Solar Skins: An opportunity for greener cities

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FOREWORD

Solar photovoltaic (solar PV) electricity has recently become the lowest cost source of electricity in most parts of the world. Solar PV supports a socially just and acceptable energy transition and integrated applications, as well as new business opportunities. This report is focusing on one of these new business opportunities. It aims at describing the added value of Building Integrated Photovoltaics (BIPV) for a successful energy transition in European cities, as well as the related opportunities for EU businesses. It describes the regulatory and market framework needed for sustainable business models for BIPV, that are adapted to city planning constraints and specificities.

By gathering the expertise of researchers, representatives of the BIPV industry, architects and city planners, the report identifies the main barriers preventing the uptake of BIPV in European cities and offers a set of illustrative case studies, as well as a "best practices checklist", that the European Commission, city leaders, politicians and any stakeholder in the BIPV value chain can use to facilitate the development of BIPV in Europe.

About SolarPower Europe

SolarPower Europe's aim is to ensure that more energy is generated by solar than any other energy source by 2030 and to lead its over 200 upstream and downstream member organisations across the entire solar value chain to make solar the core of a smart, sustainable and inclusive energy system.

About European Technology and Innovation Platform for Photovoltaics (ETIP PV)

The European Technology and Innovation Platform for Photovoltaics provides advice on solar photovoltaic energy policy. It is an independent body recognised by the European Commission and the SET Plan Steering Group as a representative of the photovoltaic sector. Its recommendations may cover the areas of research and innovation, market development including competitiveness, education and industrial policy.

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BIPV

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The report can be downloaded at: http://www.solarpowereurope.org/category/reports/ or https://etip-pv.eu/publications/etip-pv-publications/. Please get in touch with SolarPower Europe and/or ETIP PV if you have any comments or feedback on the report and its content in order to enrich our ongoing work in this field.

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1 EXECUTIVE SUMMARY

Buildings contribute 36% of greenhouse gas emissions in European Cities.[1] Overall, Europe should reduce its GHG emissions by 80% by 2050 to fulfill the Paris Agreement goals, with the building sector facing the most severe obligations, with reductions of around 90%.

Among various renewable energy technologies, solar PV energy generation has seen enormous progress over recent years and today, is one of the lowest-cost energy sources in Europe. PV is a modular energy unit and can be integrated into almost all infrastructure as a construction element, including building roofs and façades, what is commonly known as Building Integrated PV (BIPV). Therefore, it is also a keystone for Nearly Zero Energy Buildings (NZEBs).

BIPV constructions have achieved a high level of technical maturity. There is also ample evidence for impressive design flexibility in numerous model buildings all over the EU. The biggest portion in the value chain of BIPV installations is and will come from within the EU, where the frontrunners in these novel construction technologies are located.

An increased share of BIPV in the building stock would contribute significantly to a reduced ecological footprint, would create jobs in the PV construction and installation industries and improve the quality of life and attractiveness of European cities overall. Distributed energy generation within the premises of a municipality would also reduce requirements for grid extensions and increase resiliance and stability of the power network.

Despite its potential, there are several hurdles to overcome if we are to see BIPV as a common part of our cities' landscapes. These hurdles are mostly related to the low renovation rates and slow integration of on-site renewables in cities, but also with the historical lack of awareness of the benefits of BIPV products.

Municipal authorities can actively promote BIPV and embark on an accelerated route towards greener cities:

1. by converting their own building stock into Plus-Energy-Buildings by using BIPV, and therefore, generate best practice examples
2. by promoting new financing schemes for private property owners, such as energy contracting and leasing models for BIPV installations
3. by setting up efficient policies, grid regulations and incentives for a systematic electrification of buildings, heating and cooling, and transport.

1 https://ec.europa.eu/energy/en/topics/ energy-efficiency/energy-performance-of-buildings

At a global level, cities consume more than two-thirds of the world's energy resources and are responsible for around the same share of CO_2 emissions.[2] Buildings alone are responsible for 36% of global final energy consumption and nearly 40% of total direct and indirect CO_2 emissions.[3]

The IPCC report highlighted that at the current pace, the global energy use in buildings could double or even triple by 2050, as the world's population living in cities is projected to increase further in the next decades.[4] European cities are no exception: today 75% of Europeans live in urban areas, already facing increasing challenges related to poor air quality, energy poverty, and living in highly inefficient buildings.

To cope with the size of the challenge and become carbon-neutral by 2050, European cities will have to accelerate the deployment of renewable energies and foster significant investments in energy efficiency, with a particular focus on their building stock, which accounts for 49% of Europe's energy demand[5] and 36% of CO_2 emissions at EU level.[6]

FIGURE 1 THE DECARBONISATION OF EU BUILDING STOCK IS A POWERFUL DRIVER TO REACH A NET-ZERO ECONOMY BY 2050

Source: EU, OECD, DESTATIS.

2 C40 Cities. https://www.c40.org/ending-climate-change-begins-in-the-city
3 https://www.iea.org/topics/energyefficiency/buildings/
4 IPCC Fifth Assessment Report. https://www.ipcc.ch/sr15/
5 http://www.estif.org/policies/epbd0/
6 IRENA Renewable Energy Prospects for the European Union. https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2018/Feb/IRENA_REmap-EU_2018_summary.pdf?la=en&hash=818E3BDBFC16B90E1D0317C5AA5B07C8ED27F9EF

The fight against climate change and the transition to greener city environments is an unprecedented opportunity for European cities to develop, become more innovative, create local jobs and growth their economies ensuring a more attractive and sustainable environment for their citizens. For these reasons, an increasing number of cities have committed to building a zero-carbon economy and pioneer a decentralised approach to the energy transition. Initiatives such as the Covenant of Mayors, C40 and Energy Cities clearly demonstrate how European cities have embraced their role as leaders in driving global action to address climate change.[7]

While energy efficiency investments are often characterised by high up-front costs and potential long-term ROI,[8] renewable generation has become an affordable and cost-effective option to decarbonise and complement energy efficiency investments, with direct savings on the energy bill. However, enormous efforts are required to achieve these goals, as renewables today supply only 24% of energy for buildings in cities.[9] In addition, the development of renewable energies in cities is also subject to specific geographical, aesthetic and physical constraints related to urban planning, architectural requirements and preserving cultural heritage.

While rooftop solar installations (Building Applied PV, BAPV) are becoming increasingly competitive and market-ready, the rooftop only represents a minor fraction of the building's available surface area and thus most of the building's potential for generating renewable energy on façades remains untapped. The unique nature of Building Integrated PV (BIPV) technologies offer an opportunity to address this challenge and significantly multiply the contribution that now mostly stems from rooftop solar installations. In order to achieve sustainable goals in cities, harvesting the full potential of the building stock (façades, windows, etc.) for renewable energy generation is required. This local photovoltaic infrastructure provides direct on-site renewable electricity generation, not only for heating and cooling, but also for e-mobility. It reduces the need for massive grid extensions and improves grid stability in a progressively "electrified" city infrastructure. The combination of localised PV electricity, storage, and local supply and demand management makes buildings the smallest unit in a smart grid of its own. Once the necessary technology and control mechanisms are developed, the next step of linking multiple smart buildings will contribute to the widespread deployment of smart grid technology. This requires the development of control systems for grid-feeding, self-consumption, and local storage and standardisation of the interoperability of such control systems.

Europe is a world leader in BIPV technology with unique properties. These innovative products promise to become the construction product of the future. BIPV modules as a construction element may be combined with insulation and other elements to improve the energy efficiency of a building. Its modular nature adapts to almost any urban environment: roofs, façades, windows, sound barriers, roads. A very valuable asset is also its flexible design enabling cities to preserve their architectural identity and comply with heritage preservation.

The fabrication and installation of a "solar skin", a BIPV installation, requires a local industry. This industry needs to be promoted and cultivated as it can transform Europe's urban energy landscape, improve the living conditions of urban dwellers and create jobs. This new industry is a key prerequisite to reduce the carbon footprint of cities.

Furthermore, the manufacturing of PV modules as building materials can develop into a worldwide market with huge opportunities for the European industry. Driven by Near-Zero-Energy Buildings (NZEB)[10] policies and subsequently Plus Energy Buildings (PEB), design and innovation with new BIPV materials and concepts

7 https://www.c40.org/press_releases/global-cities-commit-to-make-new-buildings-net-zero-carbon-by-2030

8 Independently of the strong macroeconomic incentives to make such investments or not (IRENA, 2017e). Furthermore, energy retrofits and higher standards for new buildings generate the largest quantity of stranded assets. This particularly affects developed economies, calling for policies that enable retrofits of residential, commercial and industrial property. In developing economies, ambitious building standards and regulations for new buildings will be more important. Both in developed and developing economies, the buildings sector will be the most affected: IRENA REmap calculates USD 5 trillion of asset stranding, compared with USD 4 trillion for upstream energy.

