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D8.18 Lessons learnt in PVSITES BIPV installation process: acceptance and use of BIPV elements

T 8.3. Installation and commissioning of installation

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"Building-integrated photovoltaic technologies and systems for large-scale market deployment"

Start date: January 2016. Duration: 4.5 Years

Summary

Deliverable D8.18 is a description of the difficulties encountered and lesson learnt in executing the demonstrators, in particular those related to the acceptance and use of the BIPV elements (as opposed to normal construction elements).

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1 EXECUTIVE SUMMARY

Deliverable D8.18 is a description of the difficulties encountered in executing the demonstrators, in particular, those related to the acceptance and use of the BIPV elements (as opposed to normal construction elements).

The document basically includes a short description of the installation process, emphasizing the lessons learnt in permitting and commissioning, and, finally, the lessons learnt in the design and installation of BIPV Systems. Besides, the real pictures of the installation works and the final results of the systems come to suitably illustrate the explanations.

More detail about permitting, installation and commissioning can be found in D8.6.

1.1 Description of the deliverable content and purpose

Deliverable D8.18 distributes its content in several chapters. After the executive summary, a second chapter is dedicated to describing good practices to be taken into consideration in BIPV systems installation process, from planning and design to installation and commissioning. For new construction or refurbishment and for installation in existing buildings. The content of this chapter was explained during the Training sessions to installers held in each demo site within task T9.6.

Later a chapter is dedicated to each demo-system. Since the carport system was implemented in two different demo-sites the correspondent chapter includes the lessons learnt in design, installation and commissioning report of both systems.

As said in the summary, the demo-systems implementation results include a brief descriptions and real pictures of the installation, permitting and commissioning works.

1.2 Relation with other activities in the project

The activities carried out in the framework of T8.3, and the results documented in deliverable D8.18 in T8.3, are directly related to the tasks and reports listed in the table below, which are referred to the demo-systems' design, to the manufacturing of the developed products, and to the installation and commissioning of BIPV systems.

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

Project activity	Relation with current deliverable
Task	**Deliverables**
Task 8.1. Design of demonstration installations	D8.3 Design pack for every demo site
Task 8.2. Manufacturing of prototypes	D8.5 Prototypes for demo sites - Second batch
Task 8.3. Installation and commissioning of installation	D8.6 Report on general architectural, photovoltaics, operational, economic, and environmental assessment of the demo-sites.
T9.6 Training courses for installers	D9.19 Training courses on the BIPV software tool

1.3 Reference material

This document does not content any reference external to the project.

1.4 Abbreviation list

BAPV: Building Attached Photovoltaics.

BIPV: Building Integrated Photovoltaics.

EKZ: Elektrizitätswerke des Kantons Zürich.

EMPA: Swiss federal laboratories for materials science and technology.

GSM: Global System for Mobile communications.

IP: Ingress Protection, Intellectual Property

nZEB: nearly Zero Energy Building

PV: Photovoltaics.

RD: Real Decreto (Royal Decree).

2 PLANNING, DESIGN AND INSTALLATION PROCESS IN BIPV

The planning, design and construction process of new buildings has different stages with different actors. BIPV is a small, but sometimes complicated part of this process. In case of new construction or refurbishment of existing buildings, the BIPV design and installation process, is also part of the overall process.

In case of the installation of a BIPV system in an existing building, without other construction or refurbishment work done, the process will be different.

First, we will describe the planning, design and construction process for new buildings including the BIPV system. Second the planning, design and installation of a BIPV system without other construction.

Table 2.1 Overview of the design and construction process in different countries (related with the demosites)

	Spain	France	Belgium	Switzerland
Brief	Programa	Programme	Programma van eisen	Grundlagenermittlung
Concept design	Diseño conceptual	Concept de design	Voorlopig ontwerp	Vorplanung
Preliminary design	Diseño final	Conception finale	Definitief ontwerp	Entwurfsplanung
Detailed design(1)	Planos de construcción	Conception détaillée	Constructie tekeningen	Ausführungsplanung
Tender	Oferta	Appel d’offre	Aanbesteding	Vergabe
Construction	Construcción	Construction	Uitvoering	Konstruktion
Commissioning	Entrega	Mise en service	Oplevering	Inbetriebnahme

(1) To speed up the process, tenders are done after the preliminary design and the construction drawings are made after the tender in cooperation with the main-contractor.

2.1 New Construction or refurbishment

2.1.1 The brief

The brief is written by or on behalf of the client. It is an important start of the design process.

Professional developers will write the brief themselves or (for complex projects) hire a consultant or project management firm. For smaller projects, the architect will assist the client to write the brief.

The brief is in general the starting point for the design. The architect will make his design based on the brief from the client, the location and the local regulation.

BIPV aspects in the brief

Different requirements are possible:

- Does the brief have a goal for the building like nZEB - nearly Zero Energy Building, Passive House or Energy Neutral?
- Does the brief have requirements like sustainability or green design or an assessment like BREEAM or LEED?
- Does the brief have the requirement for the installation of PV?

Impact for the design

Each of these requirements have a different impact on the design.

1. In case of the goals like nZEB, an energy balance has to be made very early in the process. That means that the dimensions of the BIPV system will be calculated very early and can play a role in the design of the building.
2. In case of a green assessment like BREEAM, the guidelines for the assessment have to be followed but the contribution of the BIPV system to the energy balance is more flexible.
3. In case the brief asks for a BIPV system, more information is needed to understand the reason behind the BIPV installation. It can be one of the first two reasons but also to showcase the green imago of the company. Depending on the reasons, an energy balance is needed or just a fancy application.

2.1.2 Concept design

The concept design is the most critical phase of the design process to apply BIPV.

The architect has to make design proposals that include the integration of the PV system. In the design he has to decide where to apply BIPV. Will it be a roof system, a facade system or building components like a shading system?

If the choice for a BIPV system is not made in the concept design, it will be more complicated in the next stage of the design. It is possible that in the next stage of the design, huge changes are the result if the design does not fit for BIPV. It is also possible that the design is not suited for a BIPV system and the project ends with a poor designed BAPV system.

The cost for BIPV will be higher if there are many changes in the design needed or if the only solution is to have customized PV modules.

