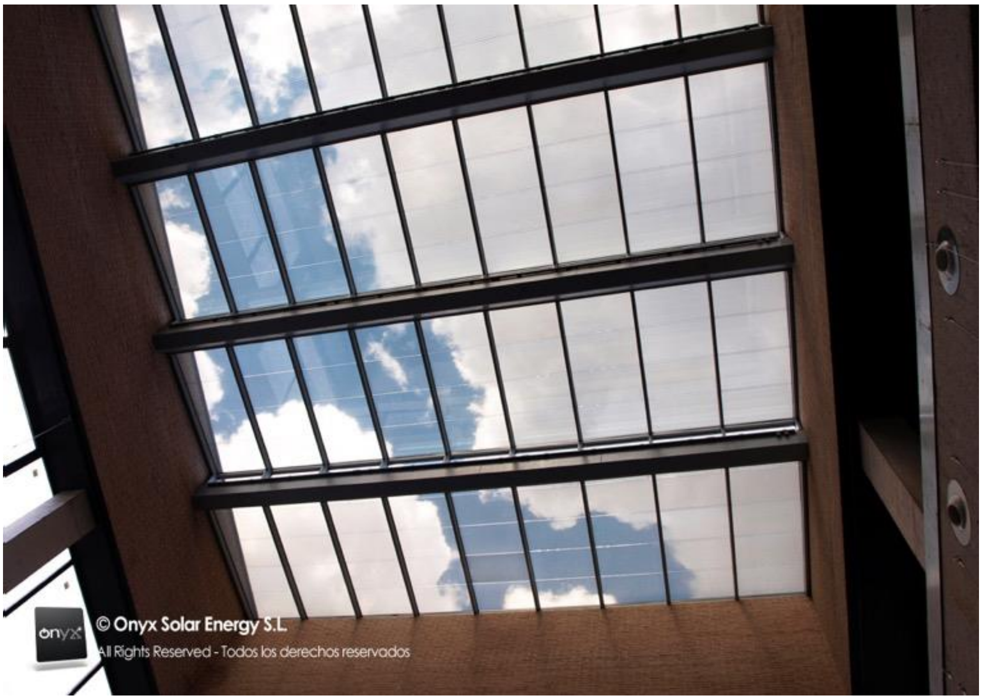
The facade modules were manufactured to fit the building. The front glass used for the BIPV facade modules is a structured patterned glass Albarino P. The glass has a deep textured surface which, in addition to reducing glare, increases PV module efficiency.

The building is rented by an agency and the tenant is in charge of the maintenance of the BIPV system. Initially the tenant faced some problems with the maintenance as the glass cleaning service was scared to break the glass and refused to clean it. This issue was resolved by informing the cleaning service about the acceptable load on the glass sheets of the PV modules compared to the load of the cleaning system.

The Treurenberg building won a MIPIM Award in the category "Best Innovative Green Building" at the MIPIM Awards 2016.

Lessons learned

The lessons learned related to the business model are the importance of teamwork between business partners with different competence and levels of experience. A good collaboration can create optimal solutions and each partner will become more knowledgeable and experienced.



Facts and figures

Type of installation
Skylight

Building type
Refurbished commercial building

Year of installation
2010

Size
Area: 168 m^2
Installed power: 6.5 kWp
Product dimensions: 3.22 m^2
(2 810 x 1 147 mm)
Double glazing system
(6+3+6 / 12 / 6+6)

Incentives for PV or BIPV
None

Investment cost
117 600 € (700 €/m²)
(modules + structure + BOS)

Cost comparison
Higher than ordinary skylight

Electricity production
7 700 kWh/year

Level of self-consumption
100 % of produced PV electricity is self-consumed

Electricity revenues
Self-consumption: 0.12 €/kWh

2.5 San Antón market, Spain

The building is a traditional market in the center of Madrid (Spain), owned by Madrid City Council. A refurbishment project was initiated by the Association of Traders of San Antón Market. The idea of BIPV skylight came from the architects in charge of the project as part of the refurbishment work performed in 2010. The motivation for this choice was the combination of energy production, natural light and passive properties offered by the solution. The system includes tailor-made amorphous silicon PV glass modules with 20 % transparency in double glazing configuration, manufactured in Spain by Onyx Solar, with an installed power of 6.5 kWp (168 m^2) and 7 700 kWh annual power production.

Business model summary:
Multi-functionality was highly valued by the stakeholders. The installation provides a brand image of green identity and modernity.

Business model

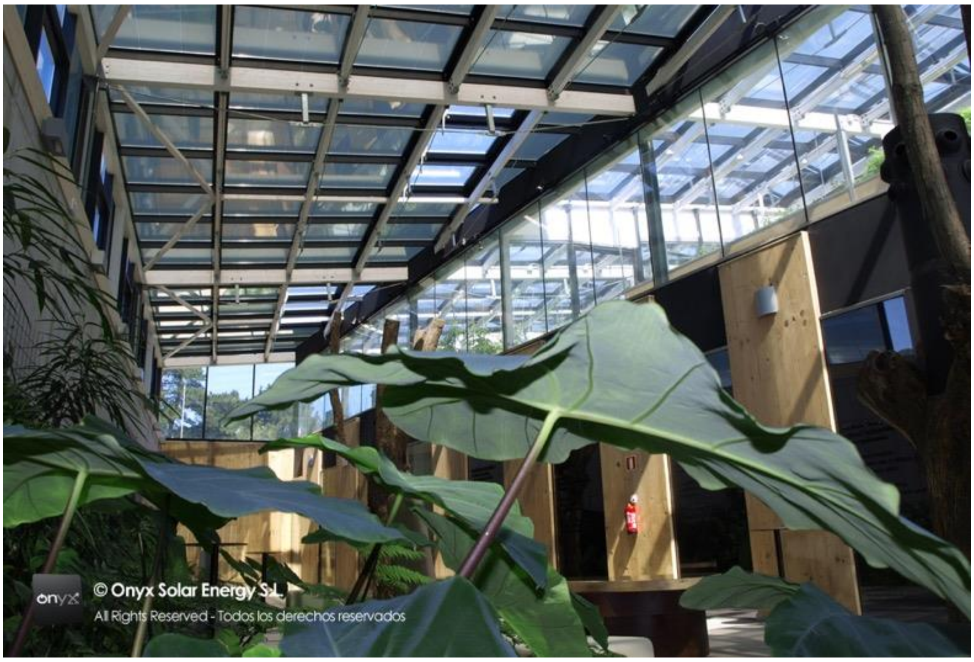
The building is owned by Madrid City Council. The refurbishment project was initiated by the Association of Traders operating in the market. The whole refurbishment work was funded by several organizations, including Madrid City Council, but no specific funding for BIPV was available. No legal incentives for PV or BIPV were used. The generated energy is 100 % self-consumed within the building.

The proposal to include a BIPV installation was made by the architect in charge of the project during the early design stages. The architect convinced the Association of Traders to work with the manufacturer Onyx Solar through the construction company Geocisa. The PV system was designed jointly by Onyx Solar, the project architect and the construction company. The aluminium mounting structure was manufactured by Schüco.

Multi-functionality with the passive benefits (natural lighting, thermal insulation) and energy production) offered by the solution was highly valued in order to take the decision to install BIPV. The integration of renewable energies along with energy efficiency in a traditional building provides a brand image of modernity which is highly valued for the traders operating in this market area.

Lessons learned

As explained above, it was extremely important for all the stakeholders to be fully aligned with the BIPV installation details and owner's objectives. The interest for BIPV by a specific person or group was needed to keep BIPV on track and push the project, even in the case where the property belongs to a public institution. It is also worth mentioning that no specific funding for BIPV was needed, since more important factors were the aesthetic aspects, the multi-functionality capability, the environmental and eco-friendly public image (brand image), which could improve the business expectative of a given stakeholder/sector (e.g. Association of Traders of San Antón Market). The complexity of actors and stakeholders in the decision process could make the whole project, from the design to final installation, take longer time. Thus, collaboration is important and as demonstrated in this case study, the complexity of decision process was not a definitive barrier for the BIPV system.



Facts and figures

Type of installation
Skylight and curtain wall

Building type
Refurbished commercial building

Year of installation
2014

Size (BIPV)
Area: 200 m²
Installed power: 21 kWp
Product dimensions: 2.3 – 4.4 m²
Double glazing system
(6+3+6 / 12 / 6+6)

Incentives for PV or BIPV
13% PV funding

Investment cost
385 000 € (770 €/m²)
(modules + structure + BOS)

Cost comparison
Higher than ordinary skylight/facade

Electricity production
16 400 kWh/year

Level of self-consumption
100 % of produced PV electricity is self-consumed

Electricity revenues
Self-consumption: 0.12 €/kWh

2.6 Iturralde Winery, Spain

The building is a winery, part of the Azurmendi complex in the Basque Country (Spain), including a three Michelin stars restaurant. The refurbishment project was initiated by the winery owner, who also took the initiative to include a PV installation in the building. The aim was to combine energy production with natural light entrance and passive performance. The final decision on the BIPV system was taken during an advanced stage of the design process. A BIPV semi-transparent curtain wall and skylight were integrated in 2014, based on amorphous silicon tailor-made modules manufactured by Onyx Solar. The total installed power is 21 kWp, with 16 400 kWh produced annually. Both the design and the installation of the BIPV system were done by Onyx Solar. The building is LEED-Gold certified and was awarded as "World's most sustainable restaurant" in 2014 by the "World's 50 best restaurants" magazine.

Business model summary:
Multi-functionality was highly valued by the stakeholders. The BIPV installation provides a sustainable brand image and contributed to receiving the award *"World's most sustainable restaurant"*, which made the restaurant widely renowned.

Business model

The decision to install a BIPV system was initiated by the owner, with the objective of maximizing sustainability and energy efficiency within the building and obtaining LEED certification. The global design was performed by an architect firm. The BIPV system was manufactured and installed by Onyx Solar, contracted by the building company in charge of the works.

The PV installation was partially funded by the Basque Energy Agency (Basque Government), through its support program for investments on renewable energies. The program supports the costs related to modules, mounting structures, fixing elements and interconnections, up to a total nominal power of 100 kW. It covers up to 30 % of the total costs, with 7 €/Wp for 5 kW and 1 €/Wp for the remaining power. The size of the installation was not influenced by this financial support.

The energy production of the 21 kWp installed is self-consumed to 100 %, where one part of it; 3.6 kWp is used to power in-house storage heaters.

The multi-functionality and the passive benefits, i.e. natural lighting, thermal insulation and energy production offered by the solution were highly valued in order to take the decision to install BIPV. A sustainable brand image for the winery and the restaurant is highly valuable and the BIPV installation contributed to a large extent to the “World’s more sustainable restaurant” award and the restaurant becoming widely renowned.

Lessons learned

Although there was public funding partially supporting the CAPEX of BIPV installation, financial support is not usually the main motivation for this sort of PV systems. A project of a BIPV installation initiated by the building owner can have different motivations, and in many cases the brand image is improved. In this case, this sustainability image has even been awarded, which has become a key drive for the restaurant business.