9 IRENA Renewable energy in cities 2016. https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2016/IRENA_Renewable_Energy_in_Cities_2016.pdf

10 The EU wide Energy Performance of Buildings Directive (EPBD) requires all new buildings to be nearly zero-energy by the end of 2020. All new public buildings must be nearly zero-energy by 2018. For example, the Italian legislative decree 28/2011 based on the EPBD, states that from the 1st of January 2018, new buildings and buildings undergoing deep retrofit have to comply with the following requirements (among others): 50% of the heat and DHW demand must be covered by renewables and A certain minimum electrical power of renewables must be installed These two requirements do not explicitly mention PV but the end result is that the most common and economically viable solution is to install PV in combination with heat pumps. The regulation does not apply for buildings connected to district heating networks.

and combinations of energy efficient building materials with BIPV become essential parts of the development strategies of both the PV sector and the building sector. This calls for a multidisciplinary research and development (R&D) programme involving, among others, the PV manufacturing industry and the building materials industry, as well as certification bodies. Breakthroughs in technology, applications and business models are required to transform today's BIPV niche market into a future mass market.

The European Strategic Energy Technology Plan (SET Plan) and the 'Declaration on Strategic Targets in the context of an Initiative for Global Leadership in Photovoltaics (PV)' outline the topics that are essential for the enhanced diffusion of BIPV in cities: As modules account for around 50% of system costs, efforts also need to be directed at reducing the costs of Balance of System (BoS) technologies while introducing new functionalities for grid services. Among the targets outlined in the declaration, "Enabling mass realisation of "(near) Zero Energy Buildings" by BIPV through the establishment of structural collaborative innovation efforts between the PV sector and key sectors from the building industry" is included.

3

SOLAR SKINS:

THE PERFECT MATCH FOR CARBON-NEUTRAL CITIES

Fostering the uptake of BIPV technologies in urban environments is a powerful driver to accelerate the decarbonisation of Europe's building stock and increase the share of renewable electricity. The required BIPV technology is ready for implementation as all of the following examples demonstrate.

3.1. Solar skins: an aesthetic, cost-efficient and multifunctional approach to new building stock and retrofits

BIPV and Building Applied Photovoltaics (BAPV) solutions adapt to a variety of surfaces - rooftops, windows and façades - and provide integrated solutions for both the passive and active components needed to achieve a NZEB.

First, BIPV provides a protective skin to the building (passive function), including thermal and acoustic insulation as any other common construction product.

FIGURE 2 THE TREURENBERG BUILDING, LOCATED DOWNTOWN IN THE CITY OF BRUSSELS, IS THE FIRST NET-ZERO ENERGY OFFICE BUILDING (NZEB) TO BE COMPLETED IN BRUSSELS. THE ORIGINAL BUILDING CONSTRUCTED IN THE 1960S HAS BEEN DEMOLISHED AND THE NEW BUILDING WITH NINE FLOORS OFFERS 9,800 M^2 OF OFFICE SPACE THAT CAN ACCOMMODATE UP TO 750 PERSONS. THE BIPV INSTALLATION COVERS AN AREA OF 667 M^2, WITH AN INSTALLED POWER OF 122 KWP (50% BIPV, 50% BAPV) ENOUGH TO COVER 100% OF THE ELECTRICITY CONSUMPTION OF THE BUILDING.

Source: Issol - Assar Architects - Brussels 2015.

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Second, the passive function is complemented by an active function – the PV component – that generates renewable electricity that can be directly used in the building, contributing to more sustainable heating and electricity consumption and, in general, to a more energy efficient building stock. This "active role" is a unique feature of BIPV construction products.

Third, BIPV can also complement the smart functions of buildings, something not possible for conventional building materials. For example, innovative configurations of BIPV components can offer real-time thermal or lighting regulation (activating ventilation systems depending on the irradiation or reacting to light to control the indoor illuminance). All these functionalities (PV conversion, acoustic protection, thermal regulation, shading, etc.) are joined every day by more innovations that make BIPV more economically attractive.

Overall, BIPV provides a cost-efficient and integrated solution system that allows the user to decarbonise its electricity consumption, with additional savings provided by the insulation of the building.

For new building stock, innovative design concepts of BIPV installations combine flexibility, versatility and aesthetic beauty that fit perfectly with the requirements for ZEBs and PEBs. The decarbonisation of Europe's existing building stock will require significant investments. This will be a growing challenge for public investors and European cities. Specifically, achieving a carbon-neutral building stock will require complex investments in energy efficiency and utilities for heating and cooling.

In this context, BIPV can play a decisive role in the refurbishment of buildings. For existing buildings, BIPV technologies can reduce the overall cost of deep

COULD BIPV MAKE INVESTORS MORE INTERESTED IN ENERGY EFFICIENCY RETROFITS?

For example, the "Million Programme" in Sweden shows the positive synergy effects of installing building integrated solar at the same time as achieving the last steps of a step-by-step retrofit to Passive House Standard.[11]

FIGURE 3 KOLLEKTIVHUSET STACKEN, A CLASSIC, 50-YEAR OLD SWEDISH "MILLION PROGRAMME" BUILDING WITH 35 APARTMENTS IN GOTHENBURG, WHICH HAS LONG BEEN RUN AS A COOPERATIVE, HAS DEMONSTRATED A COST EFFECTIVE STEP-BY-STEP DEEP RETROFIT TO THE INTERNATIONAL PASSIVE HOUSE STANDARD WITH A BUILDING INTEGRATED PV (BIPV) FAÇADE AND ROOF. THE EXISTING CONCRETE FAÇADE WAS EXTERNALLY INSULATED AND COVERED WITH THIN FILM AMORPHOUS SILICON SOLAR MODULES AND MORE EFFICIENT CRYSTALLINE SILICON SOLAR MODULES WERE INSTALLED ON THE ROOF.

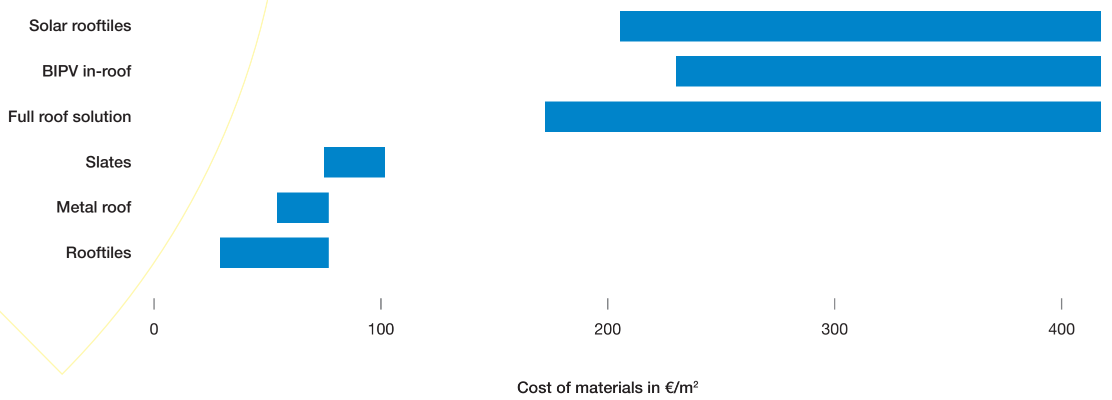
Source: Kollektivhuset Stacken, Gothenburg.

11 https://www.stacken.org/ https://passipedia.org/planning/refurbishment_with_passive_house_components/step-by-step_deep_retrofit_and_building_integrated_facade_roof_on_a_million_program_house

renovation investments and create a real business case for ambitious energy efficiency strategies, by providing savings in materials (substituting conventional construction materials with PV) and additional revenue from on-site electricity generation.

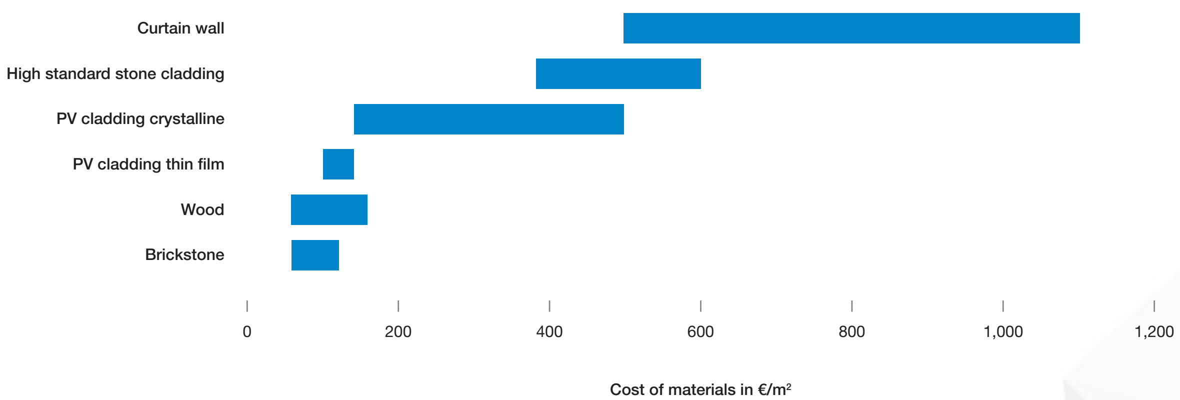
A cost comparison between classic roofing and façade materials and BIPV claddings is shown in the following two graphs. It can be stated that the BIPV materials in roofs are somewhat more expensive than simple classic roofing materials. However, in most cases, this add-on cost is more than offset by the additional revenue generated through the electricity produced. In any case, detailed analysis depends on the orientation of the roof as well as general climatic and insolation conditions, which need to be simulated case by case in order to determine the financial profit.

