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International Energy Agency
Photovoltaic Power Systems Programme

Task 15 Enabling Framework for the Development of BIPV

PVPS

Development of BIPV Business Cases

Guide for stakeholders

2020

Report IEA-PVPS T15-10:2020

What is IEA PVPS TCP?

The International Energy Agency (IEA), founded in 1974, is an autonomous body within the framework of the Organization for Economic Cooperation and Development (OECD). The Technology Collaboration Programme (TCP) was created with a belief that the future of energy security and sustainability starts with global collaboration. The programme is made up of 6.000 experts across government, academia, and industry dedicated to advancing common research and the application of specific energy technologies.

The IEA Photovoltaic Power Systems Programme (IEA PVPS) is one of the TCP's within the IEA and was established in 1993. The mission of the programme is to "enhance the international collaborative efforts which facilitate the role of photovoltaic solar energy as a cornerstone in the transition to sustainable energy systems." In order to achieve this, the Programme's participants have undertaken a variety of joint research projects in PV power systems applications. The overall programme is headed by an Executive Committee, comprised of one delegate from each country or organisation member, which designates distinct 'Tasks,' that may be research projects or activity areas.

The IEA PVPS participating countries are Australia, Austria, Belgium, Canada, Chile, China, Denmark, Finland, France, Germany, Israel, Italy, Japan, Korea, Malaysia, Mexico, Morocco, the Netherlands, Norway, Portugal, South Africa, Spain, Sweden, Switzerland, Thailand, Turkey, and the United States of America. The European Commission, Solar Power Europe, the Smart Electric Power Alliance (SEPA), the Solar Energy Industries Association and the Cop- per Alliance are also members.

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What is IEA PVPS Task 15?

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. IEA PVPS Task 15 is an international collaboration to create an enabling framework and to accelerate the penetration of BIPV products in the global market of renewables and building envelope components, resulting in an equal playing field for BIPV products, Building-Applied PV (BAPV) products and regular building envelope components, respecting mandatory, aesthetic, reliability and financial issues.

To reach this objective, an approach based on five key developments has been developed, focused on growth from prototypes to large-scale producible and applicable products. The key developments are dissemination, business modelling, regulatory issues, environmental aspects, and research and development 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 single-family dwellings to large-scale BIPV application in offices and utility buildings.

Michiel Ritzen (operating agent IEA PVPS Task 15 Phase 1)

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IEA PVPS
Task 15

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COVER PICTURE

Picture of the Town Hall of Freiburg im Breisgau. Credits: Philippe Macé

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TABLE OF CONTENTS

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EXECUTIVE SUMMARY

Over recent years, continuous price decreases of PV system components and technological improvements, leading to better efficiency and reliability, contributed to reinforce the attractiveness of this technology [1]. This is a trend that also benefitted building-integrated photovoltaic (BIPV) systems, which have become more affordable [2]. In addition, it appears that the sector is dynamic and able to gain traction, as the significant number of competitors on the market tends to demonstrate [3] [4]. Nevertheless, in spite of this multiplicity of existing integrated PV products and the apparent market opportunities, deployment of BIPV solutions remains limited. Among the explanatory factors for this observation, one can cite the lack of appropriate business models or, at least, the lack of business models with a clear value proposition for BIPV systems.

Possible drivers for BIPV system installation are crucial in order to define a value proposition that is as efficient as possible, as well as a business model. To refine the understanding of these drivers, the first chapter of this report explores these aspects in depth in section 2. The value of BIPV is not purely the economic value from electricity generation; it can also be connected to contributing to the local transition of the energy system, locally produced electricity, sustainability and marketing. The value of BIPV can be leveraged by companies willing to highlight a vision or mission that reaches beyond profit-oriented goals. Also, as a building component, BIPV can provide the same or better building functionalities as other building materials and help at the same time to meet legal requirements in terms of energy performance of buildings. Finally, the ability of BIPV solutions to improve real estate value is evoked as well, increasing the attractiveness of such investments, provided that the involved stakeholders can take advantage of this value.

Different stakeholders involved in the business models are highlighted. They constitute the focus of section 3, in which they are characterized by their specific interests and role in BIPV projects, to guarantee the efficiency of the designed business models.

In the following section, the framework used to conduct the analysis and frame the discussion on business models is presented. It is directly followed by the main section of the report, where examples of business models related to different building typologies and central stakeholders, i.e. product or service providers, are presented. The first examples are based on projects for residential buildings, while the second is based on a product for commercial buildings and the third is a service for commercial buildings. Each example is followed by discussions regarding key values and stakeholders, the main touchpoints of the business model as well as the pitfalls to avoid. Remaining challenges to the implementation of such business models are also listed. This section demonstrates that BIPV business models, with various degrees of innovation, can be designed, even if implementation remains to be tested for some of them. Specific business models can be developed with the help of, or with ideas from, the generic versions in this report.

Ultimately, the purpose of this report is to provide a guide for design and application of business models to be used by stakeholders involved in the design process, for example existing and new businesses in the energy and construction sectors or housing and real estate companies. The guide aims at helping by highlighting the critical points of attention, allowing stakeholders to ask the relevant questions, but also by providing some ideas and answers on business model design and on how to maximize value creation and recognition. Some technical aspects are included but they are not the focus of this report.

1 INTRODUCTION

This report, which has been developed within IEA PVPS Task 15 Subtask B, aims at providing elements to tackle the lack of business models with a clear value proposition for BIPV systems, for example, by helping all interested stakeholders in designing profitable business models for various applications of BIPV, in different situations. To do so, it is first crucial to understand that BIPV solutions, as construction materials, are – or can be – included in business models that differ greatly from those applicable to building-applied PV (BAPV) systems. Then, a clear understanding of values linked to BIPV solutions is necessary, completed by a vision of how these values can be quantified, if possible, and captured by the involved stakeholders. In previous work of Subtask B, ten BIPV case studies were collected and analysed. The results showed added value other than electricity generation as a drive behind installations. Examples include aesthetics, BIPV contributing to an environmental sustainability profile, and multifunctionalities of BIPV. Results showed a difficulty in fully assessing the added value linked to the passive characteristics of BIPV systems, i.e. linked to functionalities of building components. It also demonstrated that it is even more challenging to quantify and capture the values through an appropriate business model. The difficulty to fully assess the BIPV added value can be caused by a misperception of the risk associated with BIPV and lack of knowledge of the involved stakeholders, from investors to occupants and property managers [5].

To stimulate the development of these BIPV applications, attractive business models, with an ensured added value for all stakeholders, are required. As a business model is a way to describe how value can be created for the customer together with economic sustainability for the company delivering the product or service, some elements first need to be analysed. First, values linked to BIPV are discussed. These are key elements of business models, and can be of many types, as demonstrated in the following section. They vary according to the function of the stakeholder considered, and so does the possibility to quantify them, which directly impacts the ability to include them in business models. Moreover, the stakeholders to be potentially involved are also inventoried, and their interest and role in BIPV business models identified. These analyses allow discussion of the potential business models to be created, in order to develop attractive business cases and promote BIPV development. These are presented in section 5 of this report, using a well-established business tool.

2 ADDED VALUE WITH BIPV

The company values can be expressed in a vision or a mission and these values go beyond the economic goals of a company, for example a vision to create a fossil-free business. The framework used for business model development in this report is based on values.

A core question affecting decisions for an increased implementation of BIPV is: Which added values do the different features of a BIPV system potentially have and how do different stakeholders perceive them? The purpose of this chapter is to shed light on the major values of BIPV systems and to discuss their role for actual valuation.

It is worth pointing out that the value of a BIPV system strongly depends on the actor considered. The investor, who takes the decision of whether to apply a BIPV system or not, has of course the highest interest among all stakeholders in identifying the values created. Nevertheless, the investor acts in a context where knowledge exchange, e.g. through consultation processes with architects, technical planners, installers and manufacturers, may affect investment decisions. Thus, the values discussed here are of relevance for all groups involved in the decision-making process and ultimately in the system establishment. This is also reflected in the subsequent chapter on business models for different stakeholders and building segments.

2.1 Values specific for BIPV

A major feature of BIPV is its multi-functionality, which results in a range of potential value perceptions and assessments. Specifically, BIPV systems:

- Provide building functionalities by replacing other building elements or materials
- Produce electricity with improved architectural design as compared to building-applied PV (BAPV)
- Result in marketing aspects and an attractive living or office place.

2.1.1 Values relating to building functionalities

As shown in a previous IEA PVPS Task 15 report [1], profitability of BIPV systems is already given in specific cases, in particular due to the replacement of alternative construction elements. BIPV systems can take over a range of building functionalities which would otherwise need to be provided by conventional building components. If BIPV results in improved functionalities compared to conventional material, an additional value is provided. These functionalities primarily relate to the resistance, safety and stability of the building, its water and air tightness, noise protection, shading, insulation, daylight and comfort. An example of added value is that solar energy transmittance (g value) and thermal transmittance (U value) are reduced in the case of semi-transparent PV glazing compared to standard glazing, thereby lowering the need for heating in winter and cooling in summer [6] [7] [8]. At the same time, it also has an impact on the daylight factor, that must be taken into account when designing semi-transparent PV and lighting systems. In addition, privacy can be mentioned as a function, for instance in the case of balconies where BIPV elements can serve as view protection as well as serving as fall protection.

BIPV underlies potential challenges such as safety (e.g. fire risk, wiring) that do not apply to the same extent to the conventional alternative. Therefore, standardisation and certification are crucial elements to facilitate the use of BIPV as a replacement of conventional building components. A deeper analysis on building functionalities and BIPV system requirements and standardisation is presented in the IEA PVPS Task 15 reports on user needs for BIPV and BIPV functions [8] as well as on standardisation [9].

2.1.2 The aesthetic value – improved design with BIPV

The aesthetic value in combination with marketing value is recognised as a driving factor behind BIPV installations today [1]. BIPV provides a broad range of design options, since BIPV products with a variety of colours and sizes are available and under further development [10]. BIPV products are compatible with existing building components and processes in the construction industry. Aesthetics may materialize in two fundamentally different ways. Either BIPV is explicitly made visible in order to highlight its presence or it is visually integrated to an extent that it may not be recognizable anymore. Both features have their value, depending on the specific user needs. Depending on the specific case, one or the other may be favoured in order to harvest, e.g., an increased reputational impact. In the case of complete visual integration, it may for example be more difficult to leverage in the corporate communication.

BIPV gives an even better opportunity to introduce solar cells into the building from the beginning. The possibility of adjustments in colour and shape can facilitate acceptance, in comparison to BAPV, which can be perceived as not meeting aesthetic expectations. The PV function becomes an added value of BIPV to the building and design, especially if the starting point is no solar cells.

Improvements in aesthetic integration are often due to the visual adaptability and flexibility of specific products or PV technologies, a feature that is demanded of BIPV manufacturers. A transition is expected from customized BIPV products to commodity products for the building skin [11]. The development towards commodity products may be focused on different attachment systems and methods for manufacturing the products, not necessarily that they will have the same size or colour as other parts of the building skin, at least not when it comes to facade solutions.

It is also worth highlighting that facades are significantly more important in terms of design and image than roofs. Therefore, the higher aesthetic value of facades gives an advantage to BIPV, compared to BAPV.

2.1.3 Energy performance regulations

It has been emphasized that the future main driving factor for the BIPV market will be taken over by energy performance regulations, such as the European Directive [12], when BIPV products go from being visible and supporting an image to becoming invisible and regular building components [11]. In Europe, this is in line with the European Strategic Energy Technology (SET) Plan, which recognises that “Building-integrated PV offers huge potential to exploit roofs and facades as a local energy source, also enabling the electrification of heating and cooling, and transport.” [13] and foresees “mass realisation of ‘(near) Zero Energy Buildings’ by Building-Integrated PV (BIPV)” being enabled [14]. BIPV will have a benefit when BAPV or energy efficiency alone are no longer enough to cost-efficiently meet energy-related requirements. This may be the case when BAPV is not in line with the design requirements of the owner or when roof surface areas are not large enough or not available for PV.

BIPV is better adapted to utilize larger parts of the surfaces of a building, compared to BAPV using standard module sizes. Even if BIPV is less efficient per unit area, a larger area can be covered, resulting in a higher electricity yield in total.

2.1.4 Land use

Local PV electricity generation on buildings has the advantage of not exploiting new land, which is a benefit from an environmental point of view. Assuming a yearly energy yield of 1 000 kWh/kWp for a PV plant, this corresponds to a module area of 5.6-5.9 km2 per TWh, with a module efficiency of 17-18%. Besides the energy yield at the location and the PV module efficiency, the land area needed for ground-mounted PV plants also depends on the design and technology used for the PV system. A study in the US gave the result of 11-22 km2 land area per TWh, depending on the technology used [15]. This can be compared with PV on buildings where no new land is exploited. In this context, BIPV has a clear advantage over BAPV as a larger surface area of the building can be used for electricity production in cities or areas lacking suitable land areas for ground-mounted PV plants.

2.2 Values common to BIPV and BAPV

Added values, such as locally produced renewable energy, are common to BIPV and BAPV. These values do not provide a specific benefit for BIPV compared to BAPV, but they contribute to the evaluation of the profitability of BIPV and should therefore be mentioned. These values include:

- Environment and resource efficiency, contributing to energy system transition and mitigation of climate change
- Economic value
    - Savings and proceeds from electricity generation
    - Possibly higher property value and increased income from rents
- Generation of renewable electricity on site, thereby reducing distribution losses in the electricity grid, without exploiting new land
- A feeling of more independence from the electricity grid, e.g. “cut the wires” campaign in Spain [16]
- A greater insight into the energy demand / energy production balance at the building level, hence the possibility to encourage a prosumer attitude
- Contribution to grid services, either utility grid or micro-grid, e.g. supply of reactive power
- Services by smart hybrid inverters are becoming more multifunctional
    - Management of PV and batteries
    - Solutions of power-to-heat and smart homes
    - Coupling with e-mobility and demand side management

2.2.1 Economic values relating to renewable electricity generation

In Bullier’s analysis of green value [2], energy was the most important criterion for several market value components, not only due to the cost of energy. Self-consumed PV electricity will reduce the electricity bill, so it can be valued in a similar way to energy efficiency measures for the property owner. The value of energy is supported by diverse studies focusing on the valuation of energy efficiency in the building sector. For instance, Eichholtz et al. [5] found that office buildings with environmental or energy-related certification generate economic premiums, and that among green buildings, increased energy efficiency is fully capitalized into rents and asset values. At the same time, an increasing supply of green buildings may reduce their relative premium on rent and asset value if the demand for green buildings does not follow the supply [3].