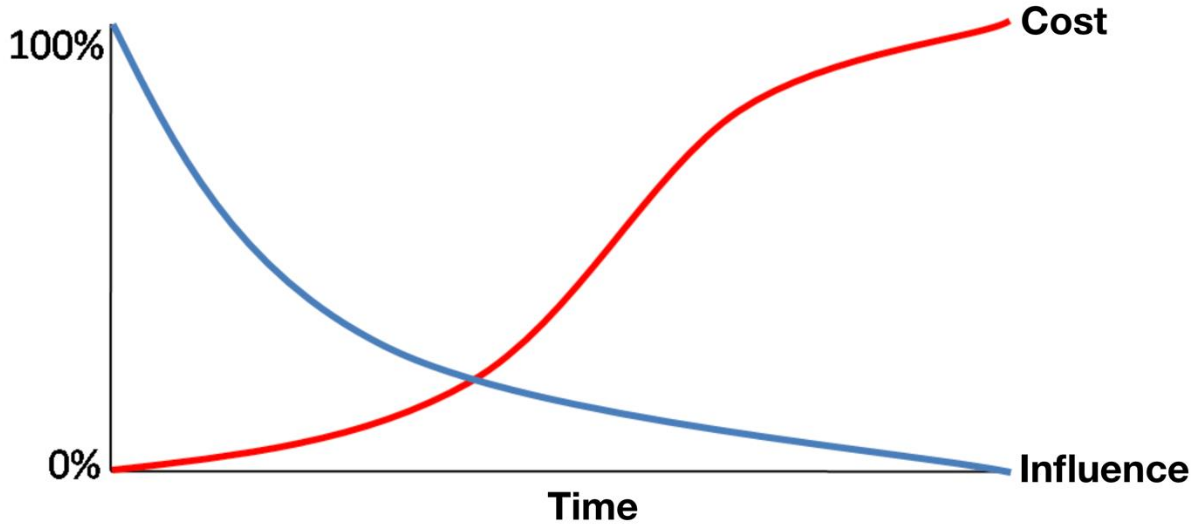


Figure 2.1 The graph shows how the cost of design changes are increasing during the design process while the influence on the design becomes less.

BIPV aspects

1. The energy balance has to be made on the concept design and the contribution of the BIPV system has to be calculated.
2. The area for BIPV (roof or facade) should match the dimensions of the BIPV system. In this stage the design can be easily adjusted to meet the dimensions of standard modules.
3. An indication of inverters is needed and space has to be reserved for the inverters.

Impact for the design

1. First the architect will use some rules of thumb to get to know roughly the area of BIPV that is needed.
2. After the concept design is drawn in 2D or 3D, energy calculations can be done (Here the PVSITES software can be used). The area of BIPV has to match with the energy balance and the requirements from the brief.
3. A logical space for inverters and the shaft for cables has to be reserved in the building.
4. The architect has to check if there are no obstacles that can cause shading of the modules.

Special attention

As glass buildings reflect sunlight, it is important to check if there will be any hindrance by reflection of a BIPV facade.

In general, the BIPV system will be grid-connected. It is advised to consult the utility as early as possible.

Process

In the traditional process, more people get involved during the phases of the design. The construction company comes in after the open tender is done.

There are more possibilities like a “Design & Build” team that is involved all along the design and construction process. Others are “Turm Key” or “Build, Operate, Finance & Transfer”

The government and some public organizations are not allowed to do the one-to-one tender but in general can do a closed tender with a minimum of three parties that are pre-selected.

In the “Design & Build” team, the contractor (construction company) and other engineers and consultants are involved in the process to make an easy move from the concept design to the preliminary design. The BIPV system can be designed by a BIPV consultant, the electrical consultant, the installer or the supplier of the system.

In the traditional process, at least two parties are involved: the BIPV consultant or electrical consultant during the design process and the installer/supplier after the tendering.

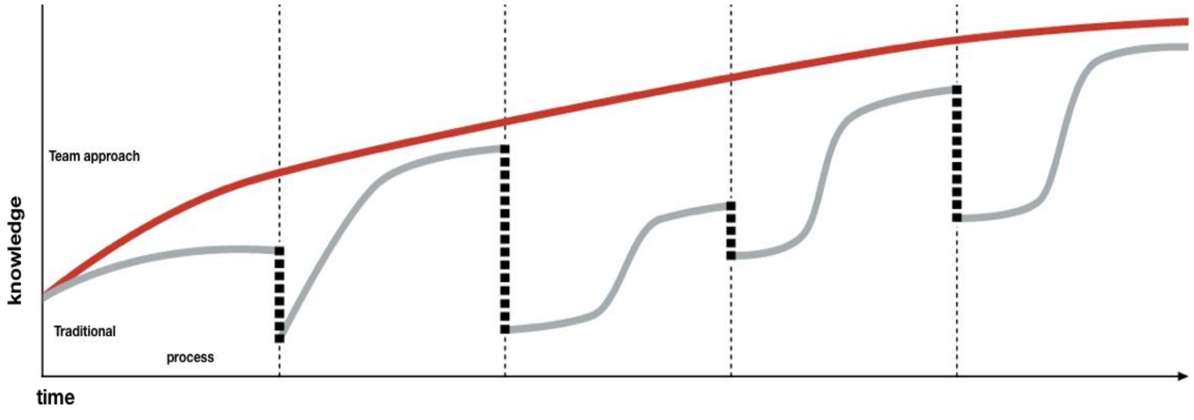


Figure 2.2 Difference between a traditional process and a team process

In the traditional process, each stage has new actors with potential loss of information while in the team process, the information is growing constantly

2.1.3 Preliminary design

In this stage the design will be made final, the drawings for the building permit and the tender process will be made, the different building materials will be chosen, the technical details and a description or specification will be made, the cost calculations will be done and the client will apply for the building permit.

BIPV aspects

1. The BIPV system has to be designed and detailed.
2. Modules have to be chosen and dimensions have to match the building.
3. Wiring lay-out and choice for inverters have to be made.
4. Specifications and tender documents will be made.

Impact for the design

In this phase, the match between module and building dimensions has to be made. Some parts of a building design (like a roof with overhangs on all sites) can be easily adapted to the dimensions of the modules. Other parts might be more difficult and it is possible that customized modules are needed.

As all installations, shafts, cabling and pipes are known, mismatches have to be investigated. The use of BIM can help to find the mismatches faster than in a traditional design process.

1. Special attention for the detailing of connections between modules and other building materials.
2. Most modules need to be ventilated from behind. So, ventilation openings are needed at the bottom and top part of the system.
3. Shading of obstacles and exhaust pipes on a BIPV system have to be checked and avoided.

Process

In the preliminary design, all consultants are available and will make their own adjustments to the design.

1. All materials with specification will be chosen. Also, the BIPV modules and inverters will be chosen. Depending on the process the BIPV consultant or electrical consultant will propose the system. In a “Design & Build” team it will be the main contractor or the installer/supplier of the system.
2. Preferable is the “Design & Build” team and have the main contractor in the design process. The main contractor is responsible for the BIPV system.

2.1.4 Detailed design

In this stage all information has to be available and clear. The architect (or the main contractor) will make the construction drawings. Further detailing is necessary and production drawings are needed. The sub-contractors will make the production drawings and the drawings will be controlled by the main contractor and/or the architect (and involved consultants).

In general, changes are not allowed in this stage and if so, they can have a huge impact on the design and can be costly.

BIPV aspects

1. Construction drawings, construction details and a cabling plan will be made.
2. The sub-contractor will produce production drawings for the production of the BIPV system. Drawings will be sent around for a check by the main contractor and the architect. Exact dimensions of modules, junction boxes and wires are fixed.
3. The sub-contractor for the electrical installation will make a production drawing for the electrical room and will do the same for placing and connecting the inverters.

Impact for the design

1. Check of construction details for dimensions, ventilation and wiring with the production drawings made by the sub-contractors.

2. Check for the cable gutters and cable feed-through with other building elements.

3. Check for the placing and dimensions of inverters.

Process

1. Check of the production drawings based on the detailed design (construction drawings).

Especially the location of cable feed-through in concrete or steel constructions.

2. Time-line planning of installing the system and components.

2.1.5 Tender

To speed up the process, tenders are in general done after the preliminary design based on the preliminary design drawings. The main-contractors who come up in the tender will ask sub-contractors to deliver a price based on the tender specifications.