FIGURE 4 COST OF BIPV ROOF TILING COMPARED TO OTHER ROOFING MATERIALS USED IN CONVENTIONAL PITCHED ROOF



Source: Adaptation from SEAC-SUPSI - BIPV Status Report 2017.[12]

FIGURE 5 COST OF PV COMPARED TO OTHER CLADDING MATERIALS USED IN THE BUILT ENVIRONMENT AS FAÇADE CLADDING MATERIALS



Source: Adaptation from SEAC-SUPSI - BIPV Status Report 2017.[13]

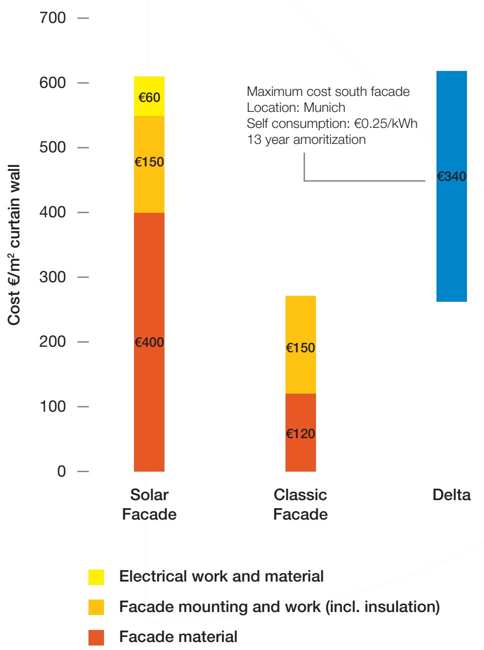
12 The graph refers to the final cost of a complete roof tiling construction, including mounting, transportation and other additional costs. For more information on conditions and origin of data, check SEAC's BIPV Status Report 2017.

13 The graph specifically refers to the cost of the cladding, namely the outer material layer that represents the exterior wall. The costs of the substructures, fixings and insulation are excluded for the conventional building material. For more information on conditions and origin of data, check SEAC's BIPV Status Report 2017.

Almost the same guideline applies to façades, although the higher visibility leads to higher requirements and expectations for the aesthetic quality of the installation, be it classic or a solar skin. The limiting cost of a BIPV façade depends on the expected amortisation period. One example of such a maximum cost calculation, including the expected energy yield for a specific location and orientation, is shown in the following Fig. 6.

Further advantages of today's BIPV products that need to be named are their design flexibility and versatility (BIPV system size can be scaled upwards to any size, starting from a few m^2 and electrical power of a few kW). As opposed to standard PV modules produced for greenfield solar power plants, BIPV solutions are flexible in size, shape and colour, meaning its design can be adapted to the shape and design of the buildings. They can contribute to energy gains in roofs, façades and even through semi-transparent windows. Consequently, the available area for generating clean energy is bigger than for traditional PV technologies. It will become a "must have" for new buildings in historical and urban areas where space is becoming rare. Thus, with one single investment, BIPV technologies tap into the full potential of the building for clean energy generation, thermal regulation and insulation.

FIGURE 6 COST COMPARISON OF SOLAR FAÇADE VS CLASSIC



Source: Avancis.

FIGURE 7 SMART PV WINDOW BASED ON LUMINESCENT SOLAR CONCENTRATORS BY ENI (LEFT) AND SEMI-TRANSPARENT CIGS BY SUNPARTNER PANELS (RIGHT). THE LSC TECHNOLOGY IS BASED ON LUMINESCENT SOLAR CONCENTRATORS, I.E. ON TRANSPARENT PLASTIC PANELS WITH SI-PV CELLS AT THE BORDERS.[14] THE SEMITRANSPARENCY PROCESS OF SUNPARTNER IS BASED ON LASER-PERFORATION OF THINFILM CIGS SOLAR PANELS.

Source: Eni.

Source: Sunpartner panels.

14 https://www.eniday.com/it/technology_it/concentratori-solari-luminescenti-lsc/

3.2. BIPV: flagship of the European clean industry driving jobs and growth

BIPV is a European technology with enormous industrial potential that remains untapped. It is also a strong asset for Europe as the BIPV market tends to be local-to-local market, gathering a wise ecosystem of SME's and local energy providers. This also applies to the raw materials and products used for the manufacturing of BIPV components: 500 km to 1,000 km is the typical travel range of glass products and 90% of flat glass is customised close to glass manufacturers.

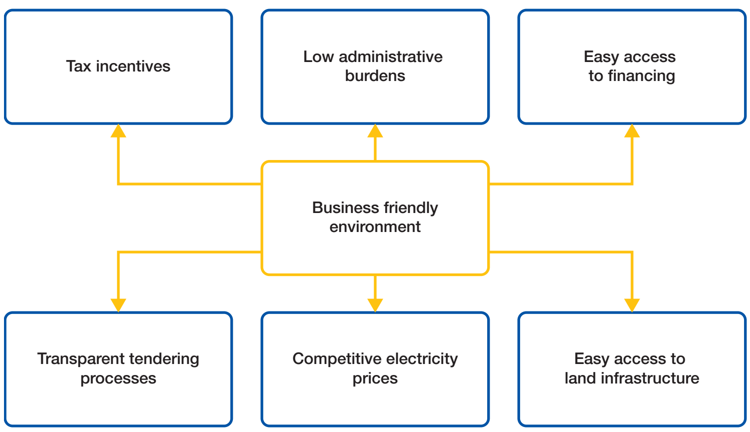
Initiatives such as the Clean Energy Industrial Forum of the European Commission[15] sees solar as a vehicle to create an industrial manufacturing hub in Europe. The BIPV value chain is a means to achieve the Energy Union's objectives (innovation, digitalisation, consumer empowerment, security of supply and decarbonisation) and cities can greatly benefit from the competitiveness and job creation opportunities that the mass market development of BIPV entails.

Finally, BIPV technology is a strong asset for improving living conditions in European cities. Some improvements can be easily quantified: cleaner and cheaper electricity, reduction of air pollution, reduction of highly inefficient building stock and energy savings. Others benefits, such as energy independence and resilience, and the freedom to combine urban planning constraints with highly-efficient and polyvalent building components, are still to a large extent unused due to the limited deployment of BIPV technologies in cities currently.

However, the BIPV industry is also subject to economic conditions. As for any manufacturing facility and during early deployment stages, EU BIPV manufacturers' need to benefit from a business-friendly environment in order to grow and diversify their production lines, and European cities can contribute significantly to create the right business environment for BIPV companies.

Besides, to unlock the true potential of BIPV, it is necessary to raise public awareness and the level of information surrounding BIPV products' characteristics. The standardisation of BIPV products could help this process but always respecting the premise that makes BIPV extremely attractive: BIPV solutions are flexible in size, shape and colour, meaning its design can be adapted to the particularities of all buildings. Furthermore, the double functionality of a BIPV product has to be taken into account from the first stages of design, merging energy, BIPV and building requirements. A close collaboration of all stakeholders, from manufacturers to planners, developers, architects and installers, will also help to accommodate the different national building codes and permits and administrative requirements.

BIPV products are covered under the common IEC certification on Low Voltage Directive but to be implemented on buildings, products have also to comply with Construction Product Regulation (CPR). Now, there is also a specific European standard for BIPV modules and systems, which supports the translation of BIPV multifunctionality into building requirements (EN 50583). At present, an international standard (IEC) for BIPV modules and systems, based on EN50583 is being drafted.[16]



15 https://ec.europa.eu/energy/en/events/clean-energy-industrial-forum-renewables

16 http://susproc.jrc.ec.europa.eu/solar_photovoltaics/docs/180611_PV_Prep_study_Standards_review_Consultation_final.pdf

FIGURE 8 8.8 MWP SUNSTYLE® ROOF INTEGRATED PLANT IN PERPIGNAN, FRANCE THE WORLD'S LARGEST BUILDING INTEGRATED SOLAR POWER PLANT IS INSTALLED IN PERPIGNAN (PYRÉNÉES-ORIENTALES) ON THE SAINT CHARLES INTERNATIONAL SITE, WITH AN AREA OF 70,000 M^2 AND A CAPACITY OF 8.8 MWP (MORE THAN 10 MILLION KWH ANNUALLY).

Source: Akuo Energy.