Facts and figures

Type of installation
Full roof (renovation)

Building type
Residential

Year of installation
2016

Size
Area: 90 m^2
Installed power: 12 kWp

Incentives for PV or BIPV
VAT refund, subsidies issued by local government (province or municipality)

Investment cost
23 000 € (250 €/m^2)

Cost comparison
Cost of BIPV is comparable to an ordinary roof with BAPV

Electricity production
10 600 kWh/year

Level of self-consumption
N/A

Electricity revenues
Self-consumption: 0.2 €/kWh
Fed-in electricity: 0.20 €/kWh

2.7 Single-family house, The Netherlands

This villa is situated in Ulestraten, close to the city of Maastricht in the South of the Netherlands. The owner (scientist and entrepreneur) was looking for a sustainable investment that could cover the relatively high energy use of the dwelling. That in combination with a need for a roof renovation led to the choice of an electricity-generating roof covered with PV modules. As a result, the roof has been renewed with 92 Solar Frontier modules, standard thin film (CIGS) modules, which are part of the full roof BIPV solution. The electricity that the BIPV system generates is used for the heat pump of the swimming pool, the electric car and household electricity.

Business model summary:
An initial drive of making sustainable impact, combined with the need of roof renovation, led to a straightforward profitable investment, with a payback time of about 8 years. The added value of green status has not been quantified.

Business model

The private homeowner of this BIPV solution wanted a sustainable investment and was already convinced of the application of PV. At the same time, there was a need of a roof renovation. The BIPV rooftop solution of BEAUsolar offers an integrated solution for both aspects of the decision to adopt BIPV.

The project was realised on time and within budget. The investment was 250 €/m^2, which is comparable to other BIPV solutions. [1]

The expected payback time of the investment is about 7-9 years, whereas about 5 years applies for BAPV.

Two additional economic incentives applied to this case but were not decisive in adopting the full roof BIPV. First, it has been calculated that energy costs will increase significantly in the coming years due to an increase in energy taxes. In addition to VAT, an energy tax and a Sustainable Energy Allowance must be paid over the costs for gas and / or electricity (the revenues from the Sustainable Energy Allowance are invested in energy efficiency by the Dutch government). Secondly, there is a net metering scheme that raises the value of excess electricity to the same level as self-consumption;

average 20 cents per kWh, price level 2017. This netting arrangement applies in any case up to and including 2019 (may be extended until the end of 2023).

The BIPV solution of BEAUsolar was installed without participation of an architect or main contractor. The supplier, BEAUsolar, offered a one-stop-shop solution involving the design, engineering and installation of the BIPV. Onsite labour was subcontracted and included removing (parts of) the existing roof and installing the BIPV. BEAUsolar is considered a technology start-up and the building is a showcase of innovative BIPV which received publicity. This type of homeowners are considered a niche market in the Netherlands and the projects conducted in this segment are used to improve the architectural design of the BIPV installation. The design is considered a key aspect to further upscaling BIPV in the private housing sector in the Netherlands.

Lessons learned

The alternatives to a full roof BIPV solution installed in this project would be an ordinary roof renovation with BAPV on top. The perceived advantages of the BIPV solution include:

- Technical advantage: provides a high quality, integrated solution for refurbishing the pitched roof and installing PV. BIPV turns out to be competitive with BAPV when it is combined with a roof renovation. Therefore, BIPV needs to be offered in-time to make the combination possible.
- One-stop-shop: single entity responsible for the design, engineering and installation of the BIPV.
- Aesthetic design: the design is preferred over BAPV (all-black, plain level design of the surface).
- Structural design: the BIPV only weights 15-16 kg/m2 which is less than conventional roof covering (tiles).
- Flexibility: despite a variety of possible obstructions in the roof surface (roof ducts, skylights, and dormer windows) the modular design offers flexibility to cover several roof typologies.
- Time: the BIPV is installed within 4/5 days. The lead time of the project, design, engineering and construction encompass 6 weeks.
- Financial feasibility: relatively short payback period of about 7-9 years; transparent cost overview, no additional cost afterwards.

To get the BIPV accepted and adopted in the market, it was learned that because of its innovative nature, potential clients need to be convinced of its maturity. Next, showcases not only create awareness of BIPV but also help potential clients to understand how the BIPV looks like. It is equally important to frame the BIPV in the correct way: ‘integrated PV’ versus ‘aesthetic roof covering producing energy’. In addition, it remains challenging to convince homeowners to adopt and install BIPV. Installing BIPV initiated by a homeowner can have different motivations and financial schemes (subsidies, energy saving loans, et cetera) are not always decisive. Market consultation has been mentioned to increase the understanding of individual based decision-making and bias against BIPV.

2.8 Multifamily residential building, Austria

The building is a private multifamily building from the beginning of the 20th century in the city of Innsbruck, Austria. The roof integrated PV plant of 5 kWp was installed by Becker ATB PHOTOVOLTAIC GmbH for the house owner in 2013. The main drive for this installation was to produce green electricity for self-consumption with a lower price than public electricity prices for households.

Facts and figures

Type of installation
Roof

Building type
Residential

Year of installation
2013

Size
Area: 33 m^2
Installed power: 5 kWp
Product dimensions: 1,66 m²
(1,68 x 0,99 m)

Incentives for PV or BIPV
20 % from Austrian Climate and Energy Fund

Investment cost
10 000 € (300 €/m²).
After subsidy 8 000 € (240 €/m²).

Cost comparison
N/A

Electricity production
5 000 kWh/year

Level of self-sufficiency
34 % of total electricity consumption (one household)

Level of self-consumption
24 % of produced PV electricity is self-consumed

Electricity revenues
Self-consumption: 0.12 €/kWh
Feed-in electricity: 0.09 €/kWh

Note: This was an early installation. The aesthetic requirement of future BIPV solutions are considered to be higher.

Business model summary:
BIPV was chosen over BAPV for improving the aesthetics and snow clearance; i.e. easier and faster snow slip off with BIPV compared to BAPV. The installation of this BIPV plant was not implemented within a roof renovation. If done so, savings from material replacement may reduce net costs for BIPV to a level comparable to BAPV.

This example highlights the need to increase self-consumption by expanding the use of BIPV electricity to other apartments in the same building (which applies also to BAPV installations on residential buildings) and to install roof-integrated PV as part of roof renovations.

Business model

The private owner of the multifamily house invested in the BIPV plant. The roof-integrated BIPV plant was installed for aesthetical reasons and for moving in direction of a more sustainable building with green energy production. This system also ensures optimal rain water discharge and snow clearance.

The owner was advised and supported by Becker ATB PHOTOVOLTAIC GmbH. ATB Becker designed and installed the plant with Solarwatt 60P Easylyn 250Wp modules (poly-si). Maintenance and operation of the plant is done by the owner with support by ATB Becker, if necessary. Operational and maintenance expenditures are very low, at the moment no maintenance contract exists. A change of the inverter after 10 – 12 years has to be considered. This will again be done by ATB Becker.

The whole investment was about 10 000 € (in 2013). The owner received an investment incentive from the Austrian Climate and Energy Fund (400 €/kWp). If the installation of a roof-integrated PV plant is implemented as part of a roof renovation by substituting part of necessary roof tiles, costs for reduced tiles can be deducted.

The annual electricity production by the BIPV plant is about 5 000 kWh, of which around 24 % can be directly used by the owner, the remaining electricity is fed into the grid. The economic benefits for the owner are related to lower electricity costs with the BIPV plant in comparison to the electricity tariff for households (IKB 2017: 18.25 cent/kWh). The feed-in tariff (FIT) paid by IKB is 8.5 cent/kWh.

Levelized Costs of Electricity (LCOE) over 25 years (discount rate of 2%) have been calculated for three cases[1]:

1. based on the total investment in the PV plant without governmental subsidies: **11.6 cent /kWh**
2. total investment reduced by governmental subsidies: **9.4 cent/kWh**
3. in addition, considering potentially saved costs for reduced need of roof tiles (€40/m^2 tiles): **7.9 cent/kWh.**

Here, case 2 applies for the BIPV plant owner. The owner would like to expand the direct consumption to other residents of the multifamily house, however up to now this has not been possible.

Lessons learned

In this business model, self-consumption of produced electricity on-site is limited, due to legal restriction regarding delivering electricity to other apartments in the same building. This recently changed with an amendment of the Austrian General Act on Electricity (Elektrizitätswirtschafts- und Organisationsgesetz 2010 ElWOG) on June 29th 2017. So, in the future, electricity from a PV plant of a multifamily house can be distributed to residents interested in using on-site produced green electricity. Certain conditions apply and there is still a need to clarify and adapt linked regulations.

This roof-integrated plant was installed already in 2013. More attention will have to be paid to good aesthetic solutions for future BIPV roofs. To reduce costs and make these systems interesting also in the social housing sector, such installations should preferably be implemented as part of roof renovations or on new buildings. The social housing sector has a high potential for future BIPV installations in Austria, if low budget solutions can be found.

[1]Based on net present value methodology as described in e.g., Fraunhofer ISE: Stromgestehungskosten erneuerbare Energien, FRAUNHOFER-INSTITUT FÜR SOLARE ENERGIESYSTEME ISE, November 2013, p36f

2.9 Residential/commercial buildings, France

Facts and figures

Type of installation
Roof

Building type
Residential/commercial

Year of installation
2016

Size
Area: 60 m²/20 m²
Installed power: 9 kWp/3 kWp
Product dimensions: 2.2 m²

Incentives for PV or BIPV
Leasing contract of 15 years with EDF

Investment cost
N/A

Cost comparison
N/A

Electricity production
N/A

Level of self-sufficiency
During first 15 years, all electricity is sold to the grid.

Electricity revenues
N/A

BIPV as part of the roof was installed on 4 buildings in Pont de Cheruy, a village near Lyon in France. In all cases standard sized modules were used. Two of the buildings have a mix of residential and commercial occupancy and have BIPV of 9 kWp each, where the BIPV consist of 27 modules and covers 60 m². Another two individual buildings have a BIPV installation of 3 kWp each, where the BIPV systems consist of 9 modules and covers 20 m².

The building developer accepted a proposal from EDF to rent out the roof for 15 years. That was the main drive for the decision to install BIPV. EDF in turn profits from the high feed-in tariff in France, for electricity produced with BIPV.

Business model summary:
This example shows a PV business model that is very convenient for the building owner (renting out the roof). The main drive is the revenue for the utility, but there are also green values which have not been quantified. BIPV was chosen instead of BAPV due to the, at the time, favorable BIPV incentives and feed in tariffs in France.

Business model

The utility EDF owns the system during the first 15 years and is also in charge of maintenance and operation. All electricity produced by the BIPV system is sold to the grid. After 15 years, the building owner becomes the owner of the BIPV installation and gets the benefit of electricity production. The BIPV system was designed by EDF and the building developer together.