The most obvious monetary value of BIPV and BAPV installations refers to electricity generation. Locally produced renewable energy can be delivered by both BIPV and BAPV. If the electricity generation is the only required value, then BAPV may be the obvious choice. However, if other values such as aesthetics are of importance, then BIPV can be the preferred solution.

BIPV can generate value by replacing conventional materials and, possibly, by improving one or more building functionalities, making alternative investment to meet energy performance requirements unnecessary. As opposed to BAPV, the electricity value is not necessarily the most important consideration in investment decisions for BIPV. For example, marketing could be a major driving factor today. If the value of electricity generation is easy to quantify, the usual PV approach for calculation of LCOE (levelized cost of electricity) allows the profitability to be assessed from self-consumption or sale of the produced electricity on a kWh basis. If the PV electricity is used to replace electricity from the public grid, the value of this self-consumed PV electricity corresponds to the cost for purchasing electricity, minus fees that may apply to the self-consumption, or with a bonus for tax exemption for avoiding use of the grid (the case in France for direct self-consumption of small generators). If all or part of the PV electricity is fed into the grid, the PV electricity value corresponds to e.g. the spot price or feed-in tariff. The value of self-consumed electricity and electricity fed into the grid can be very different from country to country. The key to the highest value in the long term is to maximize the share of self-consumed electricity since its value is generally much higher than the market value of excess electricity fed into the grid, sometimes even when financial incentives such as feed-in tariffs are given. This trend might be strengthened if subsidies are gradually taken away and net-metering or net-billing schemes are no longer supported.

When electricity is produced at the same location as it is consumed, the distribution losses in the electric grid are reduced. Maximum reduction of losses can be obtained with generation located close to consumption. This is of value for the grid operator and could possibly be monetized by the PV owner. For example, the electricity losses in the distribution network varied between ~1% and ~9% in year 2015 in a survey including 24 European countries, with an average of close to 4% [17].

In addition, locally produced electricity may have an additional value due to potential on-site marketing. This includes charging stations for electric vehicles. In the future, marketing options are also expected to go beyond the property boundaries, at least in Europe, based on the currently developed set of European regulations and directives. Such cases potentially lead to strongly different proceeds as compared to feeding the electricity into the public grid or using the electricity on-site for other purposes. Energy generation can thus go hand in hand with different products and services such as the delivery of locally produced electricity to inhabitants and broader consumer groups. In order to make this possible, it may be necessary to change laws regarding trade of electricity.

2.2.2 Property value

When solar electricity self-consumption reduces the need for purchased electricity, the future operation cost of a building is reduced, since the electricity bill is reduced. Three interviews were conducted with the Swedish property owners Klövern, Vasakronan and Örebrobostäder, which own and deal with properties. They each have a property stock valued at 2-13 billion Euro and all have a common view of how property value is affected when making an investment that results in a lower operation cost. Here is an example presented by

Vasakronan, also published in Dagens Industri, the largest business newspaper in the Nordic countries [18]. The impact on the property value is estimated as:

Added property value = Reduced yearly running costs / Expected return on PV investment (%)

- Investment for a PV system (50 kWp) 60 000 EUR (1 200 Euro/kWp)
- Annual net savings on electricity bill 4 500 EUR
- Expected return on PV investment 5%
- Added property value 90 000 EUR (4 500 /0.05)

Hence, the added property value is 30 000 EUR higher than the investment, and it can therefore be considered directly profitable for the company.

The annual savings on the electricity bill are based on the assumptions of a specific energy yield of 900 kWh/kWp, 100% self-consumption that can be appropriate in larger buildings with daytime activities and an added net value of running electricity cost of 0.1 Euro/kWh, including the cost of ownership associated with a PV system.

The expected return on the investment in a property varies between buildings and locations. In attractive city centres, a lower expected return on investment can be used than at the outskirts of a city. Figures from Sweden of 2.5-3% (city centre of Stockholm) to 5-6.5% (other parts of Stockholm and in the city Örebro) were mentioned as expected return on investments.

The increased property value is realized when the property is sold. For a company actively selling property, and with no lack of capital, such an investment is directly profitable. Other types of property owners, not dealing with properties, do not have the same possibilities to utilize a higher property value due to selling of the building. However, the decreased running costs may, in addition to a potentially increased attractiveness of the building, allow higher rents to be demanded. Another benefit from a higher property value could be lowered capital costs, using the properties as security [19]. As the capital costs of the property have increased due to the additional cost of PV, the extra cost of financing could be compensated with a lower interest rate for loans. Even if the property owners are not dealing with properties, they can still benefit from a lowered capital cost.

Meeting future energy standards for buildings may also be valued quantitatively in terms of decreased risk premiums and lower anticipated maintenance or retrofitting costs. Energy efficiency gains can reduce the need for heating/cooling and/or lighting [6] [7].

Nevertheless, an increased property value might be less easy to capture if the building owner sources income from rents. Indeed, if the investor or owner does not occupy the building, benefitting from reduced operating costs, directly or indirectly, might be difficult, especially as many regulations still do not allow the sharing of PV electricity production. This non-alignment of incentives is a key issue. The triangle "property owner - property manager - property occupant" (quite typical in the case of office buildings) is sometimes difficult to manage, with contradictory objectives. If the building owner allows the tenant to benefit from electricity savings, the owner will need to increase the rent as it would be the only way to recover his investment. Assuming that, globally, operating costs including electricity bills and the rent would not vary for the tenant or would slightly decrease, this might work and be a win-win situation. However, the administrative and legal burden might be so heavy for non-experts that it would discourage the involved stakeholders.

A price premium analysis of solar homes was carried out in the USA. In total, 22 822 transactions of homes, of which 3 951 had host-owned PV systems, were investigated in eight states during the years 2002–2013. The average premium that a buyer was willing to pay was approximately $4 per Wp or $15 000 for an average-sized 3.6 kWp PV system [20]. The price premium could also be calculated with the method used earlier in this chapter for added property, where specific energy yield, running cost of electricity and expected return on PV investment, which in turn is affected by the attractiveness of the location, affect the expected price premium. In an article in a Swedish business newspaper, it was stated that PV could raise the selling price of residential homes, according to interviewed brokers [21].

It is stated in Bullier et al. [2] that environmentally performing buildings are better valued on the real estate market. A study in the United States showed that commercial buildings with environmental labelling tend to have higher rents, occupancy rates and higher resale value than non-certified offices, all other things being equal [2].

2.2.3 Environmental and resource efficiency

The generation of renewable energy contributes to mitigating climate change and is a value for both BIPV and BAPV that also relates to the Sustainable Development Goals adopted by the UN [22], for example affordable and clean energy. As the BIPV market phase is still with early adopters, the environmental sustainability and marketing values are common drivers for BIPV installations [1].

A predominant value of PV, according to stakeholders, 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 [1]. BIPV systems can thus display the environmental commitment of a company to the public and thereby enhance its reputation. In this context, a PV installation has the potential to bring a certain green status to the buildings and their stakeholders. The green status of a building can attract customers willing to pay for this, allowing the building owner to increase the rent. Potential customers would be companies with a sustainability profile [5] [1].

Environmental sustainability is not only about renewable electricity generation. Besides land conservation, when BIPV replaces other building materials, a life cycle analysis (LCA) may inform about the comparative material consumption, and environmental manufacturing and transportation impacts regarding, e.g. CO2 emissions. Since the CO2 emissions are zero during the operation of a PV system, the energy mix during manufacturing plays a crucial role on the emissions, in addition to the emissions related to the choice of solar technology, which affect the energy payback time. Comparative environmental assessment of a BIPV system compared to a BAPV one in the same location has shown that BIPV has less negative impact, thanks to its unique ability to replace conventional building components, in addition to energy generation [1]. Nevertheless, a more in-depth analysis will have to be conducted to evaluate the environmental footprint of BIPV and whether it can constitute a competitive advantage. This is investigated in the framework of initiatives such as IEA PVPS Task 15 Subtask D or the Horizon 2020 project, BIPVBOOST.

As discussed in the previous report from IEA PVPS Task 15 Subtask B [1], the aesthetics as well as the green status and potentially resulting market value can be expected to be higher for BIPV than for BAPV. Indeed, the green status was ranked higher than electricity revenue as the major factor for the installation of BIPV systems from years 2010-2016 in six out of ten case studies analysed in that report. However, if broken down to harder facts such as green building certification (e.g. LEED, BREEAM and Passive House standards) and low net energy demand, the marketing value becomes more apparent.

The potential marketing value from other elements of the green status of a building such as reputation and marketing aspects may equally play an important role for larger scale implementation. Overall, in a broader context of sustainable buildings, their green status is not yet sufficiently acknowledged quantitatively by the market, as building valuers and financial experts tend to take a proven perspective rather than anticipating future trends and environmental values [2] [4].

2.3 Conclusions on values

Until now, for most investors of BIPV systems, the marketing value has been a major reason for corresponding investments. BIPV in many cases has a "showcase" function, including a marketing value that is not primarily based on direct profitability of the electricity generation. However, as the BIPV market will expand, it is reasonable to assume that more easily quantifiable aspects will become more important. This includes, for example, compliance with energy regulations for buildings.

In the future, BIPV should be considered as a building component challenging conventional building envelope solutions, offering the same functionality and, as an added value, producing energy, which results in lower operation cost and higher property value for the building.

In particular, changing regulatory conditions may foster BIPV market development. From the perspective of regulation as a driver, tightening energy requirements for buildings may be an important trigger for BIPV when BAPV alone is not sufficient to meet coming energy regulations and requirements. This may occur when the available roof surface is limited or when energy efficiency of the building has reached a plateau and cannot be further improved in a cost-effective way.

In economic evaluations such as LCOE, the investment cost in BIPV should be based on the additional cost for BIPV compared to avoided costs such as for:

- Alternative building elements, including installation cost,
- Alternative measures to meet energy performance requirements,
- Energy, due to energy efficiency gains,
- BAPV not in line with the design requirements of the owner.

BIPV is valued very differently by different actors. Pure economic valuation is hard to achieve and is not necessarily required when "soft" values such as reputation linked to the "green status" dominate. Some actors such as building valuers and financial experts do not broadly take environmental values into account but valuation by stakeholders is progressing.

A summary of potential BIPV values, examples of customers and applications is given in the table below.

Table 1: BIPV – a combination of values

Value	Potential customer	Potential application
Aesthetics – high requirement	Private persons Companies Politicians	Single-family full roof Office and commercial facades Public facades
Green status – **Environmental commitment, sustainable goals**	Private persons Companies Politicians	Single-family full roof Office and commercial facades Public facades
Marketing value, in connection to green status	Companies	Facades Solar shading Balconies Entrances Atrium seen from inside Carports Fences Art installations
Building regulations – facades if roof not sufficient	Building developers	Office facades Public building facades Multi-family full roof/facade Single-family full roof
Property value – **Energy savings,** **building label certification**	Property owner, building developers	
Electricity generation	Building developers	Already expensive facades Already expensive roofs Solar shading Privacy balconies

2.4 Discussion on values

Due to the multi-functionality of BIPV, the capital expenditures used in the analysis of its economic profitability are not as clear as for BAPV. A possible approach to deal with this is to assess profitability based on the additional cost of the BIPV system as compared to the alternative, conventional building envelope solution. For instance, if the alternative is a glass facade without PV, the investment cost used should be the cost difference between the BIPV facade and the glass facade. This additional investment can then be evaluated as a separate project to be assessed. On this basis, standard PV investment indicators such as the levelized cost of electricity (LCOE), payback time, net present value or internal rate of return (IRR) can be undertaken.

The European SET plan set as a target to "develop BIPV elements, which at least include thermal insulation and water protection, to entirely replace roofs or facades and reduce their additional cost by 50% by 2020, and by 75% by 2030 compared to 2015 levels, including with flexibility in the production process" [14]. The suggested approach can be pushed even further by including more values in the calculation, as suggested in Table 2. The net investment cost is then used as the basis for LCOE calculations and other indicators. In addition, the impact of the BIPV system on the property value is discussed in section 2.2.2.

Table 2 Extended approach to calculate the net investment of a BIPV system

	Budget component	*How hard to quantify?*	*Potential impact on net investment?*
+	Total investment for BIPV system	Easy	High
–	Investment subsidies (if any)	Easy	High
–	Alternative investment for standard building functionality	Medium	High
–	Value of improved building functionality (if any)	Medium	Medium
–	Alternative investment to meet energy performance requirements	Medium	Low – High
–	Value of improved image and marketing	Hard	Low – High

A price comparison between BIPV roofs and facades on one hand and regular building materials on the other was conducted within the BIPVBOOST project and showed that, as a construction material or a building envelope solution, BIPV can hardly compete on a pure cost basis with regular building components. Nevertheless, when evaluating the net present value of BIPV projects, focusing on the additional cost mentioned here above, economic attractiveness was demonstrated in multiple countries under various business models [23].

