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PVsites

Structure, contents and operation mechanisms of BIPV products portfolio –Third Version -

Project report

BEAR, TECNALIA, NOBATEK, FLISOM, ONYX, CEA, CADCAMATION

Summary

The present document constitutes the fourth deliverable on PVSITES BIPV products portfolio. All the products and families of products demonstrated in the project will form part of a BIPV products portfolio which will be available in different formats. A first implementation will consist in an online matrix whose elements will be each product and its related information. Secondly, each product will be turned into a BIM object (WP7) and will constitute an input data for the BIPV software tool to be developed in WP7. Third, the collection of products and product information will be the basis for dissemination materials (physical catalogues, flyers, etc.), to be developed in WP9. This deliverable gathers the necessary contents about the products, after the three previous deliverables (D2.6, D2.7, D2.8) in which the structure of the portfolio was established and the information available at M24 was gathered. This document is the last update of the products information. The actual implementation of the online tool has taken place as part of WP9 in M54.

Acknowledgements

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Disclaimer

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1 EXECUTIVE SUMMARY

1.1 Description of the deliverable content and purpose

The present document constitutes the fourth deliverable on PVSITES BIPV products portfolio. All the products and families of products demonstrated in the project will form part of a BIPV products portfolio which will be available in different formats. A first implementation will consist in an online matrix whose elements will be each product and its related information. Secondly, each product will be turned into a BIM object (WP7) and will constitute an input data for the BIPV software tool to be developed in WP7. Third, the collection of products and product information will be the basis for dissemination materials (physical catalogues, flyers, etc.), to be developed in WP9. This deliverable gathers the necessary contents about the products, after three previous deliverables (D2.6, D2.7, D2.8). This document is the last update of the products information.
This fourth document is an update of the relevant information about the BIPV products (modules and inverters) provided by the partners, based on templates set in D2.6 and information contained in D2.7 and D2.8. Although this deliverable was not scheduled in the initial plan, it was later added due to an extension of the project.

1.2 Relation with other activities in the project

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

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

Project activity	Relation with current deliverable
WP2	D2.6 established the relevant templates for the information gathering performed in this document. D2.7 included the products information up to M24. D2.7 is an update of D2.6. D2.8 included the products information up to M36. The current document is an update of D2.8.
WP3, WP4, WP5	The direct information about the products comes from the development and simulation phases in WP3 and WP4 (for c-Si and thin film products respectively) and WP5 (for inverters).
WP7	The information collected will also feed the creation of BIM objects within WP7.
WP9	Within WP9, the actual implementation of the portfolio tool will be performed.

1.3 Reference material

Grant Agreement PVSITES project, 691768
D2.1: Technical specifications for BIPV modules
D2.5: Specifications for energy conversion and management systems
D2.6: Structure, contents and operation mechanisms of BIPV products portfolio
D2.7: Structure, contents and operation mechanisms of BIPV products portfolio (update 1) – Structure and contents for products description
D2.8: Structure, contents and operation mechanisms of BIPV products portfolio (update 2) – Structure and contents for products description

1.4 Abbreviation list

Bc: Bare cell
BIPV: Building-integrated photovoltaics
CIGS: Copper Indium Gallium (di) Selenide
C-Si: Crystalline silicon
Cz: Cell zone
LCA: Life cycle assessment
PV: Photovoltaics
Tz: Transparent zone
WP: Work Package

2 INTRODUCTION

BIPV products portfolio online tool

All the products and families of products demonstrated in the project will form part of a BIPV products portfolio which will be available in different formats. A first implementation will consist in an online matrix whose elements will be available for each product and all its related information. Secondly, commercial products will be turned into a BIM object (WP7) and will constitute input data for the BIPV software tool to be developed in WP7. Third, the collection of products and product information is the basis for dissemination materials developed in WP9.

The portfolio contains all the information available on the product: PV technology, nominal power, possible architectural applications, customization, life cycle, price, etc. As for operation mechanisms, it will implement a search tool in order to select the optimum product at project design level; it will perform preliminary production estimates as a function of location, orientation, tilt, etc. to facilitate a first evaluation of economic viability (though more accurate, project specific predictions will be available through BIPV software tool, WP7). This tool will also contribute to the labour of the installation professionals by means of setting up maintenance and dismantling guidelines within the portfolio. Task 2.1, as well as the work packages (that focus on BIPV systems technology, lifecycle analysis and demonstration activities) feed from this portfolio and self-consistently provide feedback to it.

The online portfolio and the BIPV software tool developed in WP7 are highly complementary in the sense that the portfolio will provide general information, data sheets and some degree of optimization and customization by the user (project design architects), while the BIPV software will allow detailed calculations on the performance of both the BIPV systems and the building in specific integration works, together with detailed analysis of economic viability. Final users of the software are design architects, thermal engineers, installers, construction products manufacturers, etc.

Protocols will be defined in order to add, correct, delete and comment information in the portfolio to improve contents and search methods. The selection of structure, contents and operational protocols has been performed by BEAR, Onyx, Flisom, Nobatek, CADCAMation and TECNALIA. The specific gathering of information to be fed into the tool has been performed by TECNALIA. The specific implementation of the online portfolio has been made in WP9, as part of dissemination & communication activities.

3 PRODUCTS AND TEMPLATES

Structure

The technical templates for the BIPV modules (products X1 to X12) are structured in 11 groups of information:

- General description, design and materials of BIPV modules.
- Mechanical performance of BIPV modules.
- Architectural integration of BIPV modules.
- Electrical performance of BIPV modules.
- Thermal performance of BIPV modules.
- Optical performance of BIPV modules.
- Estimation of PV production of BIPV modules.
- Simulation of passive performance of BIPV modules.
- Maintenance and dismantling.
- Life cycle assessment.
- Economical evaluation of BIPV products.

For inverters (X13 and X14), 6 different templates have been generated:

- General description and design.
- Installation.
- Electrical performance.
- Monitoring and control.
- Maintenance and dismantling.
- Life cycle assessment.

Each template has been filled with the most relevant information about PVSITES BIPV modules and inverters. This information will be updated in the M25-M36 period and the operation mechanisms for the portfolio will be defined (D2.8).

Table 3.1 depicts the BIPV products within PVSITES project which are covered by this document. Note that during the development process X2 and X4 were combined. To avoid misunderstanding, the numbers already given to the products have not been changed.

Table 3.1: Overview of PVSITES products

Code	Product	Manufacturer	Demo site / Test bench	Implementation
X1a	eRoof - CIGS roofing shingle on metal substrate	Flisom	Demonstrated in a single-detached dwelling – Belgium (D1)	Roof
X1b	eCarport - CIGS roofing module on metal substrate	Flisom	Demonstrated on two carports – Zürich, Switzerland (D3)	Roof
X2	eFacade - CIGS large area flexible roofing membrane and bendable elements	Flisom	Demonstrated in a façade – Geneva, Switzerland (D2)	Façade
X4	eRoof - Industrial - CIGS large area flexible roofing membrane and bendable elements	Flisom	Demonstrated in an industrial roof in Barcelona, Spain (D4)	Roof (façade)
X5	C-Si glazed products with hidden bus bars and L interconnections	Onyx	Demonstrated in a residential building – Lille, France (D5)	Facade
X6	Glass-glass products with back contact c-Si cells	Onyx	Demonstrated in an office building – San Sebastian, Spain (D6)	Facade
X7	Curved glass-glass, CIGS technology	Onyx	CEA	
X8	Framing system for c-Si large area glass	Onyx	CEA	
X9	C-Si semitransparent low concentration and Solar control BIPV system – skylight configuration	Onyx, Tecnalia, Film Optics	CEA TECNALIA	Roof, On ground
X11	C-Si semitransparent low concentration and Solar control BIPV system – shading element configuration	Onyx, Tecnalia, Film Optics	- ACCIONA	Facade
X12	Glazed modules treated for improved passive properties	Onyx	-	
X13	Inverter with storage system and DC coupling	Tecnalia	Demonstrated in FD2 and Vilogia.	
X14	SiC based inverter	CEA	Demonstrated in Tecnalia and Cricursa.	

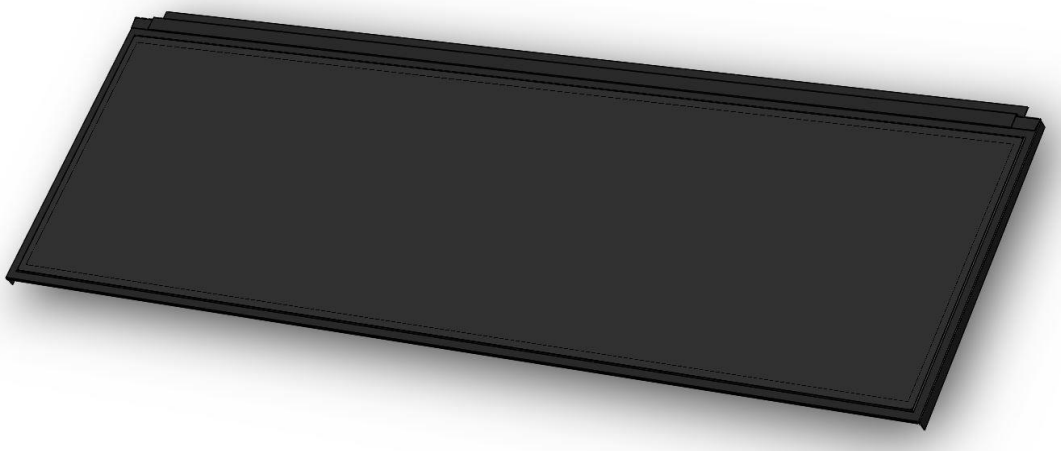
Products X3 and X10 are discarded or combined with other products.

4 X1a - CIGS ROOFING SHINGLE ON METAL SUBSTRATE (eRoof)

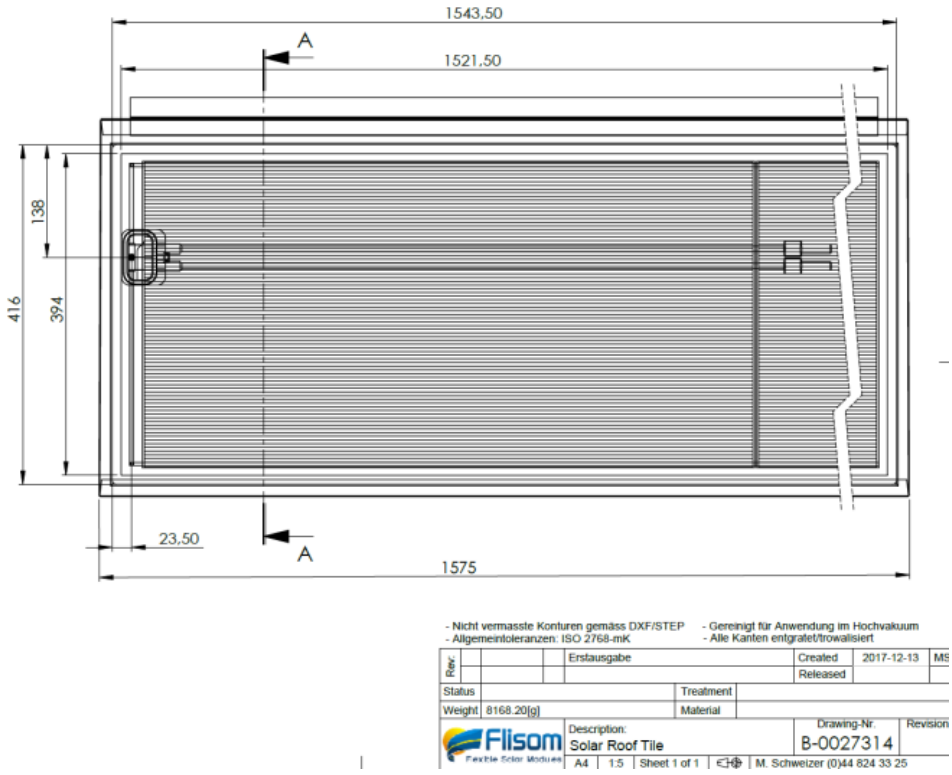
4.1 General Description, Design and Materials – X1a

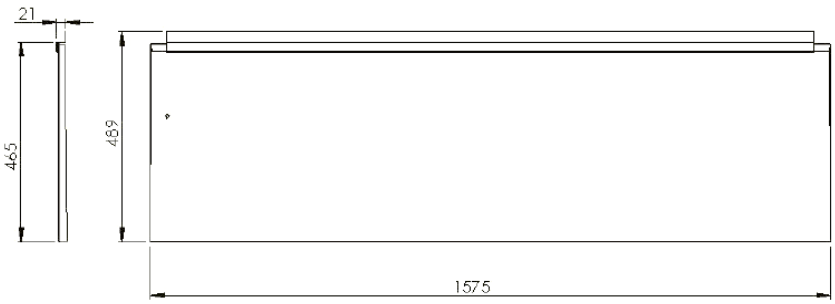
TECHNICAL TEMPLATE REFERENCE	
Technical subject	General description, design and materials of BIPV modules.
Partner	Flisom / Tecnalia
Author	Julian Perrenoud / Daniel Valencia

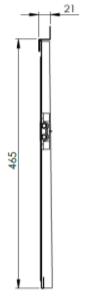
PRODUCT CODE	
Project	PVSITES. Task 2.6. BIPV products portfolio
Category	Roofing shingle
Denomination	X1a-eRoof-Shingle
Partner/s	Flisom

PICTURES
EXPLODED DRAWING / ARTIST IMPRESSION

Observations: Semi-flexible and lightweight solar panel designed for BIPV roof tile installations

DESIGN DRAWINGS







SCHNITT A-A

DETAILED DESCRIPTION	
Definition	The roofing shingle module is a semi-flexible and lightweight solar panel designed for BIPV roof tile installations
Construction unit	Roofing shingle
Architectural location	Roof
Geometrical design	Rectangular
Dimensions	1575 x 489 x 21 mm
Geometrical shape	Rectangular

Materials	Descriptive value
Configuration	Monolithic unit
Layers	Layers from backsheet to frontsheet in order of application: Mild steel backsheet with PVDF coating, black RAL 9005 / Encapsulant TPO 0.4 mm /PV film CIGS grown on polyimide with Mo and ZnO electrical contacts / Encapsulant TPO 0.4 mm / Barrier film 0.4 mm. the module is sealed with edge seal ~1cm width
Frame structure	Frameless
PV technology	CIGS (Thin film)
Encapsulant	TPO
Surface treatments	Surface textured
Thermal insulation	none
Acoustic insulation	none
Physical features	Semi-flexible and lightweight solar panel
Weight	6 Kg / unit
Rigidity	Semi-flexible
Opacity	Opaque
Mobility	n.a.
Active energy features	Electricity production
Photovoltaic power	50-60 Wp/unit
Additional gain	n.a.
Passive energy features	n.a.
Optical transmittance	Opaque
Thermal transmittance (U value)	Thermal features
Observations: Explanations/ Reference conditions/ Data source/ Copyrights/ Other	

4.2 Mechanical Performance – X1a

TECHNICAL TEMPLATE REFERENCE	
Technical subject	Mechanical performance of BIPV modules
Partner	Flisom / Tecnalia
Author	Julian Perrenoud / Daniel Valencia

PRODUCT CODE	
Denomination	X1 - eRoof-Tile

DESIGN/DATASHEET VALUES						
BIPV UNIT						
General characteristics	The roofing shingle module is a semi-flexible and lightweight solar panel designed for BIPV roof tile installations					
Manufacturer	Flisom					
Model	Roofing shingle – Format D2					
Shape	Rectangular					
Physical characteristics	Value 1	Unit 1	Value 2	Unit 2	Value 3	Unit 3
Height/ Length/ Thickness	1575	mm	489	mm	22	mm
Weight	6	kg			-	-

4.3 Architectural Integration– X1a

TECHNICAL TEMPLATE REFERENCE	
Technical subject	Architectural integration of BIPV products
Partner	BEAR / Flisom
Author	Tjerk Reijenga / Julian Perrenoud

PRODUCT CODE	
Denomination	X1 - eRoof-Tile

DEFINITION AND LOCATION	
Definition	The roofing shingle module is a semi-flexible and lightweight solar panel designed for BIPV roof tile installations
Construction unit	Roofing shingle
Location	Grandglise (Belgium)

Architectural location	Roof

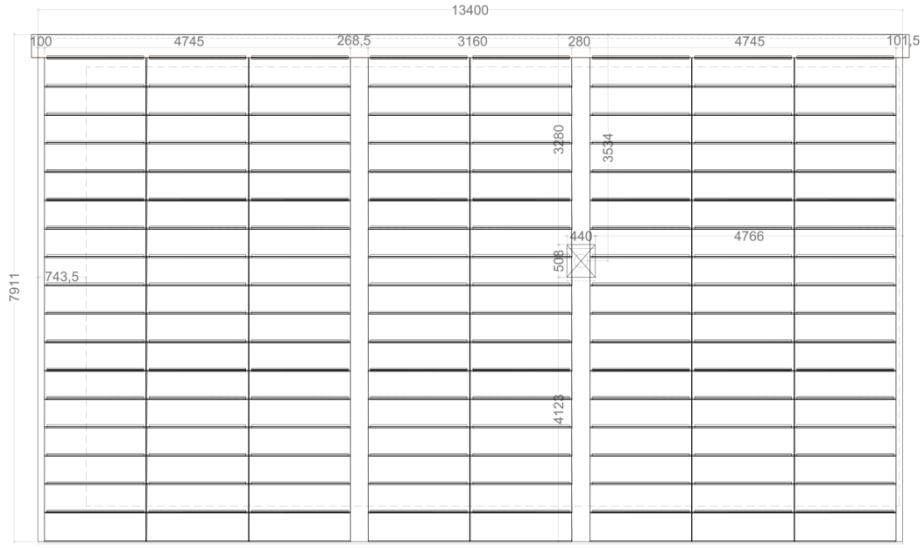
CONSTRUCTION UNIT FEATURES						
Physical properties	Length	Unit 1	Width	Unit 2	Height	Unit 3
Shape	Rectangular					
Dimensions	1575	mm	489	mm	21	mm
Weight	6	kg				
Materials and devices	Bended steel sheet with glued cells on top					
Configuration	Steel sheet					
Frame structure	Frameless					
PV technology	CIGS (Thin film)					
Thermal bridge	No					
Aesthetical features	Descriptive value					
Opacity	Opaque					
Cells colour	Very dark blue / black					
Background colour	Black RAL 9005					

INTEGRATION AND MAINTENANCE MEASURES	
Construction	n.a.
Mounting system	The roof structure is made of wood. The modules will be screwed on horizontal bats. Each module has a 25 mm overlap with the next module. Modules are connected in vertical direction with a click-connection. Mounting start with the lowest module and then goes up to the ridge.
Secondary construction	n.a.
Procedure	
New construction permits needed	Part of building permit. Based on local regulation.
Retrofitting permits needed	Building permit needed
Maintenance	Cleaning depending on location.
Inspection	Physical inspection
Sequence of inspection	Yearly

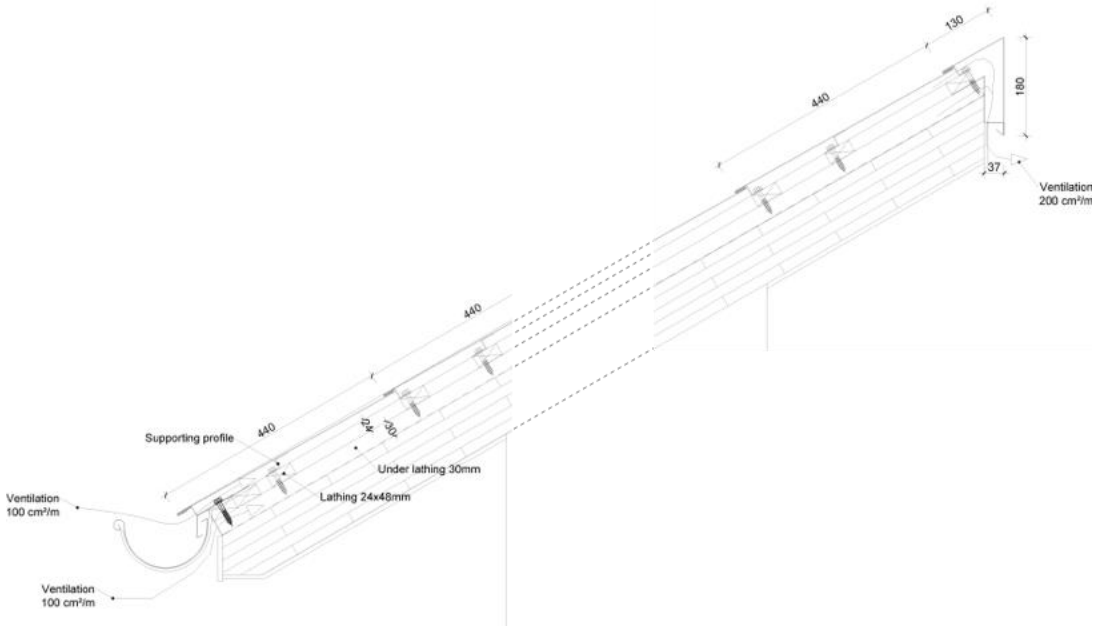
PICTURES

The passive house with a tile covered roof.

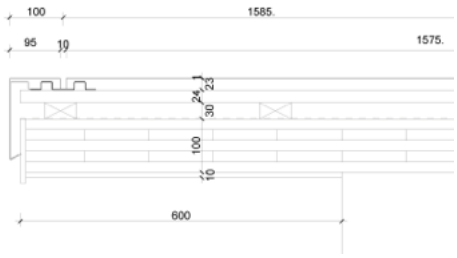
The house after the roof renovation with BIPV shingles.



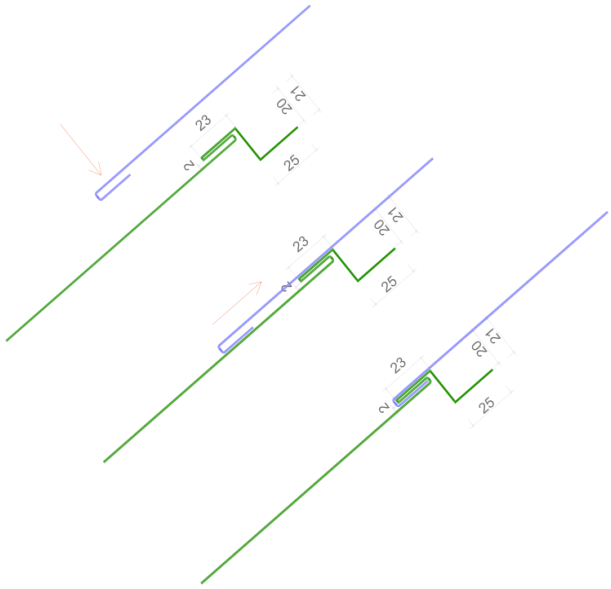
Roof layout



Vertical section of the roof with BIPV shingles.



Horizontal section of the roof overhang.



Installation steps:
1. All old tiles have to be removed.
2. Place the roof battens according to the drawing of the tile manufacturer.
3. Install the tiles and connect the cables according to the string plan.

Integration / details

Observations:
Flisom modules can be operated in the range of -40°C to 85°C. Depending on the area it is necessary to protect the modules from standing water, snow or extreme soiling. At consistent solar radiation Flisom PV modules generate more power at lower temperatures. To improve the energy yield of the plant increasing cooling or ventilation is an option.
Flisom PVSITES modules use thin metal sheets as backsheet. Hence, they can bend by applying forces while installation (e.g. dropping on the corner). Please handle with care. Store modules in a dry place. Do not transport modules without packaging. Do not put modules on top of each other to avoid small scratches (this can accelerate module degradation by environmental factors). Do not use JB cables as handles to carry or lift the modules. Be cautious when frontsheet is wet since the surface could lose grip. Do not apply solvents, adhesives, paint or stickers on the frontsheet. Do not place the modules face-down in direct contact to abrasive surfaces
Keep a minimum distance of 5mm between the edges of single modules to take thermal expansion into account. Only use compatible materials.

4.4 Electrical Performance – X1a

TECHNICAL TEMPLATE REFERENCE	
Technical subject	Electrical performance of BIPV modules
Partner	Flisom / Tecnalia
Author	Melani Schweizer / Daniel Valencia

PRODUCT CODE	
Denomination	X1 - eRoof-Tile

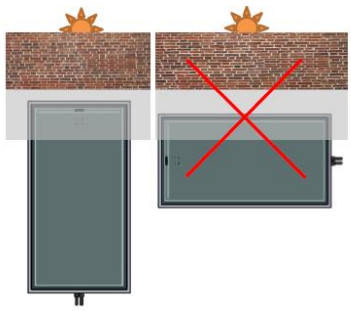
DESIGN/DATASHEET VALUES						
PHOTOVOLTAIC CELL/ ARRAY						
General characteristics	The roofing shingle module is a semi-flexible and lightweight solar panel designed for BIPV roof tile installations					
Manufacturer	Flisom					
Cell type	Flexible CIGS					
Shape	Rectangular					
Colour	Dark blue/ Black					
Frame	None					
Connection Box	Back side					
Connectors	MC4					
Physical characteristics	Value 1	Unit 1	Value 2	Unit 2	Value 3	Unit 3
Height/ Length/ Thickness	1575	mm	489	mm	21	mm
Electrical characteristics	Value 1	Unit 1	Value 2	Unit 2	Value 3	Unit 3
Ppm	50-60	W				
Vpm: max. power voltage	34-36	V		-		-
Ipm: max. power current	1.47-1.66	A		-		-
Voc: open circuit voltage	46-48	V		-		-
Isc: short circuit current	1.72-1.91	A		-		-
Thermal parameters	Value 1	Unit 1	Value 2	Unit 2	Value 3	Unit 3
Isc (α) Temp. coefficient	0.01	%/ºC				-
Voc (β) Temp. coefficient	-0.3	%/ºC				-
P (γ) Temp. coefficient	-0.35	%/ºC				-
Operating range						
Temperature	-40 – 85	ºC				
Maximum System Voltage	1000	V				

Maximum Wind /Snow Load	2400	Pa				

Observations:
For elevated areas irradiation can be higher than at STC. Therefore, multiply ISC- and VOC- values with a factor of 1.25 for the electrical layout of cables, fuses and converters (worst case scenario). For a serial connection the voltage of a single module is multiplied by the number of modules to calculate the system voltage. Make sure that you are always within the limits of the maximum system voltage. Use an adequate device for overcurrent protection (fuse, blocking diode). Maximum Isc multiplied by a factor of 1.56 to protect a string in parallel configuration.
The maximum number of modules connectable in series is calculated by adding Voc of each single module multiplied by 1.25 up to the maximum system voltage which you can find on the label.

Backsheet of Flisom PVSITES modules are made of metal and have to be connected to the ground. Also ground the support structure and arrange an adequate lightning protection. Do not use materials which can cause corrosion. The hole for the grounding cable can be drilled anywhere in the edges of the module frame as in fig. 1. If the backsheet of the module and the support structure/clamps are conductive it is not necessary to ground every module. The grounding of the support structure is sufficient. Make sure that you do not damage the edge seal or frontsheet.
Do not use PV modules of different power classes or configurations in the same PV system. Flisom tile modules use MC4 connectors. Only use these connectors or compatible connector types which are authorised from both producers.
Use solar cables for outside use (ø 2.5 to 4mm² and min. 90 °C).
Secure all electrical connections and use stress relief appliances. Do not go below the minimum bending radius of the cables. Use cable guides to prevent connectors and cables from lying in excess water, snow or dirt.

The junction box is not to be opened. The diode cannot be repaired.
In general, the modules can be mounted either in portrait or in landscape mode, depending on different limiting factors
Orientation of the shadow on the active surface is crucial: the panel may only be installed in parallel. To compare, shading the complete length of several full cells. This type of casting shadow will negatively affect the power.



Suitable inverter configurations are central inverters, string inverters, multi-string inverters, inverters on single module level.

POWER MANAGEMENT SYSTEM (demos)						
General characteristics	The roofing shingle module is a semi-flexible and lightweight solar panel designed for BIPV roof tile installations					
Manufacturer	Flisom					
Model	eRoof-shingle for single family house					
Physical characteristics	Value 1	Unit 1	Value 2	Unit 2	Value 3	Unit 3

Length/ Width/ Thickness	5782	mm	458	mm	2	mm
Electrical characteristics	Value 1	Unit 1	Value 2	Unit 2	Value 3	Unit 3
Total DC Peak Power	8.16	kWp		-		-
Module DC Peak Power	56.7	Wp				-
Total PV area	105.5	m2				
Inverter characteristics	Value 1	Unit 1	Value 2	Unit 2	Value 3	Unit 3
Overall efficiency (50530) (PV to Grid)	95.7%	%				
PV voltage Range	200-1000	V				
PV MPPT voltage Range	200-800	V				
Max PV Input Power	10	kW				
Max AC Output Power	10	kW				
Number of Phases	3					

4.5 Optical Performance – X1a

TECHNICAL TEMPLATE REFERENCE	
Technical subject	Optical performance of BIPV modules
Partner	Tecnalia
Author	Maider Machado/ Daniel Valencia

PRODUCT CODE	
Denomination	X1 - eRoof-Tile

DESIGN/DATASHEET VALUES						
BIPV UNIT						
General characteristics	The roofing shingle module is a semi-flexible and lightweight solar panel designed for BIPV roof tile installations					
Manufacturer	Flisom					
Model	eRoof module					
Shape	Rectangular					
Physical characteristics	Value 1	Unit 1	Value 2	Unit 2	Value 3	Unit 3
Height/ Length/ Thickness	1575	mm	489	mm	21	mm

Weight	…	kg	5.9	kg/m^2	-	-
PV ratio (PVR)	~100	%	-	-	-	-
Optical characteristics	Value 1	Unit 1	Value 2	Unit 2	Value 3	Unit 3
Visible transmittance	0	%	-	-	-	-
Solar transmittance	0	%	-	-	-	-
Visible reflectance (tz)	-	%	-	-	-	-
Solar reflectance (tz)	-	%	-	-	-	-
Visible reflectance (cz)	5.0	%	-	-	-	-
Solar reflectance (cz)	8.9	%	-	-	-	-
Visible absorptance (tz)	-	%	-	-	-	-
Solar absorptance (tz)	-	%	-	-	-	-
Visible absorptance (cz)	95	%	-	-	-	-
Solar absorptance (cz)	91.1	%	-	-	-	-

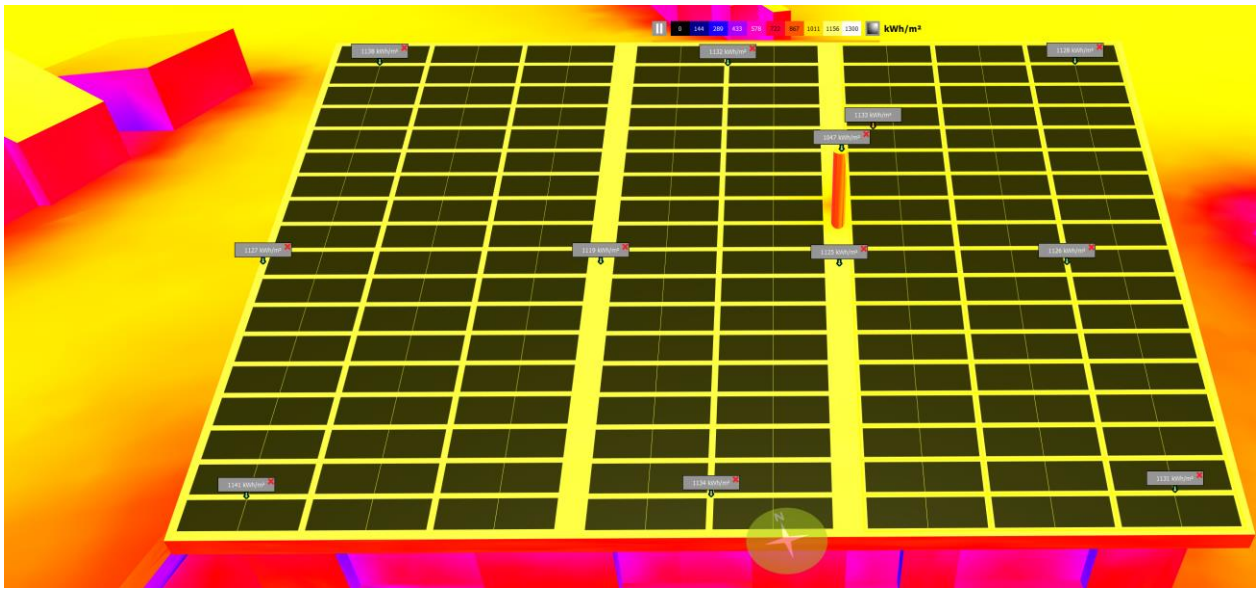
Observations:
Absorptance is calculated from transmittance and reflectance values. Acronym (tz): transparent zone. Acronym (cz): cell zone.