The BIPV system was funded by the utility EDF and a rental fee for the roof space is paid to the building owner. For the building developer, there were no additional costs or burden of installation. An additional value is the green identity, with an expected higher resale value of the buildings. BIPV was the only solution eligible to benefit from the roof leasing contract, due to the favorable feed-in tariff for BIPV. The situation in France is currently evolving to a less favorable situation for BIPV compared to BAPV. Since 2017, self-consumption is most favorable with new regulations (see Chapter 4).

Lessons learned

The “leasing roof scheme” was very favourable at the time the project was achieved.
It is very straightforward for the building developer and building owner as the design, paper work, and construction of the PV installation are taken care of by EDF. Moreover, during the first 15 years, EDF ensures the maintenance. Considering that common quality issues (infant mortality of a component or problem of implementation at the PV system level) occur in the first months or years of a PV installation; this is a safe way to have PV on one’s roof without having to deal with possible technical problems.
After the contracted 15 years the installation becomes property of the building owner who will then be responsible for the service of the inverter.

This business model was safe and simple but it is no longer available in France today since it can no longer be driven by favourable feed-in tariffs.

Facts and figures

Type of installation
Roof

Building type
Residential

Year of installation
2016

Size
Area: 3 m^2
Capacity: 0.5 kWp

Incentives for PV or BIPV
National regulations on energy performance in buildings.

Investment cost
2 500 € (830 €/m²).
(claimed by building developer)

Cost comparison
Significantly higher than standard roof tiles.

Electricity production
N/A

Level of self-sufficiency
Low percentage of total electricity consumption.

Level of self-consumption
100 % of produced PV electricity is assumed self-consumed

Electricity revenues
Self-consumption

2.10 Single dwellings semi-detached houses, France

BIPV as part of the roof was installed in a residential area with new individual houses in France. In the first part of the area, installations were made in 2012 when 41 BBC Houses (Low energy Building RT 2012) were built with 16 m² PV tiles. The 50 BBC houses built in 2016 in the second part of the area, had installations with 2 PV modules as shown in the picture.

The BIPV installation was motivated by the building developer as an asset to sell to the customers, especially since the price of the houses was similar to a house without PV. Another reason was to comply with the EPBD.

The Energy Performance in Building regulation in France (RT 2012) requires a minimum of 5 % of RES in all new construction, and limits the level of primary energy consumption to a certain level according the climatic zone (roughly between 50 to 100 kWh/m²/year). A PV system on the building allows for a bonus of 12 kWh_{pe}/m²/year.

Note: This was an early installation. The aesthetic requirements of future BIPV solutions are considered to be higher.

Business model summary:
For the building developer, PV was a way to comply with national regulations on energy performance and also gain green value. For the owners, the installation was not noticeable in the total price of the building. BIPV was chosen over BAPV because of more favorable regulation regarding tax reduction.

Business model

The building developer GANOVA, a family company, was mainly involved in the process and took the decision to install BIPV and also designed the system. The buildings with BIPV systems were sold and are now privately owned. The electricity produced is used to cover part of the basic demand of the houses.

The cost of BIPV was integrated in the building price. At the time of the project start in 2014 there were favourable incentives for BIPV in France in terms of Feed-in tariff and tax reduction. The construction company estimates that BIPV is an asset to sell BBC houses, especially when the offer is at the same price as similar houses without PV. An additional value is the green identity with an expected higher resale value. The investment cost given by the building developer is considered overestimated as it is used as a sale argument for the buyer. The actual cost is most likely half or even lower than that.

The green value and the use of locally produced modules (French PV manufacturer Photowatt) were the main arguments for the small construction company to install BIPV. The size of the installation, small size standard technology with microinverter (Enphase), was influenced by the deal between the PV manufacturer and the construction company buying about 100 BIPV systems. They opted for a conservative solution: small unit, only 2 modules with standard technology (500 Wp), where the generated electricity is self-consumed.

Both the investment cost and the expected savings (200 €/year) given by the building developer are considered overestimated, as they were used as a sale argument for the buyer. The actual figures are most likely half or even lower than that.

Lessons learned

At the time of the project start in 2014 there were favourable incentives for BIPV in France in terms of Feed-in tariff and tax reduction. As a consequence, the installers tend to sell at very high cost compared to neighbouring countries.

The legal incentives for PV have recently changed and there is no longer a tax credit for BIPV alone in France. However, there is an upgrade of the allowed maximum primary energy consumption of 12 kWh/m²/y for buildings with PV.

In this case the electricity is self-consumed, so for the constructor, the system is simple and there is no extra cost for grid connection.

The building owner seems to be happy to have PV on their roof (green identity) even though the savings are not very significant today, as the price for electricity is low in France.

3. Status of BIPV Business Models

A business model is essentially a way to describe how value is created, delivered to the customers and partly captured by the company to generate profit. Hence, it includes for example information regarding the value proposition to the customers, the definition of target customers and how they are reached, the internal organization of the company, the external value chain or the profit equation.

3.1 A word on values

At the current early stage in development of the BIPV market, it is not essential to look into the details of how existing companies run their business, but at how the core of the business model – the value proposition – can be developed to create new business cases and companies. Thus, the focus in this report is to identify different value components and the driving forces behind BIPV installations, which could eventually become the foundation in new viable business models.

A predominant value of BIPV according to stakeholder is to reduce the world's dependence on fossil fuels and thus mitigate climate change. This is acknowledged by individuals and organizations as an emotional value and drive. In this context, a BIPV installation has the potential to bring a certain *green status* to the buildings and its stakeholders. To be considered a sound investment, many organisations also require the PV installation to be *profitable*. For standard PV installations, the main component in this regard is the electricity revenues, even though on certain markets, political incentives are still significant and disrupt the competitiveness evaluation of this technology, for example publicly funded investment subsidies and electricity sales bonuses. Usually, such incentives are given to PV in general, but there are examples where BIPV is specifically favoured. This is further described in chapter 4.

A comparison of the main value components of PV and BIPV is found in Table 1. However, BIPV - a building component with PV used to replace other materials - can and should not always be compared to BAPV. A comparison might as well be with the other building materials being replaced. Therefore, BIPV potentially implies additional cost savings – although the price of BIPV depends on the type of BIPV. A price comparison between PV roofs and façades on one hand and regular building materials on the other is found in the *Product overview for solar building skins.* [1] Furthermore, a BIPV installation usually comes with higher aesthetical aspirations than the ordinary PV installation. This aesthetic value could add significantly to the general status of the building and through this also improve its 'green' status. There might also be a *marketing value* attached to making the building 'green'. The combination of green status and aesthetics holds the potential of a substantial marketing value of the project as well as the final market value of the building.

***Table 1**. The main value components of BIPV compared to PV in general.*

	PV	BIPV
Basic value components	Electricity revenues Marketing value Status	Electricity revenues Replacing building materials Added marketing value Higher status
Additional public funding	Investment subsidy Tax reductions/exemptions Electricity sales bonus	Investment subsidy Tax reductions/exemptions Electricity sales bonus

An important parameter in the economic analysis of any PV installation on buildings is the different electricity revenues from self-consumption and excess production fed to the grid. Generally, the self-consumed electricity has a high value as the reduced electricity bill includes a reduction of energy tax and other additional cost parameters such as grid costs. The income from sales of electricity, on the other hand, is much lower and sometimes at the wholesale market price. In some countries, various types of publicly funded sales bonuses will make up for these differences, but in the long-term future it is likely that such bonuses will diminish (see further discussion in chapter 4).

As BIPV is often used to fill large areas, such as full roofs or facades, the problem with surplus electricity can be more prominent than for BAPV systems. On the other hand, when BIPV is used on many surfaces with different orientations, the level of self-consumption can be higher instead.

3.2 Analysis of the main drives of studied examples

The studied examples in chapter 2 cover BIPV facades, BIPV skylights and BIPV roofs and various building types. The focus of the analysis lies on values and drives in these examples that can serve as foundation for developing new business models for different building segments later on. The examples from chapter 2 can be divided into two categories, where the main drive for the BIPV installation is either *electricity revenues* or *green status*. The replacement of other materials was the main drive in only one case, but it has often helped to improve the economic output in both categories. In one case, the main drive was to comply with national regulations on energy performance, where an inclusion of PV was favourable. A summary of the examples is found in Table 2.

Table 2*. Summary of the examples in chapter 2.*

Case	Country	Building type	BIPV type	Architectural significance	Main drive
1	Denmark	School	Facade	Yes	Green status
2	Sweden	Residential	Facade	Yes	Green status
3	Norway	Office	Facade	Yes	Green status
4	Belgium	Office	Facade	Yes	Green status
5	Spain	Commercial	Skylight	Yes	Green status
6	Spain	Commercial	Skylight, facade	Yes	Green status
7	The Netherlands	Residential	Roof	Yes	Both
8	Austria	Residential	Roof	No	Electricity revenues
9	France	Residential	Roof	No	Electricity revenues
10	France	Residential	Roof	No	Green status

The main drive for example 8 and 9 are not so different from ordinary building applied PV (BAPV) installations. Apart from the emotional or status enhancing values of environmental awareness, the main economic drive was the electricity revenues. In the Austrian example, BIPV was chosen to (slightly) improve the aesthetics and to improve the snow clearance of the roof, compared to a BAPV installation. In the French example, there was a higher feed-in-tariff for electricity produced by BIPV systems in comparison with BAPV systems. This French case hence includes a strong policy-driven component, which will be discussed in the next section. It also provides an interesting business model demonstration, where the customer rents out the roof rather than making the PV investment and operating the system.

The examples 1-6 show higher aesthetic aspirations. The reduced cost for replaced materials contributes to the economical outcome, but the main drive identified is the status that comes along with the green identity. Examples 5-6 are special cases where the multi-functionality itself was a significant drive. Many of these cases also hold a significant marketing value, which was generally not initially recognized by the stakeholders. One interesting fact from the Swedish and Norwegian examples is that the added cost, even for a large PV facade, was below 2 % of the total cost of the building.

Example 7 is the case with the most balanced combination of electricity generation and status. The full roof BIPV installations were made to produce electricity at a competitive cost, after subtracting the cost of an ordinary roof. At the same time, the roof is highly visible with appealing aesthetics, which enhances the green identity.

Example 10 shows a different way to obtain green identity, with small PV systems on many buildings. The main drive for the building developer was improved status or green identity. The private persons buying the dwellings will also benefit from green identify – even though it can be questioned to which extent such small installations enhance the green status.

3.3 Description of applied BIPV business models

The analysis and descriptions developed in chapter 3.3 and 3.4 are based on previous initiatives on the same topic [2] [3]. The most straightforward business model for a BIPV installation focuses on cost savings from the replacement of other materials and from revenues from the electricity generation. A schematic description can be found below, highlighting the stakeholders involved and the relationships between them. Especially, examples 7, 8 and 9 can be put in this category, even though the cost savings from material replacements are low in these examples.