FIGURE 9 THE SOLAR EMERALD ("SOLSMARAGDEN") IN NORWAY IS A SEVEN-STOREY COMMERCIAL BUILDING THAT HOLDS OFFICE SPACE FOR 450 PEOPLE. THE BUILDING COMBINES A TRADITIONAL BAPV SYSTEM ON THE FLAT ROOFTOP, THAT ALSO PROVIDED POWER DURING THE BUILDING PHASE, WITH A 115 KWP BIPV SYSTEM ON THE EAST, SOUTH AND WEST FAÇADES OPERATIONAL SINCE JANUARY 2016. THE PAYBACK TIME IS 11 YEARS WITH ANNUAL SAVINGS REACHING €18,400 PER YEAR.

Source: Enova SF.

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4 CREATING BUSINESS OPPORTUNITIES FOR GREENER CITIES

We have shown in Chapter 3, that the PV industry has significantly improved the technical performance and flexibility of its products for building integration. In principle, that would pave the way for mass-scale deployment in Europe.

However, despite such progress and the industrial leadership of the European Union in such technologies, the global potential of BIPV has remained significantly untapped. The current BIPV market is a niche market and prospects are predicted to be rather moderate. Recent studies show that the cumulative potential for BIPV installations in EU27, Switzerland and Norway is 5 GW by 2030 (with a cumulative BIPV façade surface area of around 24 km^2) at the current growth rate.[17] This share remains insignificant compared to the development of regular rooftop PV, which SolarPower Europe estimates could reach 10 GW by 2022.

On the other hand, we have shown in Chapter 2 that densely populated cities desperately need novel concepts to reduce their CO_2 emissions, which are a result of fossil fuel-heated houses and fossil fuel-powered cars. In the following sections, we will outline a comprehensive set of active policy measures that enable European cities to effectively contribute to decarbonising their energy supply for heating, cooling and transport by utilising BIPV on a massive scale, while at the same time growing local and regional BIPV businesses.

To generate long-term and sustainable demand for BIPV products, the report proposes to reverse the focus away from technology and towards a specific and relevant customer, namely the city administration, their planners, policymakers and municipal utilities.

In order to find the right business model, we have to first identify possible market and implementation hurdles for BIPV, and in general, the renovation of their building stock. Derived from that analysis, we will explore how municipal authorities can actively promote BIPV by developing "market-pull" instruments for the uptake of BIPV. This will require building stronger ties between European cities and the private sector.

17 https://www.researchgate.net/publication/325078072_BIPV_FACADES_MARKET_POTENTIAL_OF_RETROFIT_APPLICATION_IN_THE_EUROPEAN_BUILDING_STOCK

4 CREATING BUSINESS OPPORTUNITIES FOR GREENER CITIES / CONTINUED

FIGURE 10 ENZIAN OFFICE, BOLZANO (BZ), ITALY. THE ENZIAN OFFICE IS A 10-STOREY, ENERGY SELF-SUFFICIENT BUILDING LOCATED IN THE INDUSTRIAL ZONE OF BOLZANO. THE WHOLE BUILDING IS COVERED WITH PHOTOVOLTAIC MODULES INTEGRATED INTO THE BUILDING'S GLASS FAÇADE AS WELL AS MODULES PLACED ON THE ROOF, THAT COMBINED, PRODUCE AROUND 113 MWH/YEAR. THE PV MODULES ARE MADE OF AMORPHOUS SILICON THAT HOMOGENISES THE EXTERNAL SURFACES, SO THAT THE DIFFERENCE BETWEEN OPAQUE AND SEMI-TRANSPARENT PARTS OF THE FAÇADE IS NOT RECOGNISABLE. BESIDES THIS, THE PV MODULES ARE INTEGRATED INTO DIFFERENT BUILDING COMPONENTS, PROVIDING EXAMPLES OF HOW PV MIGHT BE USED IN PLACE OF TRADITIONAL BUILDING MATERIALS: THE PV SUBSTITUTES THE SEMI-TRANSPARENT PARTS, THE INSULATED WINDOWS, THE EXTERNAL PARAPETS AND THE EXTERNAL CLADDING.

Source: Eurac Research.[18]

4.1. Solar skin for cities – identifying challenges

The business model canvas delivered by Oswalder & Pigneur (2010), provides a valuable insight into the multiple dimensions of a successful business model, with all dimensions being closely intertwined. SolarPower Europe and ETIP PV have applied this concept to systematically identify the key components of a BIPV business model with the key municipal stakeholders, not just as customers but also as facilitators for the private sector.

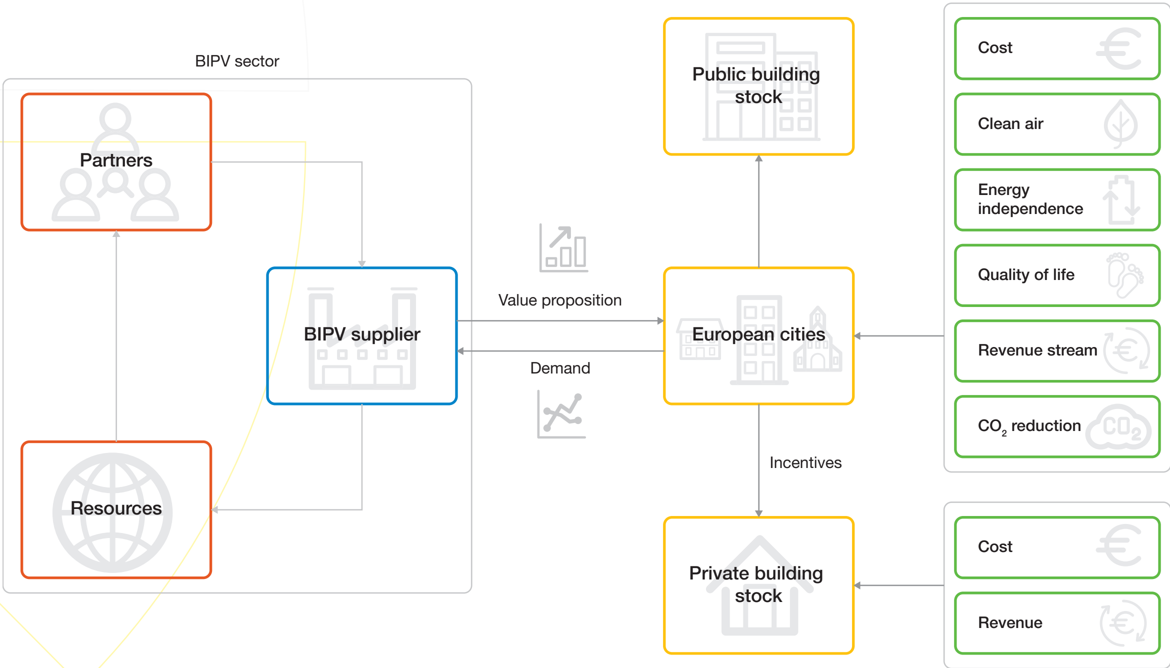
With key stakeholders, we mean responsible policymakers and planners, that have an interest in renovating old building stock in their municipality. That old building stock is only partly a municipal property, but predominantly in private hands, meaning that the actions and incentives needed for their refurbishment will have to be designed differently according to the specific needs and motivations of public and private stakeholders.

Therefore, we will have to ask ourselves how can municipal stakeholders increase the renovation rate of their own buildings, but also how can they motivate private owners and investors to refurbish the private stock.

To do so, we first need to identify what are the main hurdles slowing down the renovation of the EU's building stock, and the ones hindering the integration of PV, once the decision to renovate has been made.

18 https://bipv.eurac.edu/en/case-studies/enzian-office.html

FIGURE 11 ELEMENTS OF THE BUSINESS MODEL FOR BIPV IN CITIES



4.1.1. Increasing renovation rates in cities

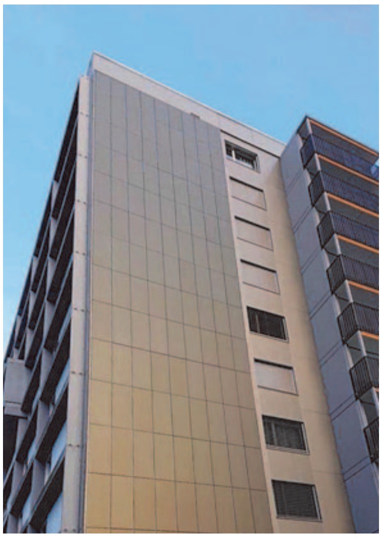
For the EU to meet its long-term climate and energy targets, the rate of deep energy renovation should be increased from today's 1% to 3% per year. According to Renovate Europe platform, this means around 200 million buildings would have to be renovated by 2050.[19]

To achieve these targets, public money is not enough, therefore private investments need to be triggered. A multi-financial framework able to allocate more private money for the renovation of buildings would help fill this gap. Other obstacles of a different nature, like rigid Historical Building Regulations, hard to obtain permits and lack of information about how to proceed and invest in energy-efficient refurbishments, need to be removed.

19 https://www.renovate-europe.eu/about-the-campaign/

4 CREATING BUSINESS OPPORTUNITIES FOR GREENER CITIES / CONTINUED

FIGURE 12 BIPV INSTALLATIONS CAN BE PART OF BUILDING RENOVATION PROJECTS, COMBINING THERMAL INSULATION WITH CURTAIN WALL BIPV FAÇADES. THE TWO EXAMPLES SHOWN HERE ARE BOTH FOUND IN BERN, SWITZERLAND.