After the tender, the quotations will be reviewed and compared. A main-contractor will be selected and a contract will be made.

After the contract is signed, the architect will make the construction drawings in cooperation with the main-contractor.

The tender process can be done by the architect as representor of the client. In complex buildings the client might hire a project management firm that has to organise the process, guard the budget and the time spend. In general, the architect will control the work of the main-contractor and sub-contractors in cooperation with the project manager.

BIPV aspects

1. Selection of BIPV supplier and installer by the main-contractor.
2. Approval by the architect or project manager of the sub-contractors.

Process

In the traditional process, the main-contractor is selected after the tender procedure. In a team approach, the main contractor is already in the team and will arrange the quotations and make the contracts with sub-contractors. The architect or project manager will check the documents and the quotations. A final contract and quotation will be made for signing by the client.

2.1.6 Construction

After the contract is signed, the main contractor will start his preparations for the construction. This process is parallel with the construction drawings produced by the architect.

Process

The architect or project manager will control the building process, timeline, check the materials and the work on site, based on the construction drawings, contracts etc. In general changes will be noted and after construction, the construction drawings will be updated.

Commissioning

After the main contractor or sub-contractor finishes the work, the BIPV system will be tested. This will be done as soon as possible to have the ability to make updates or repairs if needed.

Process

1. The BIPV system will be pre-commissioned. Any fault or mismatch will be repaired within 2 months.
2. Final commissioning and approval of the system.

2.2 BIPV in existing building

The tender and the preparation before the tender can be much easier than in a new construction or in a refurbishment project.

2.2.1 The brief

The brief is written by or on behalf of the client. As this only focuses on the placement of a BIPV (or BAPV) system, the brief can be short.

Professional developers will write the brief themselves or (for complex projects) hire a consultant or project management firm. For smaller projects, the architect will assist the client to write the brief.

The brief is in general the starting point for the design. The architect will make his design based on the brief from the client, the location and the local regulation.

BIPV aspects in the brief

1. Does the brief have requirements for the electricity output or the total area of BIPV? This can be related to other aspects as the use of electricity to charge the batteries of electrical cars.

2. Does the brief have requirements like sustainability or green design or an assessment like BREEAM or LEED?

3. Is it part of measurements to make the client greener or less independent from the grid.

Impact for the design

The architect has to investigate how much PV is required and where it is possible to place a BIPV system. As the building is existing, he can use the PVSITES software to make a quick scan of the possibilities with different types of BIPV modules. To do this a 3D model in Sketchup or Revit is required.

2.2.2 Concept design

In the concept design the possibilities of BIPV systems will be designed and shown to the client.

BIPV aspects

1. The PVSITES software can be used to make a quick scan of the possibilities and to predict the energy output.

2. The impact of shading on the modules can be analysed with the PVSITES software as well.

3. The dimensions of the BIPV system should match the available surface for BIPV.

4. A place for the inverters has to be chosen.

Impact for the design

Impact for the design is the place of modules, inverter room and feed-through of cables. Especially the inverter room is important in relation to the length of the cables.

Process

1. The architect has to make a 3D model to be able to use the PVSITES software.

2. Calculations will be made and a pre-selection of systems.
3. For grid connection, it is important to consult the utility as early as possible

2.2.3 Preliminary design

In this stage the design drawings will be made final, technical details and a technical description will be made and the client will apply for the building permit. If a building permit is needed depends on local regulation. The depth of the drawings and details is important, as in general, no detailed design is made after this.

BIPV aspects

1. The BIPV system has to be designed and detailed.
2. Modules have to be chosen and dimensions have to match the building.
3. Wiring lay-out and choice for inverters have to be made.
4. Tender documents will be made.

Impact for the design

To make the final drawings and technical details, information from the suppliers is needed. In general, several suppliers or installers will be invited to send information and references. A first selection of suppliers (2-3) will be made.

1. Special attention for the detailing of connections between modules and other building materials.
2. Most modules need to be ventilated from behind. So ventilation openings are needed at the bottom and top part of the system.
3. Shading of obstacles and exhaust pipes on a BIPV system have to be checked and avoided.
4. In some case it might be needed to check the construction because of the extra weight of the system.

Process

In the preliminary design, the architect and/or the BIPV consultant will do the main work. Alternatively, it is possible to ask one of the pre-selected suppliers to check the proposed system. Based on the information from the pre-selected suppliers, BIPV modules and inverters will be chosen. The responsibility of the project is for the client. The supplier is only responsible for the BIPV installation. It is important to go through the process and check if aspects like damage on the building, leakage etc. are covered by the supplier or by the client.

2.2.4 Detailed design

Detailed design for the installation is not needed. The selected supplier will make his production drawings based on the preliminary design.

Impact for the design

1. Check of construction details for dimensions, ventilation and wiring.
2. Space for wires, cable feed-through has to be chosen.
3. Electrical schemes and wiring. Connection to the inverter.

2.2.5 Tender

The pre-selected suppliers will be invited to make a proposal and a quotation based on the preliminary design. After the tender, the quotations will be reviewed and compared. A final supplier will be selected and a contract will be made. After the contact is made, the supplier will make his production drawings.

BIPV aspects: Selection of BIPV supplier and installer.

Process: After the tender, the quotations will be reviewed and compared. A final supplier will be selected and a contract will be made. After the contact is made, the supplier will make his production drawings.

2.2.6 Installation

During the installation of the BIPV system, the architect will control the work on site. He/she will also check if the materials used are conform the contracts.

Process: The architect will control the production drawings, timeline, check the materials and the installation, based on the tender documents, contracts etc.

2.2.7 Commissioning

After the supplier finish the installation, the BIPV system will be tested.

Process:

1. The BIPV system will be tested. Any fault or mismatches will be repaired within 1 month.
2. Final commissioning and approval of the system.

3 DEMO-SYSTEM 1 SINGLE HOUSE IN STAMBRUGES, BELGIUM: LESSONS LEARNT IN PVSITES BIPV INSTALLATION PROCESS

3.1 Short description of the Demo installation process

Single family house

Location	Stambruges (Belgium)	**Characteristics** New construction. Detached passive wooden house, located in a rural area, with residential and professional uses (architectural office).
Typology	Residential & office	
Area	280 m^2 (219 m^2 heated floor)	
Floors	3	

Area available for BIPV
Single 30° sloped roof. Available area of 107 m^2 for implementing BIPV systems. Small shadows caused by a chimney.
Optimum orientation and inclination with maximum production guarantied.
Orientation: +14° (NNW).
Inclination: 30°.

Figure 3.1: FD2: roof tiles system integrated at a single-family house in Belgium (resp: FormatD2)

A BIPV system based on CIGS PV laminated metal tiles by Flisom was installed at FormatD2 demo-site, a single house located in Stambruges (Belgium), with 8.7 kWp power and 99,6 m^2 total area.

The BIPV roof installation started with the taking off the tiled roof at the end of April 2019 (M40), taking 2 days. The lathing and placing of the tiles started at the beginning of May (M41); only 2 days were necessary to place the tiles. In total, 8 days with 3 workers were necessary to end the works. Final result was just a successful thanks to the careful architectural integration design, highly conducive to accept BIPV solutions, and the excellent planning and execution of installation works, which required millimetre accurate.