A slight variation of this business model exists, when the regulator provides a premium for every kWh of PV electricity fed-in to the grid, called a feed-in-tariff or feed-in-premium. This premium can be paid by the utility, the grid operator or the regulator. It is included in the figure via the dotted arrow.

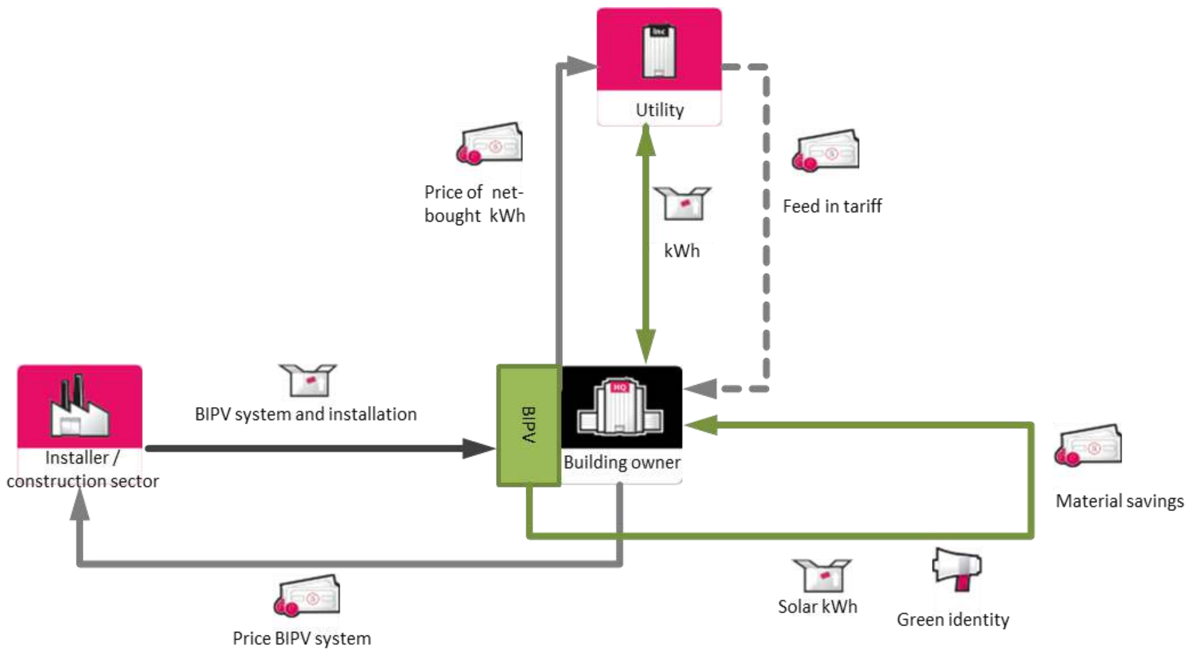


Figure 1 *Schematic description of a business model with electricity revenues.*

Note that even in the case where no premium is given for the feed-in electricity, the regulator can be involved in the business model. For example, by designing a law making the installation of renewable technology mandatory or cheaper than alternative measures to comply with energy performance regulations, as in example 10.

In one of the studied cases the ownership of the BIPV system and the building is split. In the French example 9, shown in figure below, third-party ownership is applied. The roof is leased by the utility EDF that keeps the ownership of the system for a determined period (here 15 years). EDF is also in charge of operation and maintenance and meanwhile benefits from the electricity production.

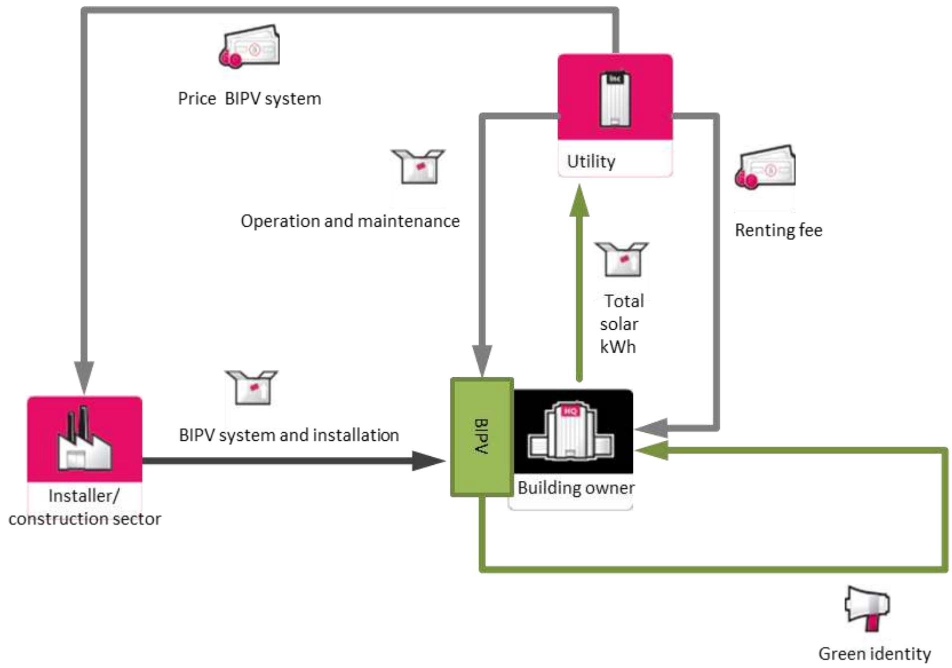


Figure 2 *Third party ownership*

Another version of third-party ownership would be when the system is leased under the form of an operational lease. The lessor, for example a utility, keeps the ownership of the system for a determined period and is also in charge of operation and maintenance, while the building owner pays a monthly fee to the lessor and benefits from the electricity production. This business model presents the advantage to overcome some barriers, such as the high upfront costs and the lack of access to capital. It also allows the building owner to limit the actual and perceived risk of investing in innovative technology. Finally, in case the investment is made by a company, it facilitates the financial reporting, as the asset is kept off the balance sheet. Note that multiple variations of business models based on third-party ownership exist. The one displayed on the figure below is only the most common of them.

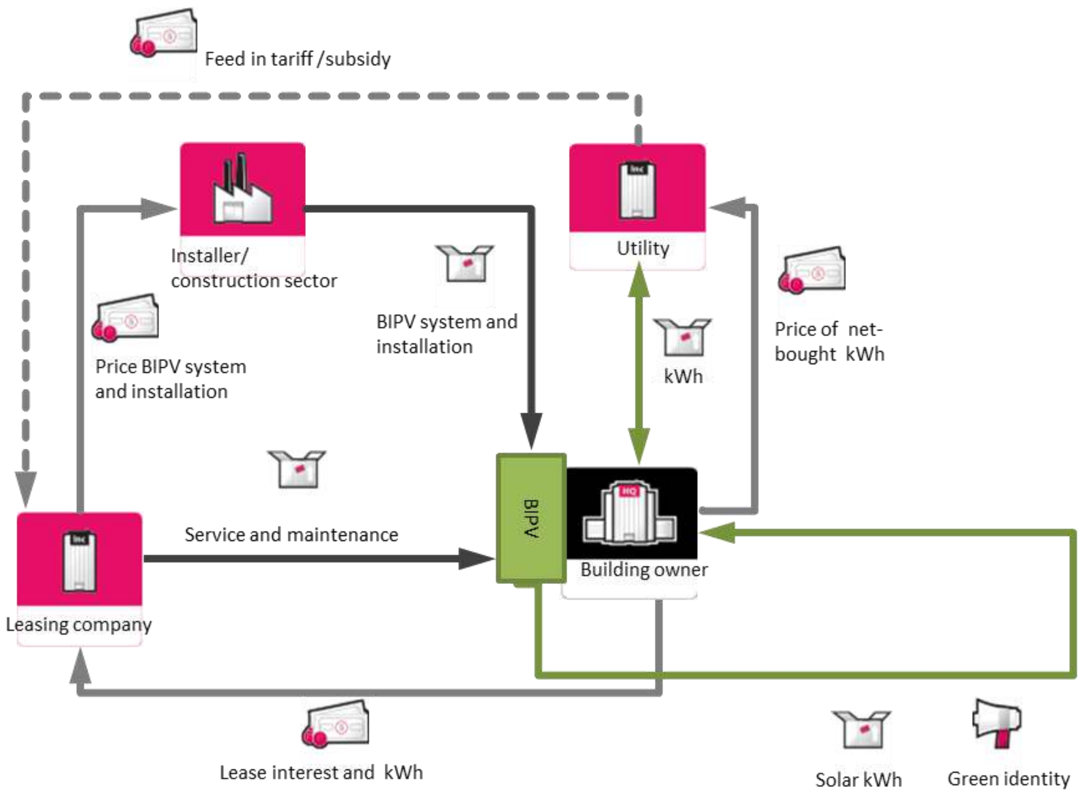


Figure 3 *Leasing arrangement*

Another kind of leasing is possible, called financial lease, where the ownership of the BIPV system remains to the lessee, in this case the building owner, whereas the lessor only provides financing, see figure 3. Consequently, some of the barriers mentioned here above are not overcome anymore. These business models based on third-party ownership are not widespread in Europe yet, but are quite frequent on other markets, such as the US residential PV market.

Finally, the last business model witnessed among the analyzed cases is the only one directly taking advantage of the “green status” associated with a BIPV installation. In the Norwegian example 3 and Belgian example 4, the building owner is able to charge a premium to the renters for occupying a building with a “green” identity and consuming renewable electricity. This is shown in figure 4. However, the time horizon required to recover the initial investment remains to be investigated. Moreover, such a business model could be unfeasible in practice, as in some countries or regions, rental market regulation is very strict and does not authorize landlords to modify level of the rents as they wish.