When evaluating the competitiveness of BIPV, revenue from electricity play a central role. However, the electricity valuation requires assumptions which are subject to high uncertainties. These uncertainties concern the development of electricity prices over a long period of time or the availability of subsidies. Whereas available subsidies may be known for a project that is close to realization, they can hardly be anticipated for the future. In addition, the future development of electricity prices and subsidies strongly depends on the national or even sub-national context. Therefore, no quantitative data on the economics of the electricity value of

BIPV systems is used in this report. Specific business cases in different countries were presented in the previous report from this subtask [1].

The value of electricity generation can also be assessed in the context of regulatory frameworks, e.g. the shift towards nearly zero energy buildings (nZEB) required by the recently amended EU Energy Performance of Buildings Directive (EU 2018/844) [13] that will come into force for all new buildings in 2021. In addition, we see the establishment of ZEB policies and goals in the USA, Japan and Korea [24]. Such regulatory requirements are anticipated to be one of the most important driving forces for future implementation of local electricity generation units [11]. Furthermore, they represent a major opportunity for the building sector and PV sector to work together. If new building requirements on energy cannot be achieved with BAPV because of limited available roof area, for instance for multi-storey buildings, this can naturally lead to the use of BIPV facades. Regulatory pressure thus has the potential to be a strong driver of the BIPV market.

However, in its current state, the nZEB regulation in EU is not always restrictive enough to really trigger a BIPV market. In some countries, the directive has been implemented in national regulation with limited ambition. In others, it will simply not make any difference as rules have already been implemented for some years, with limited impact on BIPV development, if any. In addition, to comply with nZEB, investing in energy efficiency measures is more competitive, from a purely economic point of view, than investing in on-site renewable energy generation such as PV.

In France, for example, the energy performance in the building regulation “RT 2012” limits the allowed energy consumption of new buildings to 50 kWh_{PE}/m^2, where PE stands for primary energy. In France, the factor is 2.58 between primary and final energy consumption: 1 kWh in final energy equals 2.58 kWh in primary energy for the 5 main types of usage (heating, domestic hot water, ventilation, cooling, and lighting) [20]. It is regulated according to the type of building, the location and the altitude, among other parameters. The current French regulation aims first at improving the energy performance of a building envelope, hence decreasing its energy needs. The production of energy on site comes second and is valued by an extra allowed annual consumption of 12 kWh_{PE}/m^2. The purpose is to avoid energy-inefficient building envelopes and HVAC systems being compensated by large PV installation. A new regulation will become effective in France by 2020, called E+/C-, which is quite innovative. It is a holistic approach incentivising resource efficiency and limiting the environmental impact of building envelope solutions. This regulation is aiming at increasing energy efficiency (E+) and reducing embedded and emitted (C-) carbon. The idea is to consider the global environmental impact of a building, not only during its operation phase but also during its production phase and end of life. Although the building sector is the second-largest contributor to CO_2 emissions in the world, until now the carbon footprint of buildings has not been a major point of attention. Indeed, regulation has focused on the use phase, which is less emissive compared to the construction phase, for example due to the choice of materials such as concrete, steel and glass, where manufacturing and transport have a significant environmental impact. Following this new regulation, the life cycle analysis of buildings will be assessed considering a period of 50 years and the following life cycle steps:

- Product and equipment manufacturing
- Energy consumption

- Construction work
- Water consumption

There are pros and cons for BIPV within this approach. It will be considered positively regarding the service to the local energy balance. However, in some cases, the LCA of BIPV components will probably be higher than the LCA of standard building envelope elements, in spite of electricity generation. For instance, if your compare a traditional ventilated facade with a BIPV ventilated facade, you will have the impact of the PV cells in addition to the impact of the regular materials.

3 STAKEHOLDERS

In the previous report from subtask B [1], the large number of stakeholders was described, and the stakeholders were categorized in the stakeholder map shown below in Figure 1

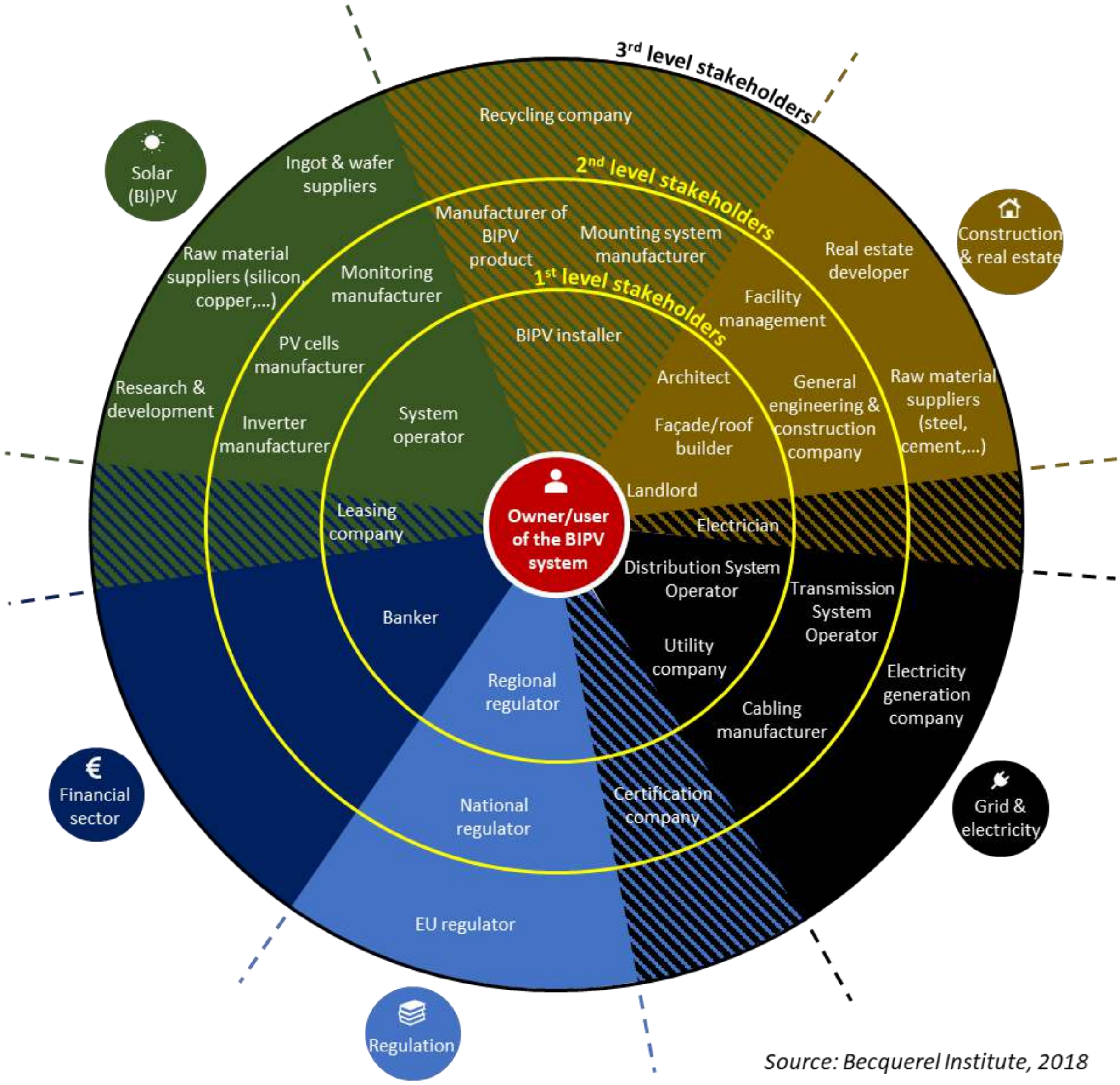

Figure 1: "BIPV stakeholders map: from production to operations" [1]

Stakeholders described as 1st level stakeholders around the end-customer of the BIPV system are the primary stakeholders, i.e. those who can have a direct impact on the business model applied to the BIPV system. This impact can take various forms. For example, BIPV installers and actors from the construction sector can directly influence the cost of installation of the system, while the banker or the leasing company impact the financing conditions of the system.

In addition, these 1st level stakeholders are often the stakeholders with an understanding of the customers' challenges, motivation and benefits when purchasing and installing a BIPV system. Their interest and motivation with regard to BIPV can vary. Some of the stakeholders are not directly involved in the selling process of a BIPV system, others have the option to supply alternative solutions not involving BIPV while some are offering a product/service that could be offered in combination with any building component.

The stakeholder creating a new business model must identify the customer needs and understand the driving forces for the other stakeholders around the customer. For some of the 1st level stakeholders, the value linked to a new business model is perceived to be low while for others it can potentially be high. The stakeholders who have the highest interest in creating a new business model are naturally the companies having BIPV systems as part of their core business, no matter whether they offer products, services, or both.

Beside the most important stakeholders, there are the 2nd level stakeholders. They are typically stakeholders who can have an indirect impact on the business model applied to the BIPV system. For example, they can have an ongoing business in an adjacent market segment, and BIPV will be a niche product until there is a stronger pull for solutions from the customers. All these stakeholders are important to involve in order to achieve the full potential of BIPV systems and maximize the effectiveness of business models applied to them.

In

Figure 2, each 1st level stakeholder has been characterized in relation to the interest in creating a new business model and their influence in relation to the final BIPV customer.

In general, the stakeholder with the highest financial interest in creating a business model is the one benefitting directly from it. This is typically the stakeholder who has a business that depends on success in the BIPV sector, like the BIPV producers and specialized suppliers. The stakeholders with medium interest are typically stakeholders who only have a few BIPV projects per year and see this as a niche market. The stakeholders categorized with low interest are typically stakeholders who are rarely in contact with the BIPV industry and barely dependent of the income coming from this field of activity.

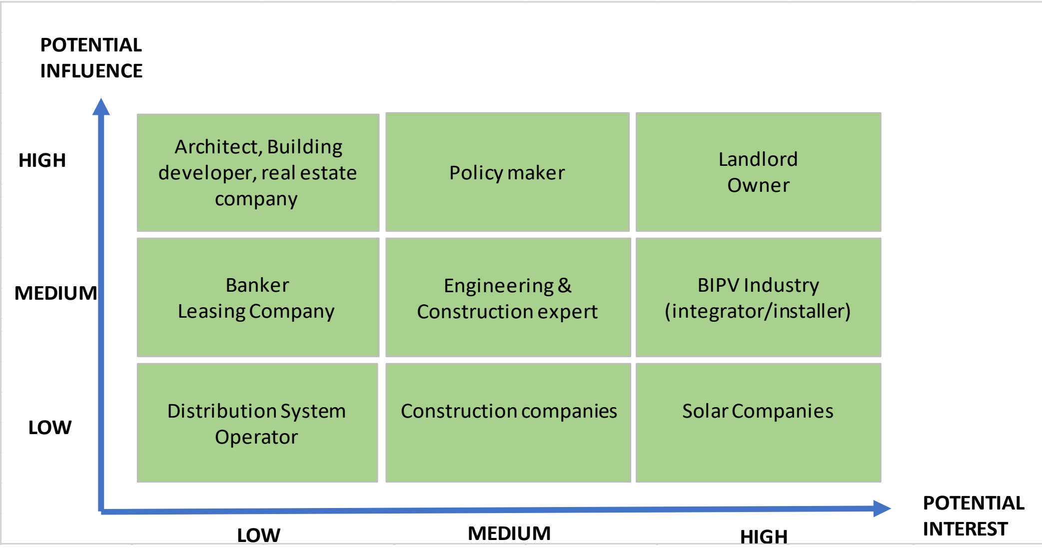

Figure 2: BIPV 1st level stakeholder mapping in relation to potential interest in a new business model

The stakeholder with the highest interest and high influence in creating a new business model is the landlord/owner. Without a sound business model for the landlord/owner, the realization of a BIPV project will be difficult. Next to the landlord/owner is the BIPV industry and BIPV specialized companies which only supply BIPV systems.

In Table 3, each 1st level stakeholder's interest and influence are briefly described in relation to the creation of a new BIPV business model.

Table 3: "Stakeholder influence/interest"

Stakeholder	Influence/Interest
Landlord/owner	The landlords or owners of the BIPV plant are the most important stakeholders in terms of influence and interest. They will be the final decision-makers and must be convinced that a BIPV system is the best solution for their building when looking at both financial, public relations and environmental values.
BIPV Industry (integrator/installer)	BIPV industry actors are the main stakeholders in the value chain and have a high interest in creating new business models. They need to have an attractive business model to accompany their product and reinforce its attractiveness, and will have to convince both the landlord/owner and his consultants that BIPV is a good solution for their project. A strong connection between these stakeholders is of high importance.
Solar Companies (façade and roof builders)	The solar companies typically have a high interest in offering a BIPV system or PV system in general and have a high interest in developing a business model. They are often not involved in the planning process and have less influence when decisions about the BIPV plant is taken. The companies can offer their products or their

	expertise in performance simulation, for example, to engineering and construction experts, and see BIPV as a potential for growth.
Policy makers	The local or national policy makers have a high influence on BIPV projects. If local urban-planning rules require aesthetic solutions, this can be an important market driver for BIPV. Also, regulatory adaptations required by the Energy Performance Building Directive impose some restrictions from which BIPV might benefit. Despite this, their interest in business models itself can be considered as low. They can also apply tariffs and fees to (BI)PV systems, hence threatening their profitability.
Engineering & Construction experts	Engineering and construction experts are often involved at a later stage in the planning of a BIPV project. If involved at an early stage, some of the challenges to fitting a BIPV system to an existing construction project's characteristic could be avoided.
Construction companies	Construction companies typically supply standard building components fitted for each project, which have been designed and developed by the architects or consultant. They have a low influence on the planning and decision-making process but might have interest in installing a BIPV plant if this is planned and can prove to expand their customer base.
Architects	The architect has a very high influence on the decision for choosing a BIPV system and is therefore an important stakeholder to convince. He/she is in direct contact with the building owner and will have a major influence on the final decision. The interest of architects is often low if they have no experience with BIPV or have another mindset about the building design. Instead, they often see it as an extra constraint to creativity.
Banker/ Leasing company	The banks and leasing companies have a low interest in BIPV business itself. They are looking at the economic model built around the BIPV plant and if the result looks good and the owner has a good financial situation, these stakeholders will finance a project. Whether it is a regular construction project or a BIPV one has limited impact, if information is sufficient, ensuring that risk perception is not biased, which could influence financing conditions. Hence, their influence is important as they could threaten the feasibility or attractiveness of the project by refusing to finance it or requiring high interest rates.
Distribution System Operator	The DSO has a low influence and interest in BIPV projects. They supply the electrical infrastructure for the project and are often nationally regulated and only allowed to operate the grid and conduct business that is directly related to grid operation. A BIPV

	project is not very different to a regular BAPV project from their point of view. Considering the current regulations in Europe, their influence is limited as they cannot refuse the connection of the installation to the grid if it has been installed by a certified company.