4.6 Estimation of PV production – X1a

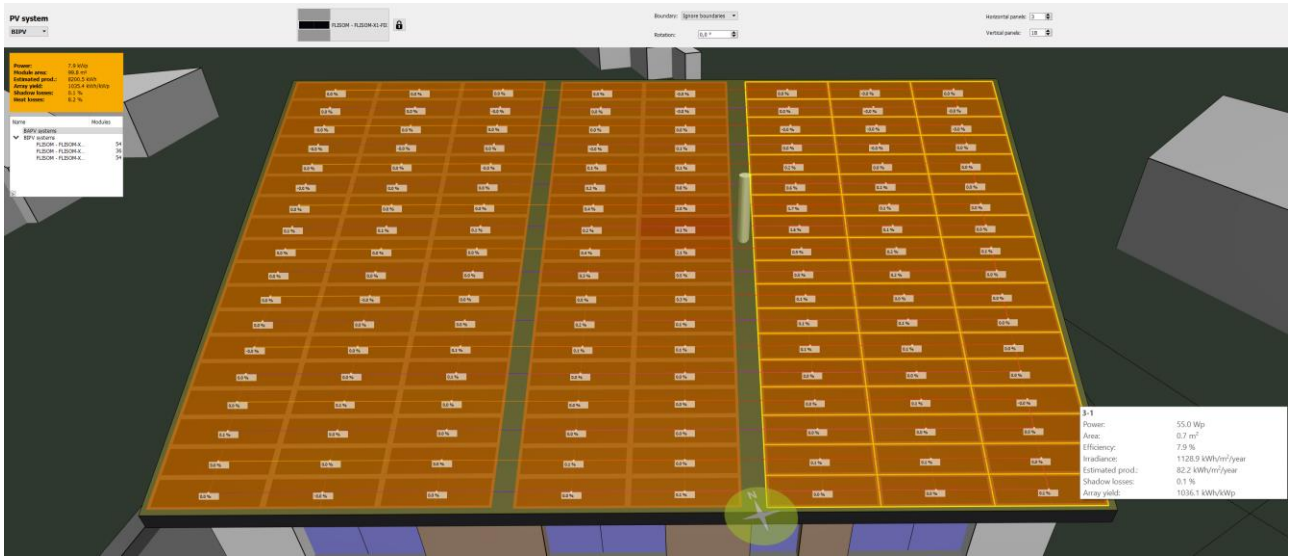
TECHNICAL TEMPLATE REFERENCE	
Technical subject	PV production of BIPV modules
Partner	CADCAMation
Author	Philippe ALAMY

PRODUCT CODE	
Denomination	X1 - eRoof-Tile

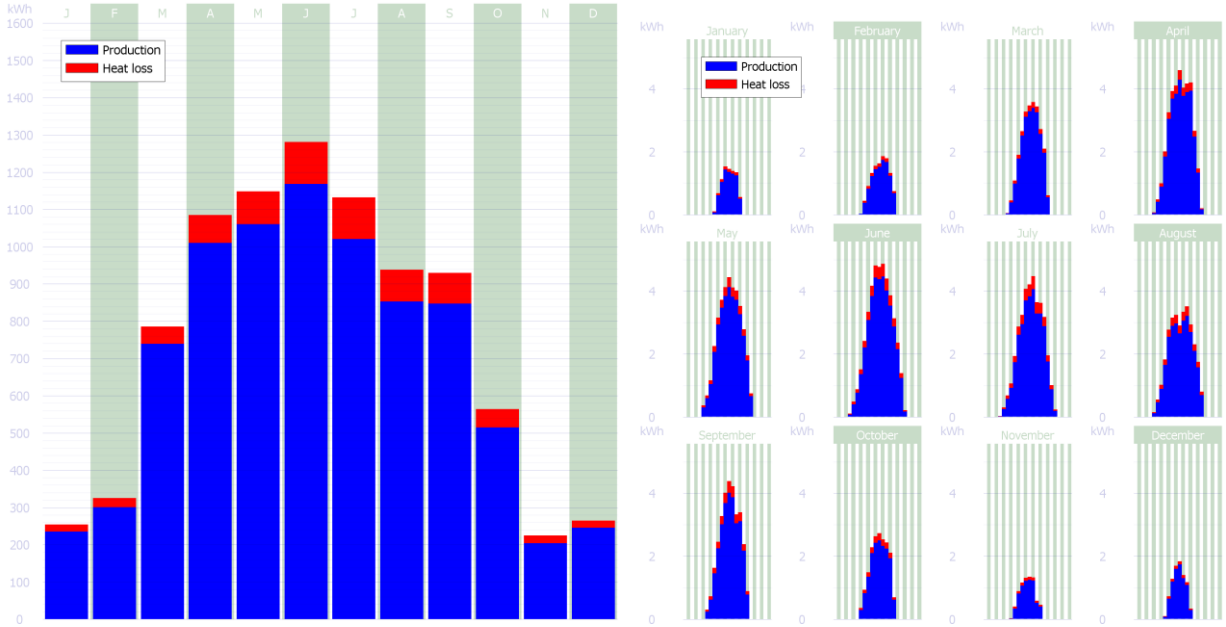
SIMULATING CONDITIONS: exact location / GRANGLISE (TMY to epw file built from PVGIS)						
ANNUAL GLOBAL IRRADIANCE	Orient E	Orient SE	Orient S	Orient SW	Orient W	Unit
Grandglise (Belgium)	…	…	1125	…	…	kW/m^2
OUTSIDE AIR TEMPERATURE	Med	Min	Max	-	-	Unit
Grandglise (Belgium)	10.59	3.40	18.38	-	-	ºC
MEDIUM WIND SPEED	Med	Min	Max	-	-	Unit
Grandglise (Belgium)	…	…	…	-	-	m/s



ESTIMATION OF ELECTRICAL POWER PRODUCTION (from ARRAY to INVERTER)						
BIPV UNIT	Orient E	Orient SE	Orient S	Orient SW	Orient W	Unit
Grandglise (Belgium)	…	…	8,200	…	…	kWh
ARCHITECTURAL UNIT	Orient E	Orient SE	Orient S	Orient SW	Orient W	Unit
Grandglise (Belgium)	…	…	8,200	-	-	kWh
PRODUCTION PER M^2	Orient E	Orient SE	Orient S	Orient SW	Orient W	Unit
Grandglise (Belgium)	…	…	82.16	-	-	kWh/m^2
PRODUCTION PER kWp	Orient E	Orient SE	Orient S	Orient SW	Orient W	Unit
Grandglise (Belgium)	…	…	1035.4	-	-	kWh/kWp
DC PRODUCTION (INVERTER)	Orient E	Orient SE	Orient S	Orient SW	Orient W	Unit
Grandglise (Belgium)			8005			kWh
AC PRODUCTION (MAX)	Orient E	Orient SE	Orient S	Orient SW	Orient W	Unit
Grandglise (Belgium)			7605			kWh



PV Production + shadow losses + Yield – Hourly step / Module level



Monthly + Average day per month PV Production + thermal losses

4.7 Simulation of Passive Performance – X1a

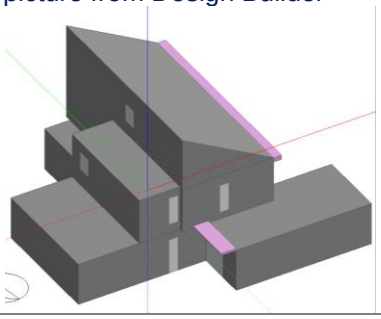
TECHNICAL TEMPLATE REFERENCE	
Technical subject	Passive performance of BIPV modules
Partner	Nobatek
Author	Baptiste Durand-Estebe

PRODUCT CODE	
Denomination	X1 - eRoof-Tile

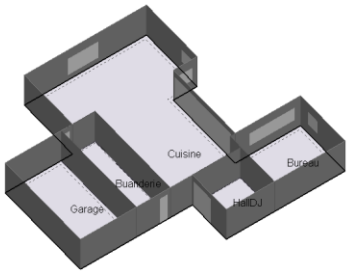
PILOT BUILDING	
Definition	The FORMAT D2 house is a residential building located in Belgium (Stambruges). It is 3 storeys high and the last storey located under the slop roof facing south only contains the archive and the attic. BIPV panels are integrated as tiles on the tilted roof.
Use	The building holds both a residential and an office space. The occupation pattern is the typical of a residential building, with an extra consumption associated to the office during the working hours and periods.
Area	Building: 219m² BIPV modules: 80m²
Orientation of PV modules	South

DESIGN PLANS

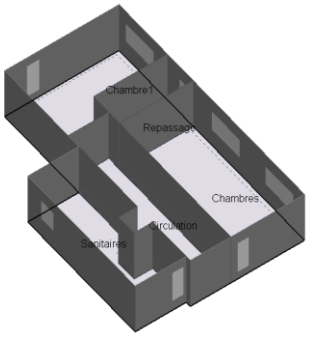
Graphic picture from Design Builder



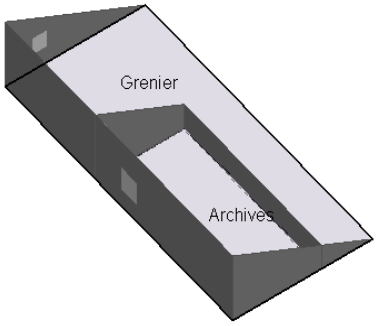
Ground floor plan



First floor plan



Roof floor plan

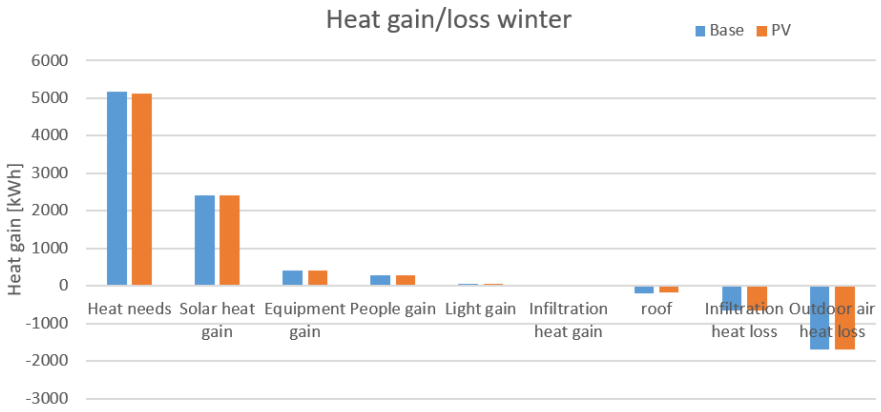


Observations.
The PV tiles are separated from the insulation by a vented cavity.

DEMAND AND PRODUCTION OF PILOT BUILDING WITH BIPV SYSTEM			
Location	Brussels		
	Baseline	**With BIPV**	**Unit**
Heating annual demand	5159	5129	kWh
Cooling annual demand	Passive comfort	Passive comfort	
Total annual H/C demand	5159	5129	kWh
Lighting needs	The BIPV system has no influence on lighting		

Overall increase/reduction	-0.4%	

Impact of the BIPV system on the demo site



FD2 internal heat gains

4.8 Maintenance and Dismantling – X1a

TECHNICAL TEMPLATE REFERENCE	
Technical subject	Maintenance and dismantling of products and installations
Partner	Flisom
Author	Julian Perrenoud

PRODUCT CODE	
Denomination	X1 - eRoof-Tile

MAINTENANCE		
BY THE USER	Periodicity (months)	Description
Action 1	3	Visual check
Action 2	When required	Remove dust and dirt (sediments, leaves, pollen, bird droppings, etc.) from the surface
Action 3	3	Check if connectors and grounding are tight and without corrosion and if the insulation is not damaged also check for loose mechanical or electrical contacts.
Action 4	3	Check if the Junction Box is securely attached and that no deep scratches are penetrating the frontsheet
Observations.		

DISMANTLING
Description of dismantling Do not use aggressive cleaning agents or scrubbing materials for cleaning Do not use steam blasting for cleaning Use soft water to avoid chalk stains Soft sponges can be used

4.9 Life Cycle Assesment – X1a

TECHNICAL TEMPLATE REFERENCE	
Technical subject	Life cycle assessment of products and installations
Partner	CTCV
Author	Marisa Almeida

PRODUCT CODE	
Denomination	X1 - eRoof-Tile

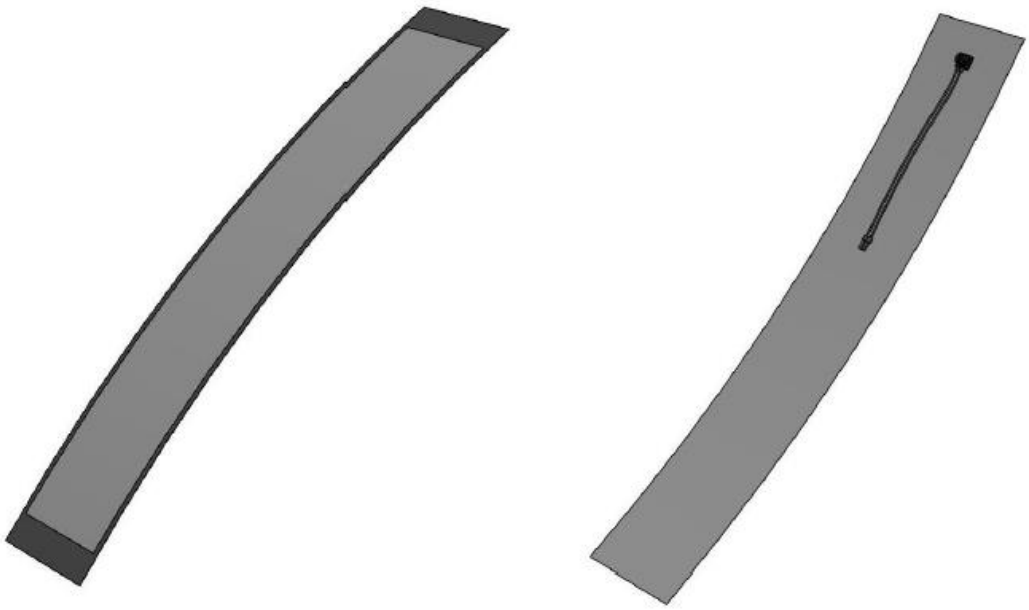
LCA INDICATORS						
	Value 1	Unit 1				
Global warming	48	Kg CO2 eq/m^2				
Acidification	0,318	mol H+ eq/m^2				
Terrestrial Eutrophication	0,0404	mol N eq /m^2				
Freshwater Eutrophication	0,0205	Kg P eq/m^2				
Photochemical oxidation formation	755	kg NMCOV eq /m^2				
Abiotic depletion	1,01E-05	g Sb/m^2				
Ozone layer depletion	1,06E-05	kg CFC-11 eq/m^2				
Human Toxicity	48	CTUh /m^2				
Observations: Provisional data based on specific ACV for this GIGs. LCA methodology: ISO14040/ISO14044 with CML and ILCD methods. Most of the results are better than the average for GIGs with similar properties.						

5 X1b - CIGS ROOFING MODULE ON METAL SUBSTRATE (eCarport)

5.1 General Description, Design and Materials – X1b

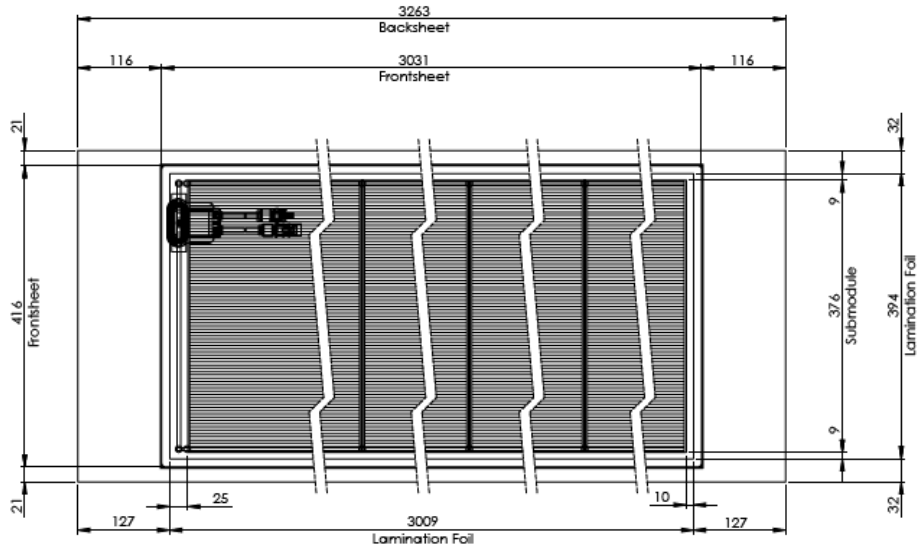
TECHNICAL TEMPLATE REFERENCE	
Technical subject	General description, design and materials of BIPV modules.
Partner	Flisom / Tecnalia
Author	Julian Perrenoud / Daniel Valencia

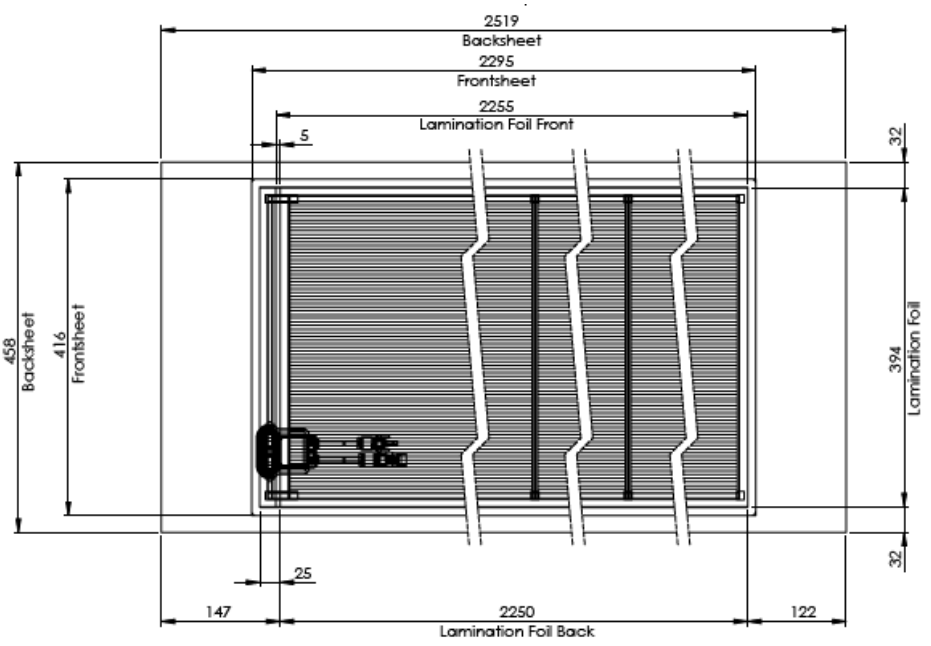
PRODUCT CODE	
Project	PVSITES. Task 2.6. BIPV products portfolio
Category	Ventilated façade/ Curtain wall/ Skylight/ Roofing shingle/ Shading system
Denomination	X1 – eCarport
Partner/s	Flisom

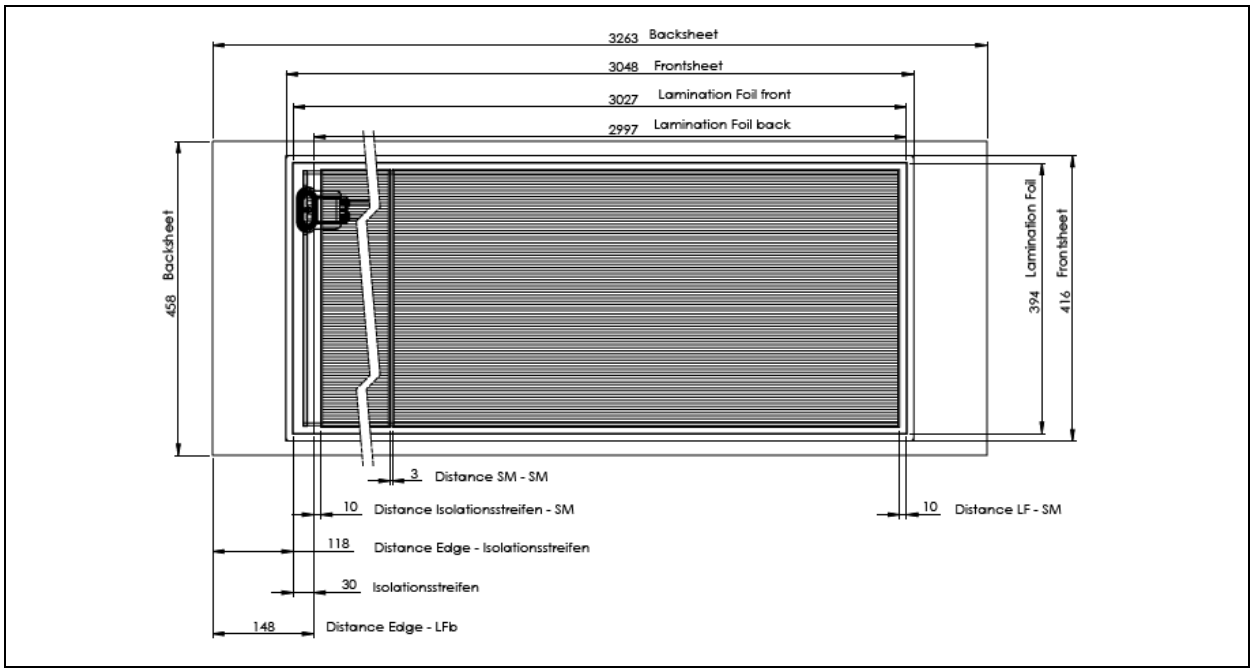
PICTURES
REALISTIC DRAWING / ARTIST IMPRESSION

Observations: Carport module is a semi-flexible and lightweight solar panel designed for a carport installation

DESIGN PLANS

From top to botton: Total length: 3263 mm / 2519 mm / 3263 mm. Total width: 458 mm
Active PV length: 3009 mm / 2250 mm / 2997 mm. ActivePV width: 376 mm







DETAILED DESCRIPTION	
Definition	The carport module is a semi-flexible and lightweight solar panel designed for a carport installation
Construction unit	Carport roof element / Roof element / Shading system / Other
Architectural location	Roof/ Other
Geometrical design	Rectangular
Dimensions	2519-3263 x 458 x 21 mm
Geometrical shape	Rectangular
Materials	Descriptive value
Configuration	Monolithic unit
Layers	Layers from backsheet to frontsheet in order of application: Mild steel backsheet with PVDF coating, black RAL 9005 / Encapsulant TPO 0.4 mm /PV film CIGS grown on polyimide with Mo and ZnO electrical contacts / Encapsulant TPO 0.4 mm / Barrier film 0.4 mm. the module is sealed with edge seal ~1cm width
Frame structure	Frameless
PV technology	CIGS (Thin film)
Encapsulation material	TPO
Surface treatments	Surface structured
Thermal insulation	none
Acoustic insulation	none

Physical features	Semi-flexible and lightweight solar panel
Weight	5.9 Kg/m^2
Rigidity	Flexible
Opacity	Opaque
Active energy features	Electricity production
Photovoltaic power	84 – 110 Wp/m^2 (2519 - 3263 mm version)
Optical transmittance	Opaque

5.2 Mechanical Performance – X1b

TECHNICAL TEMPLATE REFERENCE	
Technical subject	Mechanical performance of BIPV modules
Partner	Flisom / Tecnalia
Author	Julian Perrenoud / Daniel Valencia

PRODUCT CODE	
Denomination	X1 – eCarport

DESIGN/DATASHEET VALUES						
BIPV UNIT						
General characteristics	The carport module is a semi-flexible and lightweight solar panel designed for a carport installation					
Manufacturer	Flisom					
Model	Carport module					
Shape	Rectangular					
Physical characteristics	Value 1	Unit 1	Value 2	Unit 2	Value 3	Unit 3
Height/ Length/ Thickness	2519-3263	mm	458	mm	22	mm
Weight	-	-	5.9	kg/m2	-	-
Mechanical characteristics	Value 1	Unit 1	Value 2	Unit 2	Value 3	Unit 3
Max. mechanical load	**2400**	**Pa**				
Observations: Flisom PVSITES modules use thin metal sheets as backsheet. Hence, they can bend by applying forces while installation (e.g. dropping on the corner). Please handle with care. Store modules in a dry place. Do not transport modules without packaging. Do not put modules on top of each other to avoid small scratches (this can accelerate module degradation by environmental factors). Do not use JB cables as handles to carry or lift the modules. Be cautious when frontsheet is wet since the surface could lose grip. Do not apply solvents, adhesives, paint or stickers on the frontsheet. Do not place the modules face-down in direct contact to abrasive surfaces						

5.3 Architectural Integration – X1b

TECHNICAL TEMPLATE REFERENCE	
Technical subject	Architectural integration of BIPV products
Partner	BEAR / Flisom
Author	Tjerk Reijenga / Julian Perrenoud

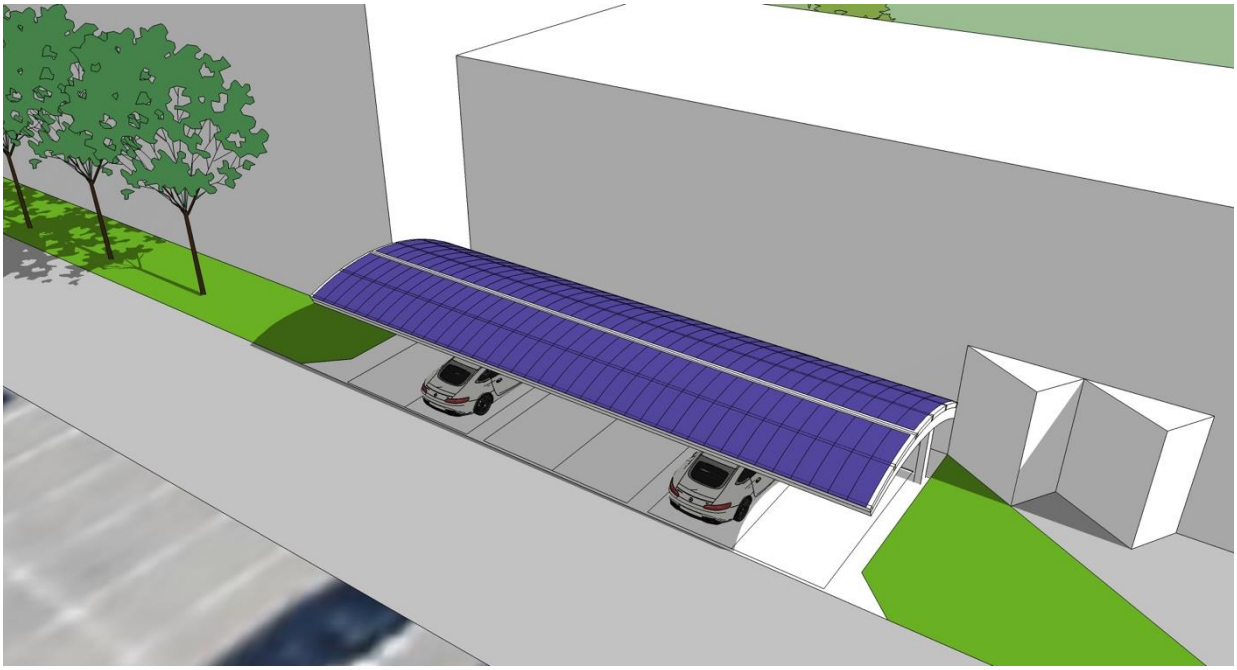
PRODUCT CODE	
Denomination	X1 – eCarport

DEFINITION AND LOCATION	
Definition	The carport module is a semi-flexible and lightweight solar panel designed for a carport installation
Construction unit	Carport module
Location	Zürich
Architectural location	Roof

CONSTRUCTION UNIT FEATURES						
Physical properties	Length	Unit 1	Width	Unit 2	Height	Unit 3
Shape	Rectangular					
Dimensions	2519-3263	mm	458	mm	21	mm
Weight	…	kg	5.9	kg/m^2		
Materials and devices	Bended steel sheet with glued cells on top					
Configuration	Steel sheet					
Frame structure	Frameless					
PV technology	CIGS (Thin film)					
Thermal bridge	no					
Opacity	Opaque					
Cell colour	Very dark blue / black					
Background colour	RAL 9005					

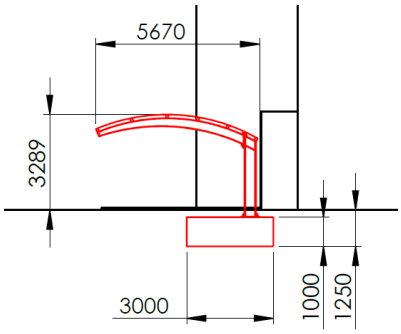
INTEGRATION AND MAINTENANCE MEASURES	
Mounting system	
	Modules are riveted together to one big module of 5.7 m length.
Secondary construction	
	Sub-construction with profiles for the module fixation
Procedure	Modules are placed and clamped with a rubber gasket into the support rail
New construction permits needed	Part of building permit. Based on local regulation.
Retrofitting permits needed	Building permit needed
Maintenance	Cleaning depending on location.
Inspection	Physical inspection
Sequence of inspection	Yearly

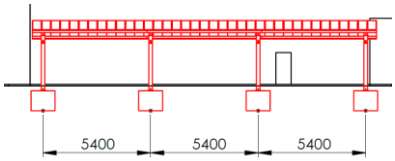
EXPLODED DRAWING / 3D

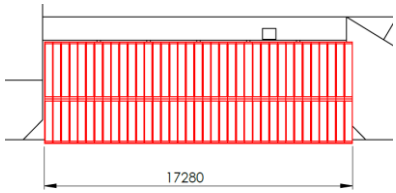


Design for carport at EMPA Zürich

Carport at EMPA Zürich after construction.





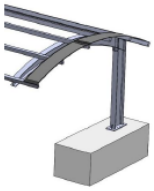


Carport construction at EMPA Zürich

Design for carport at EKZ Zürich

EKZ demonstration

Carport construction

1. Build the foundation and mount the pillars	2. Mount stiffening profiles	3. Install the first row of modules	4. Install the rest of the modules
			

Observations:
Keep a minimum distance of 5mm between the edges of single modules to take thermal expansion into account. Only use compatible materials

5.4 Electrical performance – X1b

TECHNICAL TEMPLATE REFERENCE	
Technical subject	Electrical performance of BIPV modules
Partner	Flisom / Tecnalia
Author	M. Schweizer / Daniel Valencia

PRODUCT CODE

Denomination	X1 – eCarport

DESIGN/DATASHEET VALUES						
PHOTOVOLTAIC CELL/ ARRAY						
General characteristics	The carport module is a semi-flexible and lightweight solar panel designed for a carport installation					
Manufacturer	Flisom					
Cell type	Flexible CIGS					
Shape	Rectangular					
Colour	Dark blue/ Black					
Frame	Frameless					
Connection Box	Back side					
Connectors	MC4					
Physical characteristics	Value 1	Unit 1	Value 2	Unit 2	Value 3	Unit 3
Height/ Length/ Thickness	2519-3263	mm	458	mm	21	mm
Electrical characteristics	Value 1	Unit 1	Value 2	Unit 2	Value 3	Unit 3
Ppm: max. power	85-110	W		-		-
Vpm: max. power voltage	34-38	V				
Ipm: max. power current	2.22-3.16	A		-		-
Voc: open circuit voltage	46-50	V		-		-
Isc: short circuit current	2.47-3.40	A		-		-
Thermal parameters	Value 1	Unit 1	Value 2	Unit 2	Value 3	Unit 3
Isc (α) Temp. coefficient	0.01	%/ºC				-
Voc (β) Temp. coefficient	-0.3	%/ºC				-
P (γ) Temp. coefficient	-0.35	%/ºC				-
Operating range						
Temperature	-40 – 85	ºC				
Maximum System Voltage	1000	V				

Maximum Wind /Snow Load	2400	Pa				

Observations:
For elevated areas irradiation can be higher than at STC. Therefore, multiply ISC- and VOC- values with a factor of 1.25 for the electrical layout of cables, fuses and converters (worst case scenario). For a serial connection the voltage of a single module is multiplied by the number of modules to calculate the system voltage. Make sure that you are always within the limits of the maximum system voltage. Use an adequate device for overcurrent protection (fuse, blocking diode). Maximum Isc multiplied by a factor of 1.56 to protect a string in parallel configuration.
The maximum number of modules connectable in series is calculated by adding Voc of each single module multiplied by 1.25 up to the maximum system voltage which you can find on the label.

Backsheet of Flisom PVSITES modules are made of metal and have to be connected to the ground. Also ground the support structure and arrange an adequate lightning protection. Do not use materials which can cause corrosion. The hole for the grounding cable can be drilled anywhere in the edges of the module frame as in fig. 1. If the backsheet of the module and the support structure/clamps are conductive it is not necessary to ground every module. The grounding of the support structure is sufficient. Make sure that you do not damage the edge seal or frontsheet.
Do not use PV modules of different power classes or configurations in the same PV system. Flisom tile modules use MC4 connectors. Only use these connectors or compatible connector types which are authorised from both producers.
Use solar cables for outside use (ø 2.5 to 4mm² and min. 90 °C).
Scure all electrical connections and use stress relief appliances. Do not go below the minimum bending radius of the cables. Use cable guides to prevent connectors and cables from lying in excess water, snow or dirt.

The junction box is not to be opened. The diode cannot be repaired.
In general, the modules can be mounted either in portrait or in landscape mode, depending on different limiting factors
Orientation of the shadow on the active surface is crucial: the panel may only be installed as in fig 2 (Parallel shade). To compare, fig 3 shows a series shade - shading the complete length of several full cells. This type of casting shadow will negatively affect the power.

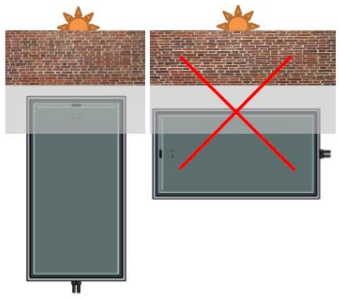
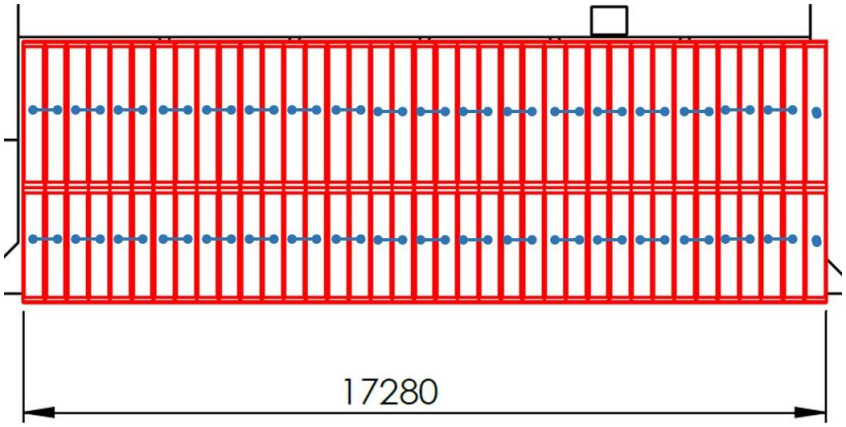


Fig 2: parallel shade *Fig 3: series shade*

Suitable inverter configurations are: central inverters, string inverters, multi-string inverters, inverters on single module level.

POWER MANAGEMENT SYSTEM (demos)	
General characteristics	The roofing shingle module is a semi-flexible and lightweight solar panel designed for BIPV roof tile installations
Manufacturer	Flisom
Model	Carport EMPA

Physical characteristics	Value 1	Unit 1	Value 2	Unit 2	Value 3	Unit 3
Height/ Length/ Thickness	5782	mm	17280	mm		mm
Number of modules	35 x (2519x458 mm / ~85 Wp) + 35 x (3263x458 mm / ~110 Wp)					
PV area	70 m^2					
Total DC power	7 kWp					
Inverter characteristics	SolarEdge SE 9 kW inverters with MPP tracker P300					
Observations: Connect always two neighbouring modules along long side together to one MPP tracker 						

POWER MANAGEMENT SYSTEM (demos)						
General characteristics	The roofing shingle module is a semi-flexible and lightweight solar panel designed for BIPV roof tile installations					
Manufacturer	Flisom					
Model	Carport EKZ					
Physical characteristics	Value 1	Unit 1	Value 2	Unit 2	Value 3	Unit 3
Height/ Length/ Thickness	5782	mm	18225	mm		mm
Number of modules	39 x (2519x458 mm / ~85 Wp) + 39 x (3263x458 mm / ~110 Wp)					
Total DC power	7.34 kWp					
Inverter characteristics	SolarEdge SE 9 kW inverters with MPP tracker P300					

Observations: Connect always two neighboring modules along long side together to one MPP tracker**.**

5.5 Optical Performance – X1b

TECHNICAL TEMPLATE REFERENCE	
Technical subject	Optical performance of BIPV modules
Partner	Tecnalia
Author	Maider Machado/ Daniel Valencia

PRODUCT CODE	
Denomination	X1 – eCarport

DESIGN/DATASHEET VALUES

BIPV UNIT						
General characteristics	The roofing shingle module is a semi-flexible and lightweight solar panel designed for BIPV roof tile installations					
Manufacturer	Flisom					
Model	Carport module					
Shape	Rectangular					
Physical characteristics	Value 1	Unit 1	Value 2	Unit 2	Value 3	Unit 3
Height/ Length/ Thickness	2519-3263	mm	458	mm	21	mm
Weight	…	kg	5.9	kg/m^2	-	-
PV ratio (PVR)	~100	%	-	-	-	-
Optical characteristics	Value 1	Unit 1	Value 2	Unit 2	Value 3	Unit 3
Visible transmittance	0	%	-	-	-	-
Solar transmittance	0	%	-	-	-	-
Visible reflectance (tz)	-	%	-	-	-	-
Solar reflectance (tz)	-	%	-	-	-	-
Visible reflectance (cz)	5.0	%	-	-	-	-
Solar reflectance (cz)	8.9	%	-	-	-	-
Visible absorptance (tz)	-	%	-	-	-	-
Solar absorptance (tz)	-	%	-	-	-	-

Visible absorptance (cz)	95	%	-	-	-	-
Solar absorptance (cz)	91.1	%	-	-	-	-
Emissivity	-	%	-	-	-	-

Observations:
Absorptance is calculated from transmittance and reflectance values. Acronym (tz): transparent zone. Acronym (cz): cell zone.