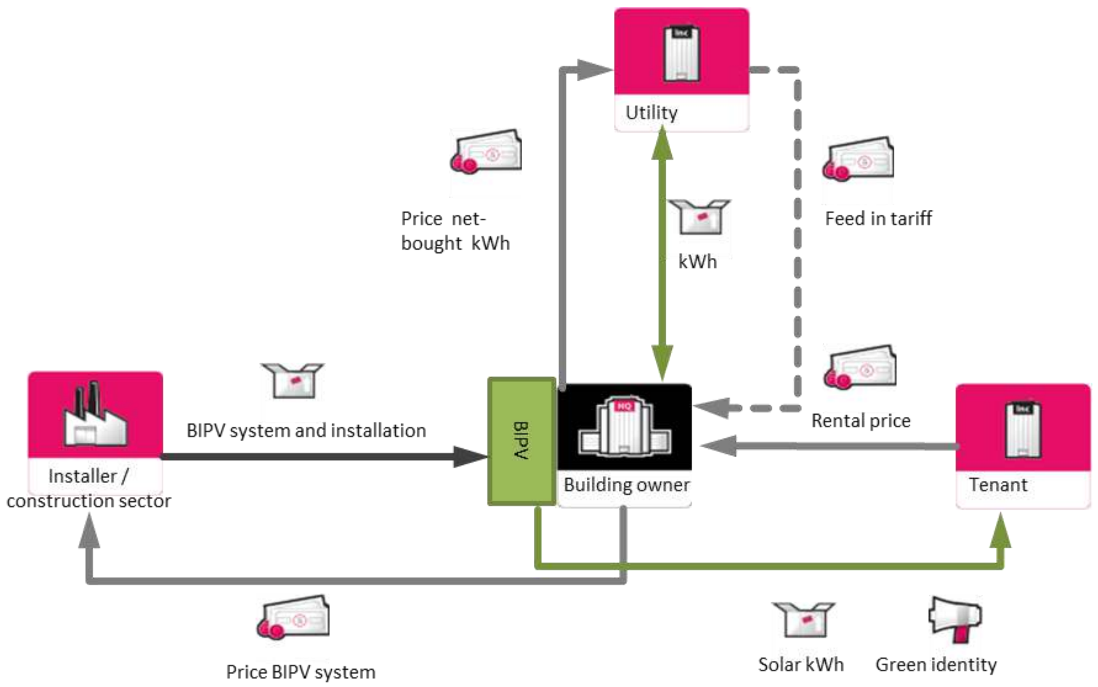


Figure 4 *Schematic description of business model with green identity*

One interesting insight from the examples is that, compared to the total cost of a new building, the added cost of an innovative BIPV facade can be quite low (only 1-2 % in the Swedish and Norwegian examples 2 and 3). Another is that the enhanced marketing value that comes along with the BIPV installation, mentioned in examples 1, 2, 4, 6 and 7, is seemingly high and generally underexploited although some owners have gained advantages. It is probable that this marketing value will diminish as BIPV becomes more common.

The ability to monetize this value of a green identity clearly differs between stakeholders. A school (example 1) or a public housing company (example 2) may not be able to increase their revenues as much as commercial stakeholders, who can gain from higher rental prices as in example 3. The green status could also be monetized by charging a premium when selling the building, as in example 10.

3.4 Other potentially viable BIPV business models

It is however difficult to assess the attractiveness of business models based on green identity, as there is no clear evaluation of the level at which the market values BIPV installation, the green status attached or simply the potential label(s) it contributes to acquire (e.g. BREEAM, LEED). Existing literature, investigating the sale price premium for buildings with a “green” certification and/or high energy performances on different segments and markets, demonstrates that it ranges from 3,5% up to 26 % more than comparable non-“green” buildings [4] [5] [6] [7] [8] [9]. However, in spite of being numerous, these studies fail to identify if this sale premium is in fact lower, equal or higher than the net installation cost, i.e. the extra investment minus the potential future revenues (e.g. energy savings), that such certification requires.
Consequently, it is advised to apply this business model cautiously. A possible solution to ensure profitability could be to look for a future buyer before the start of the project.

In future work it would also be interesting to examine how specialized businesses can improve the business model, like in case 1 where a new company was started to own the building and rent it out to the school and in case 4 where a property fund was established. Furthermore, it is likely that the

BIPV market could be stimulated by more service providers like in case 9 where the building owner simply rents out the roof.

The following paragraphs, highlights two kinds of business models which are currently non-exploited by BIPV manufacturers and installers.

The “on-bill financing” is a business model in which the financial investment in the BIPV solution is made by the regular utility company, shown in figure 5. It is quite similar to a financial lease. The customer then pays back the utility via its regular electricity-bill, which should be lower than before the investment was made, thanks to the energy savings from the BIPV installation. Such model could allow to overcome multiple barriers (high upfront costs, low access to capital, lack of awareness and confidence, risk aversion).

Some utility companies have been reluctant to widen their range of activities, seeing renewables as a threat. Hence, it would be the occasion for them to leverage their brand recognition and existing, privileged relationships with end-users. It would certainly lower transaction costs and customer-acquisition costs, which are usually high in the case of investments in new technologies. In addition, it could improve their image towards the public. Also, a strong advantage of such model is that the installation would be linked to the meter, so in case the building is sold or the occupant changes, the contract can be maintained.

The main disadvantage being that it is not the core business of utilities at all, and they lack the technical and legal know-how. But they have the resources, financial and human, to try such business model out. Furthermore, key partnerships are possible. For example, ENGIE, a multinational electric utility company, recently installed the biggest BIPV system with organic PV in the world on the roof of a school in La Rochelle, France [10]. This was done in collaboration with Heliatek, a German manufacturer of organic flexible solar films.

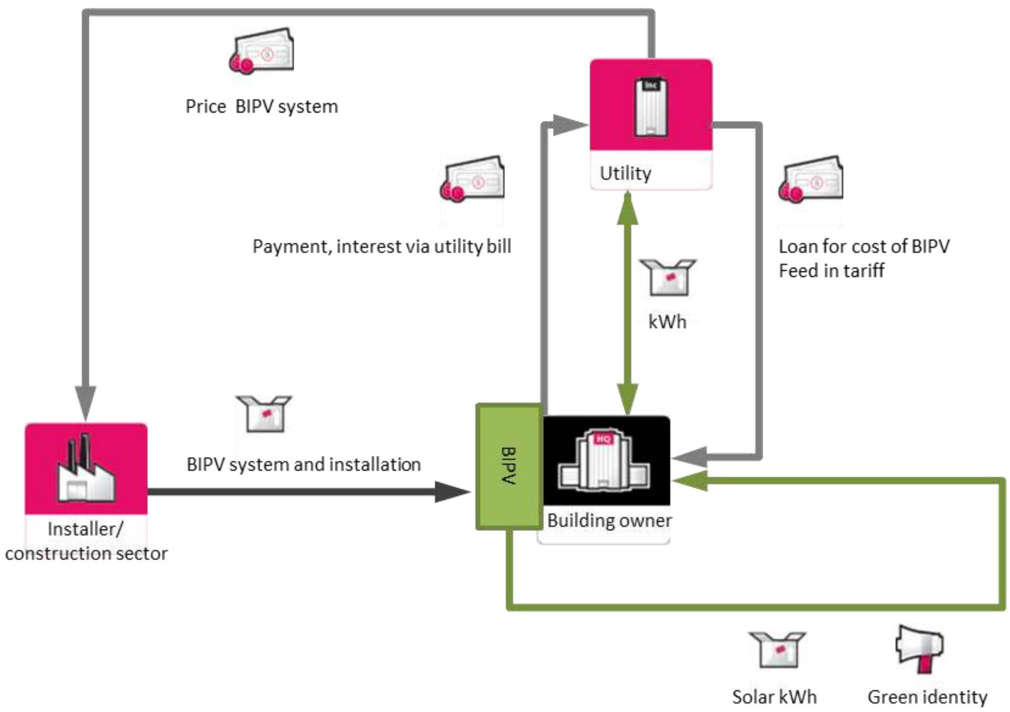


***Figure 5** On-bill financing of BIPV.*

Finally, the installation of the BIPV system, its exploitation, monitoring and maintenance, as well as the electricity it generates, can be part of a product-service system. It means that it is included in a larger package of services provided by the energy services company (ESCO), see figure 6. These additional services can be, for example, energy monitoring inside the building, development of demand-side-management tools or solutions to save energy and maximize the use of PV electricity. Such company could also take the role of utility by supplying (green) electricity. Another possibility would be for the ESCO to establish a Power Purchase Agreement with the building owner. It means that for a certain period of time, typically 5 to 10 years, a contract is signed between the two parties who agree on a fixed electricity supply cost in €/kWh. This contract also defines a quantity of electricity to be provided per year, which can cover the totality of the production of the BIPV system or only a certain share, typically 75% to 90%. The remaining share will be sold by the ESCO on the spot market or to another customer.

Under this business model, the ESCO can possibly take charge of the financing of the required investments, among which the BIPV asset, for example under the form of a lease. The main advantage of such solution is that the risks associated with the investment, i.e. the technical and the economic risks, are outsourced by the final customer to the ESCO [11]. Note also that in this case, potential subsidies to which the owner of the BIPV system is eligible, are flowing to the ESCO and not to the final customer, i.e. the building owner. However, as part of the remuneration of the ESCO, it can contribute to reduce the final cost of the services package.

This kind of business model has high potential even though it is complex and requires the use of standardized BIPV products.

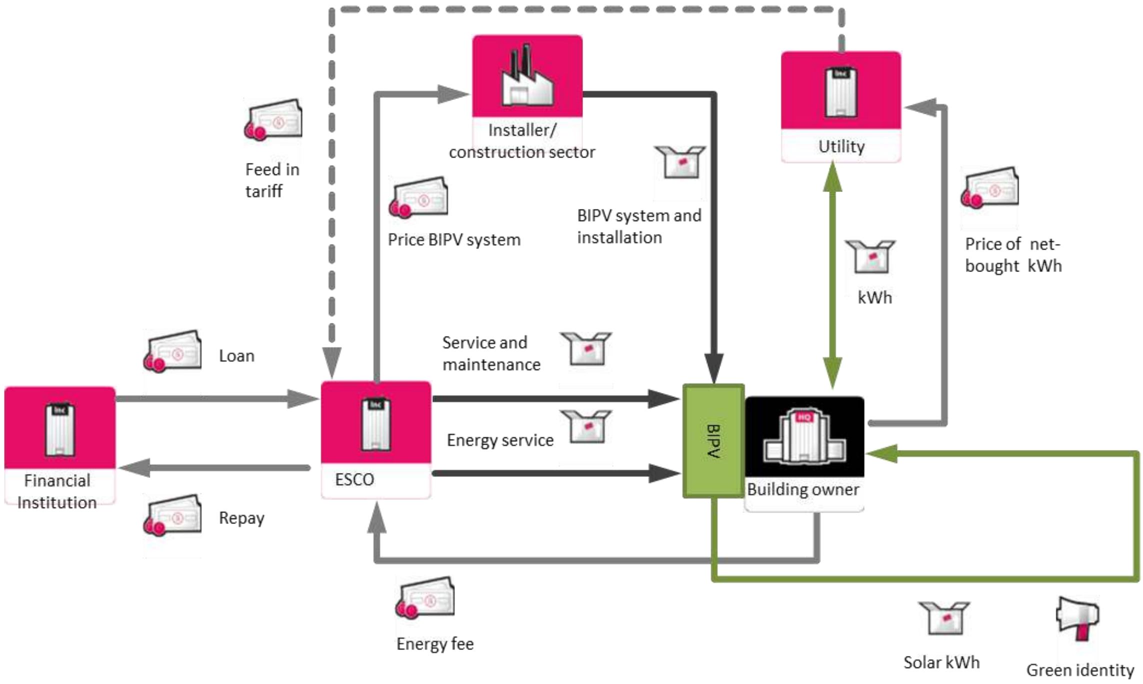


Figure 6 *Energy- contracting model with ESCO financing BIPV.*

4. Regulatory environment

4.1 Main barriers to the development of innovative business models

Main barriers to the development of new business models for BIPV applications have been identified and can be found in Table 3 below. These are based on the discussions between the participants of the IEA PVPS Task 15, with BIPV professionals and customers interviewed at the occasion of business cases' collection, as well as on other studies investigating the same problematic [2] [12] [13] [14] [15].