When a BIPV project is in the early stage of planning, there can be lack of information and unanswered questions about the whole project. It is important that key BIPV stakeholders establish a close relationship with the customer, in which exchange of information and collaboration are ensured. These four important stakeholders are shown in Figure 3.

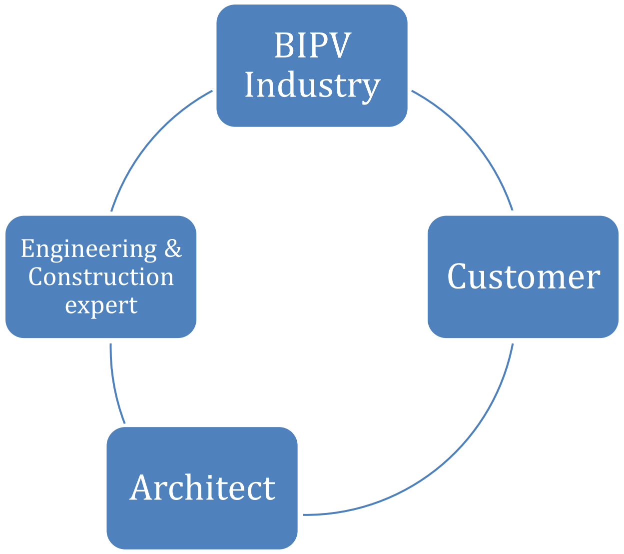

Figure 3: Links needed between the most important stakeholders

When planning a new construction with BIPV, it is important that BIPV is included in the very early stage of the planning process. To ensure that all aspects affecting the project are covered, the four stakeholders seen in Figure 3 must be involved.

In the early stage of a building project, the customer typically discusses the BIPV ideas with the architects, addressing shapes, colours and transparency levels. The architects involved need to have some basic information about BIPV to advise their client in the best way and to include BIPV in the building design. If the building design has progressed too far, it is difficult to change it and to include BIPV. Hence, the resulting solution can be suboptimal. Involving a BIPV engineer/expert in this process, as early as possible, will give a better outcome and any technical issues and challenges can be addressed prior to the final planning of the building. This expert must combine expertise in the field of construction with solar and electrical engineering.

The earlier in the planning process all four stakeholders become involved in the project, the better the result. It is common that the engineering and construction expert is involved at a late stage of the project and then BIPV is often seen as a complicated additional element to include in the building. Moreover, integration of BIPV into a building is not only a matter of the envelope but also of the electric system, which also needs to be taken into account during the design and installation phase. Not only the physical integration of cabling and power electronics must be designed well (taking safety, heat generation, etc. into account) but also the voltage of the system must be planned cleverly to optimize the need for power electronics components (micro-inverters inverters and/or power optimizers) and the overall performance of the BIPV installation.

4 INTRODUCTION TO THE FACILITY FRAMEWORK BASED ON THE BUSINESS MODEL CANVAS

Designing a business model implies defining how a company will create value, deliver it to its customers and capture a share of it to generate income. For that purpose, the business model canvas is often used as a supporting tool. The Business Model Canvas is a framework containing all key information related to the practical application of the business model, in a concise and readable form. Various versions exist, with slight differences between them. The following elements are always present:

- Value proposition
- Partners
- Distribution channels
- Target customers
- Cost structure
- Sources of revenue

An example of a typical business model canvas is shown in Figure 4 below. This is one of the most widely used templates. Other components may be included in the business model depending on the idea.

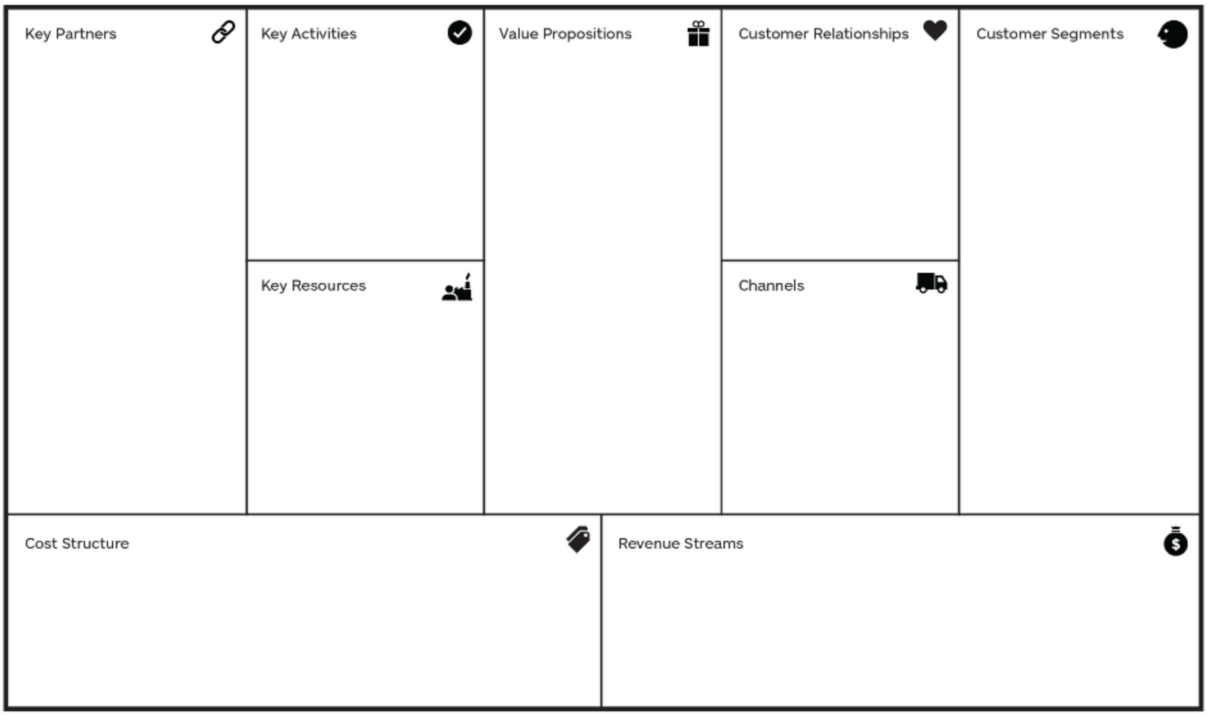

Figure 4: The Business Model Canvas (Source: Strategyzer.com)

Defining a business model is often specific to one company and one of its products or services. Relying on Business Model Canvas as a tool thus presents the risk of narrowing the scope and limiting the impact of the analysis. For that reason, this report includes an adapted version of the canvas, developed by UX Berlin as part of its Business Innovation Kit [25]. This is a values-based version of the business model canvas and is used as a guiding framework. It is considered more suited for innovative solutions for which values constitutive of the value proposition have not yet been identified exactly. In addition, the most appropriate way to communicate with customers and stakeholders is also included in such a framework, in the "touchpoints" box. Generally, the way this framework is ordered describes the thought path developed in the analysis and the structure of this report. The UX Berlin business model canvas is shown in

Figure 5 including the key questions for facilitators. The components have been structured under four subtitles. This framework aims at helping the involved stakeholders to ask themselves the right questions and identify necessary focus points. “Values-based” means that what is desirable for all stakeholders is the starting point for the development of new business models. New opportunities may arise from introducing new values to a business and new innovative business models can result from renewal of several components in the canvas. The Business Innovation Kit highlights that new normative orientations, such as sustainability, family friendliness etc., create opportunities for business innovation. Possibly, this framework will allow generic cases representative of the situation on the market to be presented.

The first step is also called “Grounding” and refers to the purpose and fundamental values of the activity. With a common ground established, the iterative process of designing business models can start. This is followed by “Demand”, where values are proposed to stakeholders, also taking customer needs into consideration. The next step, “Interaction”, is about delivering the value proposition to the customer and includes touchpoints and sources of revenue. The last part is “Performance” and describes how value is delivered, including cost structure.

A refinement phase then follows, where different business models are created, based on the ideas in the framework.

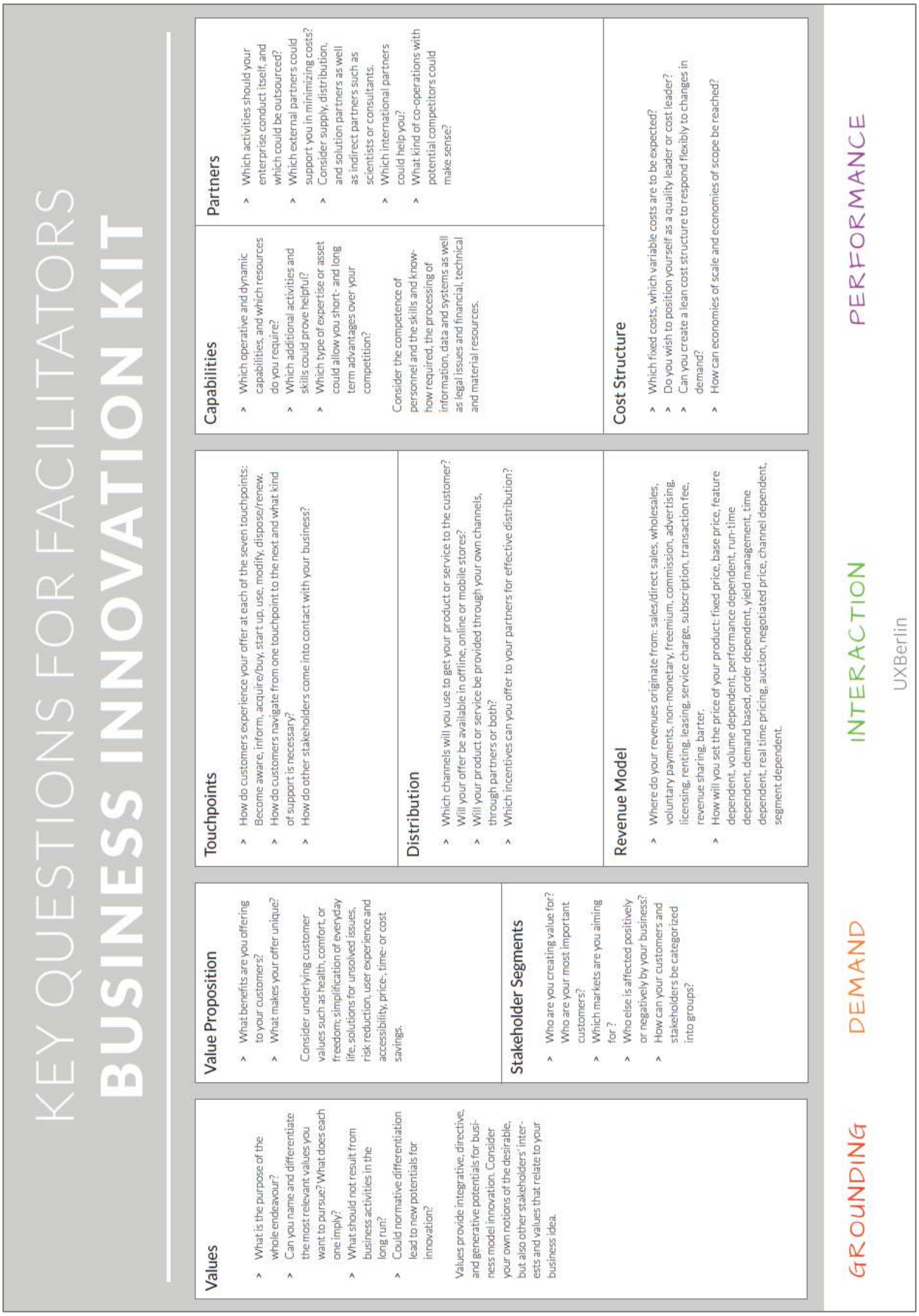

Figure 5: The "Key questions for facilitators", adapted from the traditional business model canvas (Source: UXBerlin)

5 BUSINESS MODEL CANVAS EXAMPLES

The guiding examples of BIPV business models in this section include two specific segments: residential buildings and commercial buildings. For each building type, various cases will be described, see Table 4.

Table 4: Business model cases

Case #	Building type	Building ownership	Application area	Main stakeholder considered
Case 1	Single-family housing	Owned by occupant	Roof	BIPV system installer
Case 2	Multi-family housing	Rented by occupant	Roof	(Social) housing company
Case 3	Commercial building	Owned by occupant	Roof or Facade	BIPV product manufacturer
Case 4	Commercial building	Owned by occupant	Facade	BIPV system installer
Case 5	Commercial building	Owner or rented	Facade	Energy service provider

In the case of residential buildings, (social) housing for rent will be investigated. A more classical approach will be adopted as well, considering single-family housing occupied by their private owners. In both cases, a BIPV installer supplies the system, providing the product and installing it. In the case of commercial buildings, two approaches are considered, whereby the first one is quite conventional whereas the other aims to be innovative. The first case is for manufacturers of BIPV products, i.e. modules and mounting solutions. The other encompasses the possibility of combining services with BIPV systems.