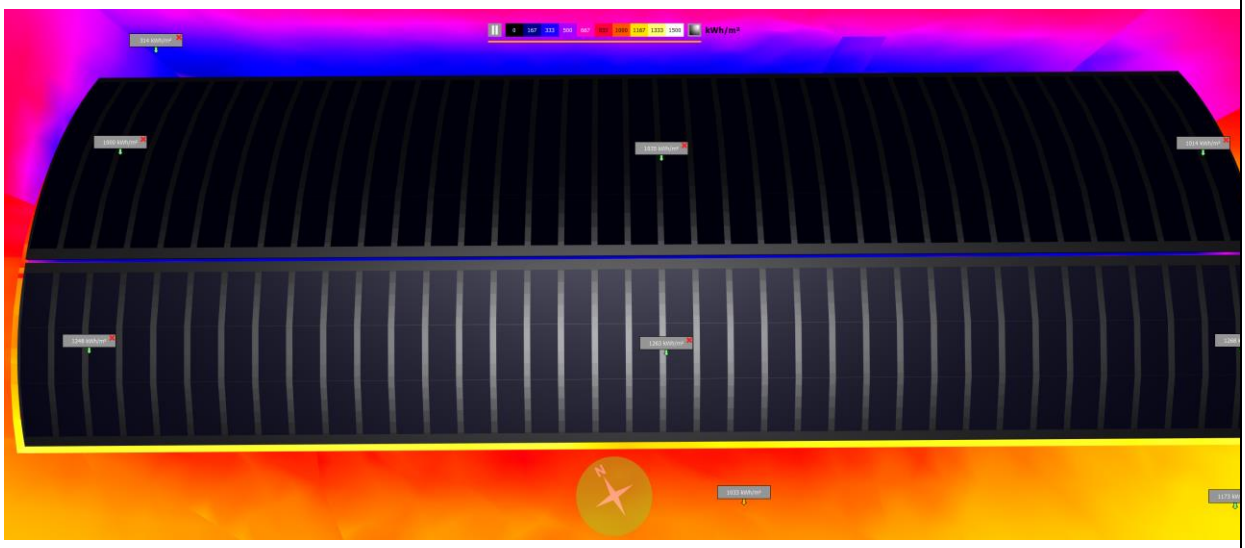
5.6 Estimation of PV production – X1b

TECHNICAL TEMPLATE REFERENCE	
Technical subject	PV production of BIPV modules
Partner	CADCAMation
Author	Philippe ALAMY

PRODUCT CODE	
Denomination	X1 - eCarport-Tile

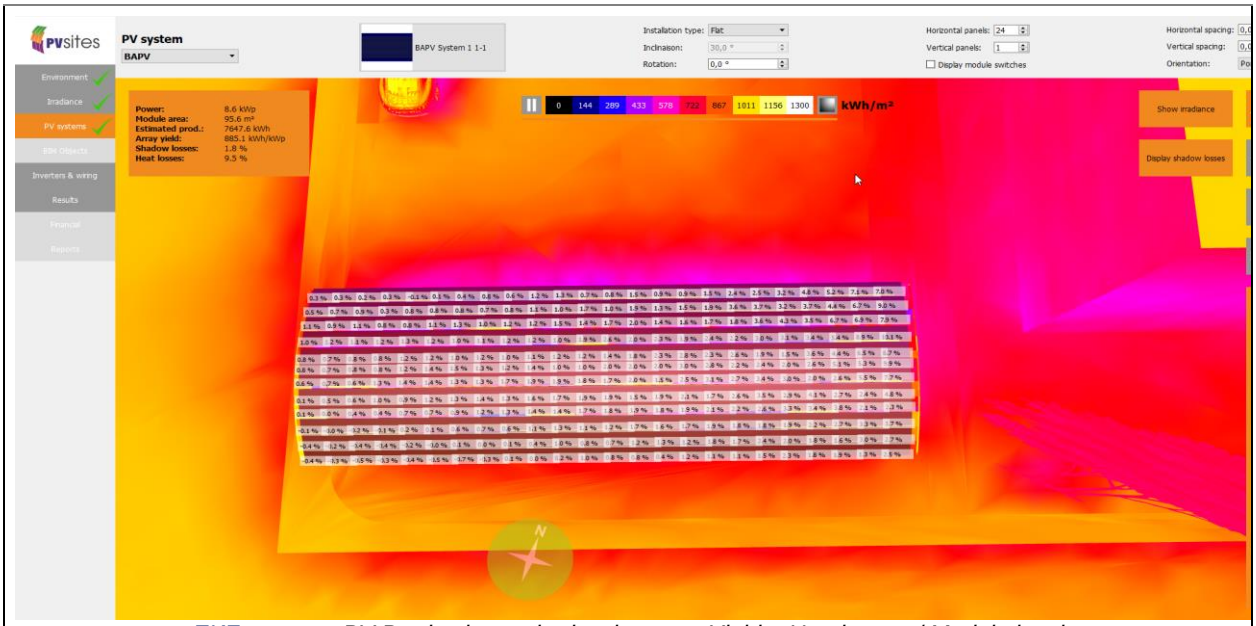
SIMULATING CONDITIONS: exact building locations (TMY to epw files built from PVGIS)						
ANNUAL GLOBAL IRRADIANCE		Orient E	Orient S	Orient N	Orient W	Unit
Zürich EKZ (Switzerland)	…	…	1375	890	…	kW/m^2
Zürich EMPA (Switzerland)	…	…	1118	1093	…	kW/m2
MEDIUM TEMPERATURE	Med	Min	Max	-	-	Unit
Zürich EKZ (Switzerland)	9.0	0.0	20.6	…	…	°C
Zürich EMPA (Switzerland)	9.0	0.7	20.6	…	…	°C
MEDIUM WIND SPEED	Med	Min	Max	-	-	Unit

EKZ Carport

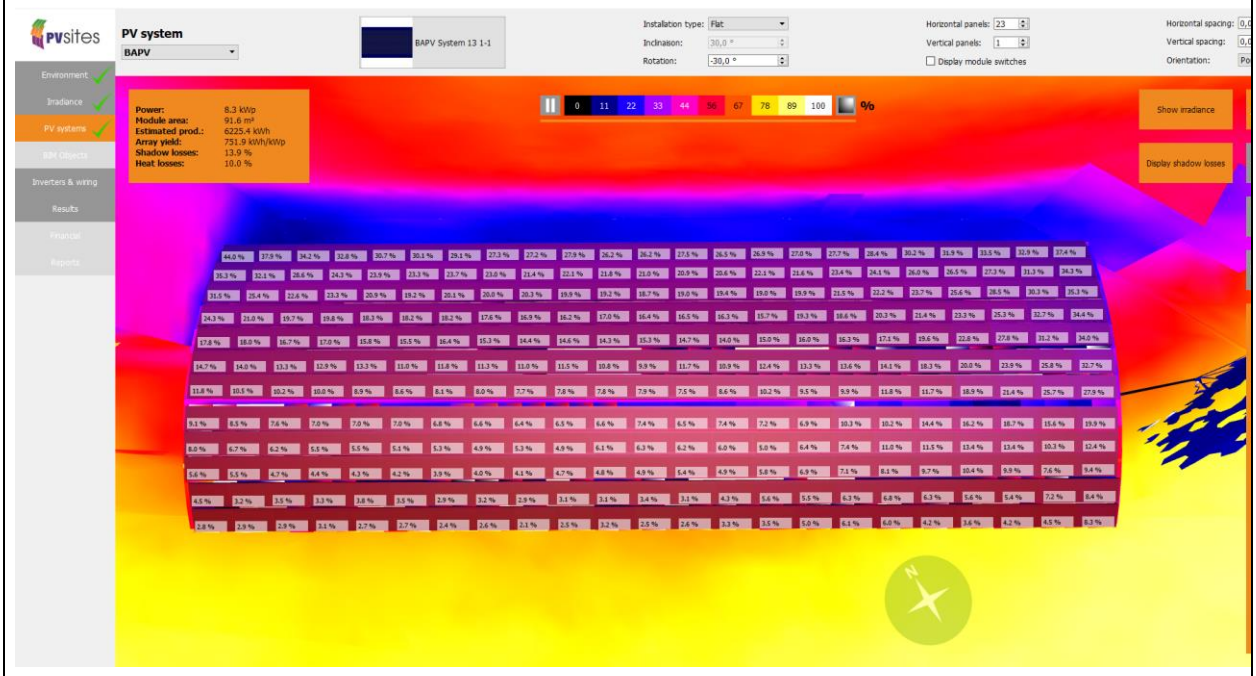


EMPA Carport

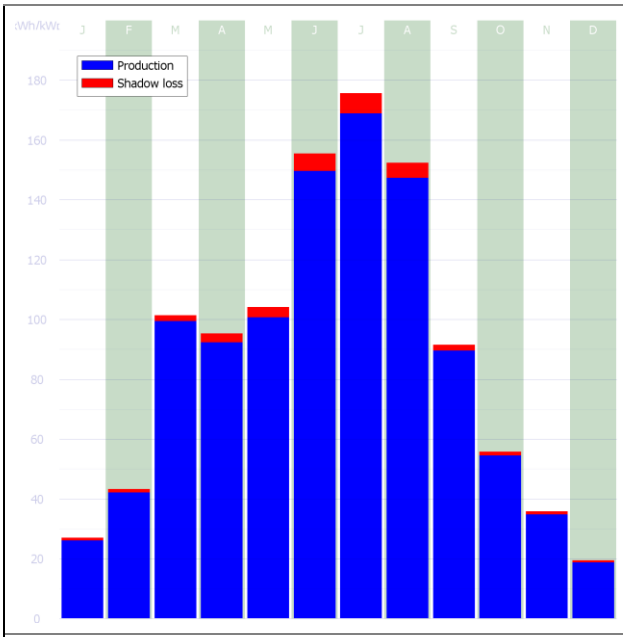
ESTIMATION OF ELECTRICAL POWER PRODUCTION (from PV ARRAY to INVERTER) - ANNUAL						
BIPV UNIT – PV PRODUCTION		Orient E	Orient S	Orient N	Orient W	Unit
Zürich EKZ (Switzerland)			4733	3056		kWh
Zürich EMPA (Switzerland)			3574	3633		kWh
ARCHITECTURAL UNIT		Orient E	Orient S	Orient N	Orient W	Unit
Zürich EKZ (Switzerland)			4733	3056		kWh
Zürich EMPA (Switzerland)			3574	3633		kWh
PRODUCTION PER M²		Orient E	Orient S	Orient N	Orient W	Unit
Zürich EKZ (Switzerland)			91.63	59.17		kWh/kWp
Zürich EMPA (Switzerland)			72.94	74.14		kWh/m²
PRODUCTION PER kWp		Orient E	Orient S	Orient N	Orient W	Unit
Zürich EKZ (Switzerland)			1246	804		kWh/kWp
Zürich EMPA (Switzerland)			993	1009		kWh/kWp
DC PRODUCTION (INVERTER)		Orient E	Orient S	Orient N	Orient W	Unit
Zürich EKZ (Switzerland)			4659	3009		kWh
Zürich EMPA (Switzerland)			3519	3576		kWh
AC PRODUCTION		Orient E	Orient S	Orient N	Orient W	Unit
Zürich EKZ (Switzerland)			4520	2919		kWh
Zürich EMPA (Switzerland)			3414	3469		kWh



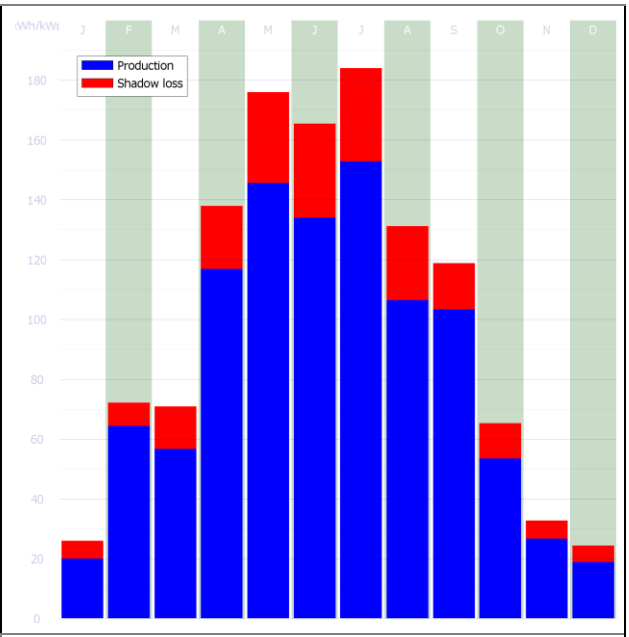
EKZ carport - PV Production + shadow losses + Yield – Hourly step / Module level



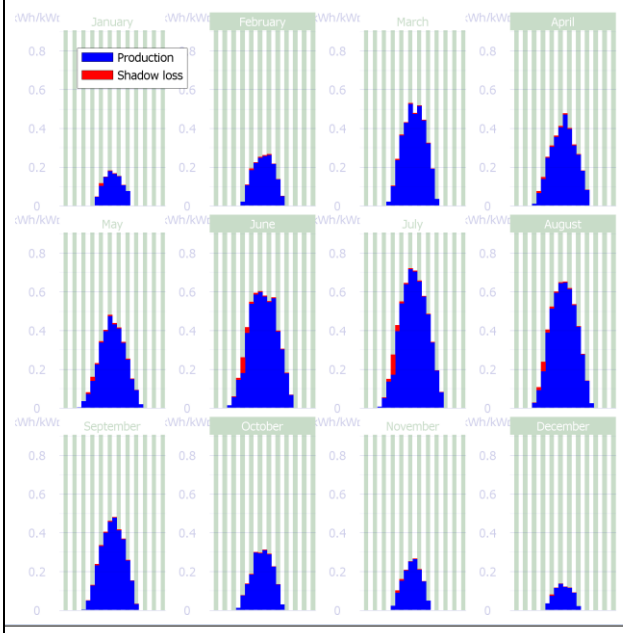
EMPA carport - PV Production + shadow losses + Yield – Hourly step / Module level



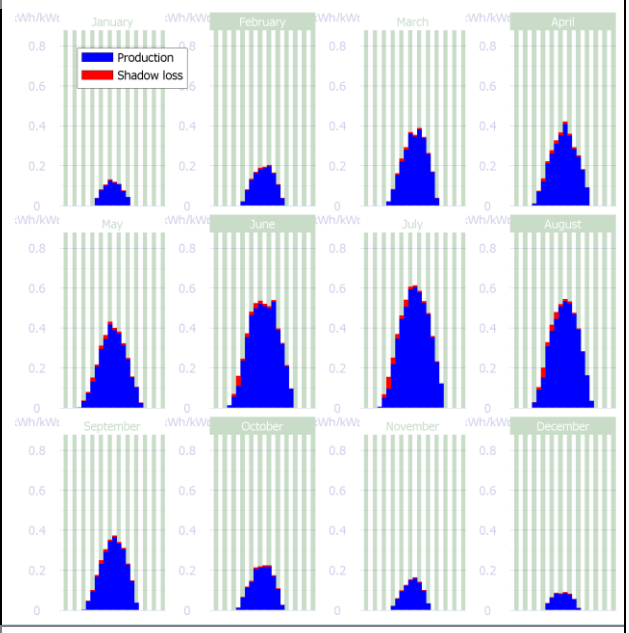
EKZ - Monthly PV Production all roof + shading losses



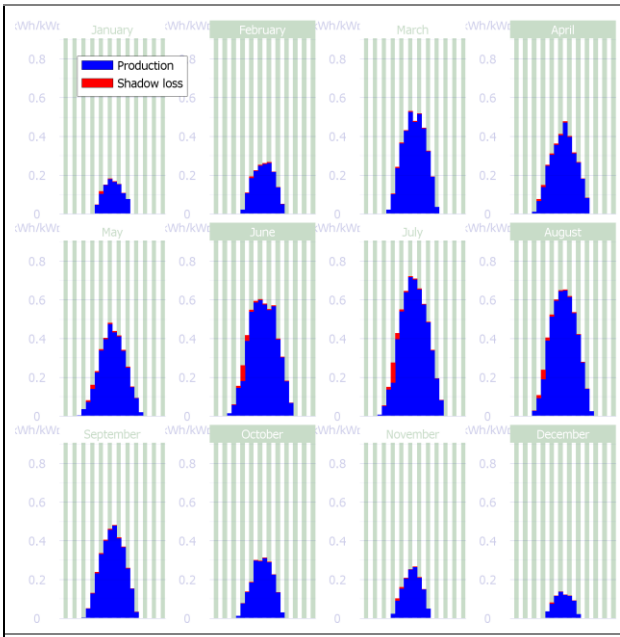
EMPA - Monthly PV Production all roof + shading losses



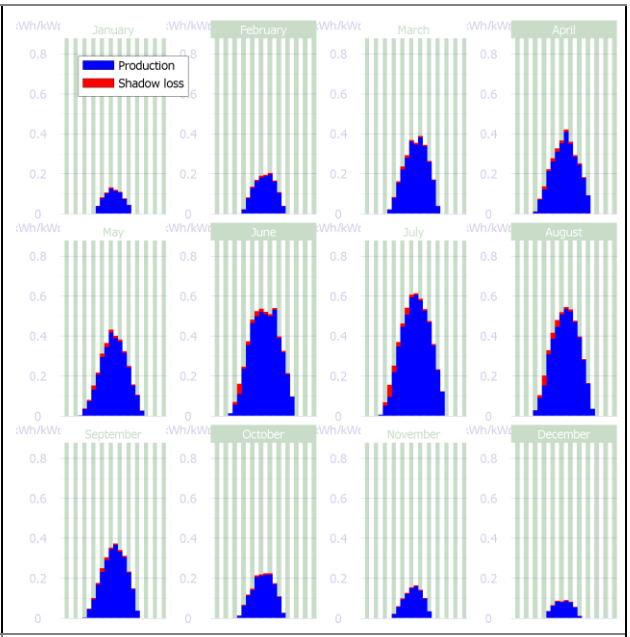
EKZ PV Production South + shading losses – Average day per month



EKZ PV Production North + shading losses – Average day per month



EMPA PV Production South + shading losses – Average day per month



EMPA PV Production North + shading losses – Average day per month

5.7 Maintenance and Dismantling – X1b

TECHNICAL TEMPLATE REFERENCE	
Technical subject	Maintenance and dismantling of products and installations
Partner	Flisom
Author	Julian Perrenoud

PRODUCT CODE	
Denomination	X1 – eCarport

MAINTENANCE		
BY THE USER	Periodicity (months)	Description
Action 1	3	Visual check
Action 2	When required	Remove dust and dirt (sediments, leaves, pollen, bird droppings, etc.) from the surface
Action 3	3	Check if connectors and grounding are tight and without corrosion and if the insulation is not damaged also check for loose mechanical or electrical contacts
Action 4	3	Check if the Junction Box is securely attached and that no deep scratches are penetrating the frontsheet

Observations. Do not use aggressive cleaning agents or scrubbing materials for cleaning Do not use steam blasting for cleaning Use soft water to avoid chalk stains Soft sponges can be used

5.8 Life Cycle Assesment – X1b

TECHNICAL TEMPLATE REFERENCE	
Technical subject	Life cycle assessment of products and installations
Partner	CTCV
Author	Marisa Almeida

PRODUCT CODE	
Denomination	X1 - eRoof-Tile

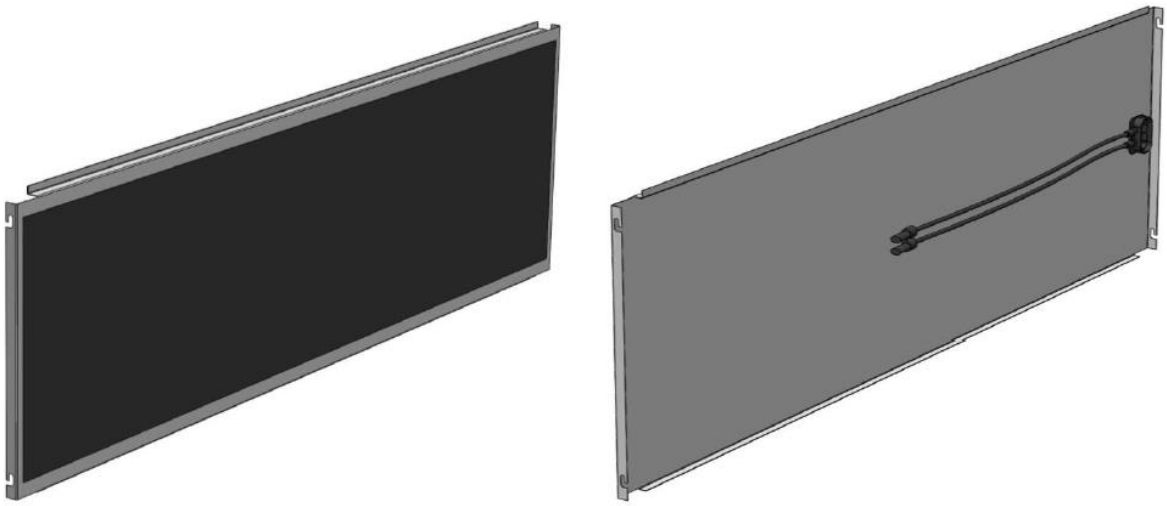
LCA INDICATORS					
	Value 1	Unit 1			
Global warming	36,2	Kg CO2 eq/m^2			
Acidification	0,236	mol H+ eq/m^2			
Terrestrial Eutrophication	0,399	mol N eq /m^2			
Freshwater Eutrophication	0,0056	Kg P eq/m^2			
Photochemical oxidation formation	0,143	kg NMCOV eq /m^2			
Abiotic depletion	1,33	g Sb/m^2			
Ozone layer depletion	6,75E-06	kg CFC-11 eq/m^2			
Human Toxicity	9,33E-07	CTUh /m^2			
Observations: Provisional data based on specific ACV for this GIGs. LCA methodology: ISO14040/ISO14044 with CML and ILCD methods. Most of the results are better than the average for GIGs with similar properties.					

6 X2 CIGS large area flexible roofing membrane and bendable elements (eFacade)

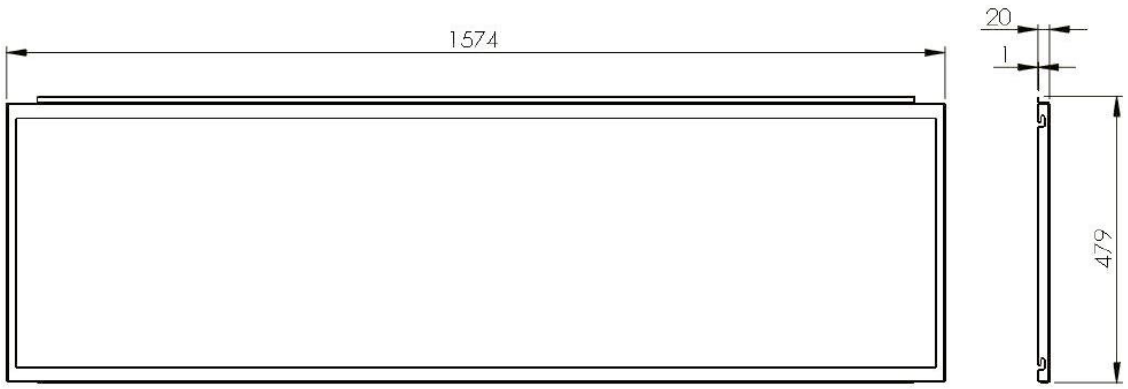
6.1 General Description, Design and Materials – X2

TECHNICAL TEMPLATE REFERENCE	
Technical subject	General description, design and materials of BIPV modules.
Partner	Flisom/ Tecnalia
Author	Julian Perrenoud/ Daniel Valencia

PRODUCT CODE	
Project	PVSITES. Task 2.6. BIPV products portfolio
Category	Façades
Denomination	X2 - eFacade
Partner/s	Flisom

PICTURES
REALISTIC DRAWING / ARTIST IMPRESSION

Observations: The EHG module is a semi-flexible and lightweight solar panel designed for BIPV facade installations

DESIGN DRAWINGS



PHOTOS

DETAILED DESCRIPTION	
Definition	Semi-flexible and lightweight solar panel designed for BIPV installations on facades
Construction unit	Module for façade
Architectural location	Façade
Geometrical design	Rectangular
Dimensions	1574 x 479 x 20 mm
Geometrical shape	Rectangular
Configuration	Monolithic unit
Layers	Layers from backsheet to frontsheet in order of application: Aluminum black elox / Encapsulant TPO 0.4 mm /PV film CIGS grown on polyimide with Mo and ZnO electrical contacts / Encapsulant TPO 0.4 mm / Barrier film 0.4 mm. the module is sealed with edge seal ~1cm width
Frame structure	No frame
PV technology	CIGS (Thin film)
Encapsulation material	TPO
Surface treatments	Surface textured
Thermal insulation	None
Acoustic insulation	none
Weight	2.5 Kg / unit
Rigidity	Semi-flexible
Opacity	Opaque
Mobility	Fixed
Photovoltaic power	50-60 Wp / unit

6.2 Mechanical Performance – X2

TECHNICAL TEMPLATE REFERENCE	
Technical subject	Mechanical performance of BIPV modules
Partner	Flisom / Tecnalia
Author	Julian Perrenoud / Daniel Valencia

PRODUCT CODE	
Denomination	X2 - eFacade

DESIGN/DATASHEET VALUES
BIPV UNIT

General characteristics	Semi-flexible and lightweight solar panel designed for BIPV installations on facades					
Manufacturer	Flisom					
Model	EHG module					
Shape	Rectangular					
Physical characteristics	Value 1	Unit 1	Value 2	Unit 2	Value 3	Unit 3
Height/ Length/ Thickness	1574	mm	479	mm	20	mm
Weight	2.5	kg	3.32	kg/m2	-	-
Mechanical characteristics	Value 1	Unit 1	Value 2	Unit 2	Value 3	Unit 3
Max. mechanical load	2400	Pa				

6.3 Architectural Integration – X2

TECHNICAL TEMPLATE REFERENCE	
Technical subject	Architectural integration of BIPV products
Partner	BEAR / Flisom
Author	Tjerk Reijenga / Julian Perrenoud

PRODUCT CODE	
Denomination	X2- eFacade

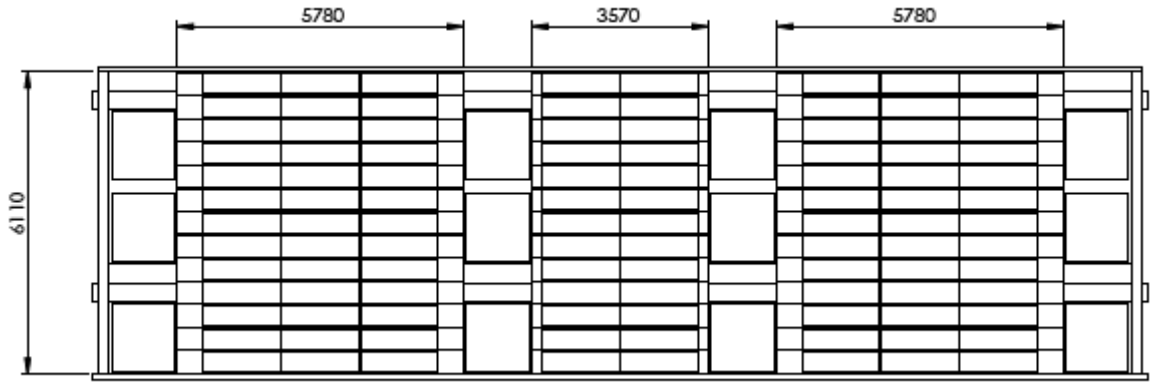
DEFINITION AND LOCATION	
Definition	Semi-flexible and lightweight solar panel designed for BIPV installations on facades
Construction unit	Ventilated façade
Location	Geneva
Architectural location	Façade

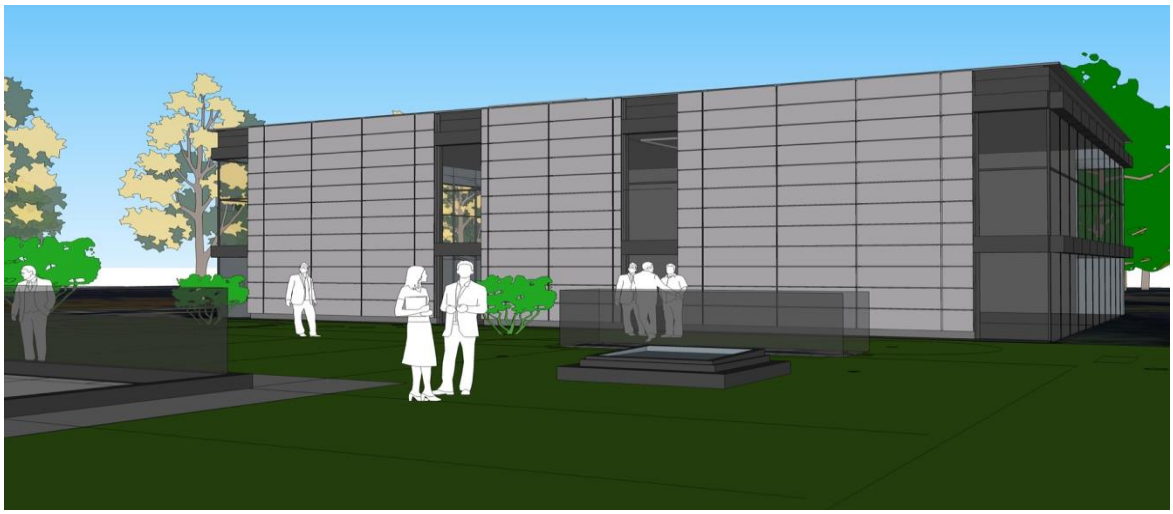
CONSTRUCTION UNIT FEATURES						
Physical properties	Length	Unit 1	Width	Unit 2	Height	Unit 3
Shape	Rectangular					
Dimensions	1574	mm	479	mm	20	mm
Weight	2.5	kg	3.32	kg/m^2		
Materials and devices	Bended aluminium/steel sheet with laminated cells on top					
Configuration	Other					

Frame structure	none
PV technology	CIGS
Location of pipes, diameters	Dimensions, drawing
Thermal bridge	No
Aesthetical features	Modules are tailor made and can fit the whole area. This increase the aesthetics and added value.
Opacity	Opaque
Cell colour	Very dark blue / black
Background colour	Black
INTEGRATION AND MAINTENANCE MEASURES	
Construction	
Mounting system	Hanging on an aluminium back frame system
Secondary construction	A secondary construction is needed to connect modules to the wall.
Procedure	
New construction permits needed	Part of building permit. Based on local regulation.
Retrofitting permits needed	Building permit needed
Maintenance	Cleaning depending on location.
Inspection	Physical inspection
Sequence of inspection	Yearly

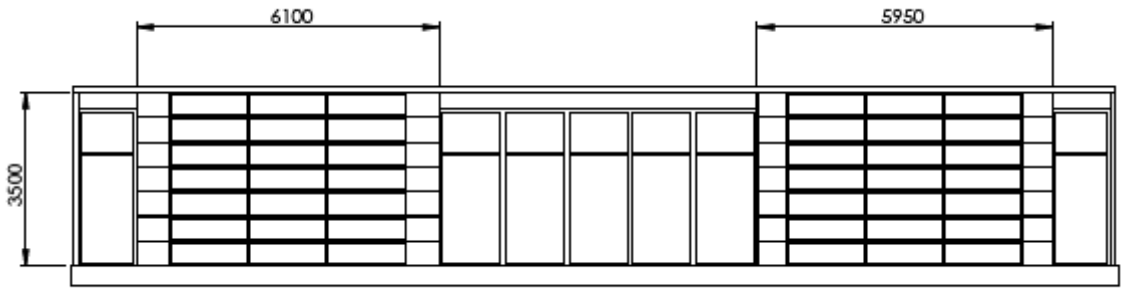
PICTURES
Integration method / details

Overview of demosite; Pavillion 1 (left) and 2 (right)



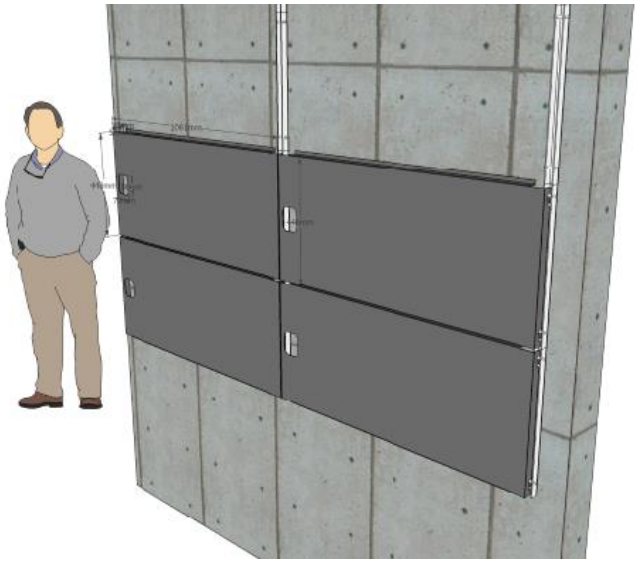


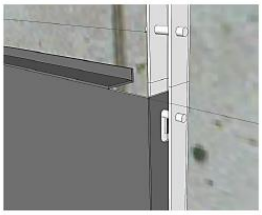
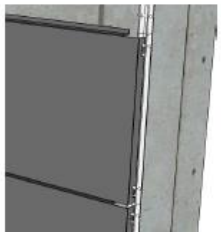
Integration proposal for EHG. Pavilion 1



Integration proposal for EHG. Pavilion 2

Mounting system (Schweizer)



1. Mount the vertical rails and check that all are parallel	2. Hang in the first module at the bottom of the row	3. Hang in the second module and connect the cables	4. Install all modules and the side covers
			

6.4 Electrical Performance – X2

TECHNICAL TEMPLATE REFERENCE	
Technical subject	Electrical performance of BIPV modules
Partner	Flisom / Tecnalia
Author	M. Schweizer / Daniel Valencia

PRODUCT CODE	
Denomination	X2- eFacade

DESIGN/DATASHEET VALUES						
PHOTOVOLTAIC CELL/ ARRAY						
General characteristics	Semi-flexible and lightweight solar panel designed for BIPV installations on facades					
Manufacturer	Flisom					
Cell type	Flexible CIGS					
Shape	Rectangular					
Colour	Black					
Front layer	ETFE					
Frame	none					
Connection Box	Back side					
Connectors	MC4					
Physical characteristics	Value 1	Unit 1	Value 2	Unit 2	Value 3	Unit 3
Height/ Length/ Thickness	1574	mm	479	mm	20	mm
Electrical characteristics	Value 1	Unit 1	Value 2	Unit 2	Value 3	Unit 3
Rated power	50-60	Wp	66-80	Wp/m^2		-
Vpm: max. power voltage	34-36	V		-		-
Ipm: max. power current	1.47-1.66	A		-		-
Voc: open circuit voltage	46-48	V		-		-
Isc: short circuit current	1.72-1.91	A		-		-
Thermal parameters	Value 1	Unit 1	Value 2	Unit 2	Value 3	Unit 3
Isc (α) Temp. coefficient	0.01	%/ºC				-
Voc (β) Temp. coefficient	-0.3	%/ºC				-
P (γ) Temp. coefficient	-0.35	%/ºC				-
Operating range						

Temperature	-40 – 85	ºC				
Maximum System Voltage	1000	V				

Observations:
For elevated areas irradiation can be higher than at STC. Therefore, multiply ISC- and VOC- values with a factor of 1.25 for the electrical layout of cables, fuses and converters (worst case scenario). For a serial connection the voltage of a single module is multiplied by the number of modules to calculate the system voltage. Make sure that you are always within the limits of the maximum system voltage. Use an adequate device for overcurrent protection (fuse, blocking diode). Maximum Isc multiplied by a factor of 1.56 to protect a string in parallel configuration.
The maximum number of modules connectable in series is calculated by adding Voc of each single module multiplied by 1.25 up to the maximum system voltage which you can find on the label.

Backsheet of Flisom PVSITES modules are made of metal and have to be connected to the ground. Also ground the support structure and arrange an adequate lightning protection. Do not use materials which can cause corrosion. The hole for the grounding cable can be drilled anywhere in the edges of the module frame as in fig. 1. If the backsheet of the module and the support structure/clamps are conductive it is not necessary to ground every module. The grounding of the support structure is sufficient. Make sure that you do not damage the edge seal or frontsheet.
Do not use PV modules of different power classes or configurations in the same PV system. Flisom facade modules use MC4 connectors. Only use these connectors or compatible connector types which are authorised from both producers.
Use solar cables for outside use (ø 2.5 to 4mm² and min. 90 °C).
Secure all electrical connections and use stress relief appliances. Do not go below the minimum bending radius of the cables. Use cable guides to prevent connectors and cables from lying in excess water, snow or dirt.
The junction box is not to be opened. The diode cannot be repaired.
Orientation of the shadow on the active surface is crucial: the panel may only be installed as in the left picture below (Parallel shade). To compare, the right figure shows a serial shade - shading the complete length of several full cells. This type of casting shadow will negatively affect the power.

Parallel shading (left) and serial shading (right)

Suitable inverter configurations are: Central inverters, String inverters, Multi-String inverters, Inverters on single module level.