***Table 3**: Recapitulative table of the main barriers to the development of innovative business models for BIPV*

Structural & regulatory barriers	Economic barriers	Technical barriers	Socio-psychological barriers
Lack of collaboration between stakeholders	Additional cost of BIPV in comparison with BAPV and regular construction material	Lack of field data on degradation and performances	Lack of knowledge among professionals of the construction sector
Complex and inappropriate regulatory framework	Lack of possibilities to monetize electricity production	Lack of standardized products	Lack of awareness among the public
Unstable regulatory environment	Lack of valorization of renewables in the built environment	Lack of clearly defined maintenance procedures	
Lack of standards and codes combining PV and building requirements			

Regulatory and socio-psychological barriers mostly influence the confidence of investors and final customers, which directly impact the amount of time and resources that BIPV manufacturers and installers must spend to settle a contract, as well as their ability to secure financing. Economic barriers, on their side, refer to the profitability of the investment and the possibilities to value BIPV. Finally, technical barriers mentioned here have an effect on business models as they directly impact the installation process and its cost. Some of these barriers, namely the lack of standards and the lack of field data, also negatively influence potential investors and final customers, leading to similar consequences as mentioned here above.

4.1.1 Multiplicity of stakeholders

One of the main issues when it comes to BIPV, as mentioned in the previous subsection, is the multiplicity of stakeholders involved in the projects. Indeed, BIPV installations are at the crossroads of the PV, construction and electricity sectors. The figure 7 below is a "Stakeholder map", which displays all stakeholders involved in the manufacturing, installation and operation of BIPV systems and its components.

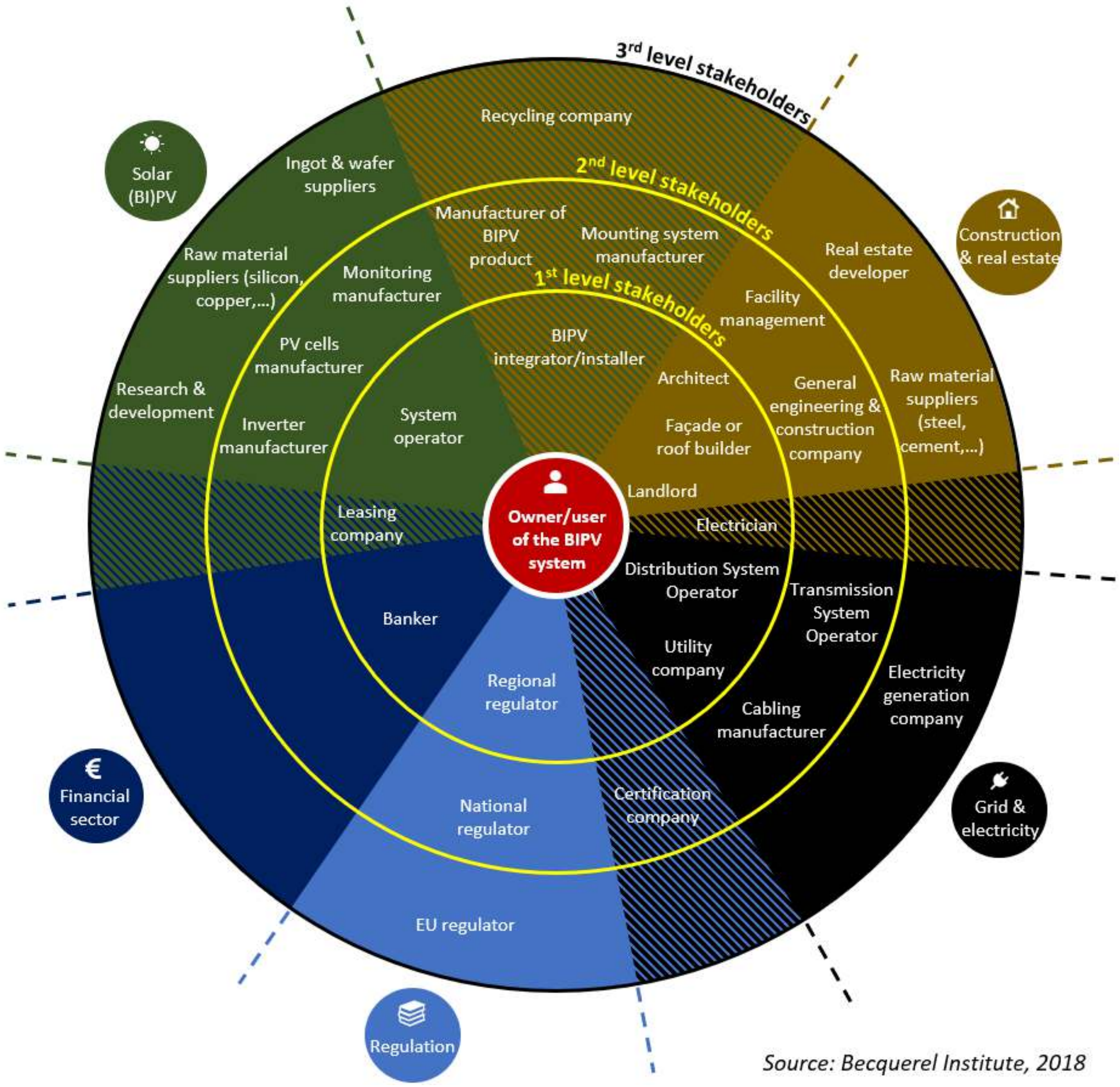


***Figure 7**: "BIPV stakeholders map: from production to operations" [19]*

They are categorized according to a three-level scale: 1st level stakeholders are directly in touch with the owner and/or final user of the BIPV system, whereas 3rd level stakeholders have the least links with the final customer and stand further away in the value chain. These stakeholders are also classified based on their sector of activities, and some of them can be considered as belonging to two sectors, such as BIPV manufacturers and installers, which are part of both the solar PV and construction sectors. Note this infographic only aims at providing an inventory of all possible stakeholders involved in the development, installation and operational life of a BIPV system, in order to demonstrate how complex it can be. But from one project to another, and from one BIPV product to another, stakeholders involved can vary a lot. It depends on, among others, whether it is a new construction or a renovation, if the installation of BIPV product is made by manufacturer or via a partner, if the financing is done by debt and/or equity, if the investor is the final user or not, etc.

4.2 Inventory of regulatory environment

This section introduces the regulatory environment identified for different markets. These studied markets are Austria, Belgium, Denmark, France, Spain and Sweden. The regulatory environment describes the main regulatory measures that can influence the profitability of a BIPV installation. Some parameters refer to PV-specific regulation (BAPV or BIPV), building-related laws or the environmental regulation. This collection of information will be used for the development of new business models as well as recommendations.

Note that the tables below are based on a methodology developed by IEA PVPS Task 1 experts in the report *« Review and Analysis of PV Self-Consumption Policies »* published in 2016. To guarantee readability, a summary of the regulatory framework for each country is displayed in table 4. Further explanations can be found in Appendix 2 when necessary.

Table 4

	Parameter	France	The Netherlands – Residential	The Netherlands – Commercial & Industrial
PV Self-consumption	*Right to self-consume*	Yes	Yes	
	Right to self-consume (collective)	Yes within the same low voltage network and if the parties involved gather under a common legal entity (company or association)	No	
	Revenues from self-consumed PV electricity	Self-consumption bonus (function of kWp and paid for 5 years)	Savings on the electricity bill	
	Charges to finance grid costs	Exemption of local and national grid costs	The grid companies do not charge PV owners a connection fee of any kind	
Excess PV electricity	*Revenues from excess electricity*	10c€/kWh P<9kWp 6c€/kWh P>9kWp No revenue in case of collective self-consumption	Full retail electricity price not exceeding own consumption over a year (net-metering) [1], excess electricity over a year lower electricity price	Depending on bilateral agreement with energy supplier
	Maximum timeframe for compensation	?	Compensation is yearly based	Depending on bilateral agreement with energy supplier
Investment and regulatory details	*Duration of the compensation scheme*	20 years	Net-metering will be available until 2023 and possibly onward	Depending on bilateral agreement with energy supplier
	Third party ownership and/or PPA accepted	?	No	Yes
	Grid codes and additional taxes/fees	None ?	Regular electricity codes, no additional taxes/fees	
	Other direct or indirect incentive to invest in (BI)PV	Self-consumption bonus (function of kWp and paid for 5 years)	VAT refund, subsidies and loans issued by local government (province or municipality)	Subsidies on national, regional and municipal level
	Other enablers of self-consumption		No	
System-linked requirements	*PV System size limitations*	<100 kWp	Max 3x80Amp and depending on grid infrastructure	Depending on grid infrastructure
Building regulation	*Building's energy and/or power consumption obligations*		No	
	Revenues from building's reduced energy consumption		Savings on the electricity bill	
	Legal limitations/obligations regarding building's aesthetics	Public subsidies (ANAH, CITE)	Yes, municipal aesthetic committee	
Environmental certification	*(BI)PV evaluation in environmental certifications*	Some protected area where material have to comply with "Architecte des Batiments de France" decision or PLU	Yes, energy related obligatory, material related voluntary	
	Are environmental certification schemes commonly used?	Label E+C- : PV prod self-consumed counted with a primary energy coefficient of 2.58, reinjected counted with a coefficient of 2.58 for the first 10kWh/m2 (floor surface)/year then coefficient = 1	Yes, mainly energy related (obligatory)	Yes, energy related (obligatory) and holistic (voluntary), e.g. BREEAM

	Environmental regulatory measures	No, HQE label is decreasing. Label E+ C- is a state label announcing 2020 regulation	