Source: Avancis.

4.1.2. Further integrating PV: risk-adversity and the "hassle factor"

In the past, the innovative and diverse nature of BIPV technologies has sometimes been seen as a handicap for further penetration in the construction sector that is risk-adverse for many good reasons. **Furthermore, the lack of awareness of BIPV technologies and on correlated "key product characteristics"**, such as electrical energy output, mechanical load bearing properties, product lifetime, decommissioning and recycling, has been holding back a broader adoption by the construction sector.

In the meantime, further standardisation and mainstreaming of BIPV products combined with an increased collaboration with the downstream value chain (installation, operation, maintenance, refurbishment) helps reduce the uncertainty on cost related to the construction project throughout its lifetime. This allows the development **of a more structured network of highly-qualified installers and service providers** capable of integrating BIPV in both new and existing buildings, ensuring these systems continue function correctly after installation (operation, maintenance, decommissioning). Undoubtedly, raising awareness about the characteristics of BIPV and **supporting the development of a more structured BIPV industry are key elements of success in encouraging European cities to become pioneers in the uptake of BIPV in buildings**.

FIGURE 13 FINANCE TOWER, LIÈGE, BELGIUM, BIPV BY ISSOL, SIMCO ITALIA, JASPERS EYERS ARCHITECTS. THE PARADIS TOWER IS COMPRISED OF A GLASS FAÇADE INCORPORATING PHOTOVOLTAIC CELLS, AN LED LIGHTING SYSTEM, AS WELL AS THIN VERTICAL METAL ELEMENTS ADDING RHYTHM TO THE VERTICAL URBAN GESTURE. RAINWATER IS COLLECTED AND USED FOR CLEANING AND MAINTENANCE OF THE EXTERIOR PARKING AREAS. THE COOLING EQUIPMENT PROVIDES COOLING PRODUCTION WITH A HIGH PERFORMING RATIO OF 7.9 WHEN FULLY RUNNING. AS A RESULT, PARADIS TOWER HAS RECEIVED A BREEAM "EXCELLENT" CERTIFICATION.

Source: Issol. © P.Andrianopoli

4.2. Unlocking the potential of BIPV for European cities

Local authorities can develop various instruments to actively promote BIPV and embark on an accelerated route towards a green city. These "market-pull" instruments will help create synergies between European cities and the private sector, subsequently resulting in a bigger uptake of BIPV.

4.2.1. Converting public building stock into Plus-Energy-Buildings

EU cities have in their hands the possibility of developing innovative public/private business partnerships with BIPV and thus generating best practice examples.[20]

Traditionally, the installation of on-site renewable generation for the building sector such as BIPV is based on a customer ownership business model: the owner of the building also owns the installation and therefore bears the risks associated with operation, maintenance and decommissioning of the installation. As BIPV was perceived as very innovative in the past, such responsibility in the long-run can be a critical barrier for city planners and mayors to integrate BIPV into a tender for renovation or construction projects.

Luckily, several new business models have emerged which have significantly simplified the access to on-site renewable generation without the uncertainty, as well as the administrative and financial burden traditionally associated with the ownership of the installation. These business models, that can be a perfect fit for the development of BIPV, are now officially recognised by EU legislation through the "Clean Energy Package" and notably include the following three options:

Power Purchase Agreements (PPAs)

A renewable Power Purchase Agreement (PPA) is a long-term agreement where a developer takes over responsibilities for design, permit, financing and installation of a renewable energy system on a local authority property. In return, the developer provides all or part of the city's electricity needs, maintaining a fixed price or renewable energy (kWh) over a period of years. This business model allows businesses and cities to manage volatile energy costs while reducing their carbon footprint and their energy bill.

The clear advantage of promoting local BIPV-based PPAs as opposed to remote central power plant PPAs, is that the need for substantial investments, both financial and in terms of public acceptance in additional power grid infrastructure,[21] will be strongly reduced. "Grid-friendly" decentralized PV generation however has to be steered and incentivized by proper tariff design and local storage requirements. Assuming these boundary constraints are met, the energy independence and resilience of cities will be greatly enhanced by the promotion of 'point-of-use power generation' that BIPV offers.

20 For example, various ongoing activities in the sector of energy efficiency and zero-carbon city initiatives by the Covenant of Mayors or C40 cities.

21 Dierckxsens et al. 2015 http://www.metapv.eu/sites/default/files/PR_PR104282_FullProjectReport_F.pdf

4 CREATING BUSINESS OPPORTUNITIES FOR GREENER CITIES / CONTINUED

Lease Contracts

The leasing model allows the city to sign a contract with a developer, paying for the use of the solar system over a specified period of time, rather than paying for the power generated (like in the PPA).

The city leases the components, paying fixed monthly lease payments for the duration of the lease term (usually 20-25 years) and consumes the electricity generated. If the lessor has a net-metering policy, the city will receive a payment for any excess electricity sent back to the grid. The lease rate may also be increased if the lessor agrees to provide ongoing O&M services.

Energy Performance Contracting (EPC)

EPC is a form of 'creative financing' which allows funding energy upgrades from cost reductions . Under an EPC arrangement, an external organisation (Energy Service Company, ESCO) implements a project to deliver energy efficiency, or a renewable energy project, and uses the stream of income from the cost savings or the renewable energy produced to repay the costs of the project, including the costs of the investment. Essentially, the ESCO will not receive its payment unless the project delivers energy savings as expected (pay for performance), so the owner does not bear upfront costs and maintenance is guaranteed. A long-term contract makes sure that the investor secures the return on investment (ROI) and offers the city long term savings.

To further mitigate risks, private and public investors can use structured financing schemes. Securitisation occurs by pooling revenue-generating assets or conventional investments with innovative assets such as BIPV, and selling them off as packages through shares, generating immediate revenue and diversifying risk.[22]

BIPV PROJECT

FIGURE 14 COPENHAGEN INTERNATIONAL SCHOOL (CIS) IS LOCATED IN THE HARBOUR IN THE NEW SUSTAINABLE DISTRICT OF NORDHAVN. THE GREEN COLOUR-CHANGING FAÇADE IS MADE UP OF 6,000 M² OF INDIVIDUALLY ANGLED PV MODULES WITH KROMATIX GLASS. ONE COLOUR CAN APPEAR IN MANY DIFFERENT SHADES AS THE LIGHT CHANGES THROUGHOUT THE DAY AND DUE TO THE VARIOUS ANGLES OF THE MODULES. IN THAT WAY, THE FAÇADE BECOMES MULTI-COLOURED EVEN THOUGH ALL THE MODULES ARE THE SAME COLOUR. THE PRIVATE SCHOOL WAS BUILT IN 2016 AND THE DECISION TO USE BIPV WAS MADE IN THE EARLY DESIGN PHASE, PRIMARILY FOR THE GREEN VALUE AND AESTHETIC REASONS. THE BUILDING IS LISTED ACCORDING TO ENERGY CLASS 2020 AND IT IS SO AIRTIGHT THAT THERE IS A NEED FOR COOLING EVEN IN WINTER. THE EXPECTED ENERGY CONSUMPTION FOR COOLING AND A REDUCTION OF DAILY OPERATION COSTS WAS ALSO A REASON FOR CHOOSING PV.THE ENERGY PRODUCTION FROM THE 700 KWP BIPV SYSTEM IS ESTIMATED TO COVER 50% OF THE TOTAL ANNUAL ELECTRICITY CONSUMPTION AT THE SCHOOL. A PROPERTY COMPANY RENTS OUT THE BUILDING TO THE SCHOOL.