POWER MANAGEMENT SYSTEM (demos)	
General characteristics	Semi-flexible and lightweight solar panel designed for BIPV installations on facades
Manufacturer	Flisom
Model	EHG module
Number of modules	117

Electrical characteristics				
DC Power (Pavilion 1 / Pavilion 2)	1.26	kWp	5.78	kWp
PV area	15.6	m^2	71.2	m^2
Inverter model (Pavilion 1 - West)	ABB UNO-2.5-I-OUTD-S			
String concept (Pavilion 1 - West)	7 strings of 6 modules in series			
Inverter model (Pavilion 2 - West)	ABB TRO-5.8_TL_OUTD-S-400			
String concept (Pavilion 2 - West)	6 strings of 18 modules in series			
Observations:				

6.5 Optical Performance – X2

TECHNICAL TEMPLATE REFERENCE	
Technical subject	Optical performance of BIPV modules
Partner	Tecnalia
Author	Maider Machado / Daniel Valencia
PRODUCT CODE	
Denomination	X2 - eFacade

DESIGN/DATASHEET VALUES						
BIPV UNIT						
General characteristics	Semi-flexible and lightweight solar panel designed for BIPV installations on facades					
Manufacturer	Flisom					
Model	EHG module					
Shape	Rectangular					
Physical characteristics	Value 1	Unit 1	Value 2	Unit 2	Value 3	Unit 3
Height/ Length/ Thickness	1574	mm	479	mm	22	mm
PV ratio (PVR)	~100	%	-	-	-	-
Optical characteristics	Value 1	Unit 1	Value 2	Unit 2	Value 3	Unit 3
Visible transmittance	0	%	-	-	-	-
Solar transmittance	0	%	-	-	-	-

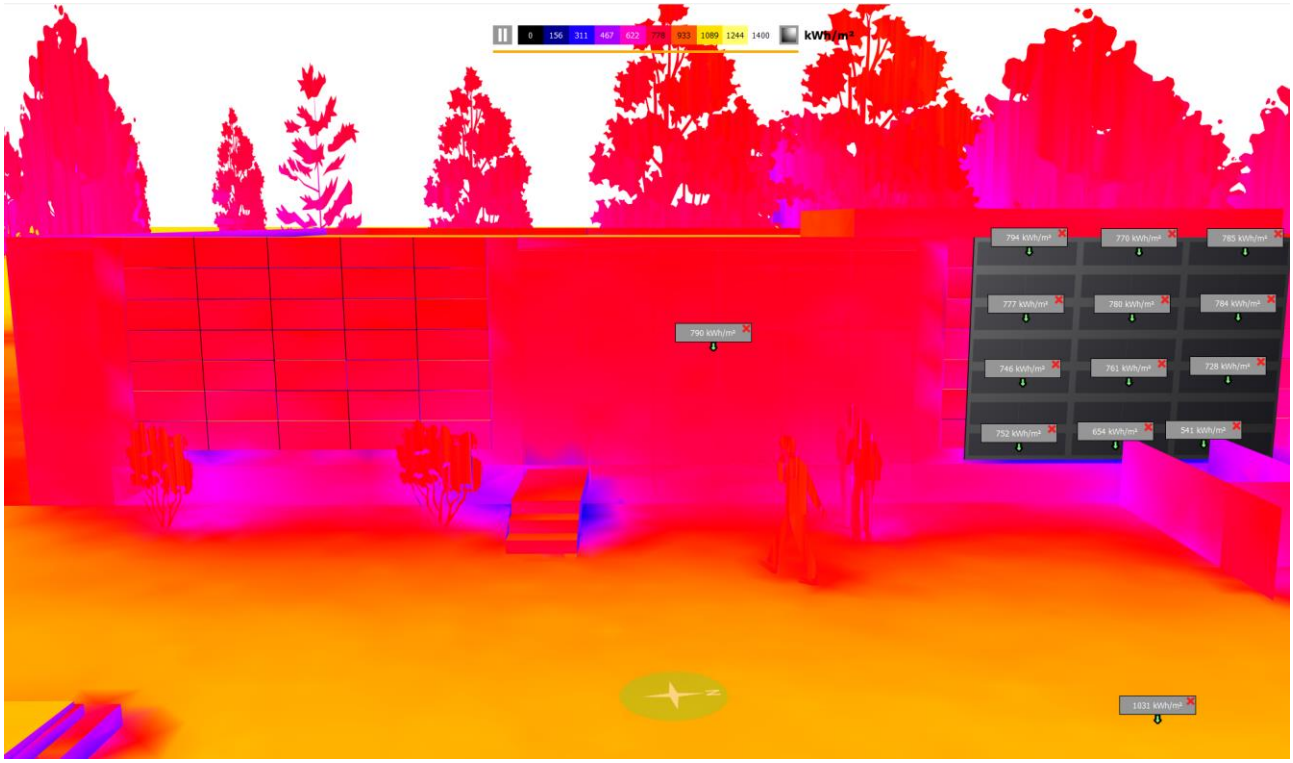
Visible reflectance (tz)	-	%	-	-	-	-
Solar reflectance (tz)	-	%	-	-	-	-
Visible reflectance (cz)	5.0	%	-	-	-	-
Solar reflectance (cz)	8.9	%	-	-	-	-
Visible absorptance (tz)	-	%	-	-	-	-
Solar absorptance (tz)	-	%	-	-	-	-
Visible absorptance (cz)	95.0	%	-	-	-	-
Solar absorptance (cz)	91.1	%	-	-	-	-
Observations: Absorptance is calculated from transmittance and reflectance values. Acronym (tz): transparent zone. Acronym (cz): cell zone						

6.6 Estimation of PV production – X2

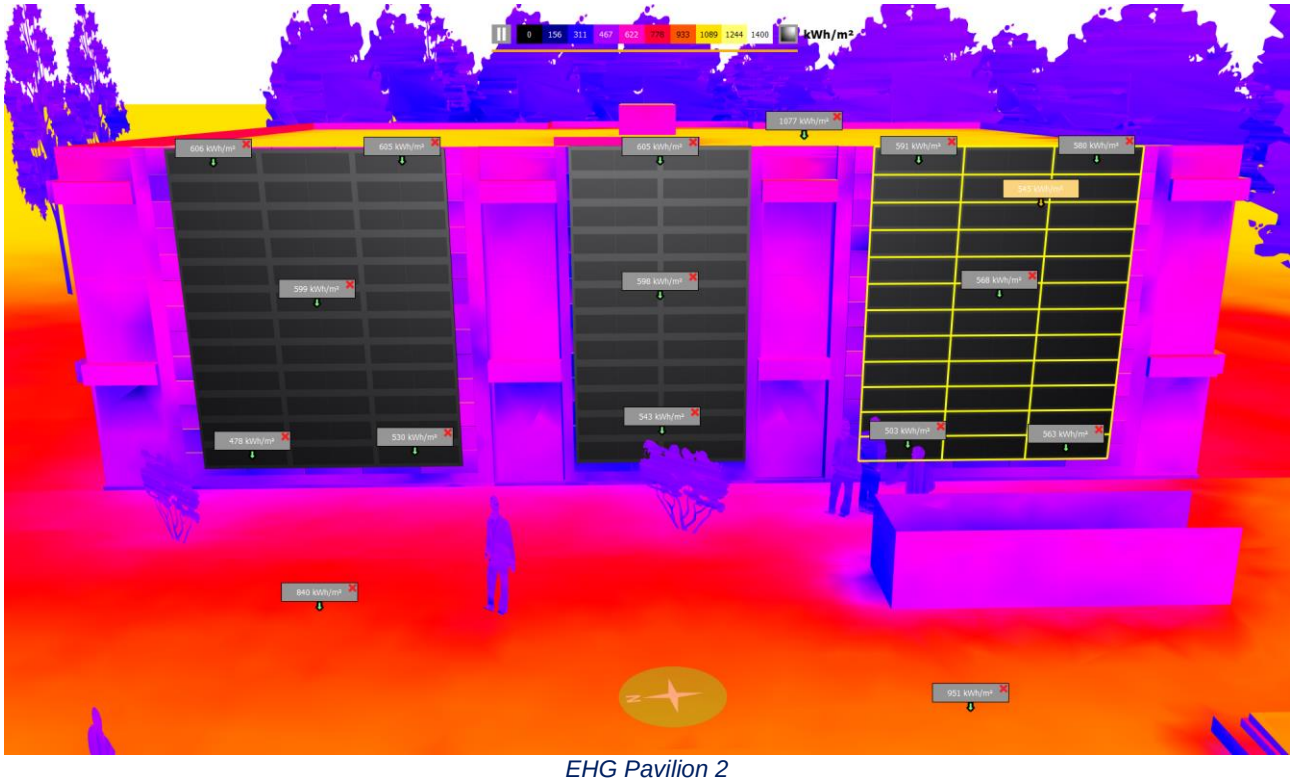
TECHNICAL TEMPLATE REFERENCE	
Technical subject	PV production of BIPV modules
Partner	CADCAMation
Author	Philippe ALAMY

PRODUCT CODE	
Denomination	X2 - eFacade

SIMULATING CONDITIONS: : exact location / EHG (TMY to epw file built from PVGIS)						
ANNUAL GLOBAL IRRADIANCE	Orient W	Orient SW	Orient S	Orient SE	Orient E	Unit
EHG Pavilion 1 (Switzerland)					749	kW/m^2
EHG Pavilion 2 (Switzerland)	559					kW/m^2
MEDIUM TEMPERATURE	Med	Min	Max	-	-	Unit
EHG Geneva (Switzerland)	10.77	2.92	19.48	-	-	ºC
MEDIUM WIND SPEED	Med	Min	Max	-	-	Unit
EHG Geneva (Switzerland)	…	…	…	-	-	m/s



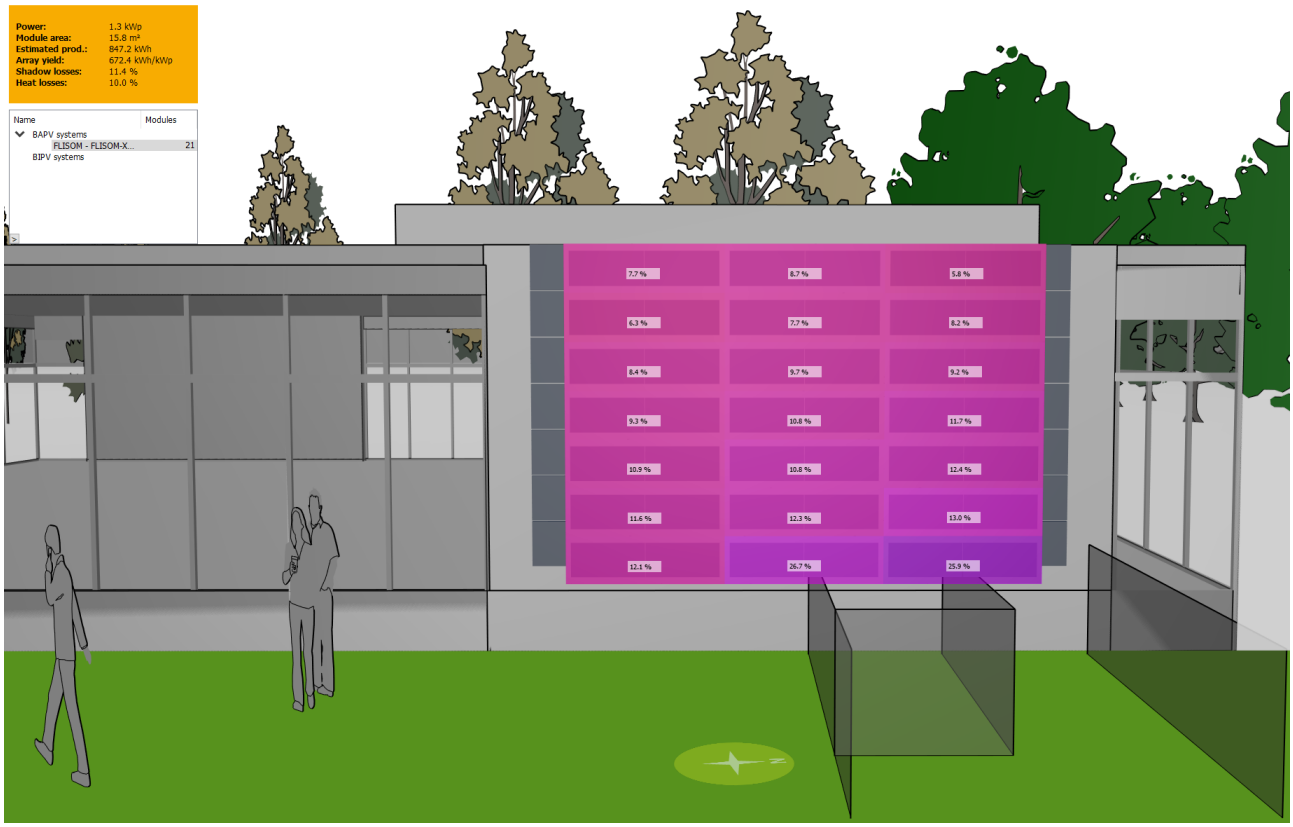
EHG Pavilion 1



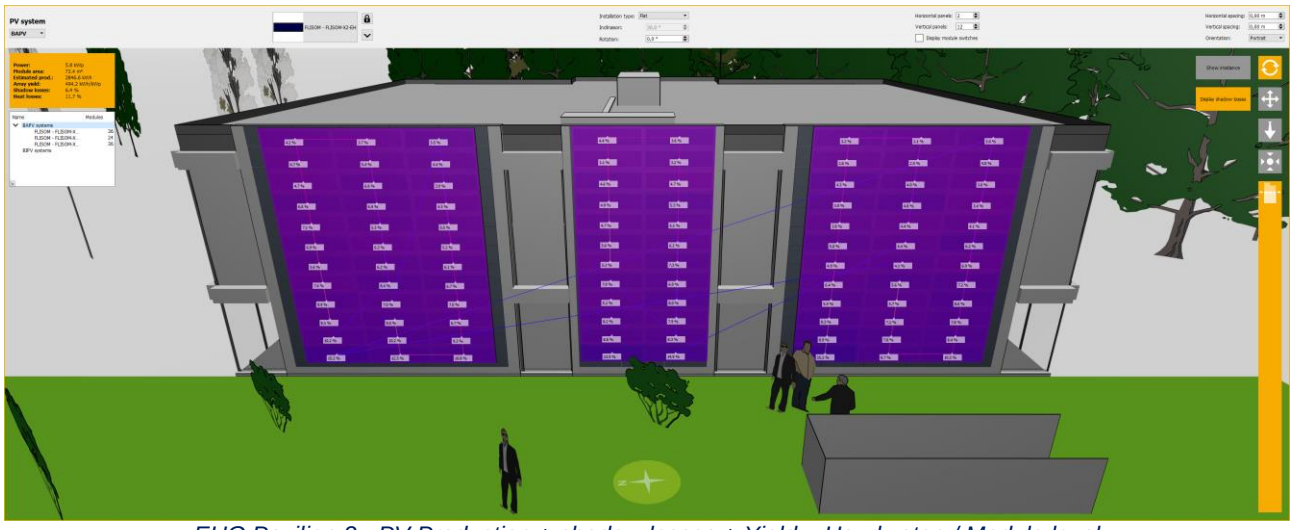
EHG Pavilion 2

ESTIMATION OF ELECTRICAL POWER PRODUCTION (PV ARRAY)						
BIPV UNIT	Orient W	Orient SW	Orient S	Orient SE	Orient E	Unit
EHG Pavilion 1 (Switzerland)					847.2	kWh

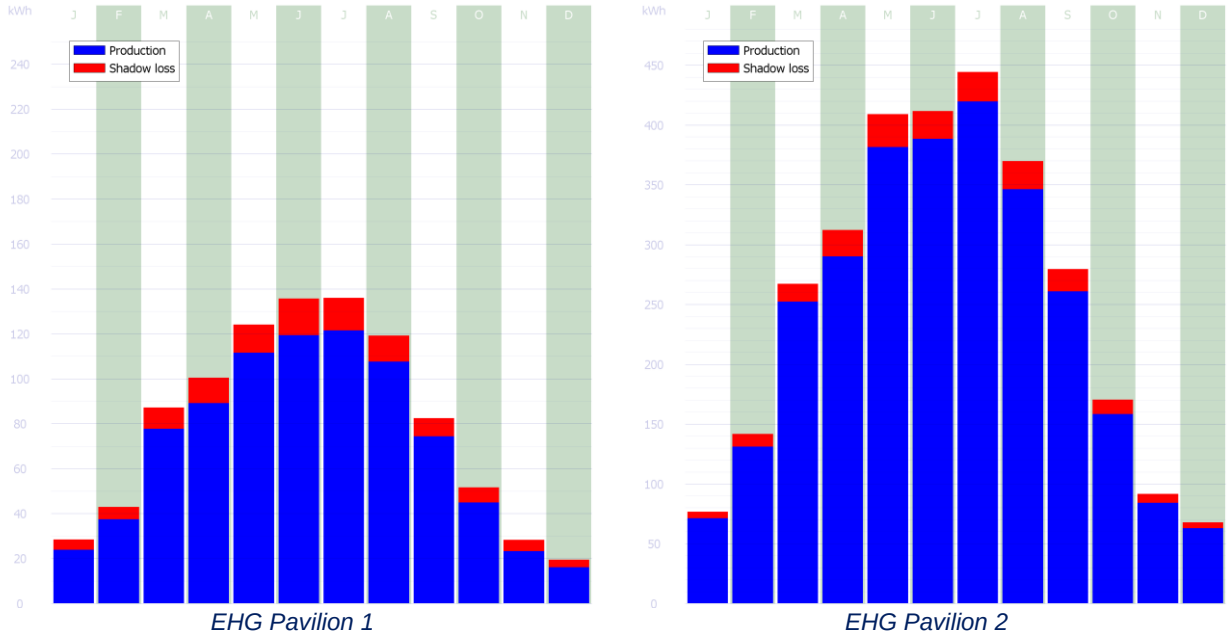
EHG Pavilion 2 (Switzerland)	2846.6					kWh
ARCHITECTURAL UNIT	Orient W	Orient SW	Orient S	Orient SE	Orient E	Unit
EHG Pavilion 1+2 (Switzerland)	3693.8					kWh
PRODUCTION PER M²	Orient W	Orient SW	Orient S	Orient SE	Orient E	Unit
EHG Pavilion 1 (Switzerland)					53.30	kWh/m²
EHG Pavilion 2 (Switzerland)	39.32					kWh/m²
PRODUCTION PER kWp	Orient W	Orient SW	Orient S	Orient SE	Orient E	Unit
EHG Pavilion 1 (Switzerland)					672.4	kWh/kWp
EHG Pavilion 2 (Switzerland)	490.8					kWh/kWp
DC PRODUCTION (INVERTER)	Orient W	Orient SW	Orient S	Orient SE	Orient E	Unit
EHG Pavilion 1 (Switzerland)					803	kWh
EHG Pavilion 2 (Switzerland)	2384					kWh
AC PRODUCTION	Orient E	Orient SE	Orient S	Orient SW	Orient W	Unit
EHG Pavilion 1 (Switzerland)					723	kWh
EHG Pavilion 2 (Switzerland)	2146					kWh



EHG Pavilion 1 - PV Production + shadow losses + Yield – Hourly step / Module level

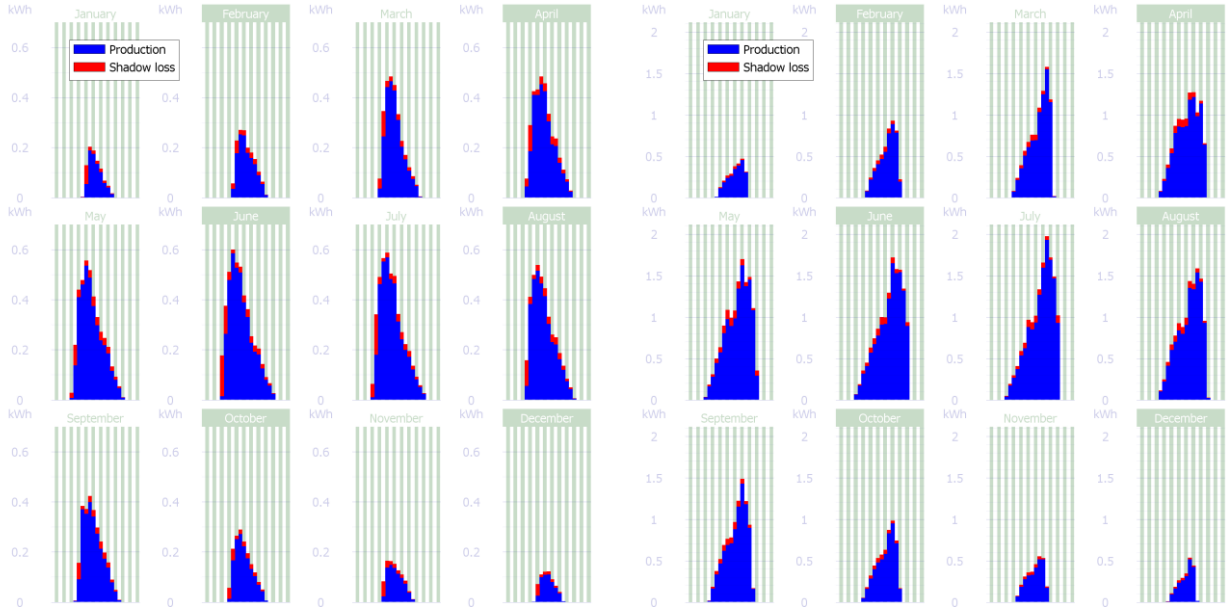


EHG Pavilion 2 - PV Production + shadow losses + Yield – Hourly step / Module level



EHG Pavilion 1 *EHG Pavilion 2*

PV Production + shadow losses – Monthly results



EHG Pavilion 1 *EHG Pavilion 2*

PV Production + shadow losses – Average day per month

6.7 Simulation of Passive Performance – X2

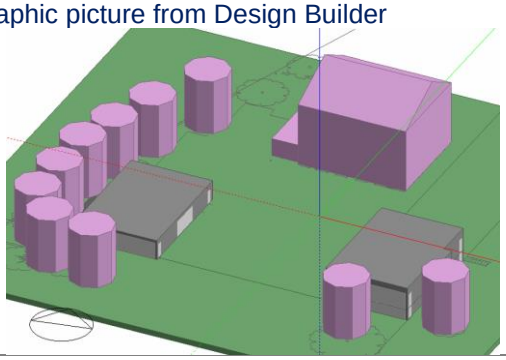
TECHNICAL TEMPLATE REFERENCE	
Technical subject	Passive performance of BIPV modules
Partner	NOBATEK
Author	Baptiste Durand-Estebe

PRODUCT CODE	
Denomination	X2 - eFacade

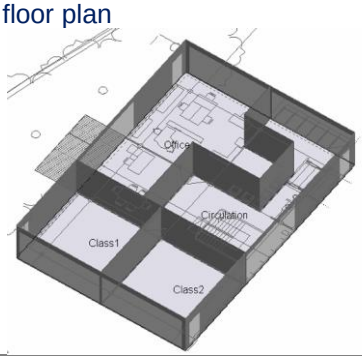
PILOT BUILDING	
Definition	The EHG site is a set of buildings which houses the hotel school EHG (École Hôtelière de Genève). The site includes not only the school facilities but also a hotel to host the students. It is composed of three buildings. The 2 candidates to host the BIPV demo-systems are the recently constructed two-storey buildings (pavilion 1 & 2) placed in the sides of the parcel.
Use	The 3 ground-level buildings house the administrative areas, a restaurant, a showroom, some classrooms and the hotel rooms. Additionally, there is an interconnected underground 4th building where a kitchen, a cafeteria and the technical zones are located. The selected buildings for BIPV installation include classrooms, rooms for students, and administrative offices.
Area	BIPV modules: 136m²
Orientation of PV modules	2 façades facing East and West are equipped with PV modules

DESIGN PLANS

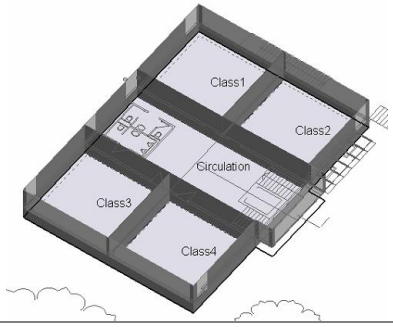
Graphic picture from Design Builder



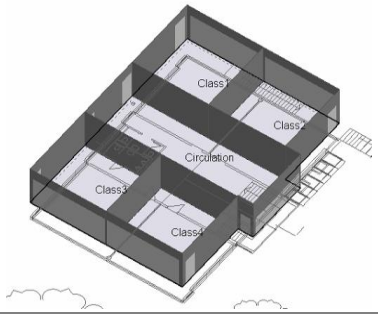
Ground floor plan



First floor plan

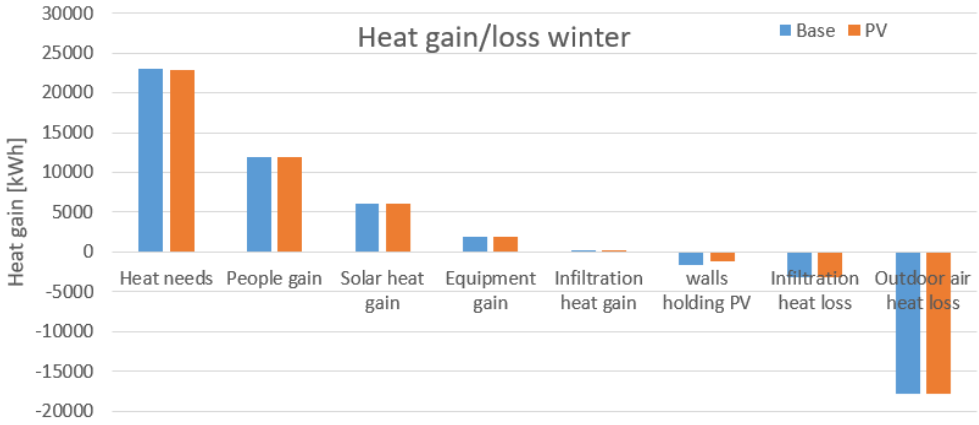


Roof floor plan



Observations.
Modelling parameters of pilot building.

DEMAND AND PRODUCTION OF PILOT BUILDING WITH BIPV SYSTEM			
Location	Geneva		
	Baseline	**With BIPV**	**Unit**
Heating annual demand	23 057	22 822	kWh
Cooling annual demand	Passive comfort	Passive comfort	
Total annual H/C demand	23 057	22 822	kWh
Lighting needs	The BIPV system has no influence on lighting		
Overall increase/reduction	-1%		



EHG internal heat gains

6.8 Maintenance and Dismantling – X2

TECHNICAL TEMPLATE REFERENCE	
Technical subject	Maintenance and dismantling of products and installations
Partner	Flisom
Author	Julian Perrenoud

PRODUCT CODE	
Denomination	X2 - eFacade

MAINTENANCE		
	Periodicity (months)	Description
Action 1	4	Visual check
Action 2	When required	Remove dust and dirt (sediments, leaves, pollen, bird droppings, etc.) from the surface
Action 3	4	Check if connectors and grounding are tight and without corrosion and if the insulation is not damaged also check for loose mechanical or electrical contacts
Action 4	4	Check if the Junction Box is securely attached and that no deep scratches are penetrating the frontsheet
Observations. Do not use aggressive cleaning agents or scrubbing materials for cleaning Do not use steam blasting for cleaning Use soft water to avoid chalk stains Soft Sponges can be used		

6.9 Life Cycle Assessment – X2

TECHNICAL TEMPLATE REFERENCE	
Technical subject	Life cycle assessment of products and installations
Partner	CTCV
Author	Marisa Almeida

PRODUCT CODE	
Denomination	X1 - eFacade

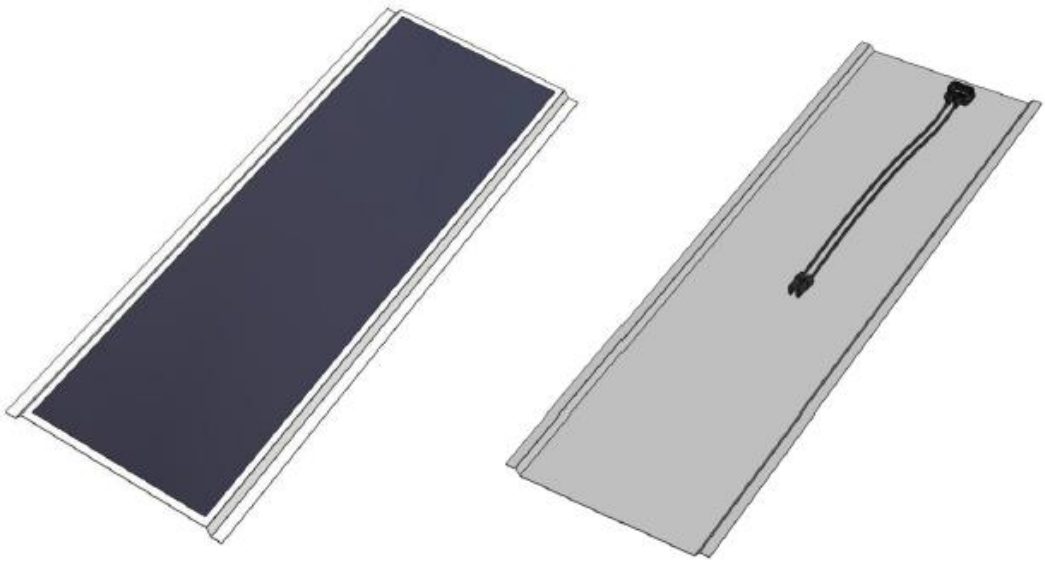
LCA INDICATORS					
	Value 1	Unit 1			
Global warming	39,7	Kg CO2 eq/m^2			
Acidification	0,264	mol H+ eq/m^2			
Terrestrial Eutrophication	0,433	mol N eq /m^2			
Freshwater Eutrophication	0,0057	Kg P eq/m^2			
Photochemical oxidation formation	0,157	kg NMCOV eq /m^2			
Abiotic depletion	1,34	g Sb/m^2			
Ozone layer depletion	1,63E-05	kg CFC-11 eq/m^2			
Human Toxicity	6,63E-07	CTUh /m^2			
Observations: Provisional data based on specific ACV for this GIGs. LCA methodology: ISO14040/ISO14044 with CML and ILCD methods. Some results are better than the average for GIGs with similar properties					

7 X4 eRoof – Industrial

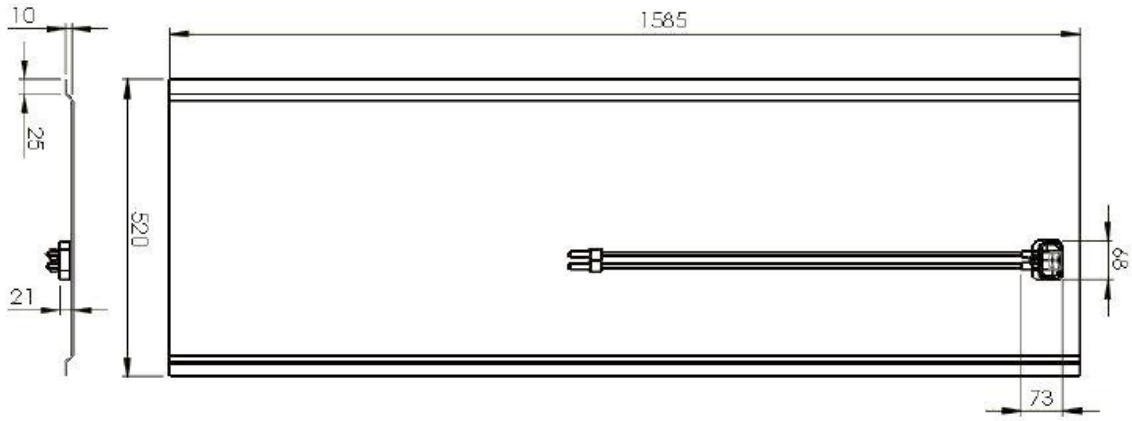
7.1 General Description, Design and Materials – X4

TECHNICAL TEMPLATE REFERENCE	
Technical subject	General description, design and materials of BIPV modules.
Partner	Flisom/ Tecnalia
Author	Julian Perrenoud/ Daniel Valencia

PRODUCT CODE	
Project	PVSITES. Task 2.7. BIPV products portfolio
Category	Roof
Denomination	X4 - eRoof-Industrial
Partner/s	Flisom

PICTURES
REALISTIC DRAWING / ARTIST IMPRESSION

Observations: The eRoof module for Cricursa is a semi-flexible and lightweight solar panel designed for BIPV installation on trapezoidal roof structures

DESIGN DRAWINGS



PHOTOS

DETAILED DESCRIPTION	
Definition	Semi-flexible and lightweight solar panel designed for BIPV installation on trapezoidal roof structures
Construction unit	Module for roof
Architectural location	Roof
Geometrical design	Rectangular
Dimensions	1585 x 520 x 21 mm
Geometrical shape	Rectangular
Configuration	Monolithic unit
Layers	The layers from back to front are: 0.7 mm mMild steel backsheet with PVDF coating, black RAL 9005; encapsulant TPO 0.4 mm; PV film CIGS grown on polyimide with Mo and ZnO electrical contacts; encapsulant TPO 0.4 mm; barrier film 0.4 mm; the module is sealed with edge seal ~1cm width.