	Parameter	**Austria**	**Belgium**	
			Residential	***Commercial & Industrial***
PV Self-consumption	*Right to self-consume*	Yes	Yes	
	Right to self-consume (collective)	Yes, since June 29th 2017 (amendment ElWOG)	No	
	Revenues from self-consumed PV electricity	Savings on the electricity bill	Savings on the electricity bill	
	Charges to finance grid costs	See grid codes, discussion to adapt structure of grid tariffs	Capacity-based “prosumer tariff” in Flanders None in Brussels & Wallonia but	None
Excess PV electricity	*Revenues from excess electricity*	FiT: 7,9 cent/kWh[4], special deal with e-provider	Full retail electricity price (net-metering)	None except if a PPA is signed
	Maximum timeframe for compensation	No	1 year	None
Investment and regulatory details	*Duration of the compensation scheme*	13 years (for FiT)	15 years in Flanders. Unlimited elsewhere.	Unlimited
	Third party ownership and/or PPA accepted	Yes (amendment ElWOG)	TPO accepted. PPA is not.	Yes, both TPO & PPA
	Grid codes and additional taxes/fees	Self-consumption surcharge: > 25 kWp or 25.000 kWh p. a.	Capacity-based “prosumer tariff” in Flanders To be introduced soon in Brussels & Wallonia	None
	Other direct or indirect incentive to invest in (BI)PV	Yes (with a cap) [1]	Green Certificates in Brussels (10 years) “Qualiwatt” premium in Wallonia (5 years)	Green Certificates in Flanders, Brussels, Wallonia (10 years)
	Other enablers of self-consumption	Battery storage incentives Demand side management	Time of Use tariffs	
System-linked requirements	*PV System size limitations*	Different legal approvals depending on size	≤ 10 kWp	> 10 kWp
Building regulation	*Building’s energy and/or power consumption obligations*	PEN[2] for NZEB and for new buildings by federal states	All regions: NZEB for new official buildings. From end 2020, applicable to all new buildings. Flanders: all new buildings must have renewables. “EPC” certificate for residential when selling or renting, for offices/schools only if new constructions. Brussels: “PEB” certificate for residential & non-residential, wen selling or renting Wallonia: “PEB” certificate for residential only, when selling or renting	
	Revenues from building’s reduced energy consumption	Savings on energy bills. Subsidies for renovation	Savings on energy bills. Access to “green loans” with a reduced interest rate	
	Legal limitations/obligations regarding building’s aesthetics	Communal building code, historic building preservation	Possible communal restriction. Historic building preservation policy depending on regional regulation	
	(BI)PV evaluation in environmental certifications	Yes (but not required)	Possible but not mandatory	

Are environmental certification schemes commonly used?	Klimaaktiv, Total Quality Building (TQB)	No	Yes, for new office buildings: LEED, BREEAM
Environmental regulatory measures	Up to now in Vienna [3]	None	

	Parameter	**Denmark**	**Spain**	**Sweden**
PV Self-consumption	*Right to self-consume*	Yes	Yes[1]	Yes
	Right to self-consume (collective)	Only possible if the consumers all are behind the same main utility meter.	Yes, since July 2017. Still need development	Yes, but only within one building
	Revenues from self-consumed PV electricity	Savings on the electricity bill	Savings on the electricity bill	Savings on the electricity bill[1]
	Charges to finance grid costs	The grid company charge PV owners a connection fee, yearly administration fee and a grid access fee.	Yes. For installations with power contracted > 10 kW there is a tax on the kWh self-consumed (energy term) and in the power term (contracted power) only if Power consumed > Power contracted. The tax is on the difference (Power consumed - Power contracted)	No
Excess PV electricity	*Revenues from excess electricity*	Electricity can be sold to an electrical trading company but it´s not common practice[2] Alternatively the exceed energy can be delivered to the grid for free.	Yes, only for installations type 2[2], just the wholesale market price. For installations type 1, no revenue is obtained (consumer injects excess of electricity for free)	In total, typically around 0.03-0.04 €/kWh without tax deduction and 0.09-0.10 €/kWh with tax deduction[2]
	Maximum timeframe for compensation	No limit on the no compensation scheme.	No limit, there is no compensation	Electricity certificates are issued during 15 years. Last year is 2035. Timeframe for tax deduction is not decided. Subject to future political decisions.
Investment and regulatory details	*Duration of the compensation scheme*	For excess electricity revenues, no limit in time.	For excess electricity revenues, no limit in time.	Investment subsidy (up to 30%) decided to last until 2020. General tax deduction for renovation in private households, no timeframe set.
	Third party ownership and/or PPA accepted	Not accepted at the moment.	Yes[3]	Yes
	Grid codes and additional taxes/fees	None	No special fees/conditions additional to a standard PV system on ground. For installation obtaining revenues for the excess electricity, extra fee of 0,5 €/MWh must be paid	There is no self-consumption fee. The balancing costs is usually deducted in the cost for compensation of excess electricity.
	Other direct or indirect incentive to invest in (BI)PV	None	Tax reductions for the investment in RES (up to 24% of CAPEX). It depends also on each Spanish region. No special incentives for BIPV.	None

	Other enablers of self-consumption	None	In several regions, direct incentives to storage solutions/self-consumption PV plants. Not at National level. Normally % of CAPEX.	There is since 2016 an investment subsidy for battery storage for private households with purpose to increase self-consumption. The subsidy is limited to 60% of the cost or maximum 50 000 SEK.
System-linked requirements	*PV System size limitations*	Systems above 50 kWp need to install a production meter owned by the utility. For each produced kWh the owner is charged a small Public Service obligations fee (PSO).	No limit for self-consumption power always that the PV power <contracted power	If the system size is over 255 kWp, energy tax has to be paid on self-consumed PV electricity.
	Additional features	None	Storage with PV is now allowed in grid injection schemes	If the PV electricity is produced on one building and used in another building energy tax has to be paid if the electricity passes the grid connection point of the building where the PV electricity is produced.
Building regulation	*Building's energy and/or power consumption obligations*	*The ´Danish Building Regulations´ (BR) operates with an ´Energy Frame´: that's the* total need for added energy to a building (heating, ventilation, cooling and hot water). All *elements can be combined freely as long as* requirements in the Energy Frame is fulfilled. *There are no specific requirements for PV but it will be difficult to fulfill Energy Frame 2020 without solar energy.*	Accomplishment of EPBD (transposed into CTE in Spain), but transposition still to be concluded.	There are rules on maximum allowed specific energy need for new buildings. In the building regulations BBR (Boverkets byggregler) it is specified that for the calculated specific energy of a building, the PV electricity is not counted if it is used for household electricity. But if you use it to produce heat for the building, with a heat pump for instance, it is counted when you calculate the specific energy need.
	Revenues from building's reduced energy consumption	Savings on energy bills	Savings on energy bills	Savings on energy bills
	Legal limitations/obligations regarding building's aesthetics	If the building is worth preserving this can be a barrier to adaption of PV ´Architectural Guidelines´ in many municipalities about what will they accept aesthetically	Not very common, only in specific areas of towns, normally in the old parts.	Yes(3)
Environmental certification	*(BI)PV evaluation in environmental certifications*	Yes	BIPV modules are considered as energy production elements contributing to the building consumption. Also as a RES element. BIPV would improve PV due to the integration in the final construction component	PV is included
	Are environmental certification schemes commonly used?	It is seen more often in new buildings. Marks like EU Ecolabel, BREEAM, Aktivhus,	Only in specific buildings (e.g. Companies HQs, office buildings, hotels...)	Pretty often (Swedish "Miljöbyggnad", LEED and BREEAM)
	Environmental regulatory measures	None	Not known	None

4.3 Analysis of the regulatory environment

The first noticeable element of this analysis is that most regulatory frameworks do not include any specific definition of BIPV, hence these are considered as any other PV system. Today, this differentiation only exists in Austria, where subsidies for BIPV are higher than for BAPV, and in France, where residential (≤ 9kWp) PV systems which are "integrated to the building envelope" benefit from a premium for the feed-in electricity. Note that this premium in France is reduced every quarter by the regulator and will disappear by October 1st, 2018. This choice is in line with the overall trend of phase-out of support schemes currently going on in developed markets, but not exclusively. Indeed, the lack of definitions encouraged people to take advantage of the situation. Consequently, many installations of BIPV are very similar to BAPV systems, i.e. they are made without using the potential of high aesthetic value with BIPV. The case number 9 presented in Chapter 2 is an example of it. Also, business models used in these cases are the same as for any BAPV installation. This French specificity does not necessarily trigger the BIPV market or industry development. However, it does not mean that such attempt is ineffective. In Italy, for example, BIPV-specific policies existed until 2013 and contributed to stimulating the market as well as domestic industry.[2]

In most countries the main revenue sources of BIPV systems' production are the savings on the electricity bills. Thus, self-consumption is now, in all studied markets, the only possibility to ensure profitability of BIPV installations. Power Purchase Agreements (PPAs) are also being developed for systems with higher installed capacity, but even on markets with an adapted regulation, such business models have not widely spread. This attractiveness of self-consumption is especially true as on a majority of markets, excess electricity produced by the BIPV system is weakly valued. Except in Belgium, price paid for feed-in electricity is significantly lower than the full retail electricity price. Also, the Swedish tax reduction results in about the same value for feed-in electricity as the retail price for systems with annual excess production up to 30 000 kWh.

However, even though most countries try to shift from a policy-driven market to a competitiveness-driven market, one can notice that numerous support schemes, such as subsidy or tax reductions, remain in place. This can be a strong economic advantage for investors, but should not be considered as a main element of viable business models. Especially in the case of a long-term investment like BIPV, regulatory uncertainty and inconsistency already proved to have harmful consequences on economic profitability.

Another common characteristic between all these markets is the implementation of energy performance of buildings directive (EPBD) through national regulatory adaptations, imposed by the European Union.

Concerning the differences between countries, two main points can be identified. Firstly, only half of the studied markets witness a regulation allowing collective self-consumption. Although such regulatory measure is not strictly related to BIPV, it certainly has the potential to widen the range of business models that can be applied to PV systems, including BIPV ones. It could be one of the solutions to stimulate the development of innovative business models. However, in the case of existing residential buildings, ways still have to be found to encourage tenants to participate in such innovative business models.

Secondly, the diversity of regulatory measures related to environmental certification and building energy consumption is substantial. There are also variations in the level of severity with which these measures must be followed. Uniformity across countries could be an advantage by permitting the replication of business models from one country to another.

From the previous tables, one can mention the burden imposed in some countries to BIPV owners. This can take the shape of a "prosumer tariff", a curtailment of PV electricity production or taxes for each kWh self-consumed. Such rules limit the ability to develop attractive business models.

[2] Such problematic is out of the scope of this report and subtask's mission. This will be further discussed and investigated within a study conducted by the IEA PVPS Task 1 to be published in 2018.

What was also brought up during some interviews, as well as by other studies [16] [12] [13], is the lack of standardization of the products, certification guidelines and variation of these between markets. Consequently, integration to existing and new constructions is difficult.
It is also worth mentioning that from the regulatory environment and the cases presented, it appears that restrictions or guidelines regarding aesthetical modifications that BIPV can cause, are limited. It could have been a barrier to the development of BIPV, but also an opportunity. Where BAPV installations would have been forbidden because of their aesthetical aspect, BIPV would have been a less visually intrusive alternative. That being said, BIPV can still be more appropriate in the case of historical buildings, for which rules are much stricter.

The main stimulator to the creation of new business models for BIPV applications is certainly the building-regulation and how strict it is regarding energy consumption. One can see that the interest for BIPV (and BAPV) increases when such measures enter into force. NZEB regulation is an example, and already has an influence on the market, as the Belgian case of the "Treurenberg" or the case of the Winery from Spain demonstrate. But national regulation can also play a role, as it is seen with the last French case. This regulatory factor is even more important as in some situations, BIPV can clearly be more appropriate than BAPV. For example, in urban environment where the availability of roof surface is often scarce. This was confirmed by owners of the Copenhagen International School.
The revision, at the European level, of the directive on the energy performance of buildings, could play an important role in the future development of the BIPV market and of new business models. [17] For example, it could introduce harmonization guidelines of Energy Performance Certificates and a "smartness" indicator for buildings. One could imagine that BIPV installations, for which it is now quite common to closely monitor the electricity production, could contribute to this indicator. Also, by putting the emphasis on energy efficiency of buildings and pushing Member States to promote renovation of existing building stock, this directive could create new opportunities for BIPV products, which can contribute to improve insulation.
Furthermore, the revision of the renewable energy directive, which passed a first vote at the European Parliament on the 28th of November 2017, will encourage Member States to "introduce in their building regulation requirements of minimum level of renewable generation installation in new buildings and existing buildings subject to major renovation". [18] Another point is that communication towards building owners or tenants, as well as towards companies active in the construction sector, should be increased.