Source: Copenhagen International School, CF Moeller Architects, ECIS

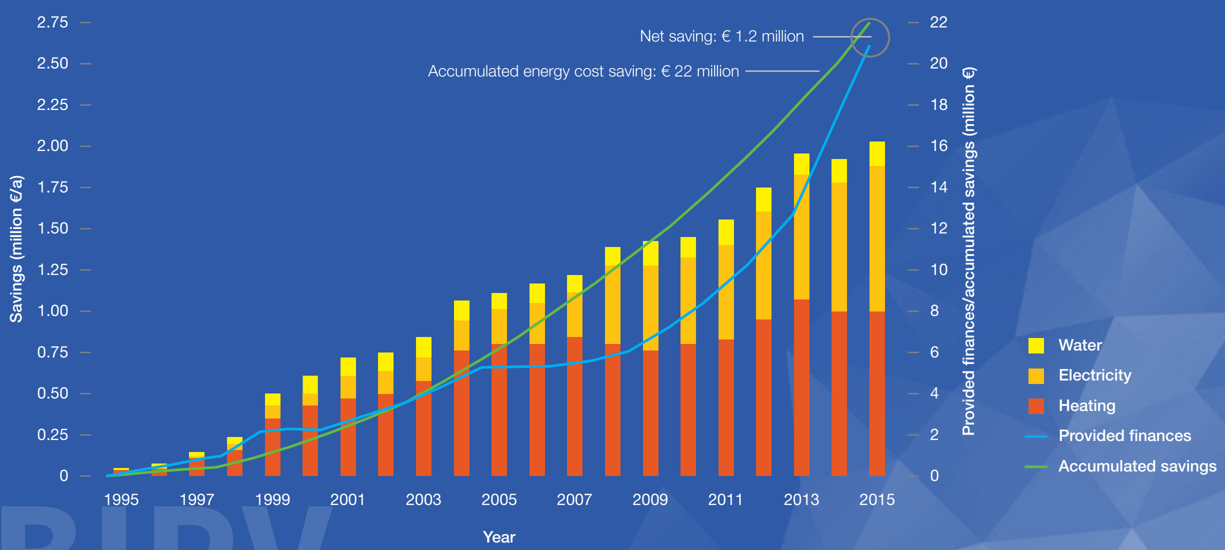
© Adam Moerk

22 Private parties can also use leasing models and ESCOs to finance energy efficiency or renewable energy projects.

CASE STUDY: INTERNAL CONTRACTING SCHEME, CITY OF STUTTGART, GERMANY

The scheme, as implemented in Stuttgart, is a ring-fenced zero-interest rate loan, entirely financed from municipal budget funds, available to technical departments wishing to implement energy saving measures. The loan is repaid into the fund from the savings made on energy costs. The management of Internal Contracting is performed by the municipal energy department, which offers energy services as an internal ESCO. The fund's operational scope covers over 1,400 municipal public buildings, including educational establishments, office buildings, housing units and sports facilities. Until 2015, 247,000 MWh, 50,000 MWh of electricity, 568,000 m^3 of water, and 118,000 tonnes of CO_2 were saved.

FIGURE 15 COST SAVINGS FOR THE CITY OF STUTTGART THROUGH INTRACTING



Source: Financing the Energy Transition – Internal Contracting.

How various financial instruments fit together in order to reduce the CO_2 footprint of a city's real estate portfolio is exemplified in the case study above.

In addition to new financing schemes cities can also modify their internal procurement procedures to support a transition towards products with a lower carbon footprint. The two following examples will help to illustrate this.

Green Public Procurement (GPP)[23]

GPP is a process where public authorities seek to source goods, services or works with a reduced environmental impact, stimulating the provision of more resource-efficient, less polluting goods, within the marketplace. It is also widely recognised as an effective means for public administrations to manage the balance between cost effectiveness and sustainable development.

In this context, energy consumption and sustainability of the materials used in construction, are relevant factors to consider while developing projects. In particular, the EU GPP criteria gives preference to designs which incorporate high efficiency or renewable energy systems. Also, the Environmental Product Declarations (EPDs) for building products help to encourage a more sustainable demand and supply of construction products.[24]

The integration of GPP principles into the city's economy enhances its reputation as an innovative, eco-efficient and forward-looking place to do business, and at the same time, facilitating the development of NZEBs.

23 http://ec.europa.eu/environment/gpp/index_en.html

24 https://www.environdec.com/What-is-an-EPD/

4 CREATING BUSINESS OPPORTUNITIES FOR GREENER CITIES / CONTINUED

GREEN ELECTRICITY FOR BREMEN'S PUBLIC BUILDINGS[25,26]

Green procurement of electricity by the city of Bremen was done for the first time in July 2008 in accordance with the policy and concept provided by the German Federal Environment Agency. Bremen adopted this practice to reduce CO_2 emissions, foster the development of renewable energies, and allow the public sector to act as a model for other purchasers.

A public tender was published at EU level by the city of Bremen to cover the electricity requirements for a number of local public entities, including Bremerhaven Municipality, from renewable energy sources. The initial contracting period was for two years – from January 2009 to December 2010, extended under the terms of the tender to the end of 2012. The contract is for the supply of 79 million kWh annually, with a total approximate cost of €7.5 million per annum.

BIPV

Innovative public procurement procedures

Even though technologies, infrastructures and services in cities are subject to public procurement processes, the traditional methods are often not suited to the purchase and deployment of innovative technologies.

The topic of innovation procurement is increasingly on the priority agenda of the European Commission.[27] The creation of an innovation policy framework, assistance programs and funding projects under different EU research and innovation programs (FP7, CIP and Horizon 2020) are examples of this effort.

For procurement, there are two types of innovation procurement that can be used in a complementary way: Pre-Commercial Procurement (PCP) and Public Procurement of Innovative Solutions (PPI). These tools enable the public sector to modernise public services while creating opportunities for companies in Europe to gain leadership in new markets. However, they are underutilised in Europe.

For BIPV, that is a mature technology that hasn't been rolled out massively yet, **Public Procurement of Innovative Solutions (PPI)** can be of help as they are used when challenges can be addressed by innovative solutions that are already in small quantity in the market and don't need new Research & Development (R&D).

4.2.2. Promoting new financing schemes for private property owners

A different alternative for cities to scale up the transformation towards low energy buildings is to tap into the private building stock. To unleash this potential, cities can promote incentives that are more fit for the city's needs and adapt better to the type of consumer that is willing to take part in the city's transformation. This energy transformation is associated with progressive electrification of the transport, as well as the heating and cooling sectors. In order to support this shift, taxes and charges on electricity need to properly reflect the lower CO_2 emissions of renewable electricity. Therefore, proper CO_2 pricing is a key element to unlock the potential of BIPV in cities. Other financial measures are described in the following paragraphs. EU cities have the possibility to design the right regulatory incentives to foster the BIPV market uptake within the urban transformation towards becoming sustainable cities.

Tax schemes, incentives and loans

Among all the possibilities to promote private renewable energy projects, access to finance stands out as a key element. Cities can resort to a suite of options to help finance BIPV projects: local tax incentives, property taxes and green bonds, energy efficient mortgages, revolving funds, soft loans, public-private partnerships (third party financing), Energy Performance

25 http://ec.europa.eu/environment/gpp/pdf/news_alert/Issue8_Example21_Bremen_Electricity.pdf

26 For more examples: http://ec.europa.eu/environment/gpp/case_group_en.htm

27 https://ec.europa.eu/info/policies/public-procurement/support-tools-public-buyers/innovation-procurement_en

CASE 1: ENERGY RENOVATION OF RESIDENTIAL BUILDINGS THROUGH SOFT LOANS AND THIRD-PARTY FINANCING, DENMARK[31]

With the objective of becoming a 100% renewable energy city by 2030, the city of Frederikshavn developed a plan to facilitate a soft loan financing scheme. The city didn't allocate any funds to the financing scheme but they were provided by partner banks in the form of soft loans. They run a creditworthiness check of homeowners, decide who gets a loan and under what conditions. All risk is borne by the partner banks.

To make this happen, first, the municipality sets up a network of independent home energy advisors to provide individual technical assistance to homeowners. Second, it established partnerships with local banks, so customer advisors were trained about the benefits of energy renovation and on the financial opportunities for energy renovation. They also negotiated with the banks concerning the development of specific soft loans for the energy renovation of housing. Third, they trained local market actors (construction companies, estate agents) and encouraged them to contribute to the municipality's objectives. Lastly, the municipality actively promoted the soft loans through dissemination of real cases.

Contracting for the private sector, public Energy Service Companies (ESCOs) (see Chapter 5.1), feed-in tariff remuneration, citizens' cooperatives or crowdfunding. These are some of the possible ways of filling the private financing gap.

Innovative financing can help make these projects more attractive to relevant stakeholders and there are already different EU initiatives that encourage this. For example, the "Smart Finance for Smart Buildings initiative" dedicated to innovative financing for energy efficiency investments,[28] including BIPV, the European Fund for Strategic Investments (EFSI) that supports sustainable energy renovation in buildings by unlocking private financing at a larger scale,[29] the Sustainable Energy Investment Forums (SEI Forums) aiming at driving large-scale investment and financing for sustainable energy by working with national stakeholders,[31] or the BUILD UP financing Schemes that apply for residential and non-residential buildings, homeowners and tenants and for municipalities, social housing and companies.[32]

What is clear is that achieving high levels of decarbonisation in the European building stock would require motivating private citizens into participating in the transformation towards sustainable cities. Giving visibility to these financing schemes and developing awareness campaigns would be essential to engage the private sector. We will describe two best practice examples from Denmark and Estonia on this and the following page.

4.2.3. Cities as policymakers

Even though the "Clean Energy for All Europeans" legislative package establishes an enabling framework to ensure a modern and energy efficient building stock in Europe, municipalities will have the final say in driving the energy transition at local level. They have the capacity to design the right regulatory incentives and to fill in any ambitious gap preventing the integration of BIPV. Initiatives like the Covenant of Mayors or Energy Cities (the European Association of local authorities in energy transition) can leverage the potential of private and public partnerships for developing BIPV, as they develop local climate and energy actions to accelerate the decarbonisation of their territories and strengthen the capacity of their member cities to stand out in the field of sustainable energy.