Frame structure	Aluminium
PV technology	CIGS (Thin film)
Physical features	Descriptive value
Weight	5.8 Kg / unit
Rigidity	Semi-flexible
Opacity	Opaque
Mobility	Fixed
Photovoltaic power	50-60 Wp / unit
Optical transmittance	Opaque

7.2 Mechanical Performance – X4

TECHNICAL TEMPLATE REFERENCE	
Technical subject	Mechanical performance of BIPV modules
Partner	Flisom / Tecnalia
Author	Julian Perrenoud / Daniel Valencia

PRODUCT CODE	
Denomination	X4 - eRoof-Industrial

DESIGN/DATASHEET VALUES						
BIPV UNIT						
General characteristics	Semi-flexible and lightweight solar panel designed for BIPV installation on trapezoidal roof structures					
Manufacturer	Flisom					
Model	Roof module					
Shape	Rectangular					
Physical characteristics	Value 1	Unit 1	Value 2	Unit 2	Value 3	Unit 3
Height/ Length/ Thickness	1585	mm	520	mm	21	mm
Weight	5.8	kg				
Mechanical characteristics	Value 1	Unit 1	Value 2	Unit 2	Value 3	Unit 3
Max. mechanical load	2400	Pa				

7.3 Architectural Integration – X4

TECHNICAL TEMPLATE REFERENCE	
Technical subject	Architectural integration of BIPV products
Partner	BEAR / Flisom
Author	Tjerk Reijenga / Julian Perrenoud

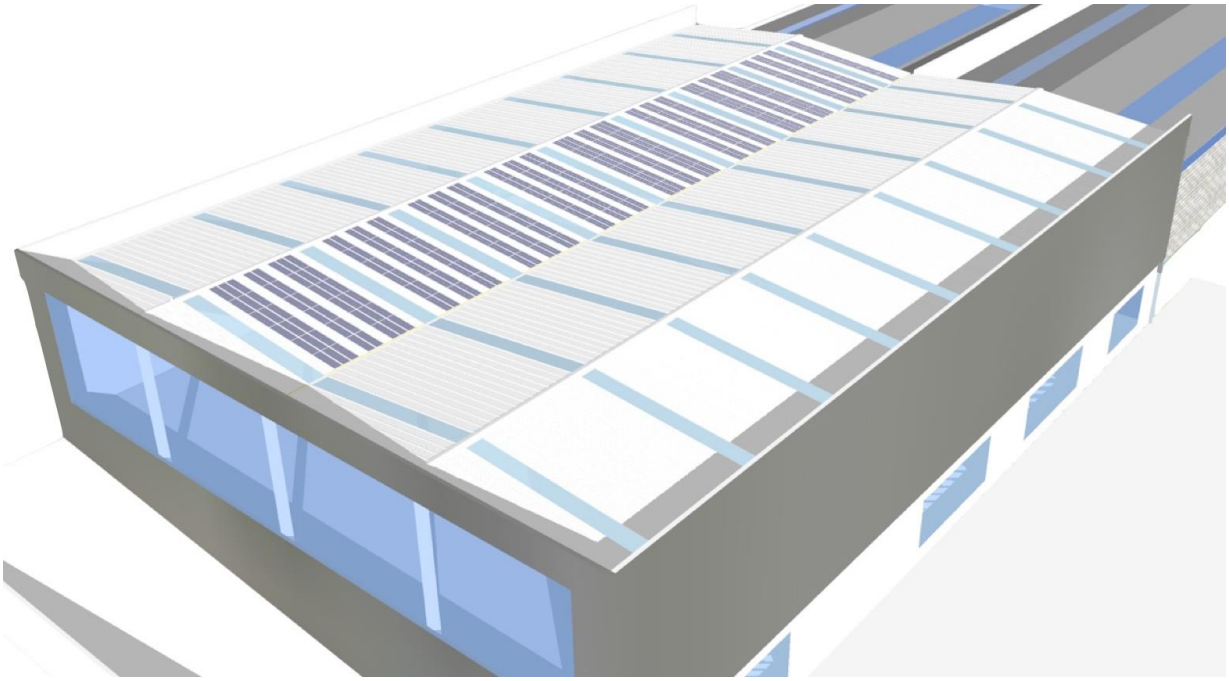
PRODUCT CODE	
Denomination	X4 - eRoof-Industrial

DEFINITION AND LOCATION	
Definition	Semi-flexible and lightweight solar panel designed for BIPV installation on trapezoidal roof structures
Construction unit	Roofing module
Location	Granollers Barcelona
Architectural location	Roof

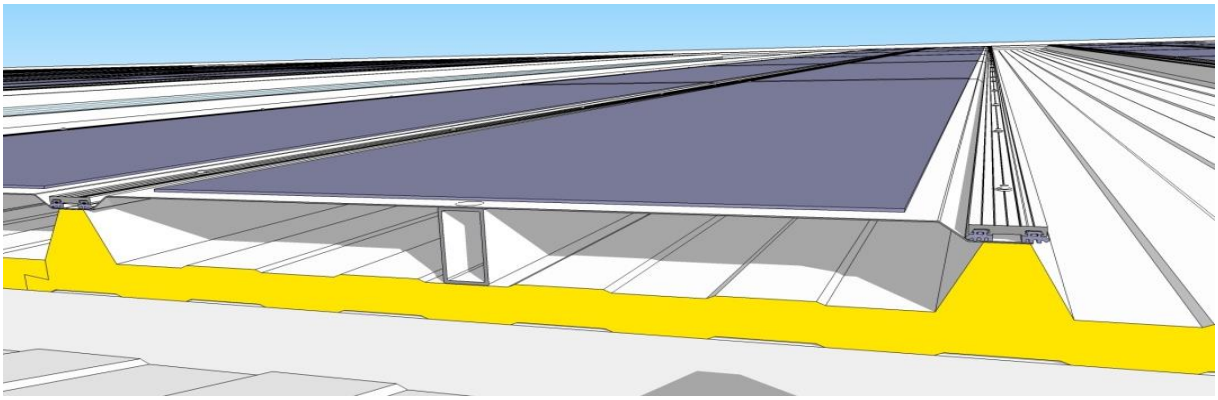
CONSTRUCTION UNIT FEATURES						
Physical properties	Length	Unit 1	Width	Unit 2	Height	Unit 3
Shape	Rectangular					
Dimensions	1574	mm	479	mm	22	mm
Weight	2.5	kg	3.32	kg/m^2		
Materials and devices	Bended mild steel sheet with laminated cells on top					
PV technology	CIGS					
Location of pipes, diameters	Dimensions, drawing					
Thermal bridge	No					
Aesthetical features	Modules are tailor made and can fit the whole area. This increase the aesthetics and added value.					
Opacity	Opaque					
Cell colour	Very dark blue / black					
Background colour	White RAL 9010					

INTEGRATION AND MAINTENANCE MEASURES	
Mounting system	Mounted on the underlying (steel) structure or roof structure

Secondary construction	n.a.
Procedure	
New construction permits needed	Part of building permit. Based on local regulation.
Retrofitting permits needed	Building permit needed
Maintenance	Cleaning depending on location.
Inspection	Physical inspection
Sequence of inspection	Yearly

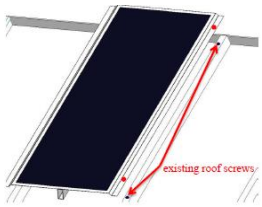
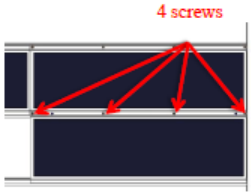
PICTURES
Integration method /details

View of the building with demo roof

Birdview of the demo roof (Simulated and actual taken with drone)



Construction detail

Flisom modules can be operated in the range of -40°C to 85°C. Depending on the area it is necessary to protect the modules from standing water, snow or extreme soiling. At consistent solar radiation Flisom PV modules generate more power at lower temperatures. To improve the energy yield of the plant increasing cooling or ventilation is an option. Flisom PVSITES modules use thin metal sheets as backsheet. Hence, they can bend by applying forces while installation (e.g. dropping on the corner). Please handle with care. Store modules in a dry place. Do not transport modules without packaging. Do not put modules on top of each other to avoid small scratches (this can accelerate module degradation by environmental factors). Do not use JB cables as handles to carry or lift the modules. Be cautious when frontsheet is wet since the surface could lose grip. Do not apply solvents, adhesives, paint or stickers on the frontsheet. Do not place the modules face-down in direct contact to abrasive surfaces. Keep a minimum distance of 5mm between the edges of single modules to take thermal expansion into account. Only use compatible materials. Use special roof screws and EPDM sealing to ensure a waterproof roof.

1. Position the first module and mark the position of the existing screws	2. Stamp out holes on the marked positions. Screw the module 4 times on one side on the roof	3. Screw the middle of the module on the roof (2 options)	4. Start the next module row and screw them together with the first row module on the roof
			

7.4 Electrical Performance – X4

TECHNICAL TEMPLATE REFERENCE	
Technical subject	Electrical performance of BIPV modules
Partner	Flisom / Tecnalia
Author	M. Schweizer / Daniel Valencia

PRODUCT CODE	
Denomination	X4 - eRoof-Industrial

DESIGN/DATASHEET VALUES	
PHOTOVOLTAIC CELL/ ARRAY	
General characteristics	Semi-flexible and lightweight solar panel designed for BIPV installation on trapezoidal roof structures
Manufacturer	Flisom
Cell type	Flexible CIGS
Shape	Rectangular
Colour	Black
Front layer	ETFE

Frame	none					
Connection Box	Back side					
Connectors	MC4					
Physical characteristics	Value 1	Unit 1	Value 2	Unit 2	Value 3	Unit 3
Height/ Length/ Thickness	1585	mm	520	mm	21	mm
Electrical characteristics	Value 1	Unit 1	Value 2	Unit 2	Value 3	Unit 3
Rated power	50-60	Wp	66-80	Wp/m^2		
Vpm: max. power voltage	34-36	V				
Ipm: max. power current	1.47-1.66	A				
Voc: open circuit voltage	46-48	V				
Isc: short circuit current	1.72-1.91	A				
Thermal parameters	Value 1	Unit 1	Value 2	Unit 2	Value 3	Unit 3
NOCT: stand. oper. temp.		ºC				-
Isc (α) Temp. coefficient	0.01	%/ºC				-
Voc (β) Temp. coefficient	-0.3	%/ºC				-
P (γ) Temp. coefficient	-0.35	%/ºC				-
Operating range						
Temperature	-40 – 85	ºC				
Maximum System Voltage	1000	V				

Observations:

For elevated areas irradiation can be higher than at STC. Therefore, multiply ISC- and VOC- values with a factor of 1.25 for the electrical layout of cables, fuses and converters (worst case scenario). For a serial connection the voltage of a single module is multiplied by the number of modules to calculate the system voltage. Make sure that you are always within the limits of the maximum system voltage. Use an adequate device for overcurrent protection (fuse, blocking diode). Maximum Isc multiplied by a factor of 1.56 to protect a string in parallel configuration.
The maximum number of modules connectable in series is calculated by adding Voc of each single module multiplied by 1.25 up to the maximum system voltage which you can find on the label.

Backsheet of Flisom PVSITES modules are made of metal and have to be connected to the ground. Also ground the support structure and arrange an adequate lightning protection. Do not use materials which can cause corrosion. The hole for the grounding cable can be drilled anywhere in the edges of the module frame. If the backsheet of the module and the support structure/clamps are conductive it is not necessary to ground every module. The grounding of the support structure is sufficient. Make sure that you do not damage the edge seal or frontsheet.
Do not use PV modules of different power classes or configurations in the same PV system. Flisom facade modules use MC4 connectors. Only use these connectors or compatible connector types which are authorised from both producers.

Use solar cables for outside use (ø 2.5 to 4mm² and min. 90 °C).
Secure all electrical connections and use stress relief appliances. Do not go below the minimum bending radius of the cables. Use cable guides to prevent connectors and cables from lying in excess water, snow or dirt.
The junction box is not to be opened. The diode cannot be repaired.
Orientation of the shadow on the active surface is crucial: the panel may only be installed as in fig 2 (Parallel shade). To compare, fig 3 shows a series shade - shading the complete length of several full cells. This type of casting shadow will negatively affect the power.

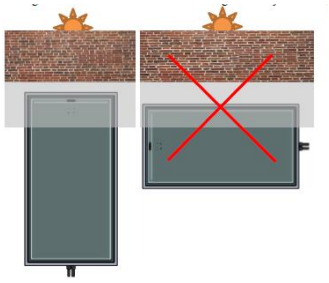
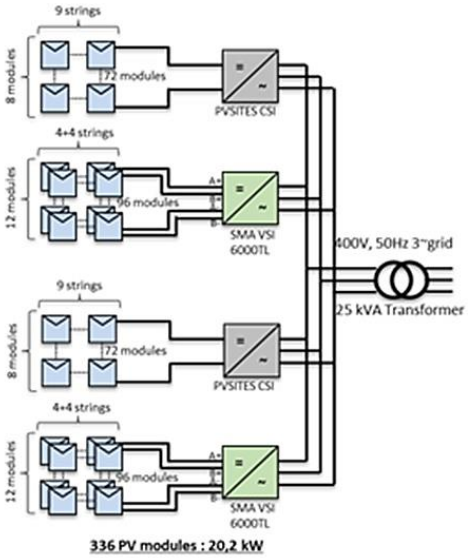


Fig 2: parallel shade Fig 3: series shade

Suitable inverter configurations are: Central inverters, String inverters, Multi-String inverters, Inverters on single module level

POWER MANAGEMENT SYSTEM (demos)						
General characteristics	Semi-flexible and lightweight solar panel designed for BIPV installation on trapezoidal roof structures					
Manufacturer	Flisom					
Model	Roof module					
Physical characteristics	Value 1	Unit 1	Value 2	Unit 2	Value 3	Unit 3
PV area	213.6	m^2		mm		mm
Total DC Power	19.3	kWp				
Number of modules	324					
Inverters	2 x (SMA VSI 6000TL) + 2 x (PVSites CEA inverter)					
Electrical DC characteristic for 1 inverter	PVsites CEA inv	SMA VSI 6000TL	Units			
PV modules in series	8	12				
PV modules in parallel	9	4 (A) + 4 (B)				
Number of PV modules	72	96				
DC max power	4.32	5.76	kW			
DC max voltage	384	576	V			
DC max current	17.19	7.64 + 7.64	A			

Observations:



7.5 Optical Performance – X4

TECHNICAL TEMPLATE REFERENCE	
Technical subject	Optical performance of BIPV modules
Partner	**Tecnalia**
Author	**Maider Machado / Daniel Valencia**

PRODUCT CODE	
Denomination	X4 - eRoof-Industrial

DESIGN/DATASHEET VALUES						
BIPV UNIT						
General characteristics	Semi-flexible and lightweight solar panel designed for BIPV installation on trapezoidal roof structures					
Manufacturer	Flisom					
Model	Roof module					
Shape	Rectangular					
Physical characteristics	Value 1	Unit 1	Value 2	Unit 2	Value 3	Unit 3
Height/ Length/ Thickness	1585	mm	520	mm	21	mm
PV ratio (PVR)	~100	%				
Optical characteristics	Value 1	Unit 1	Value 2	Unit 2	Value 3	Unit 3

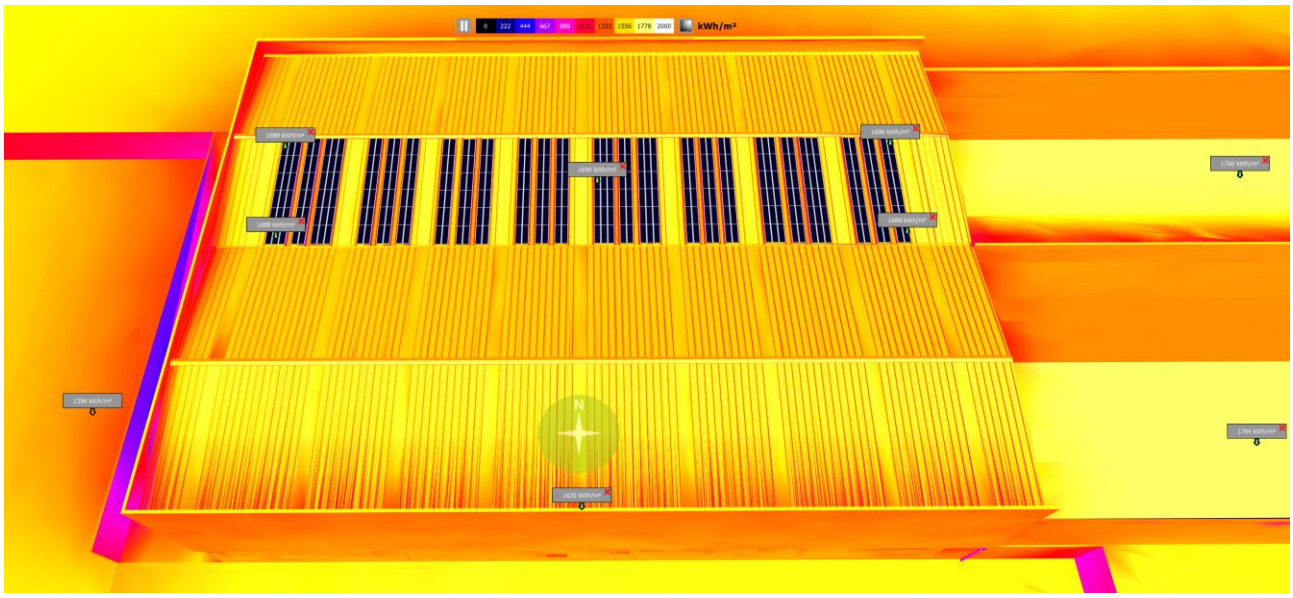
Visible transmittance	0	%	-	-	-	-
Solar transmittance	0	%	-	-	-	-
Visible reflectance (tz)	-	%	-	-	-	-
Solar reflectance (tz)	-	%	-	-	-	-
Visible reflectance (cz)	5	%	-	-	-	-
Solar reflectance (cz)	8.9	%	-	-	-	-
Visible absorptance (tz)	-	%	-	-	-	-
Solar absorptance (tz)	-	%	-	-	-	-
Visible absorptance (cz)	95	%	-	-	-	-
Solar absorptance (cz)	91.1	%	-	-	-	-
Observations: Absorptance is calculated from transmittance and reflectance values. Acronym (tz): transparent zone. Acronym (cz): cell zone.						

7.6 Estimation of PV production – X4

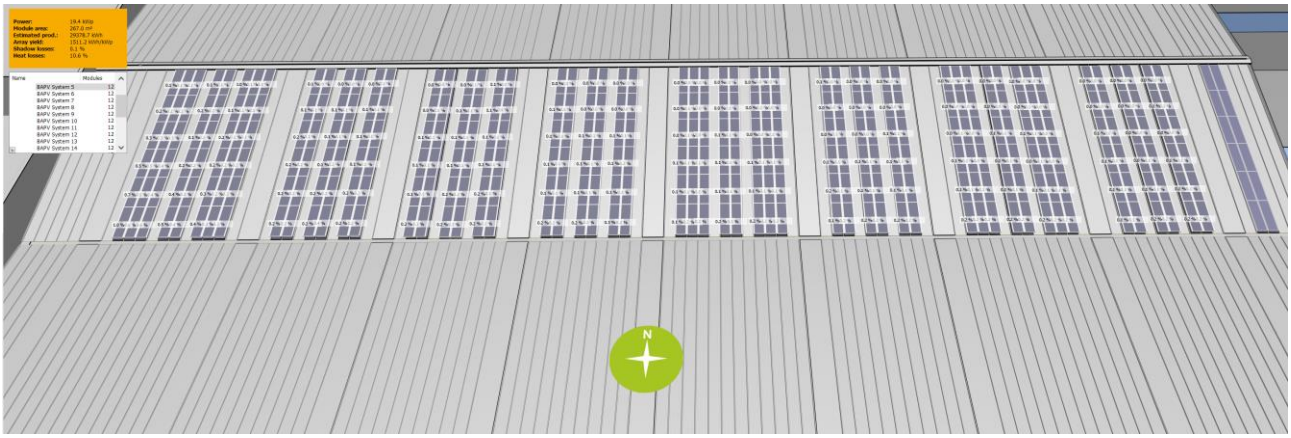
TECHNICAL TEMPLATE REFERENCE	
Technical subject	PV production of BIPV modules
Partner	CADCAMation
Author	Philippe ALAMY

PRODUCT CODE	
Denomination	X4 eRoof-Industrial

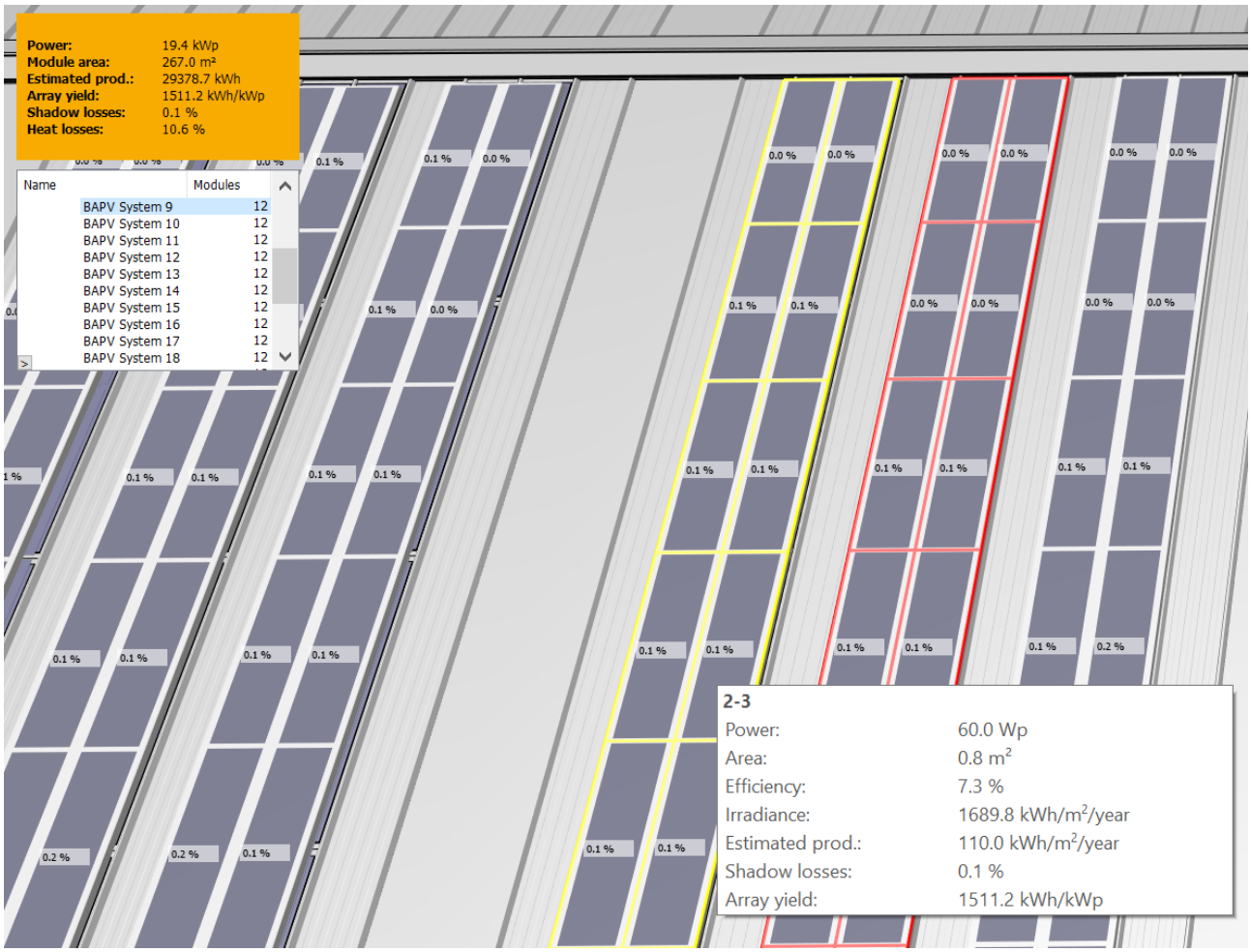
SIMULATING CONDITIONS: exact location = GRANOLLERS (TMY to epw file built with PVGIS)						
ANNUAL GLOBAL IRRADIANCE	Orient E	Orient SE	Orient S	Orient SW	Orient W	Unit
Granollers (Spain)	…	…	1690	…	…	kW/m^2
MEDIUM TEMPERATURE	Med	Min	Max	-	-	Unit
Granollers (Spain)	15.0	8.4	24.1	-	-	ºC
MEDIUM WIND SPEED	Med	Min	Max	-	-	Unit
Granollers (Spain)	…	…	…	-	-	m/s



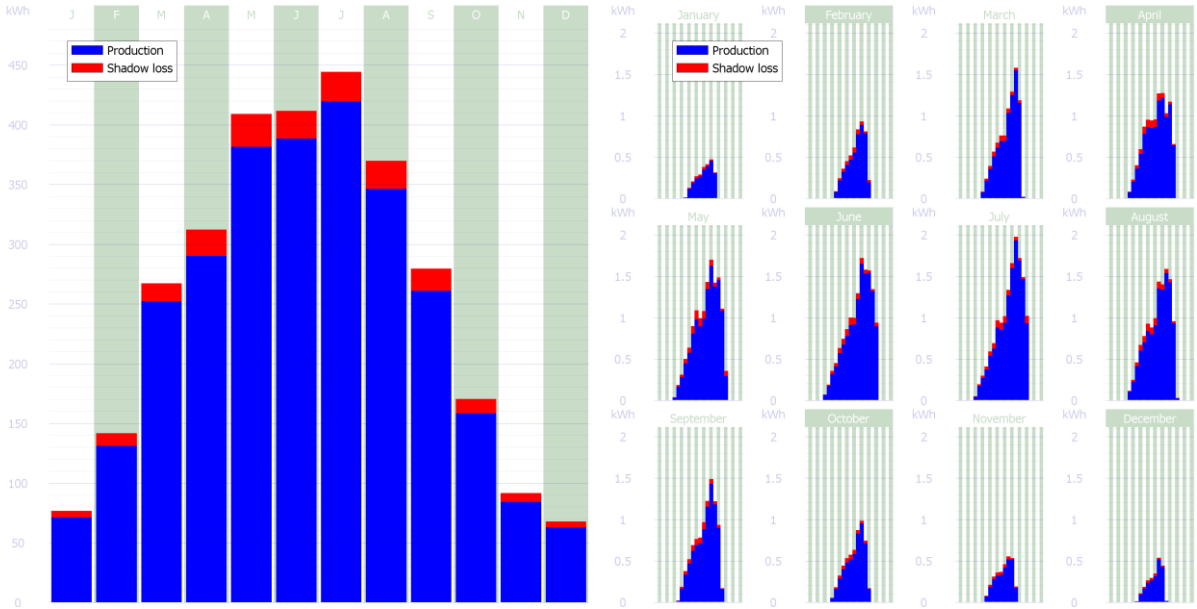
ESTIMATION OF ELECTRICAL POWER PRODUCTION (from PV ARRAY to INVERTER) - ANNUAL						
BIPV UNIT	Orient E	Orient SE	Orient S	Orient SW	Orient W	Unit
Granollers (Spain)		…	29,379	…	…	kWh
ARCHITECTURAL UNIT	Orient E	Orient SE	Orient S	Orient SW	Orient W	Unit
Granollers (Spain)	…	…	29,379	-	-	kWh
PRODUCTION PER M²	Orient E	Orient SE	Orient S	Orient SW	Orient W	Unit
Granollers (Spain)	…	…	110.03	-	-	kWh/m²
PRODUCTION PER kWp	Orient E	Orient SE	Orient S	Orient SW	Orient W	Unit
Granollers (Spain)			1514			kWh/kWp
DC PRODUCTION (INERTER)	Orient E	Orient SE	Orient S	Orient SW	Orient W	Unit
Granollers (Spain)	…	…	28,049	-	-	kWh
AC PRODUCTION (INERTER)	Orient E	Orient SE	Orient S	Orient SW	Orient W	Unit
Granollers (Spain)			27,289			kWh



CRICURSA Roof - PV Production + shadow losses + Yield – Hourly step / Module level



CRICURSA Roof - PV Production + shadow losses + Yield – Hourly step / Module level



Monthly / Average day per month PV Production + heat losses

7.7 Maintenance and Dismantling – X4

TECHNICAL TEMPLATE REFERENCE	
Technical subject	Maintenance and dismantling of products and installations
Partner	Flisom
Author	Julian Perrenoud

PRODUCT CODE	
Denomination	X4 eRoof-Industrial

MAINTENANCE		
BY THE USER	Periodicity (months)	Description
Action 1	3	Visual check
Action 2	When required	Remove dust and dirt (sediments, leaves, pollen, bird droppings, etc.) from the surface
Action 3	**3**	**Check if connectors and grounding are tight and without corrosion and if the insulation is not damaged also check for loose mechanical or electrical contacts.**
Action 4	3	Check if the Junction Box is securely attached and that no deep scratches are penetrating the frontsheet
Observations. Do not use aggressive cleaning agents or scrubbing materials for cleaning Do not use steam blasting for cleaning Use soft water to avoid chalk stains Soft sponges can be used		

7.8 Life Cycle Assessment – X4

TECHNICAL TEMPLATE REFERENCE	
Technical subject	Life cycle assessment of products and installations
Partner	CTCV
Author	Marisa Almeida

PRODUCT CODE	
Denomination	X4 eRoof-Industrial

LCA INDICATORS					
	Value 1	Unit 1			
Global warming	36,3	Kg CO2 eq/m^2			
Acidification	0,235	mol H+ eq/m^2			
Eutrophication	0,401	mol N eq /m^2			
Freshwater Eutrophication	0,0056	Kg P eq/m^2			
Photochemical oxidation formation	0,144	kg NMCOV eq /m^2			
Abiotic depletion	1,33	g Sb/m^2			
Ozone layer depletion	6,73E-06	kg CFC-11 eq/m^2			
Human Toxicity	8,78E-07	CTUh /m^2			
Observations: Provisional data based on specific ACV for this GIGsLCA methodology: ISO14040/ISO14044 with CML and ILCD methods. Most of the results are better than the average for GIGs with similar properties					

8 X5 C-Si glazed products with hidden bus bars and L interconnections

8.1 General Description, Design and Materials – X5

TECHNICAL TEMPLATE REFERENCE	
Technical subject	General description, design and materials of BIPV modules.
Partner	Onyx Solar
Author	Léo Staccioli/Elena Rico

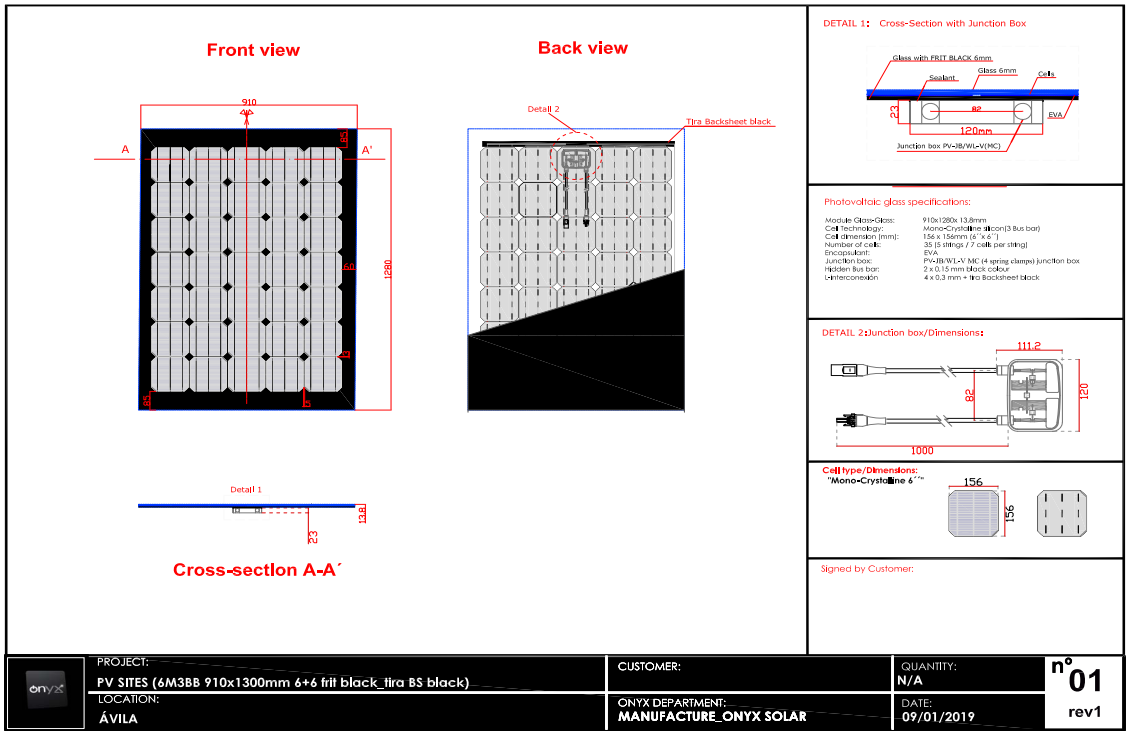
PRODUCT CODE	
Project	PVSITES. Task 2.3. BIPV products portfolio
Category	Ventilated façade/ Curtain wall
Denomination	X5 - c-Si glazed products with hidden bus bars and L interconnections
Partner/s	Onyx Solar

PICTURES	
PHOTOS	
	
Observations: Final appearance of PV rectangular c-Si opaque modules with hidden busbars and L-interconnections (1st generation) (front and back views). Technical data provided for X5 corresponds to the 1st generation prototype. In 1st generation prototypes, only L-interconnections are hidden.	

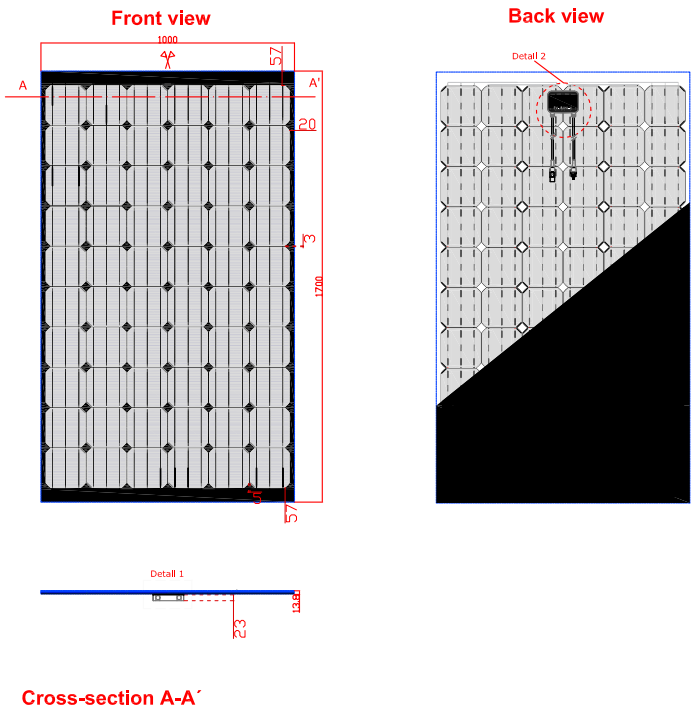
Front view

Back view

Observations:
Front and back views of hidden busbars and L-interconnections product (2nd Generation) (both, busbars and L-interconnections are hidden)



Manufacturing drawings of product X5-1 (17-02-06): 1st generation prototype drawing



Manufacturing drawings of product X5-1 (17-02-06): 2nd generation prototype drawing

PHOTOS

Installed BIPV system.