3.2 Lessons learnt in Permitting and Commissioning

No permit is generally needed for placing BAPV because the roof elements already exist and were implemented with a permit addressed to the installation of panels on existing roofs; however, for

BIPV applications the roof is composed of new elements. This circumstance is not referenced in the permit or into the urbanistic prescriptions of the place.

So, permitting process was relatively easy, with short deadlines. Special aesthetic characteristics were required to get the construction allowance of the municipality. 35 calendar days were needed to have the agreement. (period of validity of 2 years for beginning works).

Finally, commissioning was executed as planned and on time. A storage system and a solar inverter by TECNALIA were installed. A special agreement with the grid manager was achieved to use a non-commercial inverter, because all the material used should be checked according to the Belgian regulation. Once established all connections, the installation must be controlled by an accredited body.

Injection to the grid is currently permitted without being sold the surplus (balance production/consumption) but from the 1st of January 2020, a tax for the kW reinjected into the grid must be paid.

3.3 Lessons learnt in Design and Installation of BIPV system

Some of the difficulties found during installation of BIPV system are listed below.

- When mounting, enormous lost time to balance the power of the strings due to difference of tiles power (50W, 55W, 60W, 65W).
- Difference of colour between the CIGS film on tiles: blue and black.
- Lost time to open the upper folding of the tile to permit assembly; lots of details to finish perfectly the roof.
- Placement of the electrical connector under the tile (not enough spacing to the edges).
- The metallic sheet of the tile is a little too narrow; some deformation and ripple was observed.
- Not enough possibilities to adjust the height of assembly of tiles.
- Only 1 out of 10 painted steel products is suitable for BIPV. The solar standard of 1000 h 85°C at 85% relative humidity is too harsh for most painted steel substrates. Besides, solar on steel is difficult with junction box on the backside. Insulation of feed through is not trivial.

3.4 Pictures and schemes

Figure 3.2: Installation and commissioning of Demo-system 1, Single House in Belgium

4 DEMO-SYSTEM 2 EDUCATIONAL BUILDING IN GENÈVE, SWITZERLAND: LESSONS LEARNT IN PVSITES BIPV INSTALLATION PROCESS

4.1 Short description the Demo installation process

Educational building

Location	Geneva (Switzerland)
Typology	Educational building
Buildings	Pavilion 1 & Pavilion 2
Floors	2

Characteristics
The *École Hôtelière de Genève* (EHG) is a complex of buildings including not only the school facilities but also a hotel for the students hosting.

Area available for BIPV
Two brick masonry facades of two different modern pavilions, available to integrate BIPV: east facade of the Pavilion 1 (31.6 m^2), which has two windows rows at the edges and a central curtain wall; and west facade of the Pavilion 2 (78.4 m^2), which has two centered vertical windows rows.
Orientation: -80° (E) / +100° (W).
Inclination: 90° / 90°.

Figure 4.1: A façade system integrated at an educational building (catering school) in Geneve, Switzerland (resp.: FLISOM)

Two BIPV systems based on CIGS PV aluminum façade elements manufactured by Flisom have been installed at EHG demo-site, an educational building located in Genève (Switzerland), with 8.0 kWp power covering 110.1 m2 total area in the east and west façades of different buildings.

The façade tiles were produced from March to June, 2019 (M39-M42). Installation started on October 21st (M46), and has finished in December 2019 (M48).

Permitting process for achieving the construction allowance was really long and difficult at this demo-site (it can be catalogued as a nightmare!), which delayed the execution on time of the parallel and subsequent tasks more than initially expected. The permission process was led by CADCAMation. Three attempts were needed, and a 5-year limited construction allowance was finally achieved. The construction allowance was finally got on January 2019 (M37).

All façade elements were delivered with a protection foil to not being scratched at further processing or mounting stages. Installation works basically consisted of:

- Installation of vertical rails on the brick walls. Screws were fixed between the bricks in order to not damage the facade.

- PV panels were mounted bottom up, being able to be assembled to the vertical rails, and stringed together upwards, thanks to the specific shape of their edges.
- The solar inverters were placed on the roof in order to minimize their visual impact.
- The modules protection foil was removed as last step.

The installation kick-off was also a challenge due to some additional issues, such the language barrier and not having a single point high level contact on EHG side. To smoothen the installation works and to create awareness a kick-off meeting was organized on 06/06/2019. The project was presented to the director of EHG and the timeline was agreed. Installation works were originally scheduled to start end of June 2019 (M42). They were stopped as the trees in front of one facade were grown too big to access the facade and EHG did not allow to cut them. As EHG was closed for the summer holiday, no access was possible to try to find a solution. After the holidays a solution was found how the trees can be bent back without damaging them. However, now the exam session started and EHG did not allow the construction works again, due to noise emission. Finally, the confirmed installation date was set in October 11 (M46), where all stakeholders agreed on.

Finally, everything was solved and today the finishing of the installation works and the system commissioning have finished.

4.2 Lessons learnt in Permitting and Commissioning

The construction allowance was achieved after a long and difficult process. Finally, a 5 years limited construction allowance was finally achieved. The intensive negotiation with the building's property allowed a final agreement regarding the demonstration nature and scope and the installation timings and conditions. It is a big plus to work with a partner in the same country, only 30 min away. Coordination, communicating is easy and fast. Getting construction permit without local support is very difficult and it was necessary to hire a consultant.

4.3 Lessons learnt in Design and Installation of BIPV system

Language barrier is significant, even within the country. Many participants do not speak English or German.

Handling, packing and protection of Elox Aluminum is tricky. It was necessary to develop a lot around it. The handling of the 5 m long super modules needed a solution. A customized carrier out of wood was constructed for this. The module joints solution needed to be found and could be solved. We did learn that it is favourable if the installer gets the modules directly from the factory and not an intermediate transport company is involved.

Some issues came to be more relevant than expected, causing some delays in the construction works: presence of trees impeding the access to the building facades, closing of the buildings area during summer holidays, avoiding of noises during the installation works, etc. Nevertheless, all of them was solved.

4.4 Pictures and schemes

The facade with the little trees in 2017	The facade with the little trees in 2019
	
Panels being packed after PV lamination for shipment to Ernst Schweizer AG	Installation works
	
East facade system	West facade system
	

Figure 4.2: Installation and commissioning of Demo-system 2, Educational Building in Switzerland

5 DEMO-SYSTEMS 3: CARPORTS IN ZURICH, SWITZERLAND: LESSONS LEARNT IN PVSITES BIPV INSTALLATION PROCESS

5.1 Short description of the Demo installation process

Parking carports

Location	Dübendorf (Switzerland)	**Characteristics** Carports located at EMPA and EKZ facilities, with 6 parking spots each, providing energy to charge cars or to contribute to the building power supply.
Typology	Parking carports	
Area	98 m^2 / 103 m^2	
Capacity	6 parking spots	

EKZ: regional electrical provider.

EMPA: Swiss Federal Laboratories for Materials Science.