In each case, the analysis will highlight, among other aspects:

- Which are the key values and how should they be communicated?
- Which stakeholders should be involved and collaborate?
- The potential revenue model.
- Pitfalls to avoid and remaining challenges.

5.1 Project-based business models for residential buildings

The following two business cases for residential buildings differ in two aspects: ownership (see section 5.1.2) and building typology characteristics. Building typology characteristics link to the key difference in housing typology related to (nearly) zero energy buildings (nZEB), i.e. the roof surface area of multi-family buildings is simply not enough to cover the energy demand of all households located in the building. By contrast, this aspect is a key consideration for private homeowners to invest in a complete BIPV roof.

5.1.1 Single-family housing in the private homeowner market

In this section, the business model addresses a BIPV solution that is supplied for privately owned, single-family houses. Thus, the stakeholder in focus is the installer and supplier of the BIPV system.

Single-family housing is defined to include (semi-)detached and terraced houses and BIPV is mostly applied within the (pitched) roof surface. The key building block of the business case for BIPV within the private homeowner market builds upon self-consumption and the investment cost is covered by a reduction in electricity costs. Photovoltaic installations, as a key component to reach (near) zero energy, are applied to generate electricity from a renewable source to cover the household energy demand.

Regarding the application of BIPV products, the relatively large roof area of single-family housing is most efficient for this purpose, in addition to the fact that the annual total irradiance is higher than for facades, considering a similar orientation. Nevertheless, the dwellings are still connected to the grid: a surplus of electricity is delivered to the grid and, conversely during periods of insufficient production, the electricity supply is still ensured.

The stakeholder at the focus of this business model is the one-stop-shop company supplying the BIPV system. Key aspects are presented in Figure 6.

Business Model /// *BIPV Product for Privately Owned Single-family Housing*

Values
- Renewable, local electricity, for direct consumption by homeowners (reduced energy costs, self-reliant)
- Reduction of environmental impact in built environment: reduced CO_2 emission and operational energy consumption

Value Proposition
- Energy cost reduction by local electricity production for direct consumption by residents. Increased independence from grid / energy market.
- Integrated solution for homeowners who face renovation or new construction anyway
- Aesthetics, customised design, sustainable identity

Stakeholders

Private homeowners who are concerned about:
- Saving on energy bills (nZEB)
- Facing renovation of the roof anyway

Other beneficiaries:
- One-stop-shop company (system integrator)
- PV suppliers
- BIPV installer

Touchpoints
- Awareness creation and information distribution by: word of mouth; exhibitions; referrals.

Distribution

Direct contact with homeowners building upon the concept of a one-stop-shop service provider (self-employed contractor). Other distribution channels:
- Main contractors (sub-contracting)
- Service installation contractors (sub-contr.)
- Architects / consultants (prescriptive)

Capabilities
- Marketing experience; persuading homeowners to adopt
- Planning capabilities
- Design capabilities for BIPV system (reflecting mature BIPV roof solution)
- Consultance capabilities on energy efficiency
- Innovative mounting system

Partners

Building and design partners:
- PV supplier
- (Other) component suppliers
- BIPV installer (dedicated team specialized in installing BIPV)

Occasionally:
- Architects / consultants
- Main contractors

Revenue Model
- BIPV sales building upon the concept of a one-stop-shop (including consultancy, design and engineering and installation)

Cost Structure
- Operational excellence strategy
- Cost structure: PV system cost (technical components); design and engineering; subcontracting for installation of BIPV; overhead
- Economies of scale: reduction of capital cost due to purchasing technical components in large quantities

Figure 6: Business model for the one-stop-shop company supplying a BIPV system for single-family housing.

Key values

The key values of the BIPV roof solutions basically link to the one-stop-shop market approach. The one-stop-shop solution encompasses the (aesthetic) design and engineering, planning, production, on-site installation and commissioning of the BIPV roof. Homeowners who invest in BIPV roofs need to invest in a complete roof structure or need to comply with strict energy performance regulations in the case of newly built housing and have relatively high electricity costs. This implies that the value of environmental sustainability is not economically quantifiable although it can still be considered a key reason for private homeowners to adopt BIPV. These rooftops are typically framed as ”energy roofs” integrating a variety of solutions for typical roof design issues, see Figure 7 and Figure 8:

- Aesthetic roof design
- Sustainable electricity generation (and management)
- Windtightening and waterproofing, including waterproof penetrations through the roof surface (ventilation openings, chimney)
- Skylights for daylighting areas under the roof surface, in some cases
- Flexible connections between the roof surface and dormers, gables, gutters, and ridge

Figure 7: Example of a BIPV roof for a stand-alone house (renovation)

Figure 8: Example of a BIPV roof for terraced houses (new build)

The one-stop-shop solutions within the BIPV market matches Treacy and Wiersema's Operational Excellence strategy (1993; 1995), in contrast to business strategies based on vendor-customer relationships or product leadership. The strategic Operational Excellence approach to the production and delivery of products and services aims to lead in terms of price and hassle-free service by making operations lean and efficient.

The evaluation of a BIPV system by private homeowners includes the assessment of various interrelated criteria including

- Avoided costs for other construction materials, e.g. roof material and PV
- Investment costs and valuation of electricity generation
- Hassle-free service provided by the supplying company
- Aesthetic design aspects

The first component is straightforward, as the benefit of avoiding costs during construction will directly benefit the homeowner by reducing the initial investment costs compared to a regular roof and additional PV installation. The second component links to the assessment of the investment costs relative to a reduction of the electricity bill, i.e. the extent that homeowners financially benefit from self-consumption as reflected by a reduced electricity bill. In addition, in many countries, the government and energy companies have introduced feed-in or netting schemes encompassing the reimbursement that private homeowners receive for the surplus electricity delivered to the grid. This reinforces the financial attractiveness of investment in BIPV systems.

The fourth component reflects aesthetic design issues of the BIPV roof. A variety of standardized options can be selected. This makes it possible to increase the influence of clients on the design.

Key stakeholders

The key beneficiary of the BIPV roof system is typically the private homeowner. Other important actors involved in the completion of the project are the one-stop-shop company and (BI)PV suppliers and installers. The one-stop-shop company could subcontract installation of the BIPV system to dedicated specialist installers rather than employing tradespeople. The role of the architect is rather limited in this business case, i.e. during the initial development of the BIPV system, when the architectural design is established, including fixed design rules and standards. Across projects, engineers from the one-stop-shop company or external consultant engineers develop customized BIPV rooftop designs based on these fixed design rules and standards.

In the case of other ownership models like financial leasing, additional stakeholders are involved like financial institutions and insurance companies.

Potential revenue model

The one-stop-shop company share of the value generated for the stakeholders is generally captured via direct sales of the BIPV roof solution including internalized and externalized services. The primary source of revenue for the one-stop-shop company is the margin applied on internalized services. Nevertheless, externalized services can be a source of revenue if a margin is added to the cost but this depends on the competitive environment.

Pitfalls to avoid and remaining challenges

Using a one-stop-shop company brings hassle-free benefits for the customer. The externalization of services brings benefits in terms of flexibility, but it comes with a risk, such as limited capability to control the quality of externalized services. Also, a sufficient level of expertise should be maintained internally to maintain a competitive advantage. This would act as a protective barrier. Price reductions are considered a necessity to improve the attractiveness of building-integrated photovoltaics. One way to overcome these hurdles is to select partners carefully. Component suppliers which already have large-scale production facilities in place and standardized solutions that are easy to mount and connect could contribute to overcoming both the production and investment cost inertia.

Finally, three diffusion-related issues that increase risk perception need to be resolved. The consequence of risk perception is high customer acquisition cost for the one-stop-shop company, which harms its business ability to make a profit. First, market awareness of available BIPV solutions and best practice could be improved (touchpoints) by implementing information dissemination activities. Second, due to fire safety issues[1] with installations that do not follow best-practice guidelines, where poor connectors were used, homeowners have developed a negative perception and consider BIPV technology immature in its current stage of development. Third, uncertainty about government policy concerning the PV regulation makes homeowners reluctant to invest in either BIPV or BAPV systems.

5.1.2 Collective self-consumption in multi-family buildings in the rental sector

Current legal developments increasingly allow for collective self-consumption within a building. This means that the different building users consume locally produced electricity on-site. Thereby, the use for collective installations such as elevators and lighting is expanded, increasing the share of locally consumed electricity and allowing consumption for private purposes (in households, in the case presented here). To this end, the generated electricity is split between different consumers within the building. The possibility for such a model and sharing/billing modalities depend on the national legal framework. In the EU, implementation of corresponding national legislation is in process and partly in place already. The business model in Figure 9 focuses on a newly built multi-family house owned by a housing company for renting purposes. We specifically address new buildings because the offered services can be included upfront in all rental agreements. In existing buildings such a model is equally feasible but more demanding due to potentially partial participation by a subset of tenants and tenants moving away.

[1] Bende, E.E. and Dekker, N.J.J. (2019) *Brandincidenten met fotovoltaïsche (PV) systemen in Nederland (Fire incidents with photovoltaic (PV) systems in the Netherlands).* Report **TNO 2019 P10287, retrieved on May 20th:** https://www.tno.nl/nl/over-tno/nieuws/2019/4/tno-brengt-brandincidenten-met-zonnestroomsystemen-in-kaart/.

Business Model for (social) housing companies *new built multi-family house - rental sector*

Values
- Renewable, local electricity provision for direct consumption by tenants, common usage and feed-in
- Reduced grid electricity consumption
- Improved aesthetics compared to BAPV
- Larger areas available compared to BAPV

Value Proposition
- Local renewable energy
- Reduced electricity costs, potentially reducing energy poverty
- Personal sustainable identity
- Increased independence from energy market
- Extended services based on PV electricity (e.g. e-mobility)

Stakeholders
- Tenants
- Possibly neighbours (energy communities)
- Architects
- BIPV installer/system supplier
- Technical planners
- Urban planners
- Possibly finance institute
- Insurance companies
- Electricity utility
- Grid operator (DSO)

Touchpoints
- Usual advertisement / anouncements for tenants etc.
- Social media
- Energy bill
- Operating costs bill

Distribution
- Advertisement for new tenants
- Inclusion in rental agreements

Capabilities
- Experience with construction
- Experience with economics
- Contacts to technical planners and installers
- Marketing experience
- Experience with electricity billing

Partners
- BIPV producer and installer
- Mounting structure producer
- Possibly finance institute
- Insurance companies
- Grid operator
- Architects
- Potentially electricity utility

Revenue Model

Depending on housing company type (commercial or social):
- Cost coverage in usual cost components
- Increased rent, and/or
- Direct sale of electricity to residents (possibly involving electricity utility and grid operator and additional services such as charging stations)

Cost Structure
- Net capital costs: savings from substituted materials
- Operating costs
- Income from electricity sale or increased rent

Figure 9: Business model for a newly built multi-family house owned by a (social) housing company for the rental sector

Key values

The major value of such a BIPV initiative is the provision of locally generated renewable electricity to the tenants. Such a model contributes to partial independence from the energy markets and should result in lower electricity bills for tenants. The actual potential for cost savings due to reduced electricity consumption from the public grid strongly depends on the national context, such as the specific provisions on grid fees and electricity tax. Poorer segments of the population may be addressed for instance by social housing companies, potentially reducing energy poverty. In addition, values related to an awareness of the consumption of one's "own" local, renewable energy may play an important role. The aesthetics of a BIPV installation can contribute to this awareness and to the identification of tenants with the initiative. The model can be further expanded beyond consumption at the household level and encompass additional services such as the provision of charging stations for electric vehicles with the locally generated renewable electricity.

Key stakeholders

We take the perspective of the housing company as the major stakeholder in this model. Given their important role in the multi-family building sector, housing companies have an immense potential to drive BAPV and BIPV investments. Other involved stakeholders include partners for the technical implementation (e.g. the manufacturer and the installer of the PV plant, technical planners), grid operators (DSOs), architects and potentially financing institutions, insurance companies and electricity utilities. The tenants, as primary consumers of the provided electricity, are the customers and should be informed accordingly about the features that the model provides. In the simplest set-up, the housing company would invest in, and operate, the installation itself. Alternatively, the involvement of companies that offer a contracting solution could reduce the technical, administrative and possibly legal burden for the housing company and would shift the initial investment to the contractor. This would correspond to a combination with the model presented in section 5.3.2 (“BIPV as a service”). Depending on the legal context, the housing company may not be allowed to deliver electricity to the tenants itself. Currently, in some EU countries (e.g. Austria), clarification of this legal aspect is on the agenda. This would require the involvement of a utility, which would act as electricity provider. This could equally correspond to a combination with the “BIPV as a service” model if the involved energy service company (ESCO) is a utility. In that case, however, the role of the housing company may be limited. In countries where the concepts of “collective” self-consumption or “energy communities” are defined in an appropriate way, the housing company could sell electricity to the tenants on its own.

A major difference may exist between social and commercial housing because social housing companies have tight, partly strongly regulated cost structures, which limits their capacity for additional investments. On the other hand, where PV investments are possible, they underlie less strict requirements for profit generation as compared to commercial investors. If a BIPV system contributes to the reduction of electricity costs, this would directly contribute to the mission of social housing companies.

Potential revenue models

The revenue for the housing company results from the electricity provided to the tenants, directly through the sale of electricity or indirectly through increased rents. In the case of social housing companies, this model may represent a specific service to the tenants and a contribution to the social mission rather than as a business model that would allow profit generation. In all cases, the allocation to the different apartments needs to be managed. There are different accounting options to deal with the electricity from BIPV:

- A certain amount of electricity – e.g. in relation to the size of the apartment – is provided without an additional payment. The investment and operating costs may be covered by a higher rent. Tenants consequently have a further reduced electricity bill as only the remaining electricity that is drawn from the public grid needs to be paid. Attention equally needs to be paid to the legal situation, i.e., to whether the housing company has the right to deliver electricity to the tenants. In some EU countries this model is already applied for multi-family houses (e.g. Germany).
- Tenants pay separately for the BIPV electricity they consume. The solar electricity price should be below that from the public grid in order to guarantee the attractiveness of the offer. This would involve the issuance of two electricity invoices (one for the PV electricity, one for the electricity from the public grid). Depending on the legal context, the selling of electricity by the housing company itself is however difficult, as the housing company may

have to obtain the status of an electricity utility, if collective self-consumption is not allowed without the involvement of a utility. Alternatively, an external utility could be involved.