DETAILED DESCRIPTION	
Definition	PV rectangular c-Si opaque modules with hidden busbars and L-interconnections
Construction unit	Ventilated façade/Curtain wall
Architectural location	Façade
Geometrical design	Rectangular opaque module
Dimensions	Length: 1700 mm, Width: 1000 mm; Thickness: 13.8 mm

Geometrical shape	Rectangular/Customizable
Materials	PV glazing (Extraclear tempered glass, EVA, c-Si cells, Black frit patterned glass, black plastic sheet)
Configuration	Double glazing or simple laminated glass
Layers	From top to bottom: Extraclear tempered glass EVA, c-Si solar cells, EVA Black frit patterned glass
Frame structure	Frameless
PV technology	Si-monocrystalline
Encapsulation material	EVA
Surface treatments	Rear glass with black frit / Customizable
Thermal insulation	Common glazing technologies can be used (double/triple glazing, low-E coatings, etc)
Acoustic insulation	Double/triple glazing can be used.
Physical features	Similar to classic c-Si modules
Weight	30 kg/m^2 (glazing)
Rigidity	Rigid
Opacity	Opaque
Mobility	No mobile parts
Active energy features	Photovoltaic glazing that generates electricity with Sun radiation
Photovoltaic power	153 Wp/m^2. Variable depending on cell density (PVR)
Thermal transmittance (U value)	Defined by glazing system used

8.2 Mechanical Performance – X5

TECHNICAL TEMPLATE REFERENCE	
Technical subject	Mechanical performance of BIPV modules
Partner	Onyx Solar
Author	Léo Staccioli/Elena Rico

PRODUCT CODE	
Denomination	X5 - c-Si glazed products with hidden bus bars and L interconnections

DESIGN/DATASHEET VALUES		
BIPV UNIT		
General characteristics	PV rectangular c-Si opaque modules with hidden L-interconnections	
Manufacturer	Onyx Solar	
Model	c-Si Opaque PV glazing with hidden busbars and L-interconnections	
Shape	Rectangular	
Physical characteristics	PV glazing	Unit
Length / Width/ Thickness	1700/ 1000/ 13.8	mm
Weight	30	Kg/ m^2
Mechanical characteristics	Glass mechanical properties	
Tensile strength	120-200 (tempered); 40 (float)	MPa
Tensile modulus	~70	GPa
Poisson coefficients	0.22	-
Observations: Mechanical characteristics are the ones from the glass layers, which are the main mechanical material of the PV glazing		

8.3 Architectural Integration – X5

TECHNICAL TEMPLATE REFERENCE	
Technical subject	Architectural integration of BIPV products
Partner	Onyx Solar / BEAR
Author	Léo Staccioli / Tjerk Reijenga / Elena Rico

PRODUCT CODE	
Denomination	X5 - C-Si glazed products with hidden bus bars and L interconnections

DEFINITION AND LOCATION	
Definition	PV rectangular c-Si opaque modules with hidden L-interconnections
Construction unit	Ventilated façade/Curtain wall
Architectural location	Façade (Demo building France)

CONSTRUCTION UNIT FEATURES						
Physical properties	Length	Unit 1	Width	Unit 2	Thickness	Unit 3
Shape	Rectangular					
Dimensions of installed modules (not prototypes)	1280	mm	910	mm	13.8	mm
Weight			30	kg/m^2		
Materials and devices	PV glazing (double or simple). Includes junction box at the back					
Configuration	Double glazing					
Frame structure	Frameless					
PV technology	Si-mono-crystalline 156x156mm solar cells					
Location of pipes, diameters	Each PV glazing will have two cables. Cables can be housed in the structure					
Thermal insulation	Common glazing thermal insulation strategies can be used					
Thermal bridge	No					
Aesthetical features	Hidden solar cells interconnections. Fully black appearance.					
Opacity	Opaque (Black rear frit patterned glass)					
Cell colour	Dark blue					
Background colour	Black					
Surface treatments	Surface technologies for glass can be used					

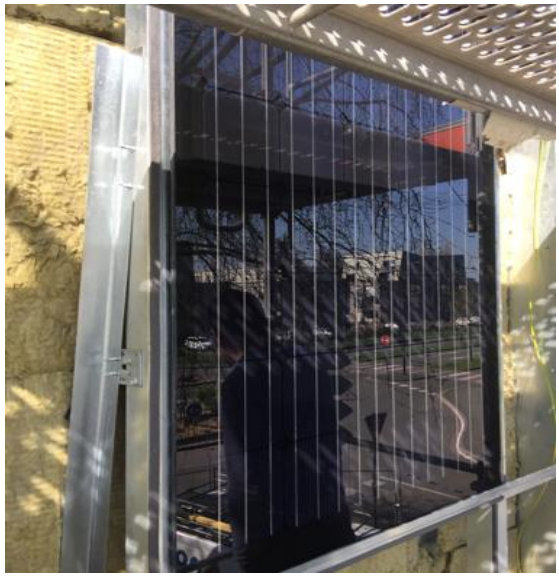
INTEGRATION AND MAINTENANCE MEASURES	
Construction	Ventilated façade
Mounting system	Common ventilated façade/curtain wall systems
Secondary construction	n.a.
Procedure	
New construction permits needed	Based on local regulations
Retrofitting permits needed	Based on local regulations
Maintenance	Cleaning periodic activities, in order to avoid performance losses
Inspection	Remote monitoring / Physical inspection ✓ Checking system connections ✓ Checking cable system ✓ Checking the sealing of the junction boxes ✓ Checking the structural pieces in the structure that supports the photovoltaic modules ✓ Checking if any glass may be fractured ✓ Checking all segments of the BOS ✓ Checking all the earth connections

Sequence of inspection	At least twice a year
Maintenance for the system	Yes
Sequence of maintenance	Cleaning activities depending on the environmental conditions
Accessibility of system	PV modules are accessible from the exterior.
Safety procedure	Description of safety procedure needed
Removal	Same removal process than normally façade elements, take care of disconnecting cables
Accessibility for removal	PV modules are accessible from the exterior.
Ease of removal	Same removal process than normally façade elements, take care of disconnecting cables
Safety procedure needed	Glazing system should comply with standards (f.i. CWCT note 67 or ETAG 034) in order to guarantee safety accessibility

PICTURES

Integration method

Before and after installation



Ventilated façade mounting system

8.4 Electrical Performance – X5

TECHNICAL TEMPLATE REFERENCE	
Technical subject	Electrical performance of BIPV modules
Partner	Onyx Solar
Author	Léo Staccioli/Elena Rico

PRODUCT CODE	
Denomination	X5 - c-Si glazed products with hidden bus bars and L interconnections

DESIGN/DATASHEET VALUES	
PHOTOVOLTAIC CELL/ ARRAY	
General characteristics	Si-mono-crystalline PV glazing
Manufacturer	Not specific cell provider required
Cell type	Mono-crystalline silicon. 156x156 mm solar cell with three BB
Module Shape	Rectangular
Colour	Dark Blue
Front layer	Extraclear tempered glass
Frame	Frameless PV glass
Connection Box	Non specific
Cables	4 mm^2 up to 1000V
Connectors	MC4
Series-parallel connection	Non-parallel connection within one module

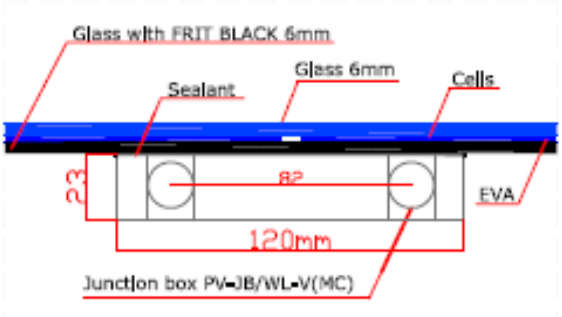
Physical characteristics	Value 1	Unit 1	Value 2	Unit 2	Value 3	Unit 3
Width/ Length/ Thickness	1000	mm	1700	mm	13.8	mm
Electrical characteristics	Value 1	Unit 1	Value 2	Unit 2	Value 3	Unit 3
Rated power	260	Wp	153	Wp/m^2		-
Efficiency	15	%		-		-
Vpm: max. power voltage	31.5	V		-		-
Ipm: max. power current	8.28	A		-		-
Voc: open circuit voltage	40.6	V		-		-
Isc: short circuit current	8.45	A		-		-
Thermal parameters	Value 1	Unit 1	Value 2	Unit 2	Value 3	Unit 3
Isc (α) Temp. coefficient	+0.08	%/ºC				-
Voc (β) Temp. coefficient	-0.361	%/ºC				-
P (γ) Temp. coefficient	-0.451	%/ºC				-
Operating range						
Temperature	-40 - +85	ºC				
Maximum System Voltage	1000	V				

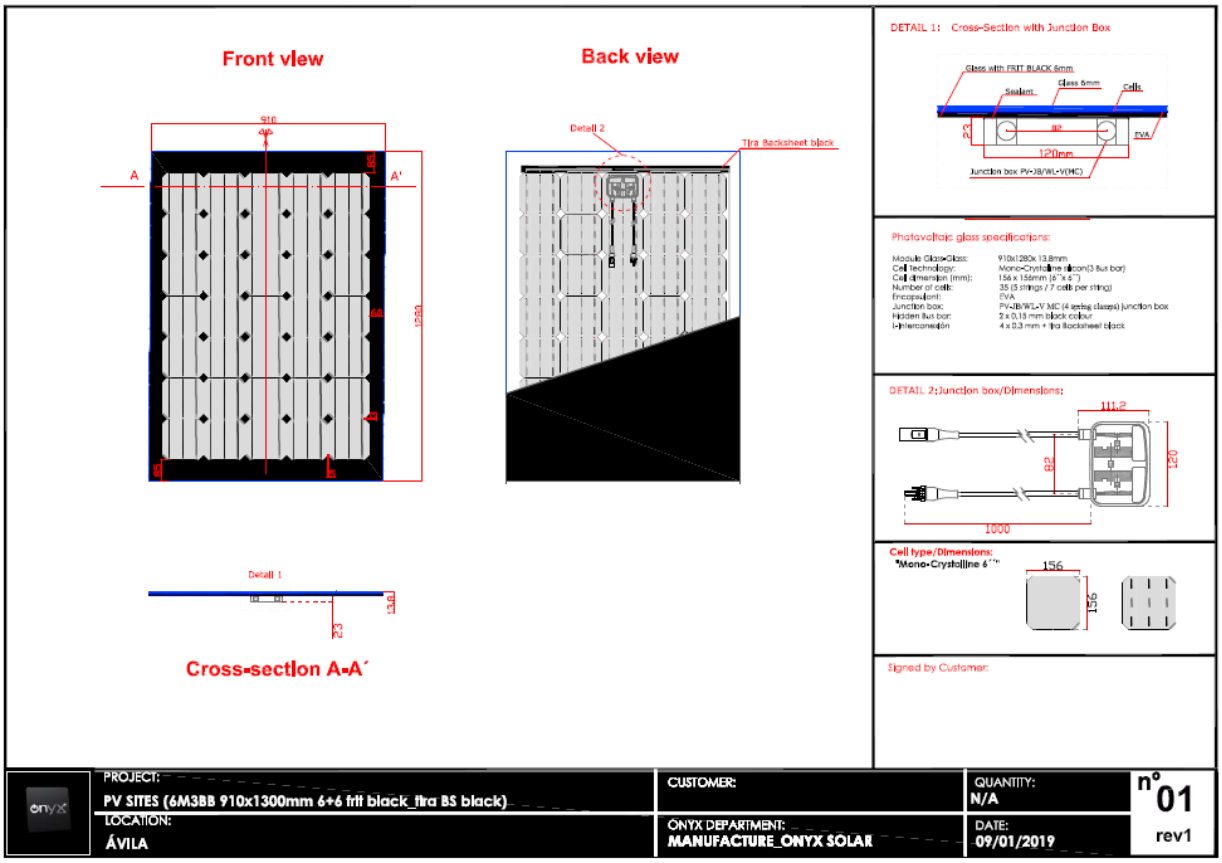
POWER MANAGEMENT SYSTEM (demos)						
General characteristics	X5 - c-Si glazed products with hidden bus bars and L interconnections (glazing)					
Manufacturer	Onyx					
Model	Façade					
Physical characteristics	Value 1	Unit 1	Value 2	Unit 2	Value 3	Unit 3
Length /Width / Thickness	1280	mm	910	mm	13.8	mm
Weight	30	Kg/m^2		-		-
IP protection	IP65					
Electrical characteristics	Value 1	Unit 1	Value 2	Unit 2	Value 3	Unit 3
Total peak power	17	kWp		-		-
Number of modules	112			-		-
Total PV area	132.5	m^2		-		-

Observations:
The modules are developed with dimensions 1700 x 1000 mm^2. For the demonstration project in Lille a smaller module is used with dimensions 1280 x 910 mm^2.

PICTURE

CONFIGURATION AND MATERIALS





Observations:
CAD drawing of configuration of PV glazing and CAD drawings of X5 product for demo site

8.5 Optical Performance – X5

TECHNICAL TEMPLATE REFERENCE	
Technical subject	Optical performance of BIPV modules
Partner	Tecnalia
Author	Maider Machado / Daniel Valencia

PRODUCT CODE	
Denomination	X5 - C-Si glazed products with hidden bus bars and L interconnections

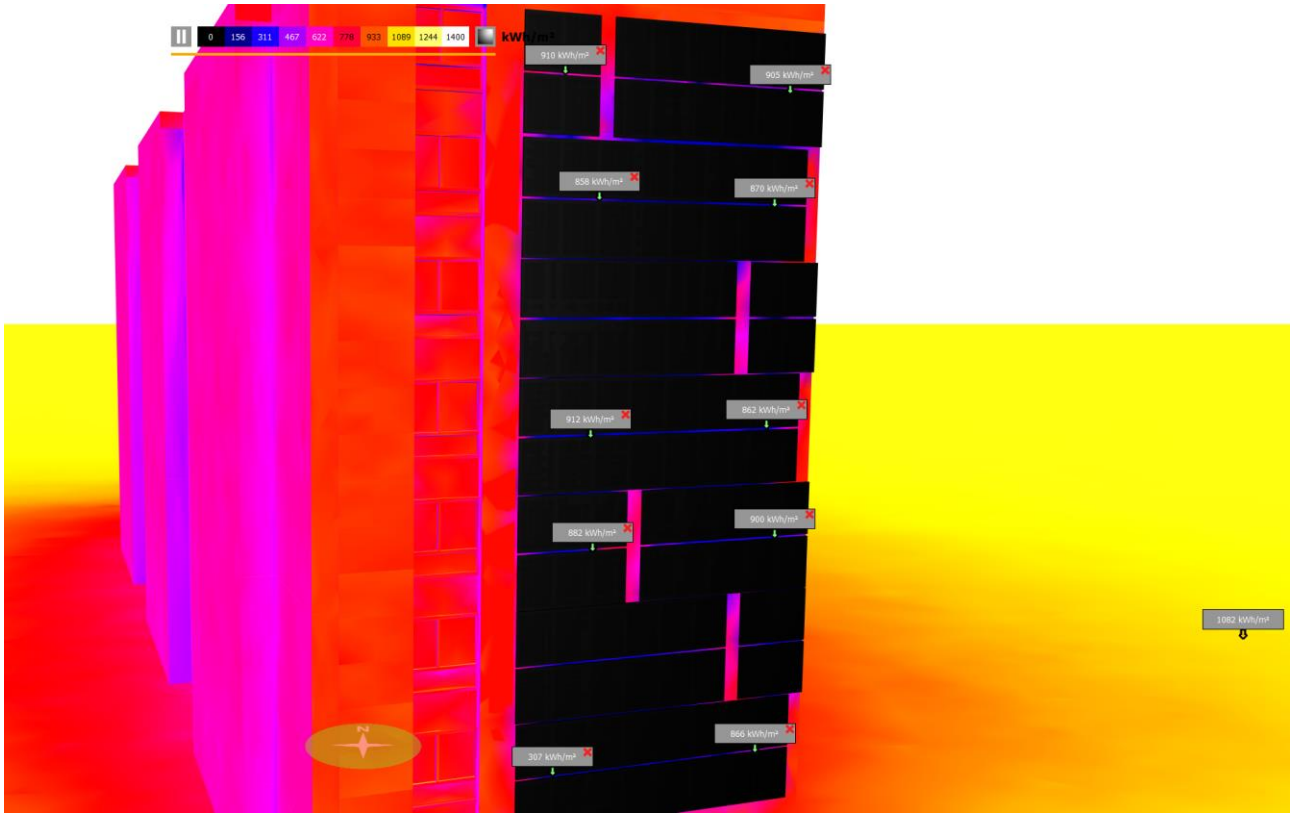
DESIGN/DATASHEET VALUES						
BIPV UNIT						
General characteristics	PV laminated glass with rows of solar cells every 3 mm					
Manufacturer	Onyx Solar					
Model	C-Si glazed products with hidden bus bars and L interconnections					
Shape	Rectangular					
Physical characteristics	Value 1	Unit 1	Value 2	Unit 2	Value 3	Unit 3
Height/ Length/ Thickness	1000	mm	1700	mm	13.8	mm
Weight	51	kg	30	kg/m^2		
PV ratio (PVR)	Variable					
Optical characteristics	Value 1	Unit 1	Value 2	Unit 2	Value 3	Unit 3
Visible transmittance	89.8	%	-	-	-	-
Solar transmittance	81.9	%	-	-	-	-
Visible reflectance (tz)	8.5	%	-	-	-	-
Solar reflectance (tz)	7.8	%	-	-	-	-
Visible reflectance (cz)	5.9	%	-	-	-	-
Solar reflectance (cz)	10.1	%	-	-	-	-
Visible absorptance (tz)	1.7	%	-	-	-	-
Solar absorptance (tz)	10.3	%	-	-	-	-
Visible absorptance (cz)	98.3	%	-	-	-	-
Solar absorptance (cz)	89.7	%	-	-	-	-
Emissivity	83.7	%	-	-	-	-
Observations: Absorptance is calculated from transmittance and reflectance values. Acronym (tz): transparent zone. Acronym (cz): cell zone.						

8.6 Estimation of PV production – X5

TECHNICAL TEMPLATE REFERENCE	
Technical subject	PV production of BIPV modules
Partner	CADCAMation
Author	Philippe ALAMY

PRODUCT CODE	
Denomination	X5 - C-Si glazed products with hidden bus bars and L interconnections

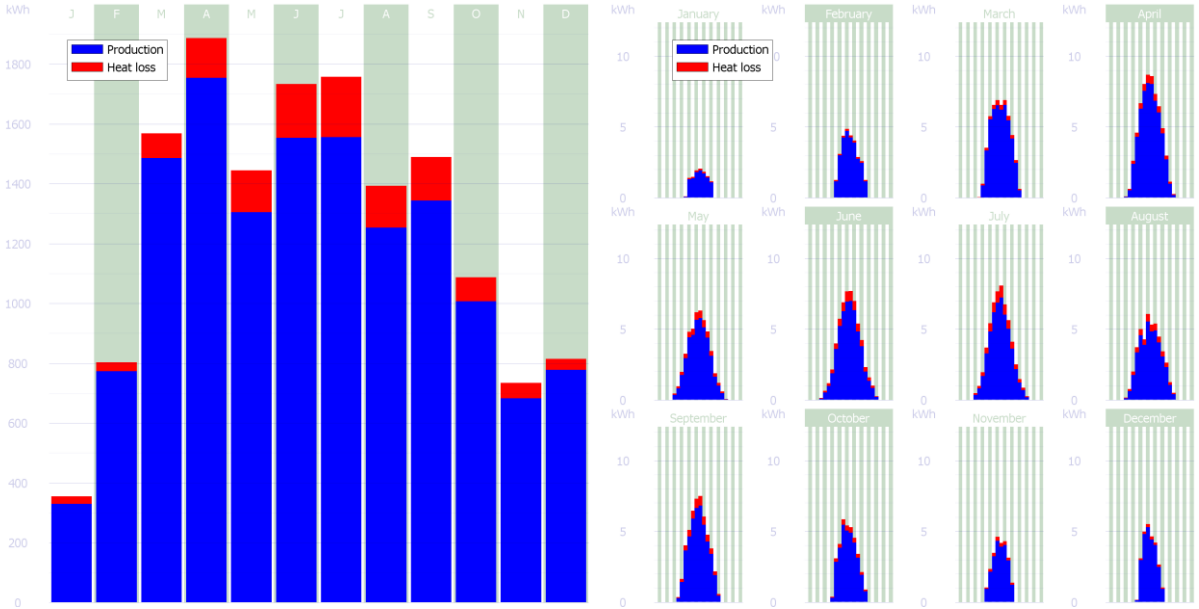
SIMULATING CONDITIONS: exact location = WATTIGNIES (TMY to epw file built with PVGIS)						
ANNUAL GLOBAL IRRADIANCE	Orient E	Orient SE	Orient S	Orient SW	Orient W	Unit
Wattignies (France)	…	…	890.6	…	…	kW/m^2
MEDIUM TEMPERATURE	Med	Min	Max	-	-	Unit
Wattignies (France)	10.0	1.4	20.0	-	-	ºC
MEDIUM WIND SPEED	Med	Min	Max	-	-	Unit
Wattignies (France)	…	…	…	-	-	m/s



ESTIMATION OF ELECTRICAL POWER PRODUCTION (from BIPV ARRAY to INVERTER) - ANNUAL

BIPV UNIT	Orient E	Orient SE	Orient S	Orient SW	Orient W	Unit
Wattignies (France)			13,819.6			kWh
ARCHITECTURAL UNIT	Orient E	Orient SE	Orient S	Orient SW	Orient W	Unit
Wattignies (France)			13,819.6			kWh
PRODUCTION PER M²	Orient E	Orient SE	Orient S	Orient SW	Orient W	Unit
Wattignies (France)			105.90			kWh/m²
PRODUCTION PER kWp	Orient E	Orient SE	Orient S	Orient SW	Orient W	Unit
Wattignies (France)	…	…	817.73		-	kWh/kWp
DC PRODUCTION (INVERTER)	Orient E	Orient SE	Orient S	Orient SW	Orient W	Unit
Wattignies (France)			13,417			kWh
AC PRODUCTION (INVERTER)	Orient E	Orient SE	Orient S	Orient SW	Orient W	Unit
Wattignies (France)	…	…	12,075		-	kWh

VILOGIA - PV Production + shadow losses + Yield – Hourly step / Module level



Monthly / Average day per month PV Production + heat losses

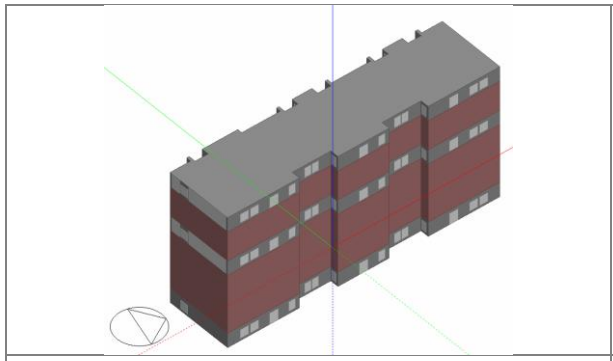
8.7 Simulation of Passive Performance – X5

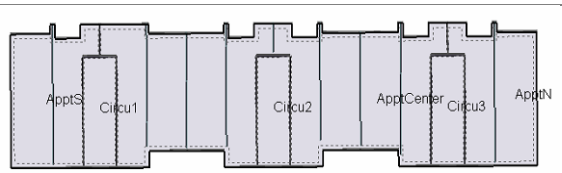
TECHNICAL TEMPLATE REFERENCE	
Technical subject	Passive performance of BIPV modules
Partner	NOBATEK
Author	Baptiste Durand-Estebe

PRODUCT CODE	
Denomination	X5 - C-Si glazed products with hidden bus bars and L interconnections

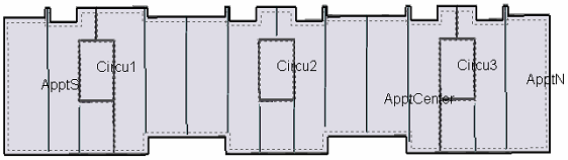
PILOT BUILDING	
Definition	The Vilogia demonstration site is located in Lille (France). It is a 3639m² residential building with 7 identical floors plus a ground floor. BIPV panels are installed as cladding system from the 1st to the 7th floors
Use	Residential building
Area	Building: 3639m² BIPV modules: 173m²
Orientation of PV modules	South
DESIGN PLANS	

Graphic picture from Design Builder	Ground floor plan

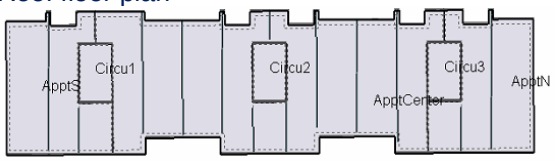




First floor plan



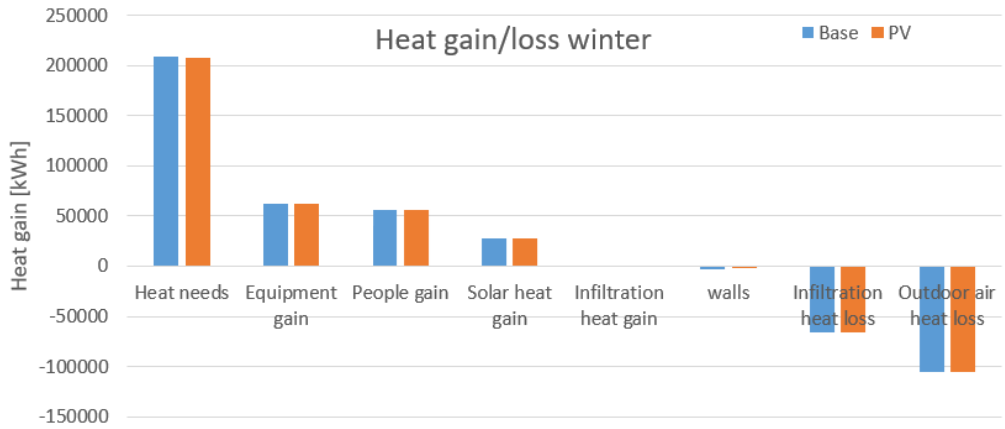
Roof floor plan



Observations.
Modelling parameters of pilot building.

DEMAND AND PRODUCTION OF PILOT BUILDING WITH BIPV SYSTEM			
Location	Lille		
	Baseline	**With BIPV**	**Unit**
Heating annual demand	209 164	207 876	kWh
Cooling annual demand	Passive comfort	Passive comfort	
Total annual H/C demand	209 164	207 876	kWh
Lighting needs	The BIPV system has no influence on lighting		
Overall increase/reduction	-0,6%		

Impact of the BIPV system on the demo site



EHG internal heat gains

8.8 Maintenance and Dismantling – X5

TECHNICAL TEMPLATE REFERENCE	
Technical subject	Maintenance and dismantling of products and installations
Partner	Onyx Solar
Author	Elena Rico

PRODUCT CODE	
Denomination	X5 - c-Si glazed products with hidden bus bars and L interconnections

MAINTENANCE		
BY THE USER	Periodicity (months)	Description
Action 1	Depending on the environmental conditions, Similar as conventional glazing	Cleaning periodic activities, in order to avoid performance losses
Action 2	Twice per year	Checking system connections
Action 3	Twice per year	Checking cable system
Action 4	Twice per year	Checking the sealing of the junction boxes
Action 5	Twice per year	Checking the structural pieces in the structure that supports the photovoltaic modules
Action 6	Twice per year	Checking if any glass may be fractured
Action 7	Twice per year	Checking all segments of the BOS
Action 8	Twice per year	Checking all the earth connections
Observations.		

DISMANTLING
Description of dismantling Same removal process than normally façade elements, take care of disconnecting cables

8.9 Life Cycle Assessment – X5

TECHNICAL TEMPLATE REFERENCE	
Technical subject	Life cycle assessment of products and installations
Partner	CTCV
Author	Marisa Almeida

PRODUCT CODE	
Denomination	X5 - c-Si glazed products with hidden bus bars and L interconnections

LCA INDICATORS					
	Value 1	Unit 1			
Global warming	192	Kg CO2 eq/m^2			
Acidification	1,51	mol H+ eq/m^2			
Terrestrial Eutrophication	2,25	mol N eq /m^2			
Freshwater Eutrophication	0,017	Kg P eq/m^2			
Photochemical oxidation formation	0,774	kg NMCOV eq /m^2			
Abiotic depletion	5,02	g Sb/m^2			
Ozone layer depletion	3,51E-05	kg CFC-11 eq/m^2			
Human Toxicity	1,23E-07	CTUh /m^2			
Observations: Provisional data based on specific ACV for this GIGs. LCA methodology: ISO14040/ISO14044 with CML and ILCD methods. Most of the results are in line with the average for PV products with similar properties.					

8.10 Economic Evaluation – X5

TECHNICAL TEMPLATE REFERENCE	
Technical subject	Economic evaluation and benefits of BIPV modules
Partner	Onyx Solar
Author	Elena Rico

PRODUCT CODE	
Denomination	X5 - c-Si glazed products with hidden bus bars and L interconnections

ECONOMIC BALANCE						
General assumptions taking into account in the economic study	**Value 1**	**Unit 1**				
Total building area	767.31	m^2				
Net conditioned building area	767.31	m^2				
South façade area	200	m^2				
Peak power of PV fully black	126	W/m^2				
Local electricity cost	0.2367	€/kWh				
Variation in electricity cost until 2020	8.18	%				
Variation in electricity cost from 2020	1.00	%				
Costs estimation of ventilated façade system	**Value 1**	**Unit 1**	**Value 2**	**Unit 2**	**Value 3**	**Unit 3**
Conventional equivalent glass Cladding material/ Fixation system/BOS	115	€/m^2	70	€/m^2	0	€/m^2
PV fully black glass Cladding material/ Fixation system/BOS	265	€/m^2	70	€/m^2	107.10	€/m^2
Energy behavior of the building before and after the retrofit	**Value 1**	**Unit 1**	**Value 2**	**Unit 2**	**Value 3**	**Unit 3**
Wall HVAC energy consumption / Renewable energy production	52140.72	kWh/year	0	kWh/year		
Wall + conventional ventilated façade HVAC energy consumption / Renewable energy production	50829.31	kWh/year	0	kWh/year		
Wall + photovoltaic ventilated façade HVAC energy consumption / Renewable energy production	50829.31	kWh/year	29418.00	kWh/year		
Total reduction of energy demand with PV fully black ventilated façade (WALL + PV VENTILATED FAÇADE versus WALL)	**Value 1**	**Unit 1**	**Value 2**	**Unit 2**	**Value 3**	**Unit 3**

ENERGY SAVINGS INDUCED BY THERMAL ENVELOPE IN 30 YEARS (A)	14817	euro	39342	kWh	…	
PV ENERGY PRODUCTION IN 30 YEARS (B)	299140	euro	794286	kWh	…	
TOTAL REDUCTION OF ENERGY DEMAND IN 30 YEARS (A+B)	313957	euro	833628	kWh	53	%
Economic metrics with PV fully black ventilated façade (WALL + PV VENTILATED FAÇADE versus WALL)	**Value 1**	**Unit 1**	**Value 2**	**Unit 2**	**Value 3**	**Unit 3**
Average reduction of energy demand	1569.78	€/m^2				
Amount to invest	442.10	€/m^2				
Amount to invest after incentives	442.10	€/m^2				
ROI	255	%				
Payback period	< 10	years				
IRR	11	%				
Times the investment	3.55	time				
Total reduction of energy demand with PV fully black ventilated façade (PV VENTILATED FAÇADE versus CONVENTIONAL VENTILATED FACADES)	**Value 1**	**Unit 1**	**Value 2**	**Unit 2**	**Value 3**	**Unit 3**
ENERGY SAVINGS INDUCED BY THERMAL ENVELOPE IN 30 YEARS (A)	0	euro	0	kWh	…	
PV ENERGY PRODUCTION IN 30 YEARS (B)	299140	euro	794286	kWh	…	
TOTAL REDUCTION OF ENERGY DEMAND IN 30 YEARS (A+B)	299140	euro	794286	kWh	52	%
Economic metrics with PV fully black ventilated façade (PV VENTILATED FAÇADE versus CONVENTIONAL VENTILATED FACADES)	**Value 1**	**Unit 1**	**Value 2**	**Unit 2**	**Value 3**	**Unit 3**
Average reduction of energy demand	1495.70	€/m^2				
Amount to invest	257.10	€/m^2				

Amount to invest after incentives	257.10	€/m^2				
ROI	482	%				
Payback period	< 7	years				
IRR	18	%				
Times the investment	5.82	time				

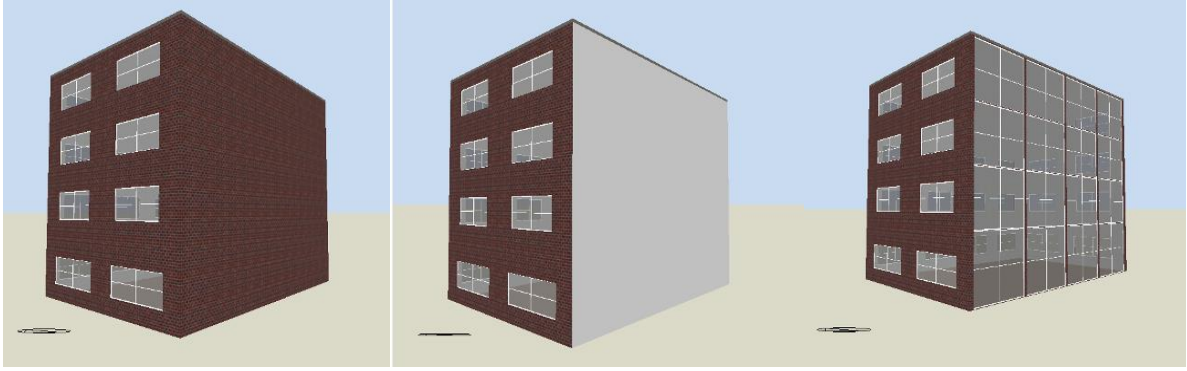
Observations:
The economic study has been conducted considering the energy savings by the BIPV products under different scenarios.

With the aim of having results of the reduction in the energy demand of a whole building due to fully black photovoltaic glass product developed, different models have been simulated with Design Builder software. An office building type has been chosen to simulate the energetic behavior under different scenarios. The south façade building is a conventional opaque wall and the idea is to analyze the implementation of different types of ventilated facades as an energy retrofit measure.

Ventilated façade is the selected system because it is the most appropriate to integrate the fully black photovoltaic product. The system is composed of an insulation material in the inner part, an air gap and a cladding material in the outer layer. The cladding layer can be made of different materials: wood, stone, composite, glass, photovoltaic glass…This system is implemented to reduce thermal exchanges and to avoid thermal bridges. Thanks to the ventilated air chamber and the application of insulating material, this system increases the acoustic absorption and reduces the amount of heat that buildings absorb in hot weather conditions. The difference between the density of hot and cold air within the air space creates natural ventilation through a chimney effect. This helps in eliminating heat and moisture, enhancing the comfort level of the occupants. By using a photovoltaic cladding material, the façade also produces clean electricity.

Therefore, the economic analysis has been done by comparison between the opaque existing conventional wall and the same wall with different ventilated façade systems. Also, an economic analysis comparing a conventional ventilated facade with the photovoltaic fully black (hidden bus-bars and L-interconnections) modules is made. Ventilated façade solution in the south façade in the city of Madrid has been used as case study. The level of irradiation in Madrid is 1663 kWh/m^{2}year.

The following figures show the 3D Design Builder models of the simulated three different façade systems on the south facade. The figure on the left represents a building with a conventional opaque facade; the figure in the middle corresponds to the same building with the implementation of a ventilated façade system, and the figure on the right to the equivalent building with a curtain wall system. The south façade is the changing one, and the rest of facades remain unchanged: conventional construction systems with conventional windows.



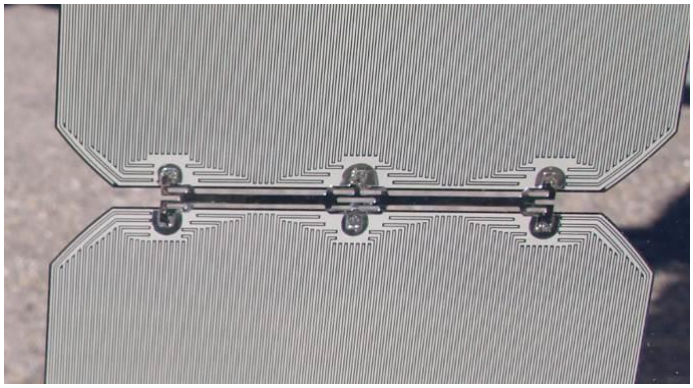
9 X6 Glass-Glass product with back-contacts c-Si cells

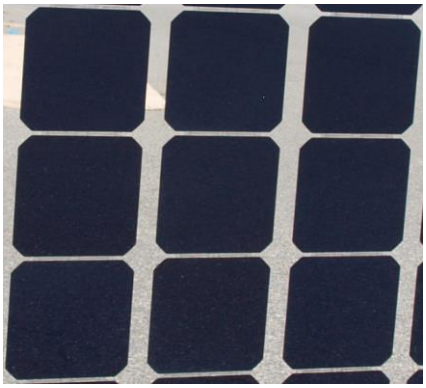
9.1 General Description, Design and Materials – X6

TECHNICAL TEMPLATE REFERENCE	
Technical subject	General description, design and materials of BIPV modules.
Partner	Onyx Solar
Author	Héctor Zamora/Elena Rico

PRODUCT CODE	
Project	PVSITES. Task 2.3. BIPV products portfolio
Category	Ventilated façade/ Curtain wall/ Skylight/ Shading system
Denomination	X6 - Glass-glass products with back contact c-Si cells
Partner/s	Onyx

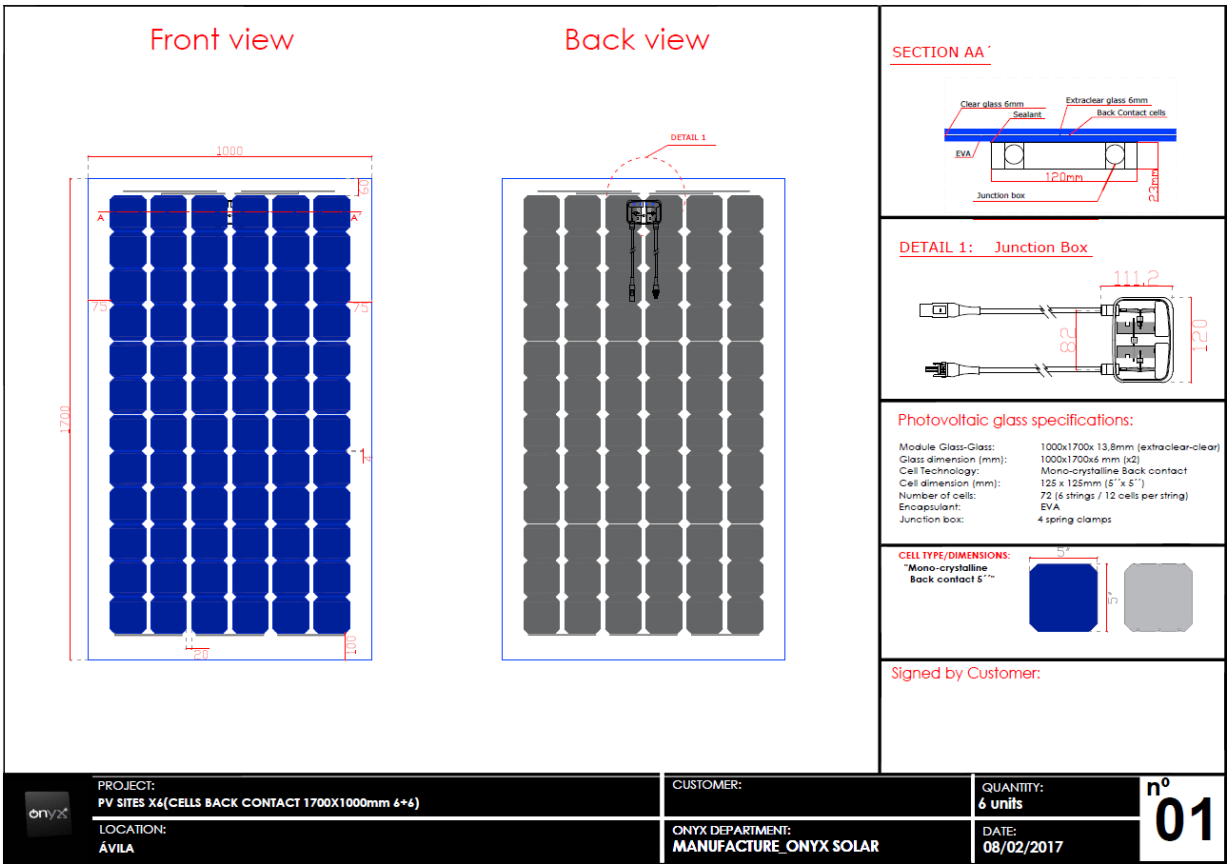
PICTURES	
PHOTOOS	
	
Observations: Semi-transparent Photovoltaic module based on back contact cells, allowing an improved aesthetics of the product and higher performances due to the absence of front bus bars.	