Figure 5.1: EKZ & EMPA: 2 solar carports systems located in Zurich, Switzerland, (resp.: Flisom)

Two solar carports systems based on CIGS PV polyamide elements by Flisom were installed at the parking of two different locations: EKS, an electricity provider for the region, with 7.6 kWp power and 103.3 m2 total area; and EMPA, the Swiss Federal Laboratories for Materials Science, with 7.2 kWp power and 98.0 m2 total area.

EKZ carport: demo-system implementation was successfully carried out thanks to the collaboration of the demo-site property and a well-conceived design, which took as a reference the existing carport design, modifying it to procure compatibility with Flisom's solar modules. EKZ took care of foundation works and permission process. Foundations were set up in between Dec, 2017 (M24) and Jan, 2018 (M25), as planned. Construction works of the carport’s structure were developed and finished in Feb, 2018 (M26). PV panels were installed later, between April and June, 2019 (M40-M42).

Delays, between the installation of the structure and the modules, occurred because of the first permission requested for EKZ carport was denied by the municipality with the argument that it is too close to the road; so it was necessary to properly justify, by energy performance reasons, the suitability of the location proposed by the partner responsible. Permission was finally granted by the municipality.

EKZ's carport is combined with an electric vehicle charging station, just located below the carport. Commissioning was carried out as planned.

EMPA carport: installation works were performed similarly to EKZ, as the carport is nearly identical. First step was foundation and putting the tubes for cables. Then, it was carried out the metal construction and, finally, the installation of PV panels and cabling.

There was no problem at EMPA site to get the needed permission from the municipality, because the carport is located in a private zone far from public areas or private households. Thus, permission was given within 4 weeks with no delay.

PV power conditioning was solved by SolarEdge devices. In this case, the new product demonstrated its capability to adopt the energy management system existing in the demo-site's facilities. In this regard, the connection to the EMPA grid was challenging, as EMPA has a sophisticated energy management system and the carport needed to be integrated using also the EMPA's EnergyHub software wise. On the other hand, access to the carport via Internet is not possible due to EMPA safety restrictions; thus, the carport monitoring was done via mobile GSM solution. Thus, communication between the carport system and the SolarEdge server is directly stablished via mobile network. Commissioning was carried out as planned.

5.2 Lessons learnt in Permitting and Commissioning

Regarding to the permitting process carried out in the two chosen demo-sites, EKS and EMPA facilities:

EKZ carport: the first permit requested was denied by the municipality because the system is close to the road. After demonstrating that the place is preferable due to a better irradiation and further back on the parking there is shadowing, permission was finally got, in order to prioritize renewable energy generation ((from the municipality was proposed a position away from the street where yearly production is estimated around 6.7 MWh/year; the location suggested by Flisom, and finally accepted by the municipality, close to the and street and with less shadowing, provides a higher generation value around 7.3 MWh/year).

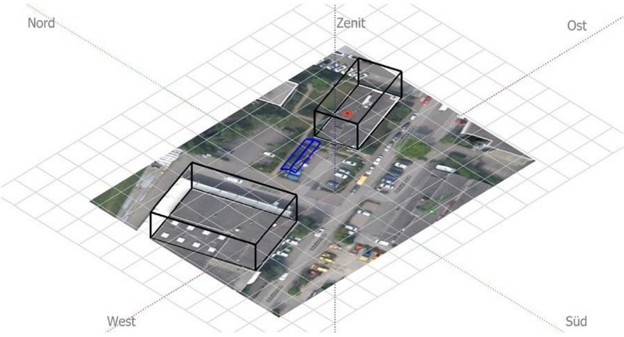
EMPA carport: as the carport is on the EMPA campus and not close to a public road or private households, there were no objections from the municipality. Thus, permission was given within 4 weeks with no delay.

Regarding the the commissioning process carried out in the two chosen demo-sites, EKS and EMPA facilities, 3 companies were involved for both carports: Eberhard did the ground construction and foundation works, put the tubes for cables and restored the parking after setting foundation, Zumstein AG delivered and mounted the metal construction, and Flisom delivered the modules. Zumstein AG mounted and connected the modules. Good communication and collaboration between the 3 companies was really important to carry out the installation as planned.

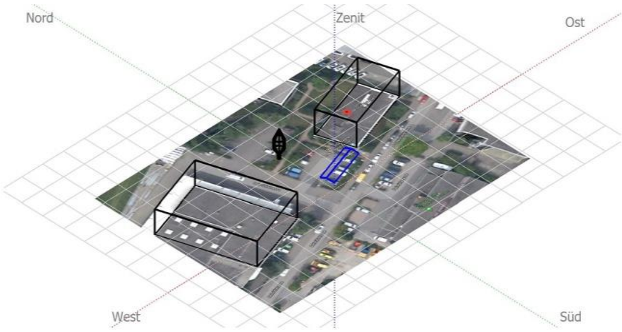
5.3 Lessons learnt in Design and Installation of BIPV system

EMPA solar carport has been integrated in the sophisticated Energy Management System (EMS) of the building (EMPA EnergyHub). EKZ solar carport has been directly connected to the EV charging station. Big plus to have construction and electrical installation from one company. The huge size of the panel (5 m) is difficult to handle. Always 2 people needed in production at every step.

Location proposed from the municipality, away from the street and with 6.7 MWh/year estimated generation.



Location preferred by Flisom, close to the street with less shadowing and 7.3 MWh/year estimated production.



Always 2 panels are always riveted together forming a nearly 200 W panel

The 5 m long panels are pulled from a wood support by 3 men and then fixes with rails

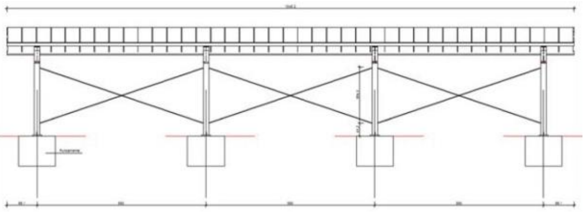
EKZ carport half covered with panels during the installation works

Final result of EKZ's carport

Figure 5.2: Installation and commissioning of Demo-system 3.1, EKZ's Carport in Switzerland

Carport foundations. The concrete foundation is needed to comply with Switzerland's regulation on snow load.

Scheme of carport construction including the foundation



PV panel mounting works carried out at EMPA's demo-site

Rubber rail fixing the PV panels but still allowing thermal expansion to happen

Final result of EMPA's carport

Aerial view of EMPA's carport

Figure 5.3: Installation and commissioning of Demo-system 3.2, EMPA's Carport in Switzerland

6 DEMO-SYSTEM 4 INDUSTRIAL BUILDING, SPAIN: LESSONS LEARNT IN PVSITES BIPV INSTALLATION PROCESS

6.1 Short description of Demo installation process

Industrial building

Location	Granollers (Spain)	**Characteristics** Industrial and office buildings dedicated to the manufacturing of glass. One of the industrial buildings has recently been constructed.
Typology	Industrial building	
Area	13635 m^2 (built area)	
Floors	2	

Area available for BIPV
The new industrial building (blue in the picture) is roofed by metal sheet. An effective BIPV implementation, in the south slope, would be possible. The available area is 530 m2 .
Orientation: +2° (S).
Inclination: 6°.

Figure 6.1: CRICURSA: industrial roof system integrated at a glass factory in Spain (resp. Cricursa).