- A mixed electricity tariff with only one invoice including both local PV electricity as well as electricity from the public grid for a reduced per kWh price. For legal reasons, this would typically involve a utility. In this case, the housing company is not at the core of the business model anymore.

In our business model canvas, we consider case 1, as this solution is the easiest to implement and least bureaucratic (e.g. no need for PV electricity billing). Partial use of the PV electricity for collectively used installations would also reduce the operating costs of the building. The combination with integrated services such as e-mobility could be of value for increasing the attractiveness for tenants and could expand the revenue streams.

Pitfalls to avoid and remaining challenges

A major, potentially constraining, factor is the legal situation regarding the general option for collective self-consumption and for electricity delivery by the housing company. In many cases, a utility may have to be involved, which may strongly reduce the role of the housing company. In addition, this involvement of another stakeholder may influence the price of the PV electricity.

In the case of implementation in an existing building (e.g. as part of a renovation), tenants may have a voice in the decision on investments, especially if this influences the future rental fee. Also, where market liberation guarantees free choice of the electricity provider, tenants may not be forced to consume electricity from BIPV if this was not an integral part of the rental contract from the beginning. In these cases, cost savings would be a major argument and good stakeholder communication is necessary.

The case presented here for the rental sector also needs to be distinguished from the case of apartment owners. This difference concerns legal aspects regarding the decision on the investment but also questions of who invests in the installation and who consumes the generated electricity to which extent.

5.2 Product-based business model for commercial buildings

In this case, the example comprises the business model that can be designed around a BIPV product for commercial or public buildings (e.g. an office building, a shopping mall, a school or a hospital). The typical case would be a rear-ventilated facade used for new constructions or renovations, but a similar business model can also be used for a BIPV product addressing roofs, balconies, solar shading etc. The stakeholder at the focus of this business model is the manufacturer of the BIPV product and key aspects are presented in Figure 10.

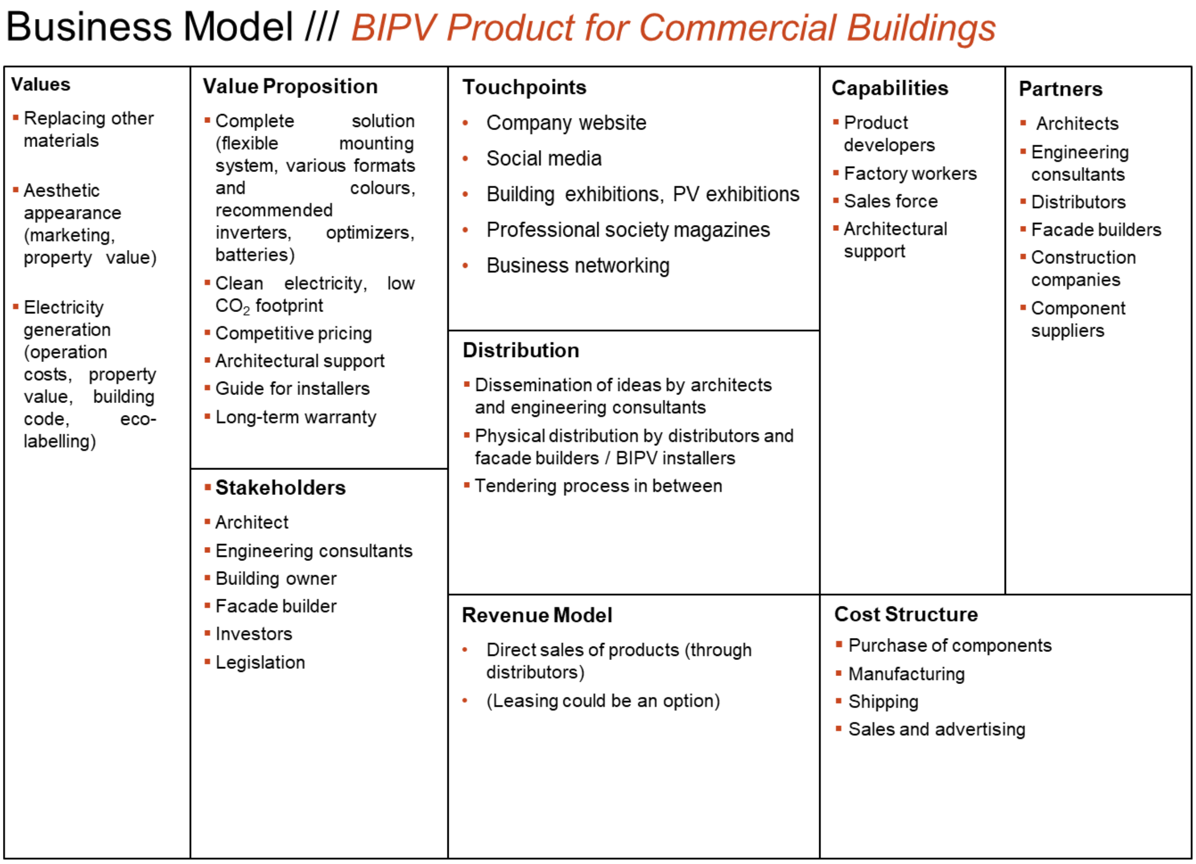

Figure 10: Business model for the manufacturing company of a BIPV product for commercial buildings

Key values

The evaluation of a BIPV system in these applications will include a combination of avoided costs for other construction materials, a reduced electricity bill and the aesthetically attractive appearance and 'green status', which can be quantified as marketing value. The first component is straightforward, as the benefit of avoiding costs during construction will directly reduce the investment. Regarding the reduced electricity bill, this could also be straightforward, if the solar electricity is self-consumed by the owner of the building. However, this value could also be lower, or harder to capture, if a large share of the electricity is fed to the grid or if the electricity is used by others than the owner of the BIPV system, such as in the case of tenancy.

The marketing value is even more complex and will vary widely from very high to almost zero, depending on the stakeholders' ability to valuate aesthetics and convert profile into money through creative marketing activities. The lowered electricity costs and the increased marketing value could also result in a higher overall value of the property. For companies actively buying and selling real estate, the impact on the property value could be an important incentive for BIPV installations (see section 2.2.2).

Key stakeholders

The owner of the BIPV system is typically the owner of the building, whereas the user of the electricity generated could be either the owner or tenants (one or several). Regarding the architectural aspects of the BIPV system, the “user” is in principle anyone who ever looks at it, or even at a picture of it, with customers and employees being the two major groups in most cases. In practice, the architect will be the main stakeholder who will decide whether to work with the appearance of the product. Other important actors in the realization of the project are engineering consultants and facade builders, or other specialized BIPV installers.

Potential revenue model

The manufacturer’s share of the value generated for the stakeholders is generally captured through direct sales of the product. In some cases, the manufacturer also provides engineering services, which are charged by the hour. More extended offers, like including financing and providing a leasing contract for the BIPV system, are probably more suitable to be developed by the installer or a third party. Such arrangements will be further discussed in section 5.3.

Pitfalls to avoid and remaining challenges

The task for manufacturers is to produce a durable and aesthetically pleasing product at a compatible price, which could easily be purchased and installed onto new or existing buildings. This involves many challenges, where two of the major ones are to reduce costs and to simplify the processes of decision making, purchase and installation.

In order to make it easy to design a building skin, it is advantageous if the BIPV manufacturer can offer a complete solution including mounting details and “dummy” modules to fill out irregularly shaped areas. There should also be reasonable solutions to handle requirements like accessibility to service functions on roofs and to make other installations like lamps, signs etc. on facades. The manufacturer is also dependent on the help from architects and engineering consultants, for the customer to be able to make an investment decision. Thus, it is crucial that these stakeholders have enough information about the aesthetic and technical specifications of the product.

Probable success factors for BIPV manufacturers are to achieve cost reductions by series production and/or to prove a high value for stakeholders by aesthetic quality and the replacement of other building materials. These are remaining challenges for most BIPV manufacturers.

Major pitfalls to avoid include providing insufficient information about technical details, aesthetic qualities and price to stakeholders interested in the project. To be able to overcome any potential objection regarding profitability or durability, it must be simple at least to design a system with the product and to purchase it.

5.3 Service-based business models for commercial buildings

In this section, possibilities are explored that add quantifiable value to BIPV systems by offering extra services combined with the BIPV system, in addition to electricity generation. The additional value will benefit the owner of the BIPV system, but a share of it can also be captured by the manufacturer of the BIPV product (facade cladding, balustrade, shading elements, etc.), the installer of the BIPV system or the partnering company specialized in advertising or communication. Globally, it could help investors to recover their initial investment faster than if they were relying exclusively on electricity revenue and allow even more innovative usage of the facade.

5.3.1 BIPV system as a communication tool

The structure of this business model is summarized in the canvas below, see Figure 11. In this section, the perspective of the BIPV installer will be taken. Simplified economic and performance estimations will also be given to demonstrate the opportunities that such a service represents.

The service considered here is based on the possibility for the customer to add a visual display on top of the BIPV module. This would be allowed by the internalization of the required competence or the establishment of a partnership with a company having the expertise. Note that, depending on the objective, part of or all the BIPV system might be covered by the display. Such visual displays can serve two purposes, influencing also the potential for additional revenue: corporate communication or advertising. In the latter case, it is imperative to establish a strategic partnership with a company specialized in this domain. Different techniques can be used to customize the appearance of the modules, each having its strengths and weaknesses, as will be discussed later in this section. The first option is the addition of a coating or a printed layer on the front glass cover of the module. The second possibility is the incorporation of LEDs within BIPV modules. The number and placement of these lights depends on the final use of the product, as well as the number of modules installed. For example, in order to advertise or display a company logo during the day, many more LEDs will be necessary than if it should only appear at night. Similarly, the associated extra capital costs will depend on the technology chosen. Finally, it is likely that such a business model would also require additional administrative work and planning preparation, further increasing the costs.

Business Model /// *BIPV Service Commercial Buildings*

Values
- Extra revenue with same asset
- Individuals aesthetics
- Self-financing
- Electricity generation
- Innovative uses of the facades

Value Proposition
- Extra income
- Accelerated recovery of the investment
- Original communication

Stakeholders
- People looking to add value to their building
- Advertising companies
- BIPV manufacturers and installers
- Coating manufacturers
- Companies looking for unusual ways of communicating

Touchpoints
- Advertisements
- Networks of the involved stakeholders:
  - Manufacturers of BIPV
  - Advertising/communication company

Distribution
- Advertising companies' channels
- Corporate communication companies' channels
- BIPV manufacturers'/installers' channels

Capabilities
- Communication with client
- Development of complex contracts
- Manufacturing of customized BIPV modules
- Legal competence

Partners
- Colouring/coating technology providers
- Advertising companies
- BIPV manufacturers and installers

Revenue Model
- Income from the advertising space
- Income from electricity generation
- Income from the extra services provided and extra value generated

Cost Structure
- Fixed costs of manufacturing and installation.
- Extra cost of coating/colouring
- Labour cost.
- Administrative and planning cost
- Potential decreases from economies of scale and technological improvements

Figure 11: Business model for the manufacturing company of a BIPV service for commercial buildings

In the following subsections, the crucial elements of the business model are further developed, such as the key values, the key stakeholders as well as the potential revenue model. This is followed by consideration of potential pitfalls and remaining challenges for the implementation of the business model.

Key values

This innovative approach could be a way for BIPV installers to expand their customer base, by increasing the economic attractiveness of their value proposition. Indeed, the final customer would be able to have a shorter pay-back time for his/her investment and even generate substantial extra revenue, for example if the visual displays are used as an advertising platform. Figure 12 shows an example from a hotel in Brussels. In such a case, the BIPV installer would have to partner with a company specialized in the renting of advertisement space such as billboards. This would be necessary for the BIPV installer to really improve the value proposition, as it would guarantee the extra revenue linked to the BIPV system for the investor, at least to a certain extent. Of course, this assumes that the extra cost due to the addition of display features to BIPV modules, compared to traditional solutions, is compensated by the extra revenue for the investor. In addition, such a service can create value for the companies willing to advertise, as the originality of the displaying space could potentially attract more attention. This aspect might also be an advantage for the advertising companies renting the space, as they could increase the fee they charge, hence generating extra revenue.

Finally, such a solution could increase the value of the property, if installed on a building where advertising potential has not yet been leveraged, as extra revenue would be generated.

Moreover, the BIPV installer, through such an innovative value proposition, could allow its customer to have a unique communication platform. Indeed, the colouring of the BIPV modules or the application of a visual display could be leveraged to promote corporate communication, by displaying the colours of the company or its logo. This might be a solution when the planned location of the BIPV system is sub-optimal and therefore, not attractive for advertising purpose. In such a case, the opportunities would come from the increased visibility for the company thanks to the originality of the communication tool, under the condition that it is noticeable that PV is installed. The visual message can even be very simple, as the BIPV system would attract attention by itself. Thus, more people would notice the logo or other type of corporate communication, for example increasing the familiarity of the company, its name and brand. As an example, the "green status" discussed in section 2 might be leveraged here for marketing and communication, promoting a sustainable image. Also, usage of (innovative) technologies such as BIPV and illuminated facades with LEDs could benefit the reputation of the company, which would appear as embracing the future. Nonetheless, it is not straightforward to quantify the added value of such a feature, even though it is likely that it will provide benefits, whether they are directly quantifiable or not.