Observations:
Back connections and front uniform appearance of the BIPV prototype with back contact cell technology

DESIGN DRAWINGS



Observations:
CAD Manufacturing Drawings of product X6 (17-02-08)

DETAILED DESCRIPTION	
Definition	Semi-transparent PV rectangular glazing based on back contact 5” c-Si solar cells
Construction unit	Ventilated façade/ Curtain wall/ Skylight/ Shading system

Architectural location	Façade
Geometrical design	Rectangular semi-transparent glazing
Dimensions	Length: 1700 mm, Width: 1000 mm
Geometrical shape	Rectangular / Customizable
Materials	Glass, EVA, back contact solar cells
Configuration	Simple laminated glass
Layers	From top to bottom: Extraclear tempered glass, EVA, back contact solar cells, EVA, Clear tempered glass
Frame structure	Frameless/ Aluminium
PV technology	Back contact c-Si solar cells
Encapsulation material	EVA
Surface treatments	May be included on PV glazing
Thermal insulation	Common glazing technologies can be used (double/triple glazing, low-e coatings, etc)
Acoustic insulation	Double/triple glazing can be used.
Physical features	Similar to other glazing skylights/glazing façade elements
Weight	30 kg/m^2
Rigidity	Rigid
Opacity	68%
Mobility	No mobile parts
Active energy features	Photovoltaic glazing that generates electricity with solar radiation
Photovoltaic power	126 Wp/m^2
Passive energy features	Same as other BIPV glazing solutions, depending on the specific application (shading effect, reducing cooling/heating needs) and the additional treatments on the glazing (low-e, etc)
Optical transmittance	27%
Thermal transmittance (U value)	Defined by glazing system used

9.2 Mechanical Performance – X6

TECHNICAL TEMPLATE REFERENCE	
Technical subject	Mechanical performance of BIPV modules
Partner	Onyx Solar
Author	Héctor Zamora / Elena Rico

PRODUCT CODE	
Denomination	X6 - Glass-glass products with back contact c-Si cells

DESIGN/DATASHEET VALUES		
BIPV UNIT		
General characteristics	Semi-transparent PV rectangular glazing based on back contact 5” c-Si solar cells	
Manufacturer	Onyx Solar	
Model	See-through Back contact solar cells glass-glass BIPV	
Shape	Rectangular / Customizable	
Physical characteristics	Value 1	Unit 1
Width/ Length/ Thickness	1000/ 1700/ 13.8	mm
Weight	30	kg/m^2
Mechanical characteristics	Glass mechanical properties	
Tensile strength	120-200	MPa
Tensile modulus	~70	GPa
Poisson coefficients	0.22	-
Observations: Mechanical properties are the ones for the glass layers, which are the main mechanical material of the PV glazing.		

9.3 Architectural Integration – X6

TECHNICAL TEMPLATE REFERENCE	
Technical subject	Architectural integration of BIPV products
Partner	Onyx Solar
Author	Héctor Zamora/Elena Rico

PRODUCT CODE	
Denomination	X6 - Glass-glass products with back contact c-Si cells

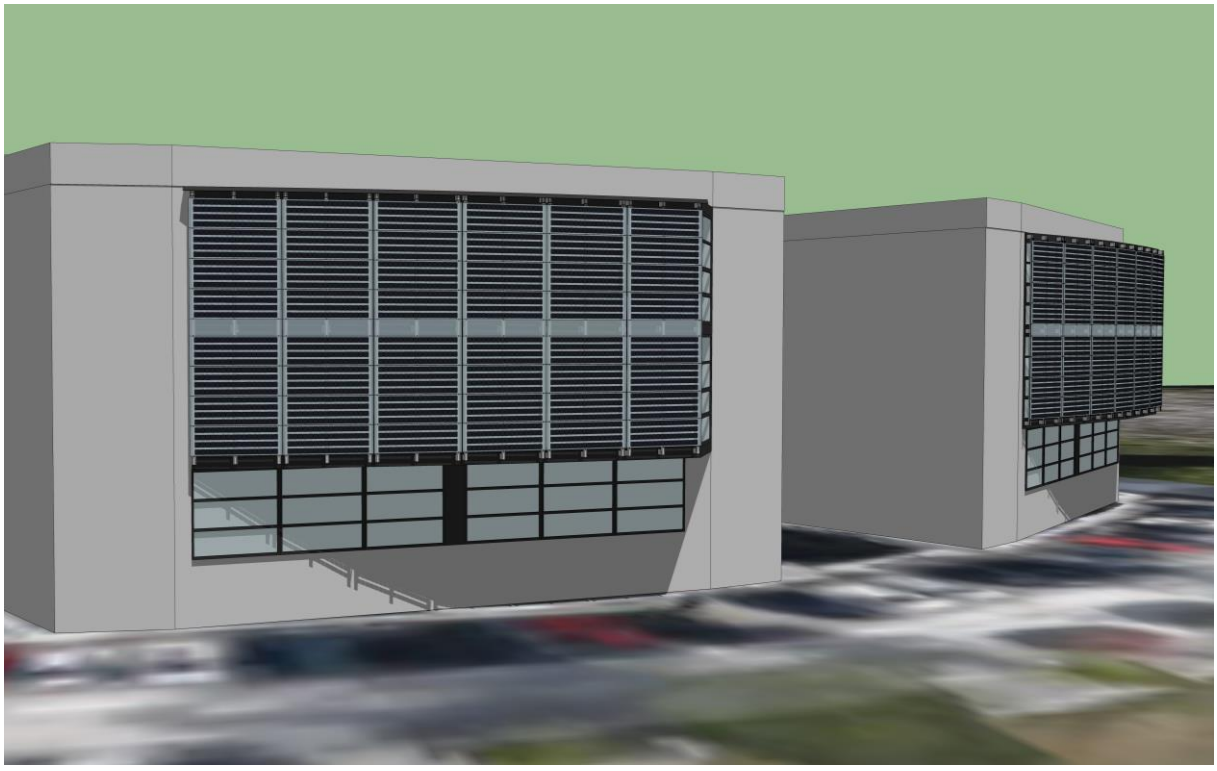
DEFINITION AND LOCATION	
Definition	Semi-transparent PV rectangular glazing based on back contact 5” c-Si solar cells
Construction unit	Ventilated façade
Location	San Sebastián (Spain), office building (Tecnalia HQ building)
Architectural location	Façade

CONSTRUCTION UNIT FEATURES						
Physical properties	Length	Unit 1	Width	Unit 2	Thickness	Unit 3
Shape	Rectangular					
Dimensions	2250	mm	760	mm	13.8	mm
Weight	51.30	kg	30	kg/m^2		
Dimensions	2212	mm	765	mm	13.8	mm
Weight	50.77	kg	30	kg/m^2		
Materials and devices	PV glazing. Includes junction box at the back					
Configuration	Double glazing					
Frame structure	Frameless					
PV technology	Si-mono-crystalline					
Location of pipes, diameters	Each PV glazing will have two cables. Cables can be housed in the structure.					
Thermal insulation	Common glazing thermal insulation strategies can be used					
Thermal bridge	Determined by structure					
Aesthetical features	Structure appearance can be customized					
Opacity	Transparent glazing with opaque PV cells (39% transparency)					
Cell colour	Dark blue (front), Grey (back)					
Background colour	Customizable					
Frame colour	Customizable					
Surface treatments	Colour or surface technologies for glass can be used					

INTEGRATION AND MAINTENANCE MEASURES	
Construction	Ventilated façade
Mounting system	Common ventilated façade/curtain wall systems. A vertical profile system is mounted in front of the existing facade. The modules are fixated with a clip system.
Secondary construction	n.a.
Procedure	
New construction permits needed	Based on local regulations
Retrofitting permits needed	Based on local regulations
Maintenance	Cleaning periodic activities, in order to avoid performance losses.
Inspection	Remote monitoring / Physical inspection:

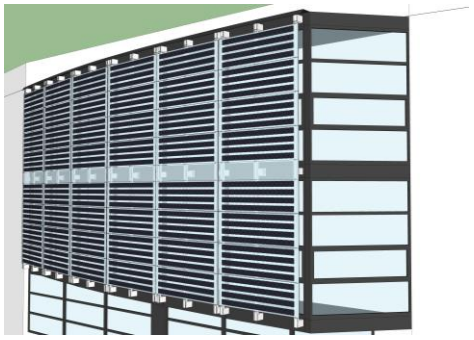
	• Checking system connections • Checking cable system • Checking the sealing of the junction boxes • Checking the structural pieces in the structure that supports the photovoltaic modules • Checking if any glass may be fractured • Checking all segments of the BOS • Checking all the earth connections
Sequence of inspection	At least twice a year
Maintenance for the system	Yes
Sequence of maintenance	Cleaning activities depending on the environmental conditions. Cleaning of the PV glazing is similar to equivalent glazing systems.
Accessibility of system	PV modules are accessible from the exterior.
Safety procedure	Glazing system should comply with standards (f.i. CWCT note 67 or ETAG 034) in order to guarantee safety accessibility
Removal	Same removal process than normally façade elements, take care of disconnecting cables
Accessibility for removal	PV modules are accessible from the exterior.
Ease of removal	Same removal process than normally façade elements, take care of disconnecting cables

PICTURES

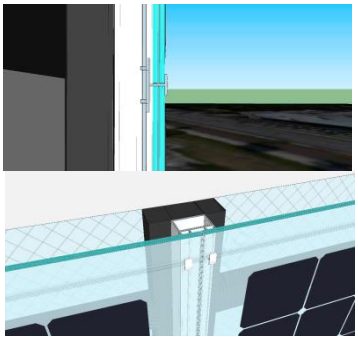


Overview of the designed demo façades

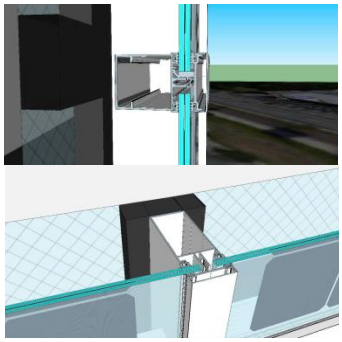
Integration method



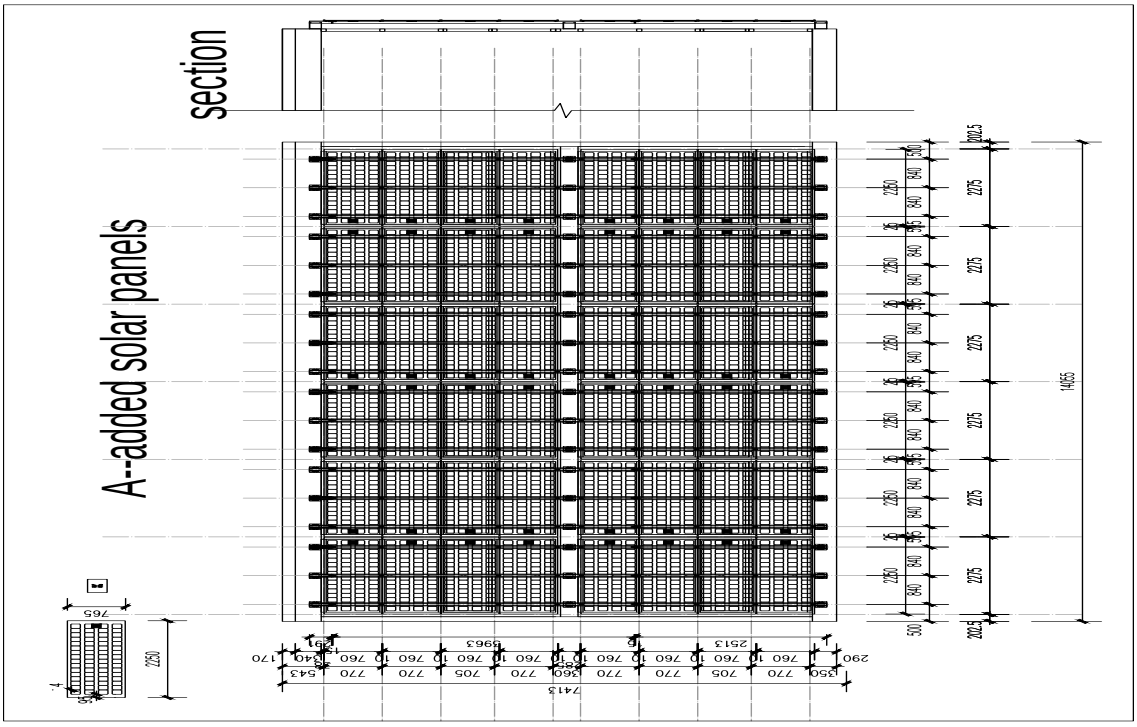
Integration as ventilated façade

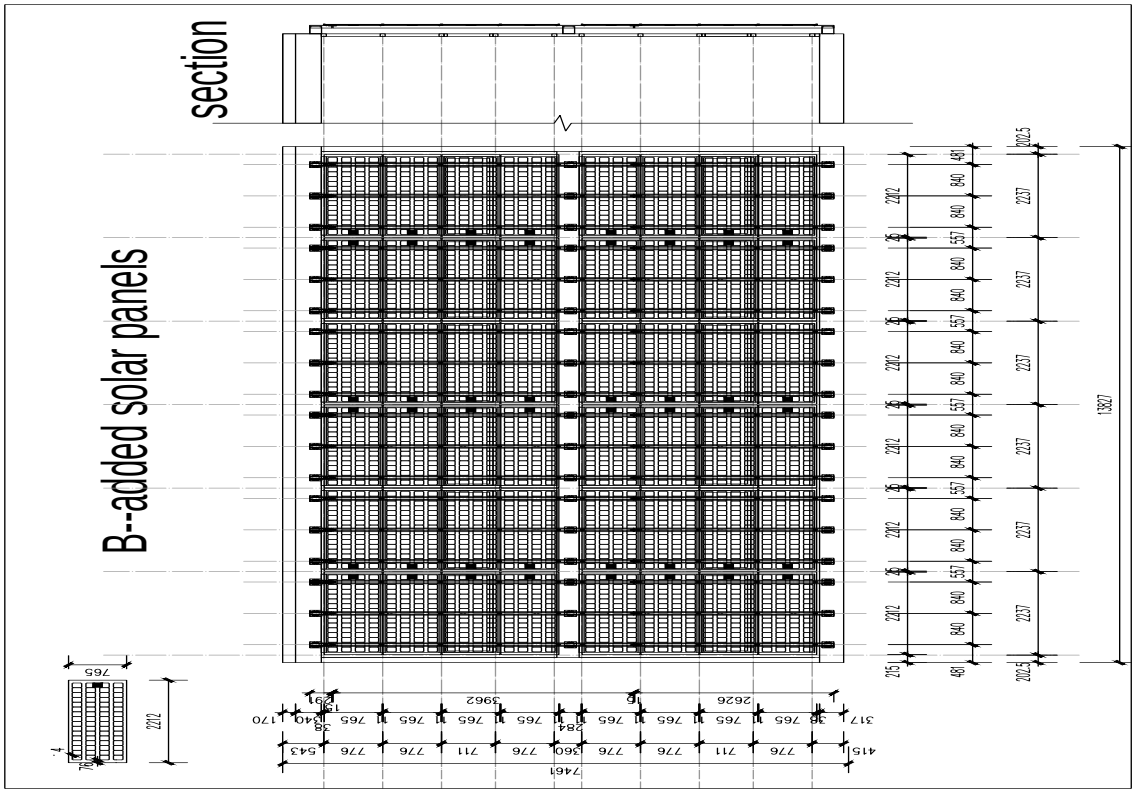


Invisible framing system

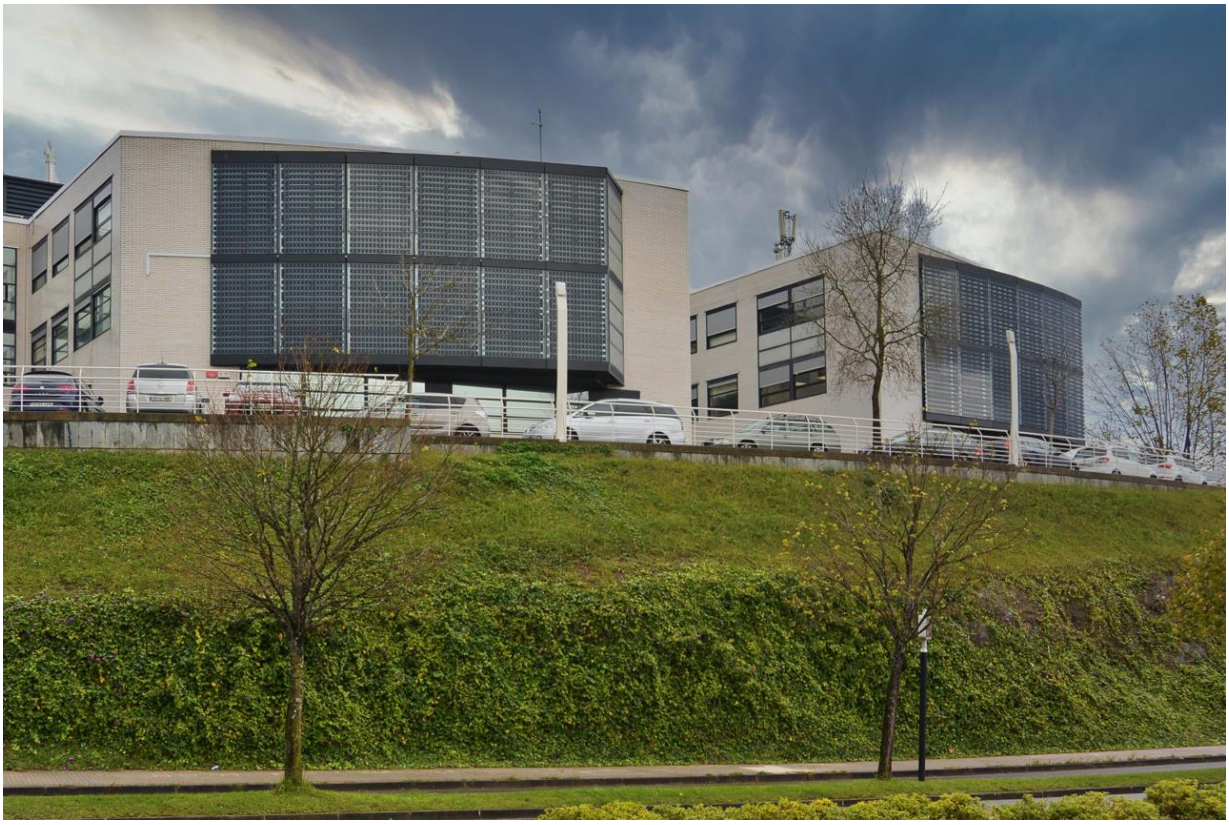


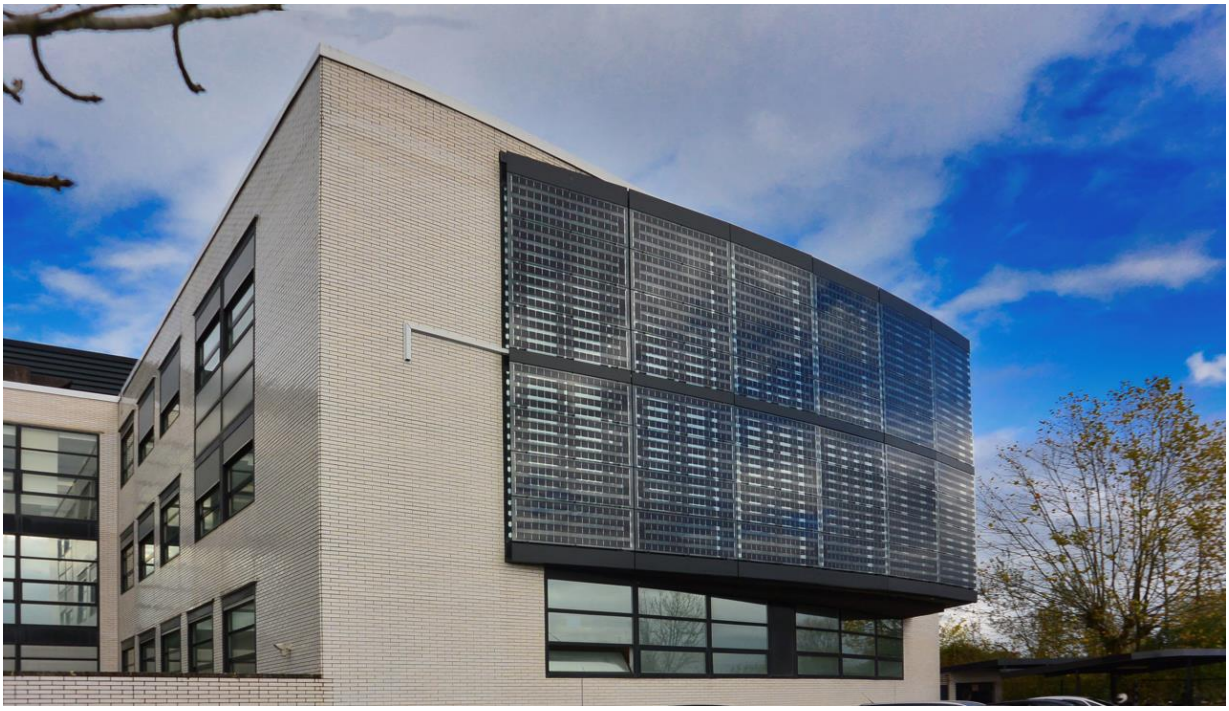
Visible framing system





Observations:
Pictures correspond with the overseen integration options for the ventilated facade solution with X6 product which has been demonstrated within the project. Façade A and B has slightly different dimensions.





Façade after installation.

9.4 Electrical Performance – X6

TECHNICAL TEMPLATE REFERENCE	
Technical subject	Electrical performance of BIPV modules
Partner	Onyx Solar
Author	Héctor Zamora / Elena Rico

PRODUCT CODE	
Denomination	X6 - Glass-glass products with back contact c-Si cells

DESIGN/DATASHEET VALUES	
PHOTOVOLTAIC CELL/ ARRAY	
General characteristics	Back contact mono crystalline PV glazing
Manufacturer	Not specific provider required
Cell type	Mono-crystalline silicon. 125x125 mm back contact solar cell
Module Shape	Rectangular
Module Colour	Dark blue solar cells. Transparent non-coloured glazing
Front layer	Low iron tempered glass
Frame	Frameless PV glass

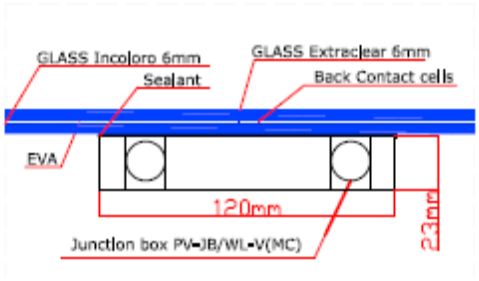
Connection Box	Non specific					
Cables	4 mm^2 up to 1000V					
Connectors	MC4					
Series-parallel connection	Non-parallel connection within one module					
Physical characteristics	Value 1	Unit 1	Value 2	Unit 2	Value 3	Unit 3
Length/Width/Thickness	1700	mm	1000	mm	13.8	mm
Electrical characteristics	Value 1	Unit 1	Value 2	Unit 2	Value 3	Unit 3
Rated power	215	Wp	126	Wp/m^2		-
Efficiency	20	%		-		-
Tolerance	±10	%		-		-
Vpm: max. power voltage	39.24	V		-		-
Ipm: max. power current	5.49	A		-		-
Voc: open circuit voltage	46.80	V		-		-
Isc: short circuit current	5.70	A		-		-
Thermal parameters	Value 1	Unit 1	Value 2	Unit 2	Value 3	Unit 3
Isc (α) Temp. coefficient	3.5	mA/ºC				-
Voc (β) Temp. coefficient	-1.74	mV/ºC				-
P (γ) Temp. coefficient	-0.3	%/ºC				-
Operating range						
Temperature	-40 - +85	ºC				
Maximum System Voltage	1000	V				
Protection	IP65					

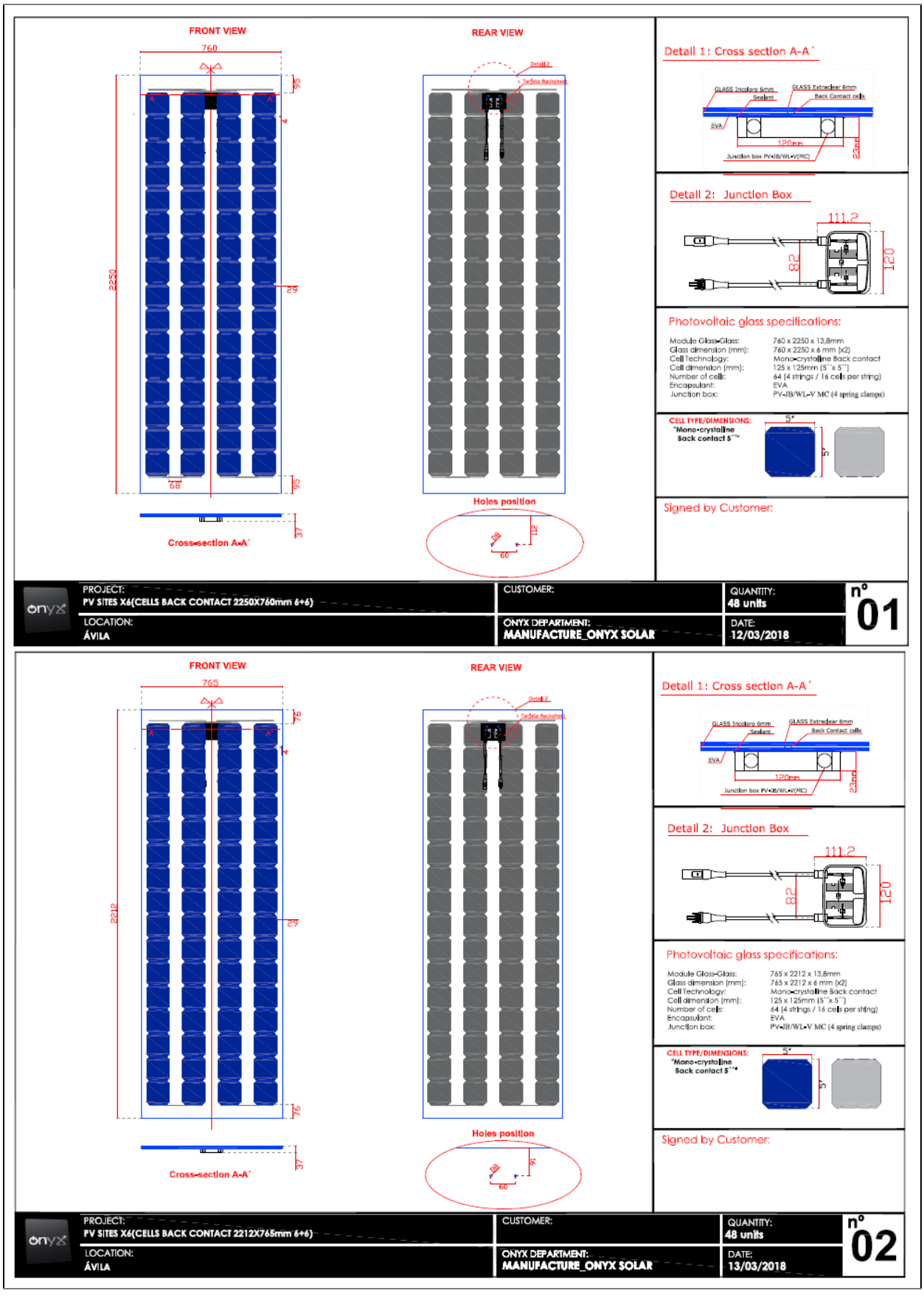
POWER MANAGEMENT SYSTEM (demos)						
General characteristics	Back contact mono crystalline PV glazing for façade configuration. Two different module dimensions are considered for demo purposes.					
Manufacturer	Onyx					
Model	Façade					
Physical characteristics	Value 1	Unit 1	Value 2	Unit 2	Value 3	Unit 3
Length /Width/ Thickness (A)	2250	mm	760	mm	13.8	mm

Length /Width/ Thickness (B)	2212	mm	765	mm	13.8	mm
Weight (A/B)	30	Kg/m^2	30	Kg/m^2		-
IP protection	IP65					
Electrical characteristics	Value 1	Unit 1	Value 2	Unit 2	Value 3	Unit 3
Number of modules	96					
Total DC peak power	18.4	kW				
Number of modules (Facade 1 / Facade 2)	48 (A)	V	48 (B)			
Number of strings	2 strings for façade. 4 strings in total					
Inverters	4 SMA 5000TL					
Observations:						

PICTURE

CONFIGURATION AND MATERIALS




FRONT VIEW
760
2250
Cross-section A-A´
REAR VIEW
Holes position
Detall 1: Cross section A-A´
GLASS Incoloro 6mm
Sealant
GLASS Extraclear 6mm
Back Contact cells
EVA
120mm
23mm
Junction box PV-JB/WL-V(MC)
Detall 2: Junction Box
111.2
82
120
Photovoltaic glass specifications:
Module Glass-Glass: 760 x 2250 x 13,8mm
Glass dimension (mm): 760 x 2250 x 6 mm (x2)
Cell Technology: Mono-crystalline Back contact
Cell dimension (mm): 125 x 125mm (5´´x 5´´)
Number of cells: 64 (4 strings / 16 cells per string)
Encapsulant: EVA
Junction box: PV-JB/WL-V MC (4 spring clamps)
CELL TYPE/DIMENSIONS:
"Mono-crystalline
Back contact 5´´"
Signed by Customer:
PROJECT:
PV SITES X6(CELLS BACK CONTACT 2250X760mm 6+6)
CUSTOMER:
QUANTITY:
48 units
n° 01
LOCATION:
ÁVILA
ONYX DEPARTMENT:
MANUFACTURE_ONYX SOLAR
DATE:
12/03/2018
FRONT VIEW
765
2212
Cross-section A-A´
REAR VIEW
Holes position
Detall 1: Cross section A-A´
GLASS Incoloro 6mm
Sealant
GLASS Extraclear 6mm
Back Contact cells
EVA
120mm
23mm
Junction box PV-JB/WL-V(MC)
Detall 2: Junction Box
111.2
82
120
Photovoltaic glass specifications:
Module Glass-Glass: 765 x 2212 x 13,8mm
Glass dimension (mm): 765 x 2212 x 6 mm (x2)
Cell Technology: Mono-crystalline Back contact
Cell dimension (mm): 125 x 125mm (5´´x 5´´)
Number of cells: 64 (4 strings / 16 cells per string)
Encapsulant: EVA
Junction box: PV-JB/WL-V MC (4 spring clamps)
CELL TYPE/DIMENSIONS:
"Mono-crystalline
Back contact 5´´"
Signed by Customer:
PROJECT:
PV SITES X6(CELLS BACK CONTACT 2212X765mm 6+6)
CUSTOMER:
QUANTITY:
48 units
n° 02
LOCATION:
ÁVILA
ONYX DEPARTMENT:
MANUFACTURE_ONYX SOLAR
DATE:
13/03/2018

Observations:
Configuration and materials CAD drawing (valid for both modules with different dimensions) and CAD manufacturing drawings of both X6 modules designed and manufactured for demonstration purposes.

9.5 Optical Performance – X6

TECHNICAL TEMPLATE REFERENCE	
Technical subject	Optical performance of BIPV modules
Partner	Tecnalia
Author	Maider Machado / Daniel Valencia

PRODUCT CODE	
Denomination	X6 - Glass-glass products with back contact c-Si cells

DESIGN/DATASHEET VALUES						
BIPV UNIT						
General characteristics	**Back contact mono crystalline PV glazing**					
Manufacturer	Onyx Solar					
Model	See-through Back contact solar cells glass glass BIPV					
Shape	Rectangular					
Physical characteristics	Value 1	Unit 1	Value 2	Unit 2	Value 3	Unit 3
Height/ Length/ Thickness	1700	mm	1000	mm	13.8	mm
Weight	51	kg	30	kg/m2		
PV ratio (PVR)	Variable	%				
Optical characteristics	Value 1	Unit 1	Value 2	Unit 2	Value 3	Unit 3
Visible transmittance	89.8	%	-	-	-	-
Solar transmittance	81.9	%	-	-	-	-
Visible reflectance (tz)	8.5	%	-	-	-	-
Solar reflectance (tz)	7.8	%	-	-	-	-
Visible reflectance (cz)	4.8	%	-	-	-	-
Solar reflectance (cz)	8.3	%	-	-	-	-
Visible absorptance (tz)	1.7	%	-	-	-	-
Solar absorptance (tz)	10.3	%	-	-	-	-
Visible absorptance (cz)	95.2	%	-	-	-	-
Solar absorptance (cz)	91.7	%	-	-	-	-
Emissivity	83.7	%	-	-	-	-

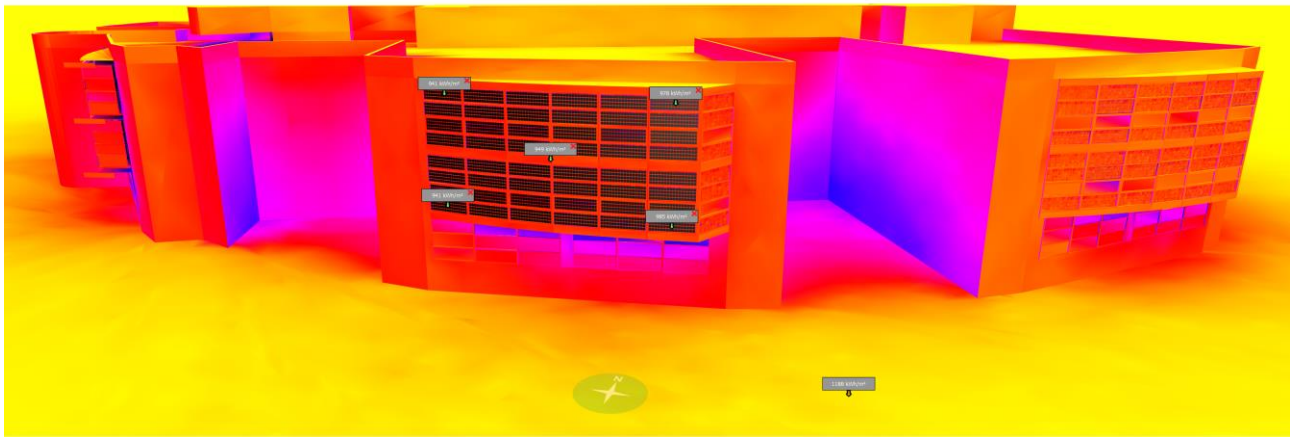
Observations: Absorptance is calculated from transmittance and reflectance values. Acronym (tz): transparent zone. Acronym (cz): cell zone.