A BIPV system based on CIGS PV metal substrate by Flisom was installed in the roof of CRICURSA factory, an industrial building located in Barcelona (Spain), with 20.2 kWp power and 276.9 m2 total area.

Demo-system installation started in June, 2019 (M42). First, the attachment of every PV panels to the roof was done. The efforts dedicated to the architectural integration design phase brought good results on site, making easy the installation works. After, the main general cabinet housing most BOS components and devices was installed outdoor, in the back yard of the pilot. Finally, the electrical connections between PV panels, inverters, and batteries were carried out. Simultaneously, monitoring sensors and meters were installed and configured with the participation of Nobatek. The demo-system was finished in July 2019 (M43).

6.2 Lessons learnt in Permitting and Commissioning

Permitting process was relatively easy. All the permissions were approved by the electrical company ENDESA during the summer of 2018. A “zero-injection” device is used under a self-consumption without energy surplus injection regimen, according to the possibilities offered by the new Spanish regulation (in place since end of 2018). At the end of 2018, permissions for minor works were granted by the municipality.

System commissioning was carried out in the second week of July, 2019 (M43), once the installation works were finished. Unfortunately, a general deterioration by oxidation was observed in the PV panels during the first months after their installation.

6.3 Lessons learnt in Design and Installation of BIPV system

Shipment of the panels turned out to be challenging. The first packaging failed, and modules fell of the pallet. The effort to make a packaging for a nonstandard product should not be underestimated, especially if it is not flat.

Logistical challenges with shipping for bend forming and then to the customer abroad. Tax declaration issues even with returning empty containers.

The mechanical installation was simplified, and we use simple but special attachment for fixing external roofs, rather than use special steel profiles that were not commercial and expensive of manufacture.

The zero-injection issue were found difficult to be accomplished. We had problems with circular toroid, and it had to be solved with a special flexible toroid much more expensive. In the other hand make these new devices work together with the CIRCUTOR CDP-0 is being not easy, although the manufacturers assure that they are compatible.

Some minor issues as working in summer in the Mediterranean region reduce working hours to 50%, and it causes delays, or the fact the interaction of the different inverters, SMA and VICTRON, is so delicate and must be check carefully.

Bending solar modules is possible without damaging the device.

1.5 m is an optimal size, as it can be handled by 1 person easily.

6.4 Pictures and schemes

Figure 6.2: Installation and commissioning of Demo-system 4, Industrial Building in Spain

7 DEMO-SYSTEM 5 APARTMENTS BUILDING, FRANCE: LESSONS LEARNT IN PVSITES BIPV INSTALLATION PROCESS

7.1 Short description of Demo installation process

Multi-storey apartments building

Location	Wattignies (France)	**Characteristics** Residential multi-storey block built in 1975, with 48 social dwellings of different typologies, currently in a retrofitting process.
Typology	Apartments building	
Area	3639 m² (built area)	
Floors	8	

Area available for BIPV

The building is in a retrofitting process aimed to improve the building energy performance.
The double wall south façade is entirely covered with brick cladding and a vertical string of windows.
An area of 140 m^2 is available for BIPV, from the first floor slab to the roof.

Orientation: -16° (SSE).
Inclination: 90°.

Figure 7.1: A façade panels system integrated at an apartment block in France (resp.: VILOGIA)

A BIPV ventilated façade system, based on c-Si PV modules with hidden bus bars by ONYX, was installed at VILOGIA's demo-site, an apartment building in Wattignies (France), with 17.0 kWp power and 132.5 m2 total area.

The demo-site was built on 70s and is on retrofitting process. The façade where the PV modules have been installed required a previous intervention, which started in January 2019 (M37), aimed to remove the existing bricks cladding and to improve its thermal and airtightness behavior. BIPV modules were attached to a metal structure fixed to the concrete wall. The final integration design was quite conditioned to aesthetical criteria, related to the architectural design of the building retrofit in process; the effort dedicated to this aspect has provided not only a good functional result, but also a great aesthetic appearance. To set up the batteries, inverters and the monitoring devices the construction of a new technical room was necessary.

The municipal permit was achieved July 2018 (M31), after a long and difficult permitting process due to the public housing character of the demo-building. In order to obtain the grid permit for connecting the PV system to the network, discussions with the owner of the network were anticipated in March 2018 (M27). Due to the fact that the technical room couldn't be placed in the basement, the choice of batteries and inverters was determined according to the dimensions of the technical room. Also, for being able to get data of consumption, the electricity meters from the common parts had to be changed. For these reasons, parallel and subsequent tasks suffered important delays for this demo-site. Today, the demo-system is successfully installed and legalized.

For the commissioning process, a lot of milestones were to be respected before the final agreement: complete definition of the system, agreement with the electricity provider for the selling of the surplus production, appointment of a “responsible of balance” to protect the network of the variations, official certification of the installation by an independent control office, etc. VILOGIA demo-system was finally commissioned in June 2019 (M42), after achieving the signature of an agreement with the electricity provider and the obtaining of a permission from the grid manager to execute the grid connection. The electricity production from the BIPV panels will be used to cover the electricity consumption for the common parts of the building (communal self-consumption). The excess of production will be sold to an electricity provider.

7.2 Lessons learnt in Permitting and Commissioning

Long and difficult municipal permitting process, due to the public housing character of the demo-building. The town permit for the construction works had been accorded since July 2018. Before beginning the installation, the support of panels, the batteries, inverters and the anti-islanding protection had to be approved by the supervising office in order to guarantee the whole installation

Several milestones were have to be respected for the system commissioning: complete definition of the system, agreement with the electricity provider for the selling of the surplus production, appointment of a “responsible of balance” to protect the network of the variations, official certification of the complete installation by an independent control office.

The technical room couldn’t be placed in the basement, and the common electricity meters were changed to enable the consumption data collection.

The electricity production from the BIPV panels will be used to cover the electricity consumption for the common parts of the building. The excess of production will be sold to an electricity provider. In order to obtain the grid permit for connecting the PV installation to the network, discussions with the owner of the network were anticipated in March 2018.

7.3 Lessons learnt in Design and Installation of BIPV system

Replacing the brick cladding was not complicated, but it was difficult to find a company with skills in such an innovative installation. Due to flooding issues in the basement, the technical room was installed in the hall of one of the building's entrances, meeting other standards.

The building integration was a real success: a great solidity against adverse weather conditions was checked. Authorization for using not commercial inverters and batteries was obtained, with the support of the partners and the French controlling office.

A collective self-consumption contract was formalised for the common parts of the building, a freshly new option in France. Installation of a storage system for PV production composed of 2 batteries was one of the innovations brought by Vilogia with this project.

Wide and deep new knowledge and competences were gained by VILOGIA about BIPV, useful to be applied in future similar projects. Collaboration with partners and EU team, which help to understand barriers and to solve them, was essential for the final success of project.