Environmental or "sustainability" certification, to a certain extent, can also play a similar role. Today, it is not mandatory and often limited to new buildings which have a demonstration character, like luxury hotels or companies' headquarters. This could stimulate the demand for BIPV products and lead to the creation of new business models if it was imposed to all new constructions, residential or not.

Finally, one should keep in mind that the regulatory framework is constantly changing. Were evoked, for example, the disappearance of BIPV definition in French regulatory framework by the end of 2018. Collective self-consumption, PPAs and third-party ownership are other elements that have been recently added, modified or should be introduced soon. These evolutions can act as stimulators but can also harm the market, the viability of existing business models or the possibility to create new ones. Indeed, defining efficient business models, innovative or not, is a complex process because of the multiplicity of variables. Regulatory environment is one of the most influencing one, and if it is not foreseeable and adapted to the reality of the market, developing BIPV-specific business model could reveal to be an impossible task.

4.4 Recommendations

The previous analysis, as well as the testimonies from the stakeholders involved in the selected projects, showed the major barriers and stimulators to the development of new business models for BIPV. From

this, a few recommendations have been produced and summarized in table 5. For each recommendation, there is an indication of the affected parameter from the regulatory environment table, the problem to be solved and how to tackle it. The stakeholder(s) that must lead the action has been designated. Other stakeholders than those listed can be involved in the process, for example as advisors or to support any lobbying activity. But to ensure readability, only most important ones are explicitly specified.
Finally, an estimation of the impact that such recommendation could have on the development of new business models for BIPV is provided. The scale is voluntarily limited to 3 levels: low, medium and high. Note that the aim is not to provide a rigorously scientific evaluation but rather a tool to help prioritizing the recommendations to be implemented.

Table 5 Recommendations

Which parameter is affected?	What is the identified problem?	What is the action to be taken?	Which stakeholder(s) should act?	Estimated impact?
Global regulatory environment	Regulatory frameworks are often inaccurate, unresponsive to market evolution and unpredictable, sometimes with retroactive measures	Policy-makers should include experts of the sector in the debate and define, together with them, an accurate, predictable and responsive regulation with a long-term vision	• Policy-makers • Analysts • Economists • Manufacturers • Service providers	High
PV self-consumption regulation	Collective self-consumption not defined at all, or still requiring improvements	Policy-makers, advised by experts, should define efficient measures allowing and framing collective self-consumption	• Policy-makers	High
Building regulation	Electricity produced by BIPV systems is not always counted in the energy-balance of buildings (e.g. in the cost-optimal methodology in EPBD directive)	Regulation should be modified to make sure that the electricity production of BIPV systems is correctly valued and used to reduce to total energy consumption of buildings	• Policy-makers	High
Environmental certification	Environmental certification of buildings is far from being commonly used	Certifications (e.g. BREEAM or others) should be imposed to all new constructions. New or adapted certifications can possibly be created to fit better the reality of residential buildings	• Policy-makers	Medium
Revenues estimation	Evaluating the total costs and benefits of a BIPV system is complex. Regular PV-related estimations such as LCOE or €/Wp are incomplete because failing to include other benefits and functions of BIPV (e.g savings of construction materials or. thermal insulation).	A standardized methodology or procedure should be created to evaluate the cost-effectiveness of BIPV installations. Considering electricity produced but also the saved costs in building materials and the functions that BIPV elements can fulfill during their service life.	• Engineers • Architects • Economists	Medium

5. Conclusions

Building integrated photovoltaics (BIPV) can have significantly different business models than traditional building-applied or ground-mounted PV installations. Business models for standard PV installations generally focus on revenues from the electricity generated, whereas BIPV has the potential to also reduce costs through the replacement of other building materials. From the studied cases, only one of the involved companies have a BIPV-specific business model in place - a business models that combines electricity revenues with cost reductions from the replacement of roof materials. This kind of business model should be studied further. Also, there is a demand for a standardized approach to evaluate the costs and savings with BIPV. A business model only focusing on electricity revenues cannot be said to be BIPV-specific.

The main drives for BIPV installations, in the studied cases, could be categorized as electricity revenues and green identity, i.e. being environmentally friendly and sustainable. A number of case studies indicate the successful effect of early implementation of BIPV in the design process. Close collaboration among stakeholders is also mentioned as a success factor in several cases. One interesting fact from the Swedish and Norwegian examples is that the added cost, even for a large PV facade, was below 2 % of the total cost of the building.

BIPV differentiation within the regulatory framework is not necessarily advantageous, neither leading to market development nor creating specific business models. Regulatory measures imposing a reduced purchased energy demand to buildings also have the potential to create a demand for BIPV. That would also be the case if regulatory measures could favour small scale electricity production as well as energy efficiency of buildings.

Business models that focus on values attached to green identity should also be studied further. Examples show possibilities to attract high paying tenants. Of major concern is how such business models should be adjusted to fit various stakeholders.

Business models heavily rely on the regulatory environment, hence policy-makers, at all levels, have a huge role to play. Experts should try as much as possible to enter the debate and influence the definition of the regulatory framework.

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For further information about the IEA – Photovoltaic Power Systems Programme and Task 15 publications, please visit www.iea-pvps.org.

Appendix

1. Questions for STB – activity B.1 analysis of status quo

Question	Comments
Who owns the PV system?	*Central for the business model, might be shared ownership*
What stakeholders are directly involved in the PV system?	*To be able to see real and possible value flows*
Who are indirectly involved?	*To be able to see real and possible value flows*
What kind of values are attached with this PV system?	*Not just economic value but also environmental, technical, architectural, aesthetical, marketing, etc*
Are there any other values attached with the organization around the PV system?	*Not directly related to the PV system but relating to this specific business model*
Who gains on this installation?	*All stakeholders, direct and indirect*
Which financial model was used?	*Was the emphasis on electricity production, design, construction elements, environmental benefits, etc. It is interesting to examine all stages and parts of the investment and operations, tell the story!*
Were there any specific incentives for BIPV used?	*If so, where these incentives crucial to the decision?*
What is the PV production cost (Levelized Cost of Electricity)?	*To be able to compare with other installations*
How much kWh is self-consumed?	*Probably impacts the business model chosen*
Was the size of the PV installation influenced by the financial analysis?	*Size have an impact of economy, but aesthetics is important and probably influenced the size more*

2. Details of regulatory environment

2.1 The Netherlands

(1) In some cases, solar panels produce more power than required. The surplus is then delivered to the electricity grid. The energy company then calculates the delivery with the electricity that the homeowner purchases from the grid. The energy company pays the same price as the homeowner (average 20 cents per kWh, price level 2017). This netting arrangement applies in any case up to and including 2019 (may be extended until the end of 2022). The netting scheme does have a maximum: if more power is supplied to the grid every year than what is purchased, the homeowner will receive a lower reimbursement for the surplus. This so-called feed-in fee differs per energy company and is approximately between 3 and 11 cents per kWh.

2.2 Austria

(1) Austrian Climate and Energy Fund (KLIEN): e.g. < 5kWp individual plant 2017: for PV € 275/kWp and for BIPV € 375/kWp. Most federal states have also funding schemes for PV and BIPV (concerted with KLIEN). Other incentives see under: http://www.pvaustria.at/forderungen/

(2) PEN = Primary Energy Need in kWh/m2/y for NZEB (OIB 2014 Document with definitions for NZEB): PEN for residential buildings = 160 kWh/m2/y, for non-residential buildings = 170). PEN for new buildings (OIB Guidelines 2015, federal states have meanwhile declared OIB Guidelines as binding in their building codes) and in energy performance certificate.

(3) Amendment of Vienna's Building code 2014: new office buildings have to install 1kWp PV plant per 100 m2 (can be conventional PV or BIPV).

(4) This level of Feed in Tariff is only valid for the year 2017.

2.3 Spain

(1) With conditions for those connected to the grid, some of them very restrictive, technically and economically. No conditions for stand-alone installations.

(2) RD on Self consumption 900/2015, established 2 types of installations:
   - Type 1 = P> 100 kW without registration
   - Type 2 (any power) registered

(3) Until now, PPAs have not developed due to regulatory uncertainties, but now there are already several examples of PPAs in Spain.

2.4 Sweden

(1) This includes:
   - Electricity cost (Nord Pool spot price or fixed price per kWh for one year for instance)
   - Electricity transfer (to grid owner)
   - Energy tax
   - Electric certificate fee
   - VAT on 1-4 (for consumers and housing companies)
   - The sum of 1-4 is typically around 0.08€/kWh and 1-5 around 0.10€/kWh

   In addition, it is possible to get electricity certificates for all produced PV electricity, including the self-consumed. However, for a residential house owner the costs for a new electricity meter and the yearly costs related to this are too high to give any net income. For larger installations it might be a net income of 0.005-0.01€/kWh.

(2) This includes:

- Nord Pool spot price (yearly average 0.02-0.03€/kWh in years 2014-2016) or another price agreed with the buyer
- Small compensation for grid owner, since the distribution losses decrease in the grid
- Electricity certificates. Prices have fallen a lot during first half of 2017, resulting in a low value 0.005-0.01€/kWh
- Guarantee of origin. Almost negligible value today
- Tax deduction. 0.6 SEK/kWh (~0.06 €/kWh). If you have maximum 100A fuse subscription. Maximum for 30 000 kWh/year or for as much electricity you buy per year.

(3) Local building codes can for example specify what colors are allowed on a roof.
For residential systems a building permit is usually not needed if the installation of the PV modules follows the slope of the roof, but if the installation deviates from the slope of the roof or the installations is made on the ground a building permit is usually needed.

2.5. Denmark

(4) This includes:

- Electricity cost (the price given from the electrical trader, can be both fixed for a period or a price following the Nord Pool stop price)
- Electricity transfer (to grid owner TSO/DSO)
- Energy tax
- VAT on 1-4 (for consumers and housing companies)
- The sum of 1-4 is typically around 0.23€/kWh and 1-5 around 0.29€/kWh

(5) Revenue from the electricity can be very low depending on the contract with the electricity trading company. If the price directly reflects the spot price ion Nord Pool the electricity will have a value of app 0.03 EUR/kWh.
The PV-owner needs to install a separate sales meter and register the exceed energy by the hour. There is a cost for the meter at. 200 – 400 EUR/year depending on the local grid company.

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