Figure 12: The PV facade of a hotel in Brussels with its corporate logo printed on the modules (Source: ISSOL)

Key stakeholders

The first important partner to involve in the design of such a business model is a BIPV manufacturing company. As their products constitute the heart of the value proposition, it is essential to closely collaborate with them, in order to permit the display of visuals on the BIPV system in an optimal way and ensure the validity of the manufacturer's guarantee. For the same reason, it might be necessary to collaborate, directly or indirectly via the BIPV manufacturer, with a specialized company which will oversee the customization of the modules, e.g. by providing the coating technology, as it is not the core business of the BIPV manufacturer.

Then, as mentioned above, a key partnership would have to be established by the BIPV installer with a company specialized in the renting of advertising space. Indeed, not all positions are suitable for advertisement, and not all suitable spaces are of equal value, as the location is crucial. Therefore, the expertise of an advertising company is very important. This advertising company, as a partner, could also bring additional customers to the BIPV installer, by suggesting the solution to its existing or new customers, or applying it to its existing advertising locations, in case it owns them.

In the same conceptual area, the BIPV installer could partner with companies specialized in corporate communication or the installation of facade graphics. As for the partnership briefly described above, it should be synergetic, with both partners improving their existing value proposition and revenue by the expertise and customer base of the other.

Therefore, key stakeholders would comprise:

- The BIPV installer
- The BIPV manufacturer who is willing and able to provide “customized” BIPV modules, potentially via another technology provider
- A company specialised in the renting of advertising space
- A company specialised in the installation of facade visuals for companies

Potential revenue models

The first potential revenue model is the typical one for advertisement space and does not bring any innovation. The increase of revenue is achieved thanks to an enlargement of the customer base. In other words, all the newly created value is captured by the customer. Such a revenue model would probably apply if corporate communication is the purpose of the visual display. In this case, the BIPV installation company relies on the products and inputs from its suppliers, such as BIPV modules, electrical components or mounting systems. It installs the system with these inputs and applies a margin to capture a share of the delivered value.

Then, extra values discussed above could be partially captured by the BIPV installation company, and possibly its partners, by increasing the margin. The final price of the solution for the customer would rise by more than simply the extra capital cost due to the visual components. Hence, a share of the additional revenue generated thanks to advertising would be captured by the BIPV installer. Such an approach is a values-based approach, in contrast to a simple cost-based one, as described in the first paragraph. If the printing, coating or LEDs would be used to advertise, such a revenue model could be applied, as additional values are easier to quantify.

Below, simple economic estimations showing the revenue potential of the discussed business model are described. They were made assuming that the BIPV installation would be used also for advertising purposes. Two options will be investigated: printing/coating and LED integration. The case of a tertiary-sector building, such as an office building or a shopping mall, has been taken. However, it could potentially be applied to any building with enough available space and an attractive location.

Taking the example of Brussels, a tertiary-sector building in an attractive location can generate up to 1000€ per year when used for advertising [6]. On the other hand, identifying the extra costs accurately is more difficult. First, possible local taxation on advertising can apply, which is not considered here. We assumed an extra cost of 100€/m² and a reduced efficiency of 30% for the printed modules [24] [2], accounting for 24 m² of the 100 m² covered by the BIPV facade cladding system (a power density loss of only 7.2% in total). Then, it is considered that the operations and maintenance cost increases when advertising is added onto the BIPV system, as printed modules must be cleaned more frequently to avoid additional power losses and keep the visuals clear. Hence, it is assumed to double, from 8€/m² to 16€/m² [11]. An 80% self-consumption ratio is assumed.

Table 5 documents the influence (in relative terms) of adding advertisement for a 10-year period, considering a system lifetime of 25 years, on some key parameters, compared to base case. It gives an overview of the potential impact on competitiveness of such a concept. Favourable effects are shown in green, and unfavourable ones are shown in red.

Table 5: The influence (in relative terms) of adding advertisement for a 10-year period, considering a system lifetime of 25 years, on some key parameters, compared to base case

Parameter	Relative variation due to advertising
System power density [Wp/m^2]	-7.2%
Total system cost [€/m^2]	+16.7%
LCOE[2] [€/kWh]	+4.9%
Project MIRR[3] [%]	+19.7%
Competitiveness [€/m²]	+15.1%

As shown above, the negative impact on cost and performance is compensated by the extra revenue generated. Indeed, the MIRR and competitiveness slightly increase. Hence it appears that such an additional service has the potential to be attractive.

Then, an estimation of the cost to establish a similar service, this time based on LEDs integrated into the BIPV modules, was made. The extra cost due to the LEDs themselves is rather limited. On the other hand, the extra material and labour required to integrate them into the existing manufacturing or assembling process are difficult to assess. Hence it was not included in the present calculations, but it should not be overlooked and must be carefully estimated by the BIPV manufacturer. Again, the simulation concerns a tertiary-sector building located in Brussels and a space of 24 m² within a total of 100 m² occupied by the BIPV system on the building façade. In addition, it is considered that the lifetime of the LEDs is the same as the BIPV module lifetime (25 years).

The first case considers the installation of LEDs at the top and the bottom of BIPV modules. The second is based on crystalline silicon PV cells and has dimensions of 1 m (width) x 1.65 m (height). As mentioned, it is assumed that 2 bands of LEDs are installed across the width of the module, each 1 m-long band including 60 LEDs (14.4 W/m), with an extra cost of 2.77€/m[4].

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[2] Levelized Cost of Electricity

[3] Modified Internal Rate of Return

[4] For example, as available on https://www.bol.com/nl/p/groenovatie-rgb-led-strip-5-meter-14-4-watt-meter-5050-led-s-12v/9200000070292169/

As the area occupied by each module is 1.65 m², 15 BIPV modules with integrated LEDs can be installed within the area of 24 m². In total, we can then position 30 LED bands of 1 m length (1800 LEDs, with a total installed power of 432 W). The associated total extra cost equals 83.1€ for the whole LED-covered surface. Considering a working time percentage of 33% per day on average (2920 hours per year), as the low density of LEDs would not allow any display during daylight, the extra consumption would be 1.26 MWh/year.

The second case assumes that multiple arrays of LEDs are placed over the surface of the BIPV module, between the strings of cells. For this option, it is assumed that CIGS PV technology is used, as the reduced size of cells allows the density of LEDs to be increased compared to the case in which crystalline silicon cells are used. Module dimensions are 0.66 m (width) x 1.6 m (height) and it is assumed that 16 bands are placed on each module, one every 10 cm of height. Each band includes 40 LEDs (14.4 W/m), with an extra cost of 2.77€/m. The area occupied by each module equals approximately 1 m², so we can place 24 BIPV modules on the defined surface area. In total, we can install 384 bands of 40 LEDs (15360 LEDs, with a total power demand of 3650 W). Considering a working time percentage of 100% per day (8760 hours per year), as the density of LEDs would allow to display elements even during daylight, the extra consumption would be 32 MWh/year. Using the average extra material cost of 2.77€/m, we can estimate the total extra cost associated with the new input materials (the LEDs) to be around 702 €.

These estimations show that such an option might be viable, as the costs appear limited in relation to the potential extra revenue, even though more detailed investigations are of course required.

Pitfalls to avoid and remaining challenges

The evaluation of the attractiveness presented above is simplistic. Multiple points need to be investigated further, and obstacles remain to be overcome. These explain also why only a 1-year period was considered in the economic evaluation in the case of coating/printing of the visual elements. The main obstacles we identified are listed below:

- Update of the visual display: the technical capability to modify the visual elements applied onto the modules depends on the printing or coating technique. In addition, potential damage to the front glass and coating due to the removal of the visual elements, as well as the cost of the update, due to material but also labour, must be evaluated carefully.
- Guarantee: if the printing or coating is not applied at the manufacturing stage, in partnership with the BIPV module manufacturer, but afterwards, the module performance guarantee might not be valid anymore. Also, the same problem could occur in the case of removal of the visual elements, as the physical properties of the modules could be modified.
- Reliability of the visual: it must be proven that colours will not change over time, at least not more than traditional advertisements on buildings over the duration of the advertising contract.
- In this estimation, the cost due to advertising is limited to extra material and process costs, assuming that the coating/printing is implemented at the manufacturing stage, hence not requiring additional labour costs. However, other elements may have to be considered. For example, as the visual elements inhomogeneously alter the irradiance incident on some

cells, the complexity of MPPT[5] increases, possibly requiring an adaptation of the algorithms used. Then, due to the same issue, the topology of the modules themselves or the system may need to be adapted. Also, extra power electronics (optimizers or inverters) might have to be installed. Nevertheless, if advertising is considered from the beginning of the BIPV project development, the extra work and costs might be limited.

- The reduction of performance might be reduced by a higher factor than the theoretical reduction of irradiance due to coating/printing, for the same reasons as mentioned above. Uncertainty concerning this aspect must be reduced because of the significant impact it can have on profitability.
- Reliability of performance: due to the print or the coating, soiling of the modules may increase, further reducing the performance. Technologies used to apply the visual elements must have proven that their impact on this aspect is negligible. In the estimation above, extra cleaning costs have been considered, as a conservative assumption. However, this could prove to be unnecessary.

Some of these obstacles could be reduced or removed by:

- Printing or applying the coating to another position, rather than applying it directly on exterior surface of the front glass cover. However, this could have an impact, positive or negative, on performance.
- To ensure that the space can be re-used and that the associated amount of work is limited, LEDs can be integrated and used to display logos, colours or messages. In this case, the extra cost and extra consumption need to be assessed. Using LEDs offers the advantage that adapting what is displayed will be much easier, and hence less expensive, compared to printing/coating. The risk of altering the physical properties of the modules will also be reduced. Nonetheless, the addition of a large number of LEDs might be difficult from a technical point of view.

In addition to the advantages mentioned in the previous paragraphs, LEDs have additional advantages compared to the printed or coated solutions:

- The programmability of LEDs allows the display over the LED surface to be changed.
- It requires only a one-off initial investment, with no update needed.
- No additional maintenance or supervision compared to the case of regular BIPV modules.
- Self-consumption ratio can be increased, as the LEDs will use the electricity generated by the BIPV modules.

[5] Maximum Power Point Tracking

5.3.2 BIPV as a service

The second possible type of service analysed in this section goes one step further. In this case, no additional service would be combined with the BIPV system. The system itself would become a service; the business model is depicted in Figure 13. In other words, the functionalities of the product would be sold rather than the product itself. These functionalities are the aesthetics, those related to its role as a building component (water tightness, air tightness…), the benefit of "green status" and of course sustainable electricity, generated on-site, at an affordable price. The company delivering these functionalities will be the focus of this discussion.

In such a case, the company offering the service would not have to be already active in BIPV. Indeed, not all types of competence need to be internalized. The crucial aspect would be the company's ability to gather and deliver the required expertise, through outsourcing or strategic partnerships. The company centralizing the key skills would probably take the form of an energy service company (ESCO). However, this could also be a new department or subsidiary of an actor from the BIPV or construction sector. In addition, this could be a service offered by a utility, for instance. Overall, the most important capability to be internalized would be linked to customer acquisition, financial and legal expertise. Furthermore, depending on the exact service provided, an accurate prediction of the electricity to be generated by the system might be essential.

Business Model /// *BIPV Service Commercial Buildings*

Values
- Peace of mind
- Energy independence
- Contribution to climate protection
- Aesthetics
- Financial security
- Architectural integration

Value Proposition
- Electricity bill savings
- Low risk investment
- No upfront cost thanks to third-party financing
- Green identity
- Operation & maintenance
- Monetize the façade & transform the building into an active asset
- Aesthetics
- Guaranteed price and power production

Touchpoints
- Energy bill
- Professional planning support and consulting
- Public demonstration, e.g. charging mobile phone for neighbours
- Architectural brochures and design tools
- Information sessions with municipalities
- Advertising through internet, newspapers, housing magazines, facade companies, general constructors
- Facade Ads asking „Do you really want this facade?"
- „Inhouse" installation

Capabilities
- Design
- Personalized service
- Sales function
- Monitoring of systems
- Constructors, architects, engineers
- Façade installers
- Energy management
- Utility/electricity producer certificate
- PV performance simulation
- Project management (financial)
- Risk management & portfolio of projects to scale and distribute risks
- Lawyers
- Market (realistic)
- Support (funding)

Partners
- Mounting system specialists
- PV & electrical components manufacturers
- Power utilities
- Municipalities
- Facade cleaners
- Battery storage system providers
- Banks/financing institutions
- Business consultants
- Legal firms
- Construction companies/real estate developers

Stakeholders
- Building owners, tenants, neighbours, neighbourhood
- Urban planners & municipalities
- Contractor, architect, project manager, electricity utility
- (BI)PV developer or installer
- Housing companies & companies investing in real estate
- Facade builders, manufacturers, suppliers of materials & services, façade cleaning company
- Regulators and certification institutions
- Service company

Revenue Model
- Initial payment and annual lease payment (service)
- Electricity sales and potential subsidies
- After 10 years: selling/renovation investment
- Advertising (other than building owner)
- Basic & optional premium services/packages
- Revenue sharing with investors and other partners (like suppliers or subcontractors)
- Pricing dependent on performance, features, volume, run-time or yield management

Distribution
- Direct contact with customers
- Investment firms & institutions
- External distributors
- Logistics
- Partnering banks

Cost Structure
- Standardization of products to lower costs
- PV and electrical components prices
- Retail electricity and wholesale market prices
- National energy policies
- Installation cost
- Demand and supply capabilities
- Customer acquisition costs (socio-cultural barriers)
- Dismantling & recycling costs

Figure 13: Business model for the manufacturing company of a BIPV as a service

Key values

As shown in the framework above, the values delivered to the final customers would encompass those already mentioned in the previous case, such as aesthetics or green status but the value proposition, in this business case, would be improved. Indeed, additional values would be provided. For example, the risk is reduced, and no high upfront cost is required, thanks to third-party financing. This can then allow the building owners to renovate their facade or roof with minimum cost, while saving on their energy bills.