7.4 Pictures and schemes

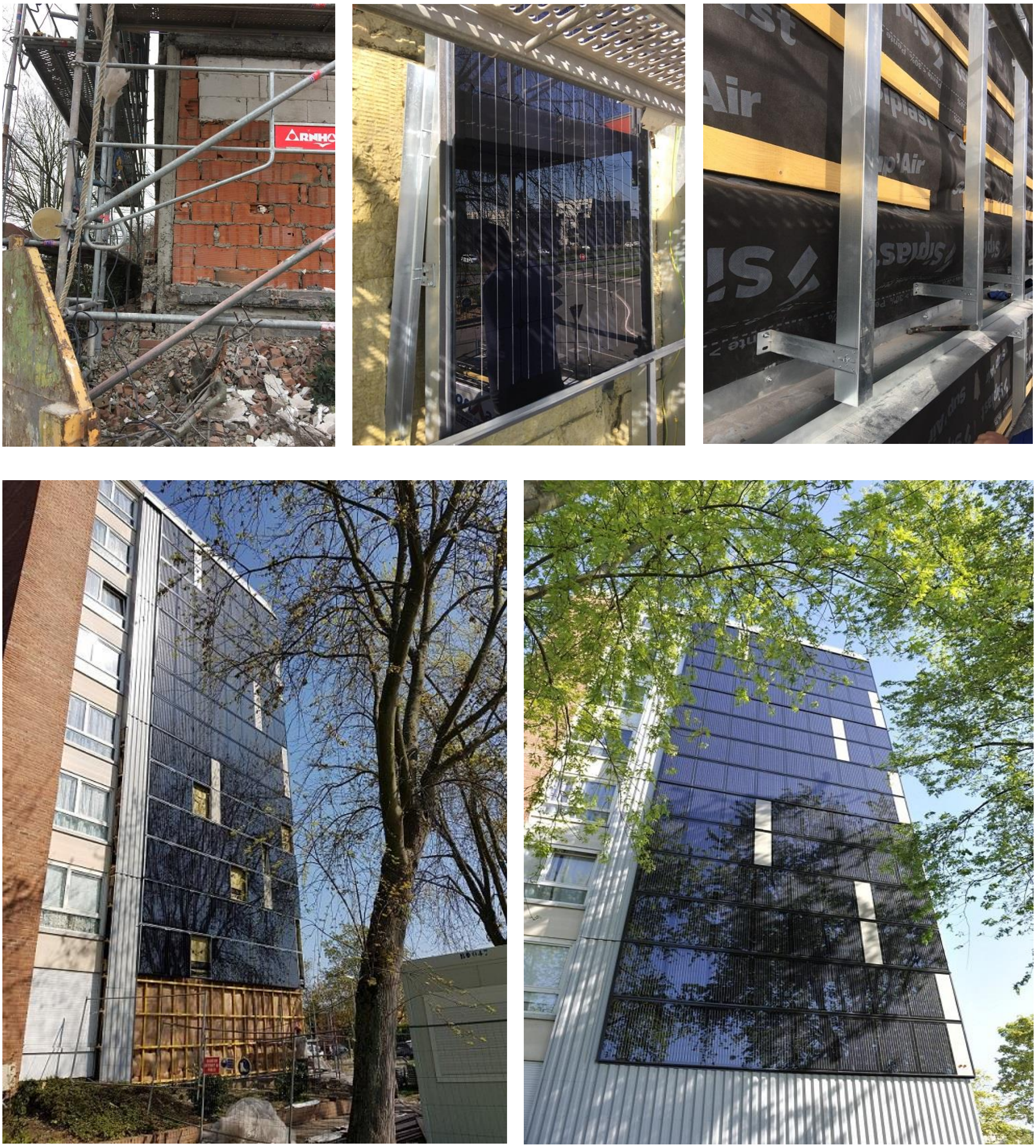


Figure 7.2: Installation and commissioning of Demo-system 5, Apartments Building in France

8 DEMO-SYSTEM 6 OFFICE BUILDING IN SAN SEBASTIÁN, SPAIN: LESSONS LEARNT IN PVSITES BIPV INSTALLATION PROCESS

8.1 Short description of Demo installation process

Office building

Location	San Sebastian (Spain)	**Characteristics** TECNALIA office building with laboratories. The most suitable zone for BIPV are the offices zone located in the 2nd and 3rd floors.
Typology	Office building	
Area	-	
Floors	4	

Area available for BIPV

Polygonal section façade with a glass cladding. The irregular geometry of the facades requires a special design effort to carry out the architectural integration, as well as a well conceived electrical connecting strategy.

Orientation:
(-1° to +4)° (S) & (-31° to -36° (SE)
Inclination: 90°.

Figure 8.1: A ventilated façade system integrated at an office building in Spain (resp.: Tecnalia)

A BIPV semi-transparent ventilated façade system, based on c-Si PV modules with hidden bus bars by ONYX, was installed at TECNALIA's demo-site, an office building in San Sebastian (Spain), with 18.4 kWp power and 162.0 m2 total area.

Installation works took place during March 2019 (M39). The singular geometry of the existing façade has required specials efforts during the architectural integration design phase and the installation works. First, measurements of the dimensions of the façade were taken by the installer to prevent deviations with respect to the drawings. Following, the metallic substructure was installed. Five full working days were required to correctly install the brackets and vertical profiles needed in each façade because of its geometrical complexity. After, the BIPV modules were installed and string connections executed. The inverters room was set up inside of the building, together with the electrical protections, meters, and zero-injection kit are installed. The connection from the inverters to the distribution panel allows the direct self-consumption of the generated energy. Final result of the installation works was highly satisfactory.

Two permits were needed to perform the installation in compliance with the municipal and country legal framework. The construction license, which required presentation of a project endorsed by the architecture school, was approved by the municipality 2 months after the submission of the documentation. The permitting process for the legalization of the PV installation licence was led by the PV installer and required the approval of the local electricity distributor. An adaptation of the original technical solution was required due to the new self-consumption Spanish regulation.

The systems commissioning was carried out in September 2019 (M45), according to this regulation, as 'PV installation without energy surplus' and a 'zero-injection' kit was installed to guarantee the functioning of the installation under this modality.

8.2 Lessons learnt in Permitting and Commissioning

The construction license, which required presentation of a project endorsed by the architecture school, was approved by the municipality 2 months after the submission of the documentation.

The permitting process for the legalization of the PV installation license required the approval of the local electricity distributor. An adaptation of the original technical solution was required due to the new self-consumption Spanish regulation.

The system works under the self-consumption modality: 'PV installation without energy surplus'. A 'zero-injection' kit was installed for this purpose

8.3 Lessons learnt in Design and Installation of BIPV system

The installation of the BIPV ventilated facade at TECNALIA's office building took place during March 2019. First, onsite measurements of the dimensions of the facade were taken by the installer to verify to what extent the drawings used during the design phase were consistent with the reality and, if needed, propose adjustments to correct possible deviations. After this preliminary verification, the metallic substructure was installed (HILTI, MFT-S2S). Five full working days were required to correctly install the brackets and vertical profiles needed in each facade, mainly due to the complexity introduced by the facet geometry of the facade.

Once the installation of the substructure was finished, the PV installer proceeded with the installation of the BIPV modules and string connection. The dimensions and weight of the glass-glass modules (2225 x 760 mm, 55 kg) made impossible the installation of the modules by a single person, and 2-3 people were needed to safely handle and install each module. The installation was performed starting from the bottom part of the facade.

Although, in theory, once the first row of modules was installed verifying the horizontality of the rest of rows should not be required, in reality a module per module verification was finally needed in each row since, in certain modules, one of the glasses was slightly off-centre (one of the glasses protruded a little bit).