28 https://ec.europa.eu/info/news/smart-finance-smart-buildings-investing-energy-efficiency-buildings-2018-feb-07_en

29 https://www.eib.org/en/efsi/index.htm

30 https://ec.europa.eu/energy/en/topics/energy-efficiency/financing-energy-efficiency/sustainable-energy-investment-forums

31 http://www.buildup.eu/en/news/overview-successful-renovations-through-innovative-financing-0

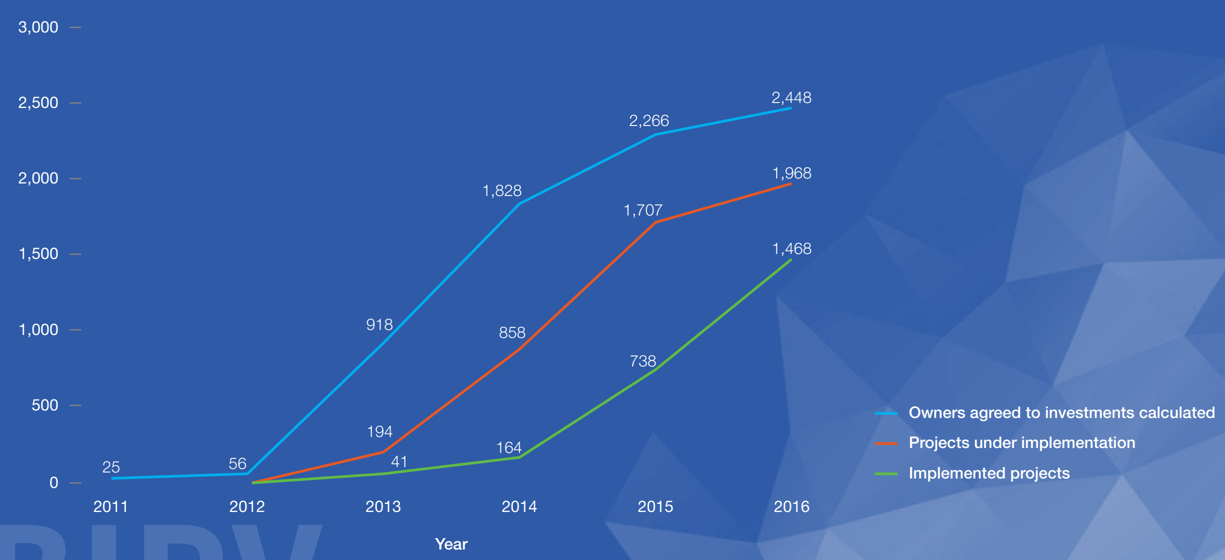
32 http://www.energy-cities.eu/db/Frederikshavn_softloans_2017_en.pdf

4 CREATING BUSINESS OPPORTUNITIES FOR GREENER CITIES / CONTINUED

CASE 2: KREDEX REVOLVING FUND, ESTONIA[33]

The KredEx Governmental Revolving Fund was the first Energy Efficiency Revolving Fund in Eastern Europe. Through the KredEx Fund, the Estonian government shifted the focus of its energy efficiency support strategy from a grant-only scheme to a more adequate support system based on a combination of loans, loan guarantees and grants. KredEx offered four types of financial support: grants for energy audits, loan guarantees, renovation “soft loans” and reconstruction grants. The funds were set up by the Government of Estonia, the Council of Europe Development Bank (CEB) and by the KredEx Foundation. The beneficiaries were cooperative housing associations, communities of apartment owners (built before 1993) and local authorities (owners of social housing). By the end of 2013, 798 buildings were renovated, namely, 415 buildings used a combination of reconstruction grants and KredEx soft loans, 185 buildings used only KredEx loans while 198 buildings used only reconstruction grants.

FIGURE 16 KREDEX REVOLVING FUND, ESTONIA



Source: Use of Cohesion Funding for Home Renovations, presentation.

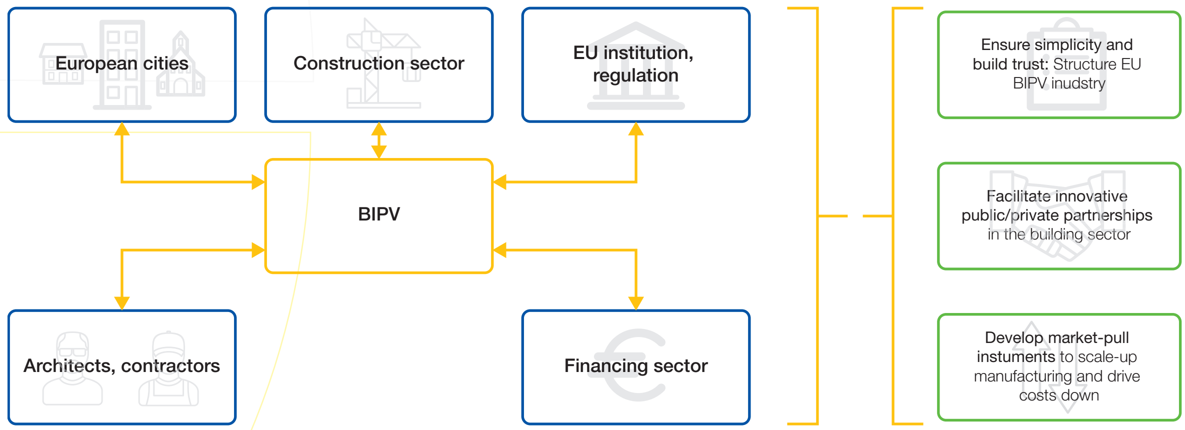
For example, the EU Smart Cities Lighthouse Projects[34] are striving towards Positive Energy Districts (PEDs). These projects bring together various stakeholders, such as real estate developers, construction companies, network operators, utility companies and many others, that will play a vital role as solution providers. All of them are in need of new business models when energy efficiency and renewable energies become standard in society. For example, Groningen’s approach to the energy transition has served the city to be appointed the title 'Lighthouse City' by the European Commission. The municipality has a goal to become CO_2 neutral by 2035, for which it will integrate energy-generating buildings and smart IT solutions. The city has started transforming whole districts to become energy neutral or positive, setting an example for other European cities. These examples, can help other cities to overcome the lack of awareness about how to use these innovations in the urban scene, delivering accessible and transparent processes and helping remove existing barriers.

Further on, municipalities can actively publish pilot projects, case studies and good practice examples to showcase the benefits. In addition to their local initiatives, cities can align within their national and European networks, such as the Covenant of Mayors, and agree on how to move EU wide policies.

33 http://www.buildup.eu/en/news/kredex-estonias-funding-revolution

34 https://ec.europa.eu/inea/en/horizon-2020/smart-cities-communities

FIGURE 17 STEPS TO CREATE A BUSINESS ECOSYSTEM FOR GREENER CITIES



But how can cities unlock their full potential within their own premises? A first step that is currently followed by some of the most successful cities in Europe, like Copenhagen or Malmo,[35] is to first develop their own energy and climate plans based on the current state and the needs of the city itself. This way, the municipality is obliged to identify those economic areas (private households, public services, business or services, industry, transport, etc.) with the largest decarbonisation potential before developing tailored policies that include the allocation of financial support.

CITY AUTHORITIES TAKING THE LEGISLATIVE INITIATIVE TO FORCE CHANGE: TÜBINGEN'S SOLAR PLAN[36]

In 2015, the city council of Tübingen (Germany) planned to reduce CO_2 emissions by 25% by 2022, compared with 2014. After exhausting its potential for hydropower, biogas and electrification of sewage plants, the city needed new ways to meet the target. In 2017 the city administration was instructed to find new ideas to do so, and this is where solar came into play.

In 2018, Tübingen's council adopted a resolution requiring solar PV to be installed on new buildings, whenever economically feasible.[37] The mechanism allows the city to purchase sites for new buildings and insert the new policy to develop the solar infrastructure before selling these sites to private buyers or building companies. This way, buyers or builders that refuse to consider PV will be excluded from the purchase. At the same time, the required PV size has been set low to reduce resistance and allow owners to discover by themselves the economic and amortisation potential of rooftop PV.

35 http://www.energy-cities.eu/IMG/pdf/local_energy_climate_roadmaps_final.pdf

36 https://foresightdk.com/tubingen-gives-rooftop-solar-extra-nudge/

37 This policy does not apply to existing buildings to stay in line with German building law. Tübingen cannot mandate solar on existing buildings, even as part of substantial modernisation such as a roof renewal because retrospective adjustments affecting granted building permits are not allowed.

4 CREATING BUSINESS OPPORTUNITIES FOR GREENER CITIES / CONTINUED

KEY ASPECTS FOR AN AMBITIOUS CO_2 REDUCTION PLAN IN CITIES:

All the previous examples show that cities can play a crucial role in providing the additional push to reach ambitious CO_2 reductions via a massive local uptake of renewables and BIPV in cities.

Setting a yearly increasing renewable energy share target to cover the city's electricity needs is therefore an important first political objective. This must be backed with an detailed investment program, financing concepts and management plan for integrating renewable energies into the renovation program of public and private buildings. Specific targets for PV in roofs and façades need to be set.