Key stakeholders

As a company providing the service and having expertise in customer acquisition and legal aspects related to the management of the installation, some technical competence could be externalized, including the necessary technical and electrical analysis, for example. If not possessed by the ESCO, this competence would have to be provided by an external stakeholder. This strategic partner would obviously be among the key stakeholders.

Then, BIPV manufacturers should become key partners and are crucial stakeholders to involve from the beginning of project development. Note that there could be more than one manufacturer involved, in order to be able to propose different aesthetic choices to the final customer. Also, depending on the customer's electricity needs, the required performance of the system can vary. Moreover, the partnering BIPV manufacturers could bring extra customers, as they have direct contacts with building owners or people involved in project development, such as architects. The structural installation of the system would have to be done by a specialist of the building envelope. To take care of the technical aspects of the installation, an electrician with experience in PV systems would be required. A company capable of maintaining the system would be needed as well. Finally, a bank or financial institution would be a crucial stakeholder to involve. This is certainly one type of competence that could not possibly be internalized.

Potential revenue models

The values described above give an idea of the revenue model applied in such a business case. As mentioned, there need not be any upfront cost for the customer. Alternatively, it could be a reduced cost, to commit the customer and cover some initial costs, such as technical studies. Then, the customer would pay a monthly fee for a certain period, as agreed under contractual terms. In other words, this would take the form of an operating lease of the BIPV asset. This monthly fee would eventually cover the incurred costs and allow a profit to be made. This profit would have to be high enough to compensate for the substantial risk taken. In this base case, all the electricity produced by the system would directly benefit the building owner or its occupants, depending on the occupancy profile. The price structure should allow overall energy cost reductions for the customer in order to guarantee the attractiveness of the offer.

Alternatively, the management and sale of the generated electricity could be part of the service offered by the ESCO. Instead of a monthly fee including the electricity, the electricity would be sold by the ESCO to the consumers. This would create additional value by simplifying the relationship between building owners, building managers and building occupants, who are often involved as stakeholders when office buildings or shopping malls are considered, for example. Moreover, the sale of electricity itself could constitute an additional source of revenue. This can be seen as an improvement of the previous revenue model and it would be based on the same logic. In this case, the ESCO would have to be able to install the system, run it and generate electricity at a lower cost than the retail electricity price, to be able to remain attractive for the final consumer. The ESCO would apply a gross margin and sell it to the building occupants. This revenue model might force the ESCO to apply for the status of a utility, depending on local regulations. Hence, we recommend exploring the regulations in detail, as the administrative burden might offset the potential extra profits. Countries where “collective self-consumption” or a similar concept is allowed are good candidates for such a business model. This means that a combination with the model presented in section 5.1.3 is an interesting option. In that case, housing companies or the final consumers would be the customers. These two models are particularly complementary because most housing companies have a limited capacity to deal with the legal and administrative issues of electricity generation and delivery and with the technical requirements of a PV system. The price paid by the final customer for the electricity delivered could be covered by a monthly fee, to maintain simplicity for the final customer.

Furthermore, it could be decided in the contract to deliver only a share of the electricity generated, or only at certain periods in time. For example, in the case of a corporate client, this could be during weekdays. At the weekend, the electricity generated would be sold on the wholesale market, although it is likely to be at a loss, or to another private customer, such as a neighbour. This latter option would certainly be preferable as the selling price would be higher. Where a feed-in tariff is available, this could also be leveraged by the ESCO, as it might increase revenue.

All these possibilities would require financial and administrative engineering, increasing the costs, but they could generate important revenue. Also, this can be almost considered as an initial fixed cost that can be spread afterwards over all installations. Once the expertise has been acquired, the processes (legal, administrative, financial, technical) and contracts templates can be replicated, with minor changes.

Finally, it is important to highlight again the crucial role of the partnering bank. In both cases, it is essential to access cheap loans and share the risk burden. A large amount of capital would be required to set up the installation, as the components constituting the system will be bought by the company. The installation itself and preliminary studies can also represent significant costs. These will create significant financial outflows, whereas monetary inflows will be limited and spread over a long period, as the service provided would be remunerated on a monthly basis. The company providing the service needs to be able to provide a reserve of cash at a limited cost. This bank could also be a good partner to limit the uncertainty and workload linked to insurance questions. Similarly, it might be valuable to negotiate with the suppliers/key partners to lengthen the payment periods.

Pitfalls to avoid and remaining challenges

The risk would be carried mainly by the company providing the service. However, rewards can be high, if difficulties are overcome and sensitive points are well managed. Among them are:

- Legal questions: These are crucial as selling electricity is possible only for utilities in most countries, today. Applying for such authorization is a long and complicated process. Markets where concepts such as “collective self-consumption” are allowed should be prioritized, as setting up business models would probably be easier.
- Decoupling ownership of the facade and the building is possible and already exists but must be done very carefully, for example concerning insurance questions. Responsibilities

must be clearly established and legally recognized by all involved stakeholders in appropriate contracts.

- The ability to generate energy at a cost lower than the retail electricity price can constitute an extra source of revenue but depends on the ability to:
    - Accurately predict the performance of the system over its lifetime.
    - Predict the evolution of retail prices. If they go below a certain level, the attractiveness for the customer might disappear.
    - Predict the evolution of electricity invoicing structure (regulated/fixed components vs. consumption-based/variable components). As fixed costs become higher, the self-consumption of PV electricity becomes less attractive.
- A strong balance sheet is required, as cash outflows will be higher than cash inflows and not match in time. High reserves of cash are required to prevent the company from collapsing due to lack of liquidity.
- The company needs to find a way to hedge the risk taken when developing such a business model, e.g. by contracting a special insurance policy. The partnering bank can help in achieving this.
- With the objective of limiting all cost items, it can be valuable to limit the variation of sizes and other features of the modules and systems. By doing so, costs will be decreased thanks to economies of scale and scope. In addition, component designs can potentially be re-used, from one installation to another, hence limiting the costs.
- Similarly, the optimization and standardization of a system's technical features should be a point of attention, as this would allow the time required for installation or replacement to be reduced.

6 DISCUSSION

The purpose of this report was to provide a guide with examples for design and applications of BIPV business models. The chosen method is an adapted version of the Business Model Canvas based on values. This BMC is one of many tools available for business model development. Once the process with the BMC is completed, refinement work follows, including e.g. SWOT analysis and the development of a business plan.

Values form a central part and the starting point in the described BMC. The value of electricity and the local regulatory framework typically have a large impact on the existing business models for PV. Other values have been the major drive behind BIPV installations so far. The aesthetic value and sustainable values, and also marketing value, have been highlighted although those values may be hard to quantify in a value proposition. In the future, BIPV components should be building components that compete with conventional building components, resulting in the same functionality and generating electricity as an added value, resulting in lower operation cost and thereby higher property value for the building.

The presented stakeholders have their own specific interests and thus impact the business models. BIPV is valued very differently by different actors. Purely economic valuation is hard to achieve and is not always required when values such as reputation linked to sustainability dominate. Some actors such as building valuers and financial experts do not broadly address environmental values but valuation by stakeholders in this respect is progressing. From the perspective of regulation as a driver, tightening energy requirements for buildings may be an important stimulus for BIPV when BAPV alone is not sufficient to meet coming energy regulations and requirements, e.g. due to the limited available roof area.

Legal obstacles still remain for some of the proposed business models. One important legal obstacle for collective self-consumption and service-based business models is the right to deliver electricity in exchange for a fee to more than one final consumer. If, for instance, ESCOs and housing companies were entitled to sell electricity to on-site consumers in multi-family housing or an office building this could significantly expand the room for local initiatives. Such developments are under way in the EU. Besides the pure right to sell the locally generated electricity, additional related aspects such as data management and protection as well as the role of DSOs and data exchange with them need to be considered. Also, the integration of local electricity consumption with additional services such as charging stations may be facilitated as the right to operate such systems is not necessarily given for all core stakeholders discussed in this report.

Another aspect is the harmonization of different fields of legislation. While the electricity regulations apply to aspects such as the sale of electricity, a much broader field of legislation is relevant in some of the presented cases. For instance, where apartments and rental agreements are involved, tenant's rights, consumer protection and other aspects are concerned. It is therefore, in many cases, necessary to harmonize different fields of legislations in order to allow smooth implementation of a growing range of business models that can contribute to an increasing share of renewable energy in the system.

Concerning BIPV, specifically the legal requirements for building elements, e.g. safety, are of high relevance. Currently, the diversity of products and a lack of standardization and corresponding authorization lead to great effort at the individual project level. While it is up to the market to develop more standardized solutions with positive effects on product prices, broad inclusion of BIPV in building-related legislation, for example, can be of great support.

The proposed future work in the second phase of IEA-PVPS Task 15 applies a technological innovation system (TIS) analysis to find out more about strengths and weaknesses in the BIPV innovation system and measures needed to increase implementation of BIPV.

REFERENCES

[1] P. Macé, D. Larsson and J. Benson, "Inventory on Existing Business Models, Opportunities and Issues for BIPV," Report IEA-PVPS T15-03, 2018.

[2] A. Bullier, J. Carassus, T. Sanchez, D. Ernest, J.-F. Le Teno and L. Pancrazio, "Assessing green value: A key to investment in sustainable buildings," ECEEE 2011 SUMMER STUDY Energy efficiency first: The foundation of a low-carbon society, 2011.

[3] A. Chegut, P. Eichholtz and N. Kok, "Supply, Demand and the Value of Green Buildings," *Urban Studies,* pp. 1-22, January 2013.

[4] Y. Deng and J. Wu, "Economic returns to residential green building investment: The developers' perspective," *Regional Science and Urban Economics,* vol. 47, p. 35–44, 2014.

[5] P. Eichholtz, N. Kok and J. M. Quigley, "The Economics of Green Building, The Review of Economics and Statistics," *Urban Studies,* vol. 95, no. 1, pp. 50-63, 19 March 2013.

[6] J. Peng, D. C. Curcija, L. Lu, S. E. Selkowitz, H. Yang and W. Zhang, "Numerical investigation of the energy saving potential of a semi-transparent photovoltaic double-skin facade in a cool-summer Mediterranean climate," *Applied Energy,* vol. 165, pp. 345-356, 2016.

[7] H. Ishii, "Thermal Performance (G-value and U-value) Evaluation of BIPV Applied to Glass Facade," in *33rd European PV Solar Energy Conference and Exhibition*, Amsterdam, The Netherlands, September 2017.

[8] S. Boddaert, J. Benson, P. Bonomo, V. Delisle, C. Erban, A. Fedorova, F. Frontini, S. Inoue, H. Ishii, K. Kapsis, J.-T. Kim, N. M. Chivelet, E. R. Medina, A. Schneider and H. R. Wilson, "Compilation and Analysis of User Needs for BIPV and its Functions," Report IEA PVPS T15-06, 2019.

[9] IEA-PVPS Task 15, "Analysis of requirements, specifications and regulation of BIPV," To be published 2019.

[10] IEA-PVPS Task 15, "Coloured BIPV. Market, Research and Development," To be published 2019.

[11] P. Bonomo, F. Frontini, E. Saretta and I. Zanetti, "Building Integrated Photovoltaics: Product overview for solar building skins," SUPSI, 2017.

[12] IEA-PVPS Task 15, "LCA for BIPV," To be published 2019.

[13] EUR-Lex, "DIRECTIVE (EU) 2018/844 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 30 May 2018 amending Directive 2010/31/EU on the energy performance of buildings and Directive 2012/27/EU on energy efficiency (Text with EEA relevance)," *Official Journal of the European Union,* 2018.

[14] European Commission, "The strategic energy technology (SET) plan," 2018.

[15] S. Ong, C. Campbell, P. Denholm, R. Margolis and G. Heath, "Land-Use Requirements for Solar Power Plants in the United States," NREL, 2013.

[16] European Commission, "SET-Plan - Declaration on Strategic Targets in the context of an Initiative for Global Leadership in Photovoltaics (PV)," Brussels, 2016.

[17] M. Westermann and O. Radovic, "European experiences in the treatment of losses / Summary of a survey among NRAs. CEER Workshop on Power Losses," in *CEER Workshop on Power Losses*, Brussels, 2016.

[18] P. Höiseth, "Här ligger Sveriges största soltak," *Dagens Industri,* 20 May 2018.

[19] K. Högdal, "Swedish Energy Agencys network for residential property (BeBo)," in *Conference Smarta Flerbostadshus*, Stockholm, 2014.

[20] B. Hoen, S. Adomatis, T. Jackson, J. Graff-Zivin, M. A. Thayer, G. T. Klise and R. H. Wiser, "Selling Into the Sun: Price Premium Analysis of a Multi-State Dataset of Solar Homes," Lawrence Berkely National Laboratory, 2015.

[21] P. Höiseth, "Solceller höjer priset på villan: Lockar den moderna och miljömedvetna," *Dagens Industri,* 29 November 2018.

[22] United Nations, *Transforming our world: the 2030 Agenda for Sustainable Development,* 2015.

[23] Becquerel Institute, "D1.1 "Competitiveness status of BIPV solutions in Europe"," BIPVBOOST H2020 Project, 2019.

[24] A. Hinge, "Zero Energy Building Definitions and Policy Activity – An international review," IPEEC, Paris, 2018.

[25] H. Breuer and F. Lüdeke-Freund, "Values-Based Business Model Innovation: A Toolkit.," in *Sustainable Business Models*, Springer, 2018, pp. 395-416.

[26] C. Reise and B. Farnung, "Uncertainties in PV System Yield Predictions and Assessments," Report IEA-PVPS T13-12, 2017.

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