The wiring is hidden and carefully organized behind the metal embellishment panels and then taken to the inverters room inside of the building, where the electrical protections, meters, and zero-injection kit are installed. The connection from the inverters to the distribution panel of the building is performed next, allowing the direct self-consumption of the generated energy.

Some of the lessons learnt during the design and installation of the BIPV system are:

- Importance of defining a specific engineering, which oversees the entire project from the beginning: project management.
- To define the roles of the agents involved (architect, engineering, installer, supplier, etc.) so that all functions are covered (project management, permitting, purchases, health and

safety coordination, installation, network connection, etc.) and to collaborate between them from the design phase.

- In the design phase is important to ensure that the architecture plans of the building match with the real execution and the tests (i.e concrete resistance test) should be done in the right place, in order to avoid surprises that can compromise the installation or increase considerably the price.
- It is advisable, as far as possible, only 1 supplier (for example the same provider for the structure + fixings, because in that case it can be ensure that the provided fixing is the best solution, and avoid difficulties during the installation).
- The big dimensions of the PV modules made their handling on the elevator difficult
- If possible, its recommended to manufacture 1 or 2 extra PV module units in case there is a break during handling or installing, in order not to delay the whole installation waiting for the delivery of the replacement units
- As a consequence, the structure provider HILTI is thinking to improve the design of their structures to make them more suitable to PV systems to ease the hiding of the wiring.

8.4 Pictures and schemes

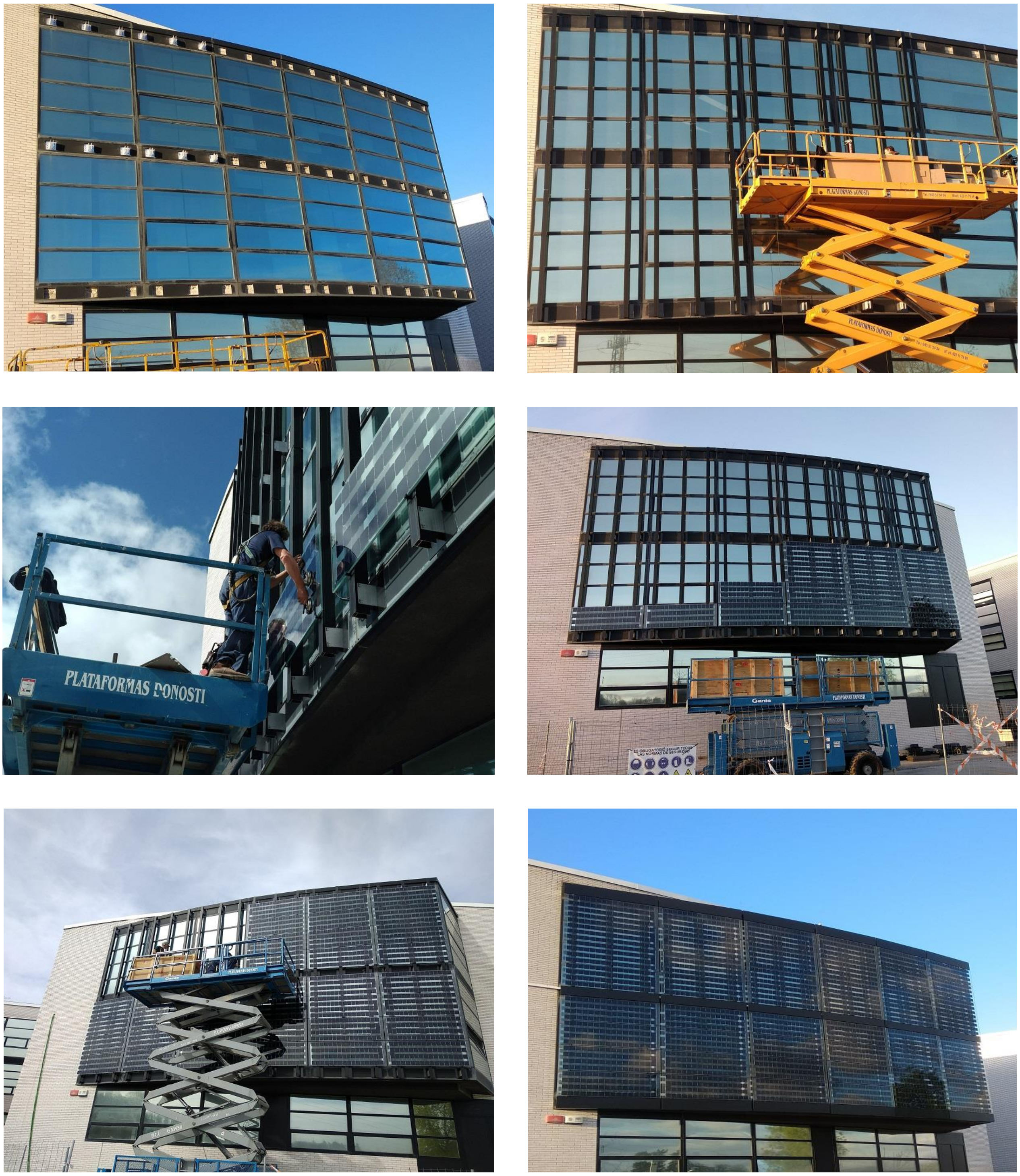


Figure 8.2: Installation and commissioning of Demo-system 6, Office Building in Spain

9 CONCLUSIONS

As a conclusion, and besides the good practices described in section 2, the most relevant learnings in general for all demos related to installation, permitting and commissioning actions, are summarize bellow:

Design and installation

- The BIPV design process must meet different specifications: owner requirements, location nZEB specifications, architectural and aesthetical characteristics of the building (as integration of the PV), local regulation, economic aspects, etc.
- Professional developers should hire a consultant or project management firm (for complex projects) or an architect (for smaller projects), to coordinate the whole process from the design to the installation and commissioning. In any case it is preferable a "Design & Build" team with a coordinator or project manager.
- Working together with a local PV installer from the beginning of the project make it easier the permitting, installation and commissioning process, even if sometimes there are communications difficulties due to the different language.
- Although it seems something obvious, it is really important to plan and execute the installation in the accurate season to avoid delays because of the weather or temperatures.
- Before installation previous meetings should be taken in order to plan the installation, analyze the design and check that the reality meets the design, doing the necessary tests, doing previous analysis of BIPV modules (most of them with special features in dimension, shapes, fastening,….), previewing the anchoring elements and auxiliary lifting means, pre-preparing the fastening parts for installation,…..Even though some difficulties can be encountered during installation, that will require general changes to solve them a solution that
- A BIPV system require millimetric works against the conventional PV solar plants that can a range of some centimeters

Permitting

The permitting process can be more or less difficult or long depending on the building functionality, building property, local regulation, etc. In case of non-commercial PV modules or inverters, they can make the process more complex.

It's recommendable to start the permitting process as soon as possible, even in parallel with the design process; and to work together with a local PV installer from the beginning of the project, which are aware of the smaller details of the local regulation.

Commissioning

The commissioning process should be done as soon as possible to have the ability to make updates or repairs if needed. Doing a pre-commissioned or partial commissioning of the PV system can shorten commissioning time.