For the full decarbonisation of our cities, authorities must also develop adequate energy system planning involving decentralized renewable energy generation. This involves sector coupling, electrification of heating and cooling as well as public and individual transport. Having a plan to incentivize and integrate inhabitants that are at the same time electricity producers and consumers (prosumers) will also help to accelerate the decarbonisation process.

Once these targets are set and plans are designed, cities have to translate them into specific actions and here, leading by example is critical as some of the case studies in this report have shown. Raising awareness about the benefits of on-site renewable energy integration, BIPV and energy efficient renovations is much easier when one can promote good practice experiences, for example on Green Public Procurement. This way one can illustrate how public authorities in Europe have successfully 'greened' local electricity generation, a public tender or procurement process. Public buildings must be the example of the successful integration of these elements and serve as a model for private investors, but facilitating access to information and adequately promoting the success stories is essential to achieve higher engagement.

Lastly, it is central for city authorities to start a joint dialogue with all involved stakeholders (architects, the construction sector, building sector, financing institutions, component producers and utilities, etc.), not only to reinforce the support of these projects and businesses, but also to be able to design and set up the right incentives for each player involved.

BIPV

FIGURE 18 NORMAN FOSTER SOLAR AWARD. INSTEAD OF REFURBISHING THE NEARLY 100-YEAR OLD BUILDINGS WITH 54 APARTMENTS, THE GENERAL CONSTRUCTION COOPERATIVE ZURICH (ABZ) DECIDED TO REPLACE IT. IN THE PLANNING OF MULTI-FAMILY DWELLINGS (MFH), CRITERIA IN TERMS OF SOCIAL COMPATIBILITY, ECOLOGY AND EFFICIENCY IN DEALING WITH LIVING SPACE AND ENERGY CONSUMPTION WERE IN THE FOREGROUND. THE AESTHETICALLY EXEMPLARY AND FULLY INTEGRATED PV SYSTEMS HAVE AN OUTPUT OF 556 KW AND GENERATE 466,300 KWH PER YEAR. THE 68 NEW APARTMENTS OF SWITZERLAND'S FIRST WOOD-BASED PLUS-ENERGY CONSTRUCTION ESTATE WILL BE HEATED WITH SOLAR-POWERED HEAT PUMPS AND GROUND PROBES. WITH A TOTAL ENERGY CONSUMPTION OF 397,200 KWH PER YEAR, THE PEB SETTLEMENT HAS ITS OWN ENERGY SUPPLY OF 117%.

Source: Solaragentur.

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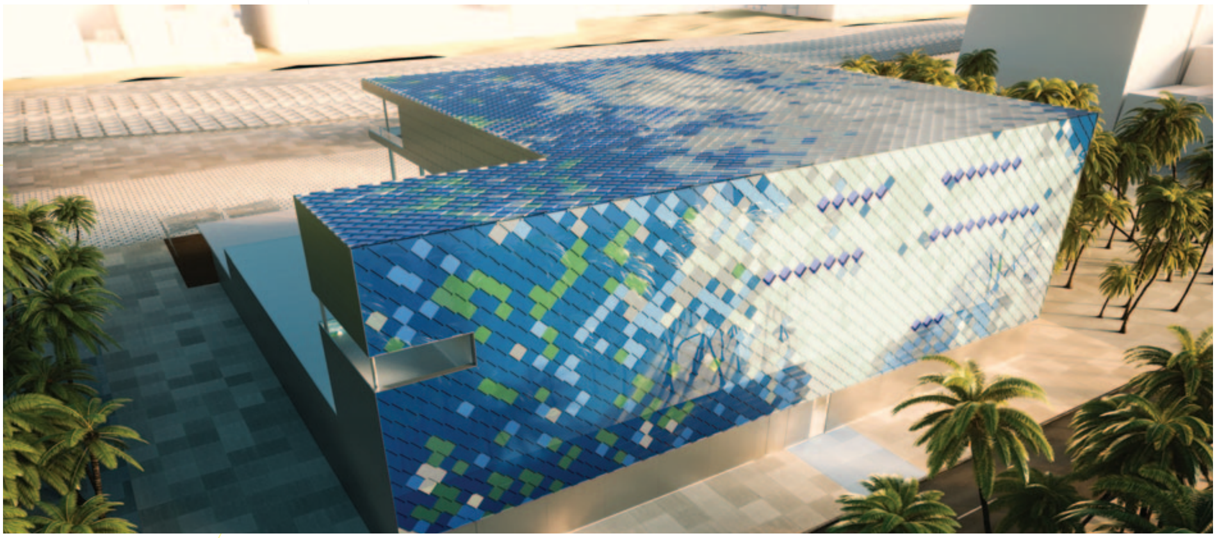
- Building Retrofit with Photovoltaics: Construction and Performance of a BIPV Ventilated Façade. Energies, July 2018. Web: https://www.researchgate.net/publication/326126195_Building_Retrofit_with_Photovoltaics_Construction_and_Performance_of_a_BIPV_Ventilated_Facade

FRENCH PAVILION DUBAI EXTERIOR VIEW OF THE PHOTOVOLTAIC TILES



Source: Akuo Energy.

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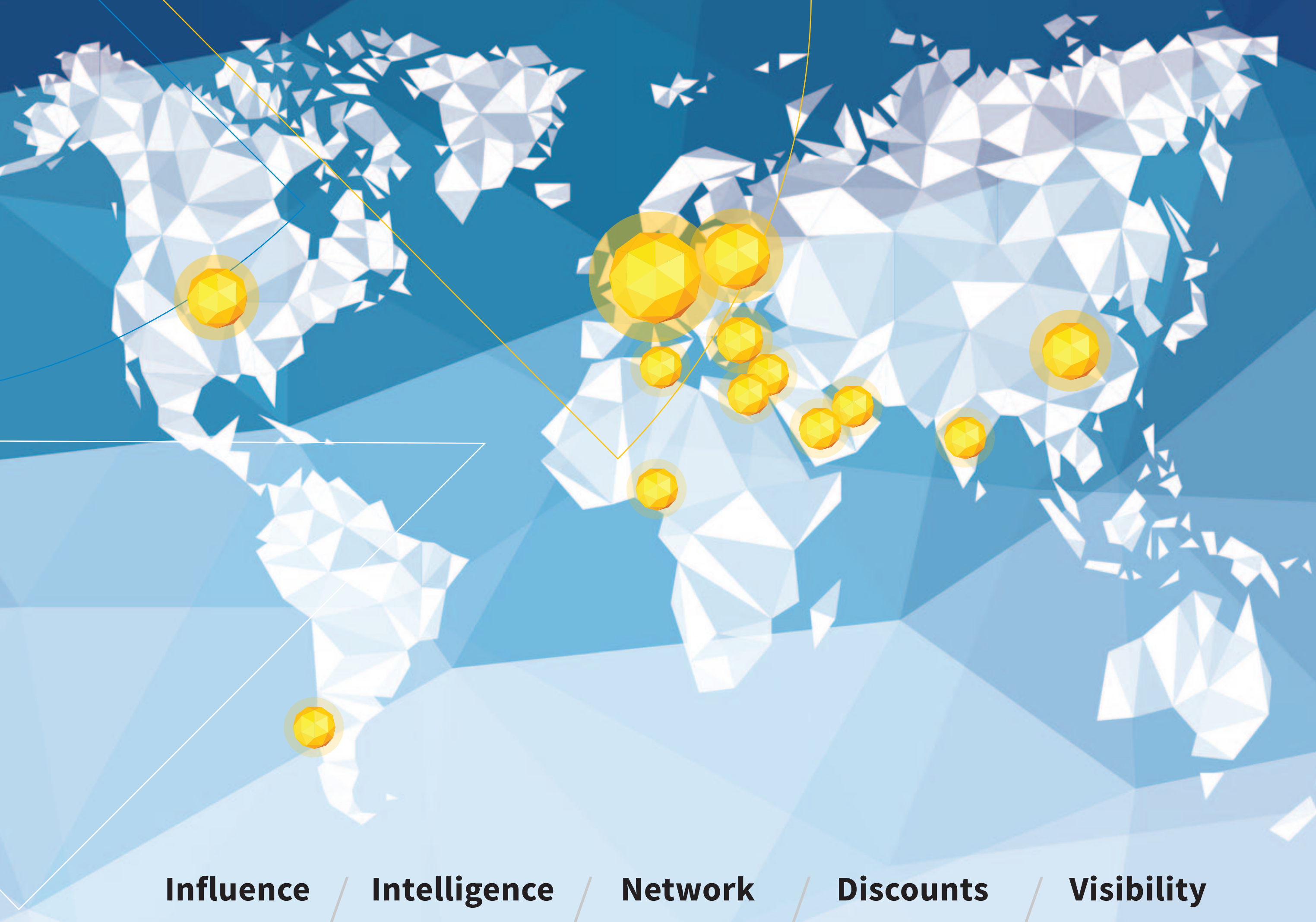

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