9.6 Estimation of PV production – X6

TECHNICAL TEMPLATE REFERENCE	
Technical subject	PV production of BIPV modules
Partner	CADCAMation
Author	Philippe ALAMY

PRODUCT CODE	
Denomination	X6 - Glass-glass products with back contact c-Si cells

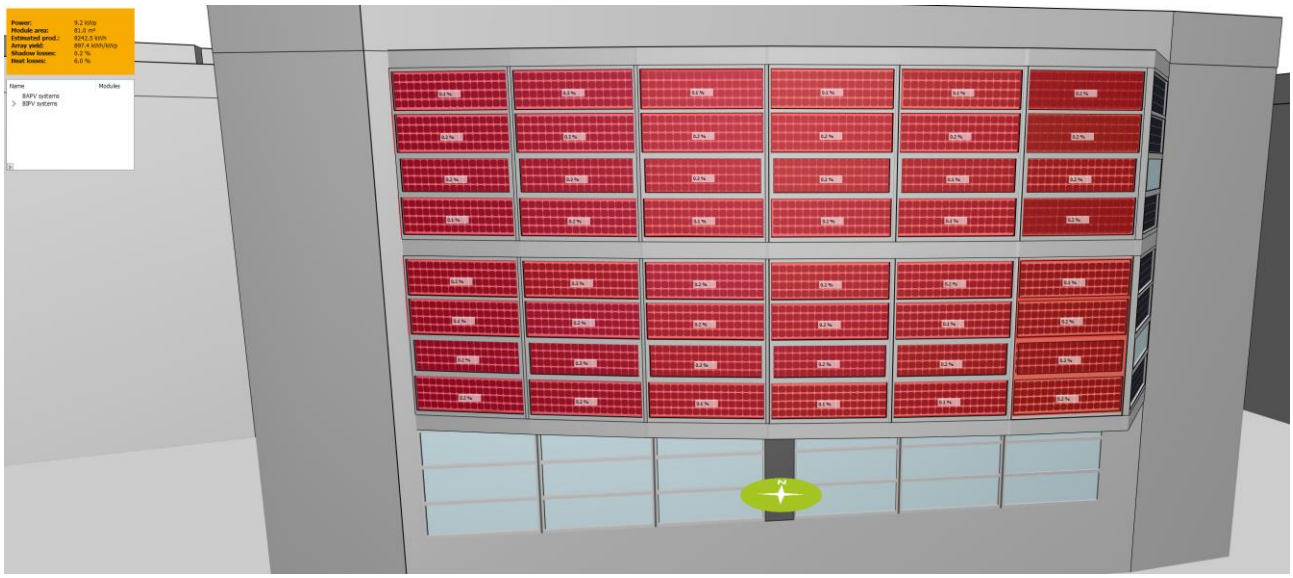
SIMULATING CONDITIONS: exact location = TECNALIA Donostia (TMY tp epw file built from PVGIS)						
ANNUAL GLOBAL IRRADIANCE	Orient E	Orient SE	Orient S	Orient SW	Orient W	Unit
San Sebastián (Spain)	…	915	954.93	…	…	kW/m^2
MEDIUM TEMPERATURE	Med	Min	Max	-	-	Unit
San Sebastián (Spain)	14.0	9.2	21.0	-	-	ºC
MEDIUM WIND SPEED	Med	Min	Max	-	-	Unit
San Sebastián (Spain)	…	…	…	-	-	m/s



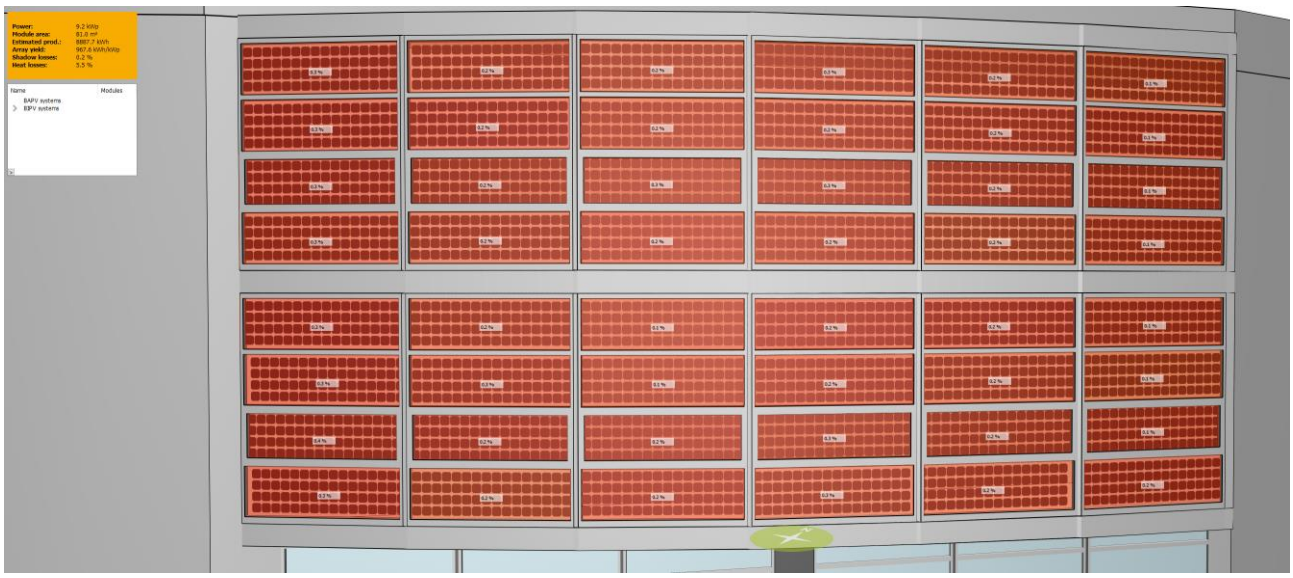
Irradiance South façade (architectural level)

Irradiance south-east façade (architectural level)

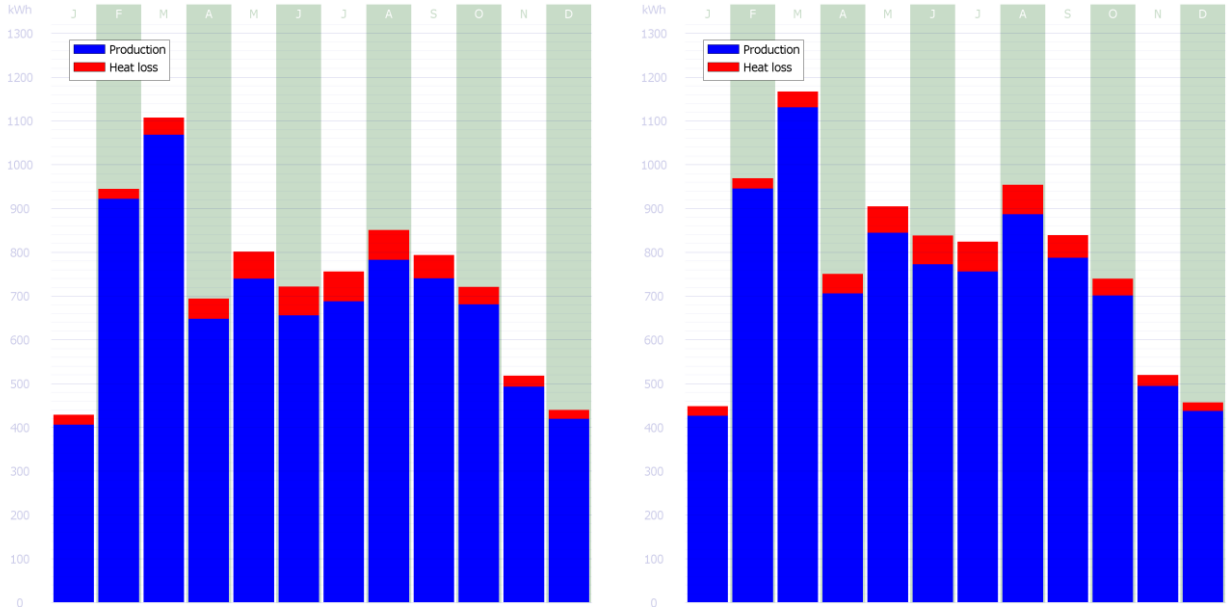
ESTIMATION OF ELECTRICAL POWER PRODUCTION (from BIPV ARRAY to INVERTER) - ANNUAL						
BIPV UNIT	Orient E	Orient SE	Orient S	Orient SW	Orient W	Unit
San Sebastián (Spain)	…	8,887.7	8,242.5	…	…	kWh
ARCHITECTURAL UNIT	Orient E	Orient SE	Orient S	Orient SW	Orient W	Unit
San Sebastián (Spain)	17,130.2					kWh
PRODUCTION PER M²	Orient E	Orient SE	Orient S	Orient SW	Orient W	Unit
San Sebastián (Spain)	…	109.72	101.76	-	-	kWh/m²
PRODUCTION PER kWp	Orient E	Orient SE	Orient S	Orient SW	Orient W	Unit
San Sebastián (Spain)	…	966.05	895.92	-	-	kWh/kWp
DC PRODUCTION (INVERTER)	Orient E	Orient SE	Orient S	Orient SW	Orient W	Unit
San Sebastián (Spain)	…	8,686	7,888	-	-	kWh
AC PRODUCTION (INVERTER)	Orient E	Orient SE	Orient S	Orient SW	Orient W	Unit
San Sebastián (Spain)	…	7,817	7,099	-	-	kWh



TECNALIA - PV Production + shadow losses + Yield – Hourly step / Module level – South façade

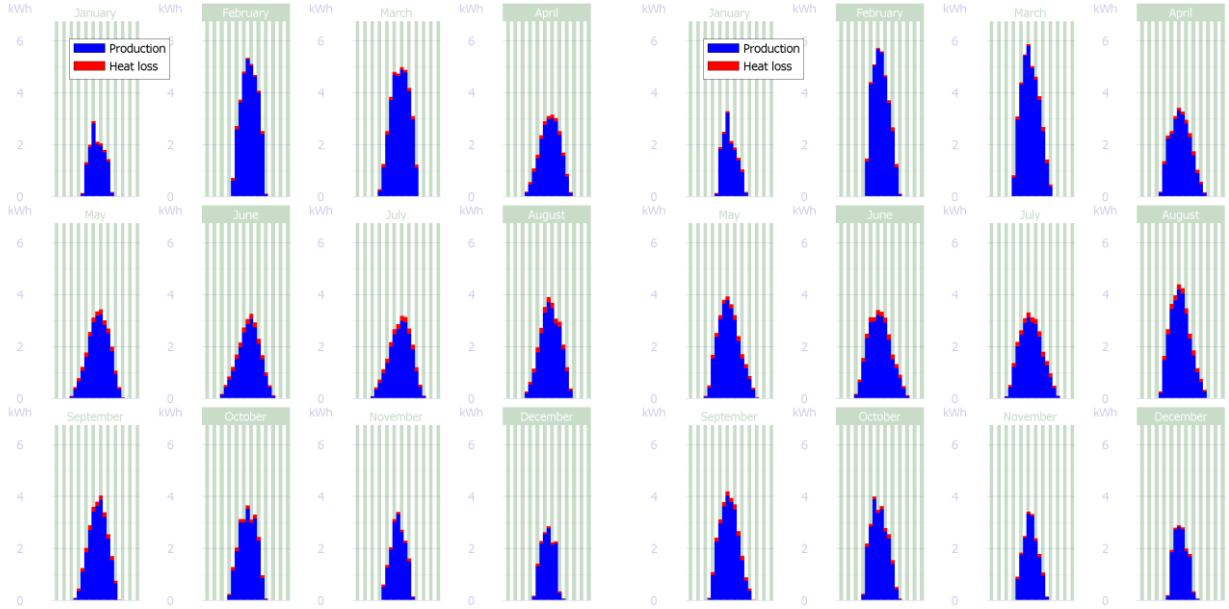


TECNALIA - PV Production + shadow losses + Yield – Hourly step / Module level– South East façade



TECNALIA - South *TECNALIA - South-East*

PV Production + heat losses – Monthly results



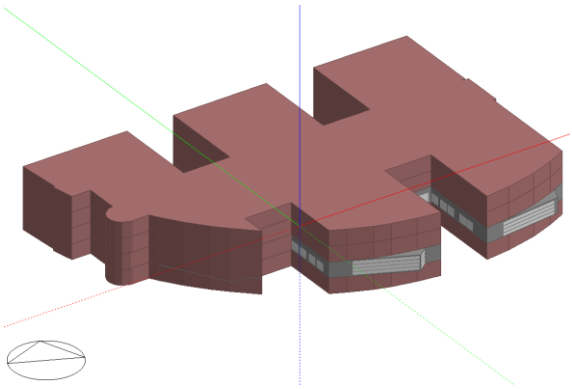
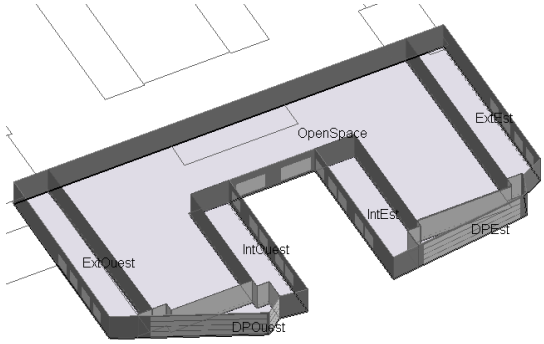
TECNALIA - South *TECNALIA - South-East*

PV Production + heat losses – Average day per month

9.7 Simulation of Passive Performance – X6

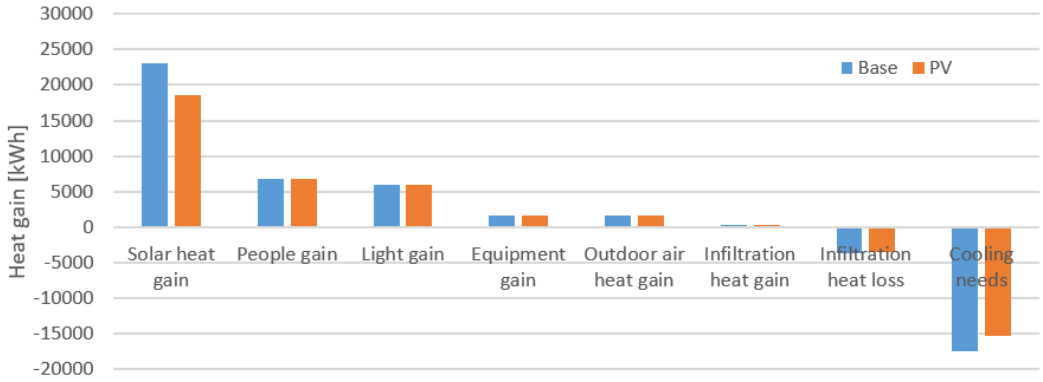
TECHNICAL TEMPLATE REFERENCE	
Technical subject	Passive performance of BIPV modules
Partner	Nobatek
Author	Baptiste Durand-Estebe

PRODUCT CODE	
Denomination	X6 - Glass-glass products with back contact c-Si cells

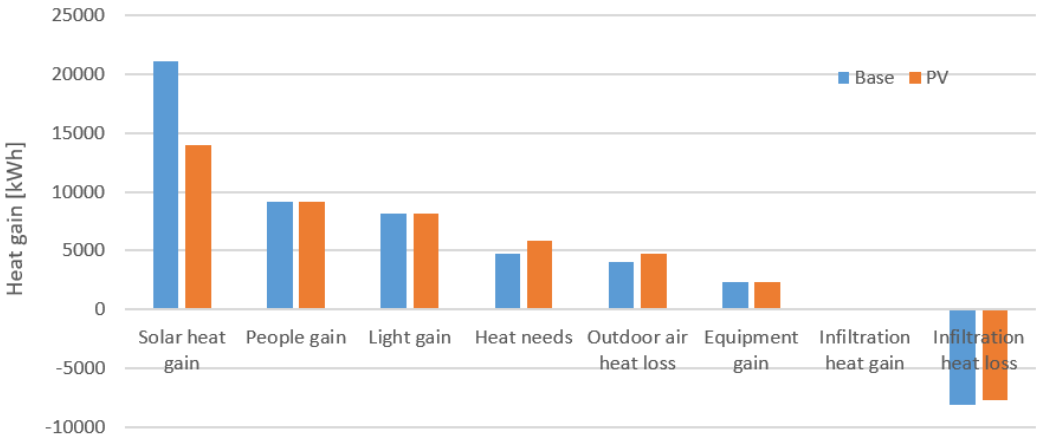
PILOT BUILDING	
Definition	Tecnalia demonstration site is located in San Sebastian (Spain). It's a 13.2m high building, with a complex floor section, an irregular polygon with several flat and curve façades oriented in different directions and with different constructive characteristics. Transparent BIPV is used to replace the actual curtain wall
Use	The building houses both office spaces and engineering and chemical laboratories.
Area	BIPV modules: 103.5m²
Orientation of PV modules	South / South East
DESIGN PLANS	
	
Graphic picture from Design Builder.	Ground floor plan
Observations. Modelling parameters of pilot building.	

DEMAND AND PRODUCTION OF PILOT BUILDING WITH BIPV SYSTEM			
Location	San Sebastian		
	Baseline [kWh]	**With BIPV [kWh]**	**Overall increase/reduction**
Heating annual demand	4 773	5 870	+23%
Cooling annual demand	17 564	15 360	-13%
Total annual H/C demand	209 164	207 876	-5%

TECNALIA Demo site heating cooling needs comparison



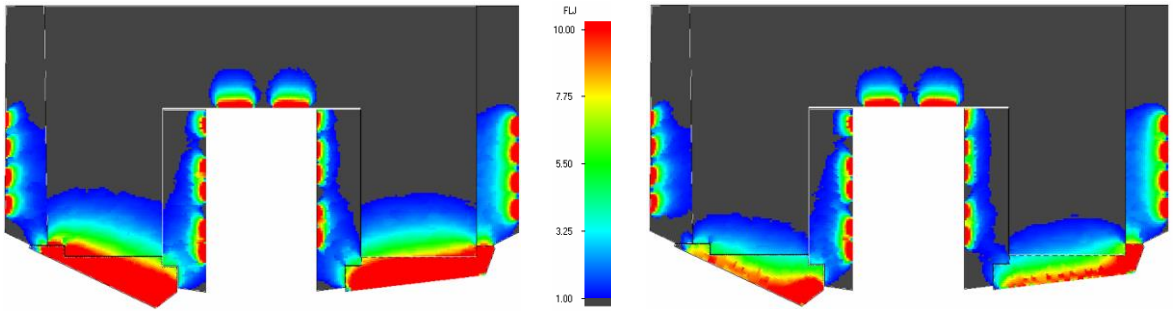
TECNALIA Demo site heat gain/heat loss for summer period



TECNALIA Demo site heat gain/heat loss for winter period

IMPACT ON BUILDING NATURAL LIGHTING			
	Baseline [kWh]	**With BIPV [kWh]**	**Overall increase/reduction**
% room office surface > 300 lux	22%	16%	-6%

TECNALIA Demo site impact on natural lighting



Baseline configuration % Daylight factor

Configuration with X6 BIPV % Daylight factor

Observations

The integration of semi-transparent BIPV in a building affects the heating needs, the cooling needs, the amount of available natural lighting, and the electricity production. Depending on the climate and on the building energy strategy, choices have to be made during the design phase regarding BIPV surface and the number of solar cells.

This aspect has been studied in details and the results are presented in the deliverable D3.7. The table below is extracted from this document and presents the distribution of the E_{need} indicator (gathering heating, cooling, lighting and PV production), depending on the Windows to Wall Ratio (WWR) and on the PV coverage ratio

(PVR). It has been computed for the South orientation and for the climate of Madrid. A heat map blue/red/yellow is applied to visually compare the configuration that will minimise the energy need.

		PVR [-]						
		0.2	0.3	0.4	0.5	0.6	0.7	0.8
WWR [%]	20	571	522	482	453	438	441	467
	30	683	576	481	400	336	297	295
	40	854	680	527	391	275	186	143
	50	1058	819	599	403	233	92	-1
	60	1279	975	694	435	208	16	-129
	70	1506	1142	798	479	192	-52	-245
	80	1733	1316	915	540	197	-100	-333
	90	1950	1480	1026	594	194	-159	-442
	100	2088	1586	1098	630	194	-194	-511

E_{need} heat map for the South façade in the city of Madrid

This table can be used to size the transparent BIPV panel dimensions. For example, a room with a curtain wall (100% WWR) having a PVR ranging from 70% to 80% will produce more energy than it requires. On the other hand, a room with a PVR of 20% will need a large amount of energy.

9.8 Maintenance and Dismantling – X6

TECHNICAL TEMPLATE REFERENCE	
Technical subject	Maintenance and dismantling of products and installations
Partner	Onyx Solar
Author	Elena Rico

PRODUCT CODE	
Denomination	X6 - Glass-glass products with back contact c-Si cells

MAINTENANCE		
BY THE USER	Periodicity (months)	Description
Action 1	Depending on the environmental conditions, Similar as conventional glazing	Cleaning periodic activities, in order to avoid performance losses
Action 2	Twice per year	Checking system connections
Action 3	Twice per year	Checking cable system
Action 4	Twice per year	Checking the sealing of the junction boxes

Action 5	Twice per year	Checking the structural pieces in the structure that supports the photovoltaic modules
Action 6	Twice per year	Checking if any glass may be fractured
Action 7	Twice per year	Checking all segments of the BOS
Action 8	Twice per year	Checking all the earth connections

DISMANTLING
Description of dismantling Same removal process than normally façade elements, take care of disconnecting cables

9.9 Life Cycle Assesment – X6

TECHNICAL TEMPLATE REFERENCE	
Technical subject	Life cycle assessment of products and installations
Partner	CTCV
Author	Marisa Almeida

PRODUCT CODE	
Denomination	X6 - Glass-glass products with back contact c-Si cells

LCA INDICATORS					
	Value 1	Unit 1			
Global warming	173	Kg CO2 eq/m^2			
Acidification	1,35	mol H+ eq/m^2			
Terrestrial Eutrophication	0,404	mol N eq /m^2			
Freshwater Eutrophication	1,998	Kg P eq/m^2			
Photochemical oxidation formation	0,687	kg NMCOV eq /m^2			
Abiotic depletion	3,31	g Sb/m^2			
Ozone layer depletion	3,18E-05	kg CFC-11 eq/m^2			
Human Toxicity	1,13E-06	CTUh /m^2			
Observations: Provisional data based on specific ACV for PV products with similar properties. LCA methodology: ISO14040/ISO14044 with CML and ILCD methods. Most of the results are in line with the average for PV products with similar properties.					

9.10 Economic Evaluation – X6

TECHNICAL TEMPLATE REFERENCE	
Technical subject	Economic evaluation and benefits of BIPV modules
Partner	Onyx Solar
Author	Elena Rico

PRODUCT CODE	
Denomination	X6 - Glass-glass products with back contact c-Si cells

ECONOMIC BALANCE						
General assumptions taking into account in the economic study	Value 1	Unit 1				
Total building area	767.31	m^2				
Net conditioned building area	767.31	m^2				
Curtain wall or ventilated facade surface area	200	m^2				
Peak power of see-thru PV mass	126	W/m^2				
Local electricity cost	0.2367	€/kWh				
Variation in electricity cost until 2020	8.18	%				
Variation in electricity cost from 2020	1.00	%				
Costs estimation of the curtain wall system	**Value 1**	**Unit 1**	**Value 2**	**Unit 2**	**Value 3**	**Unit 3**
Conventional curtain wall Glazing/Fixation system/BOS	85	$€/m^2$	=	$€/m^2$	0	$€/m^2$
Photovoltaic curtain wall Glazing/Fixation system/BOS	280	$€/m^2$	=	$€/m^2$	88.20	$€/m^2$
Over cost	227.90	$€/m^2$				
Energy behavior of the building before and after implementation of the back contact solar cells PV ventilated facade: conventional curtain wall versus conventional curtain wall with PV ventilated facade	**Value 1**	**Unit 1**	**Value 2**	**Unit 2**	**Value 3**	**Unit 3**

Conventional curtain wall: HVAC energy consumption Renewable energy production	62744.47	kWh/year	0	kWh/year		
Conventional curtain wall with PV ventilated façade: HVAC energy consumption / Renewable energy production	54536.03	kWh/year	24227.00	kWh/year		
Total reduction of energy demand thanks to the PV ventilated façade implementation	**Value 1**	**Unit 1**	**Value 2**	**Unit 2**	**Value 3**	**Unit 3**
ENERGY SAVINGS INDUCED BY THERMAL ENVELOPE IN 30 YEARS (A)	92743	€	246253	kWh	…	
PV ENERGY PRODUCTION IN 30 YEARS (B)	246355	€	654129	kWh	…	
TOTAL REDUCTION OF ENERGY DEMAND IN 30 YEARS (A+B)	339097	€	900382	kWh	48	%
Economic metrics of the building with the PV ventilated façade implementation	**Value 1**	**Unit 1**	**Value 2**	**Unit 2**	**Value 3**	**Unit 3**
Average reduction of energy demand	1695.49	€/m^2				
Amount to invest	438.20	€/m^2				
Amount to invest after incentives	438.20	€/m^2				
ROI	287	%				
Payback period	< 9	years				
IRR	12	%				
Times the investment	3.87	time				

Observations:
The economic study has been conducted considering the energy savings by the BIPV products under different scenarios. BIPV solutions generate free electricity for buildings while providing thermal and acoustical insulation, day lighting and sun control, as required by design. This combination of active and passive properties leads to outstanding return on the investments. Consequently, the building will also eliminate a significant amount of CO_2 emission. Therefore, it is important to take into account not only the electricity production of the photovoltaic glass, but also the improvement of the building envelope which means a lower consumption of lighting systems, cooling or heating, and the enhancement of the indoor comfort due to the radiation filtration with optimal natural light.

With the aim of having results of the reduction in the energy demand of a whole building due to the see-thru photovoltaic glass with back contact cells, different models have been simulated with Design Builder software.

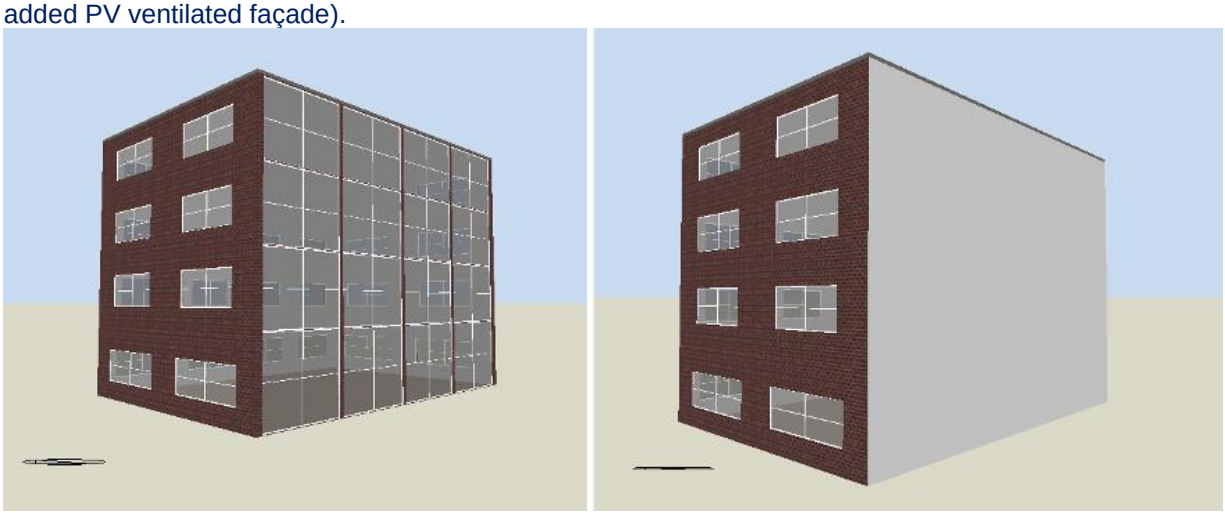
An office building type has been chosen to simulate the energetic behavior under different scenarios. Three different constructive solutions have been selected to compare the results:

- Photovoltaic ventilated façade on the south façade
- Curtain wall in the south façade.
- Skylight system on the roof.

Only the first scenario is presented in this document: Photovoltaic ventilated façade on the south façade. In this case, the south façade building is a conventional curtain wall and the idea is to analyze the implementation of a PV ventilated façade system based on back contact solar cells as an energy retrofit measure, reducing the solar radiation transmission and therefore improving the indoor comfort. Ventilated façade systems are composed of an insulation material in the inner part, an air gap and a cladding material in the outer layer. This system is implemented also to reduce thermal exchanges and to avoid thermal bridges. Thanks to the ventilated air chamber and the application of insulating material, this system increases the acoustic absorption and reduces the amount of heat that buildings absorb in hot weather conditions. The difference between the density of hot and cold air within the air space creates natural ventilation through a chimney effect. This helps in eliminating heat and moisture, enhancing the comfort level of the occupants. By using a photovoltaic cladding material, the façade also produces clean electricity.

The economic analysis has been done then by comparison between the building with the conventional curtain wall system and the same building with the added photovoltaic ventilated façade system with see-thru photovoltaic glass with back contact photovoltaic cells. Ventilated façade solution in the south façade in the city of Madrid has been used as case study. The level of irradiation in Madrid is 1663 kWh/m^{2}year.

The following figure shows the 3D Design Builder models of the comparison between the building with the conventional curtain wall system and the same building with the added photovoltaic ventilated façade (left-building with conventional curtain wall system, right- building with conventional wall system with the added PV ventilated façade).



10 X7 Curved glass-glass, CIGS technology

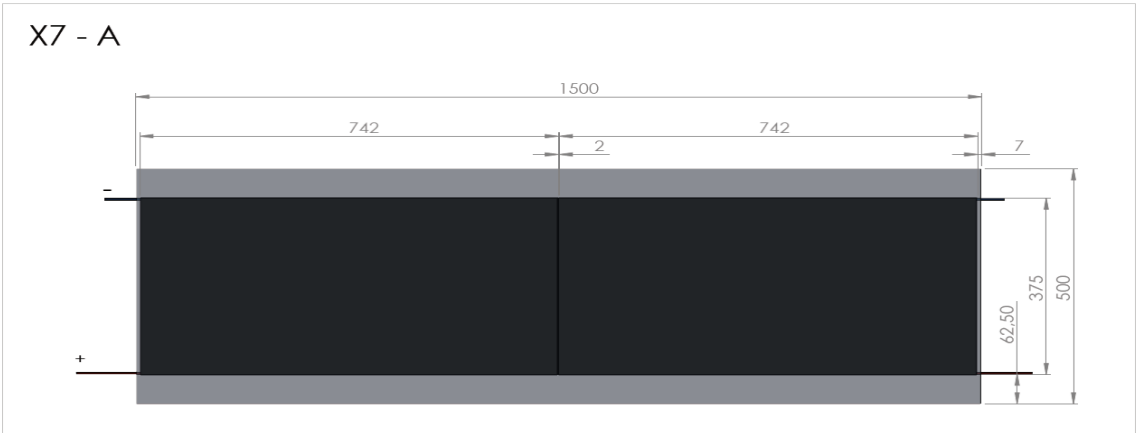
10.1 General Description, Design and Materials – X7

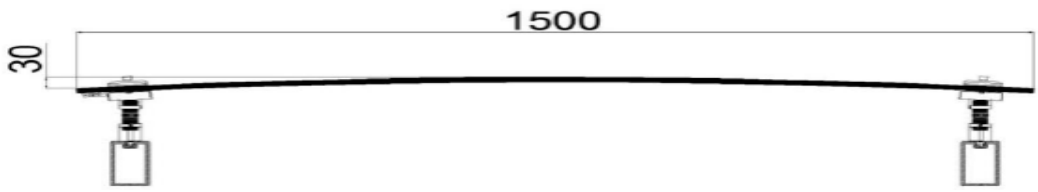
TECHNICAL TEMPLATE REFERENCE	
Technical subject	General description, design and materials of BIPV modules.
Partner	Onyx Solar, FLISOM
Author	Héctor Zamora/Elena Rico

PRODUCT CODE	
Project	PVSITES. Task 2.3. BIPV products portfolio
Category	Ventilated façade/ Curtain wall/ Skylight/ Roofing shingle/ Shading system
Denomination	X7 - Curved glass-glass, CIGS technology
Partner/s	Onyx, FLISOM

PICTURES

DESIGN DRAWING





Curved glass-glass opaque CIGS module

Observations:
Drawings of X7 product (sample X7-A, curved samples manufacture for indoor testing purposes-light soaking testing)

DETAILED DESCRIPTION	
Definition	Opaque curved glass-glass CIGS PV module
Construction unit	Ventilated façade/ Curtain wall/ Skylight
Architectural location	Façade/ Roof
Geometrical design	Rectangular curved glass-glass module based on CIGS technology
Dimensions	1500mm/500mm/11mm. Higher thicknesses can be used, but the cold bending process takes more time.
Geometrical shape	Rectangular, curved
Materials	Tempered glass, CIGS sub-module, encapsulant
Configuration	Simple laminated
Layers	From top to bottom: 4mm Front clear tempered glass, encapsulant, CIGS pre encapsulated module, encapsulant, 4mm rear tempered glass
Frame structure	Frameless
PV technology	Thin film (CIGS)
Surface treatments	May be included in front/rear side
Thermal insulation	Double glazing. Depending on the curvature required, additional technologies could be used.
Acoustic insulation	Double glazing. Depending on the curvature required, additional technologies could be used.
Physical features	Similar to other curved glazing skylights/glazing façade elements
Weight	21.32 kg/m^2
Rigidity	Rigid
Opacity	Opaque
Mobility	No mobile parts
Active energy features	Photovoltaic glazing that generates electricity with sun radiation.
Photovoltaic power	28 Wp/m^2
Additional gain	Other gains (concentration, etc.)
Passive energy features	Descriptive value
Optical transmittance	Opaque
Thermal transmittance (U value)	Defined by glazing system used

10.2 Mechanical Performance – X7

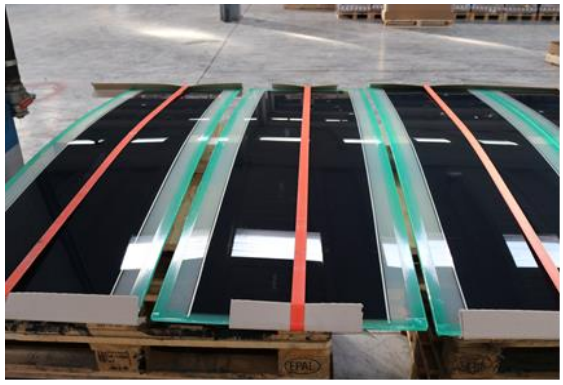
TECHNICAL TEMPLATE REFERENCE	
Technical subject	Mechanical performance of BIPV modules
Partner	Onyx, FLISOM
Author	Héctor Zamora/Elena Rico

PRODUCT CODE	
Denomination	X7 - Curved glass-glass, CIGS technology

DESIGN/DATASHEET VALUES						
BIPV UNIT						
General characteristics	Opaque curved glass-glass CIGS PV module					
Manufacturer	Onyx					
Model	Curved CIGS glass elements					
Shape	Rectangular, Curved					
Physical characteristics	Value 1	Unit 1	Value 2	Unit 2	Value 3	Unit 3
Width/ Length/ Thickness	500	mm	1500	mm	11	mm
Weight			21.32	kg/m^2	-	-
Mechanical characteristics	Value 1	Unit 1	Value 2	Unit 2	Value 3	Unit 3
Tensile strength	120-200	MPa				
Tensile modulus	~70	GPa				
Poisson coefficients	0.22	-				

Observations: Mechanical properties are the ones for the glass layers, which are the main mechanical material of the PV glazing.

Some views of X7-A samples during the cold bending process are shown as follows:



10.3 Architectural Integration – X7

TECHNICAL TEMPLATE REFERENCE	
Technical subject	Architectural integration of BIPV products
Partner	Onyx, FLISOM
Author	Héctor Zamora / Elena Rico

PRODUCT CODE	
Denomination	X7 - Curved glass-glass, CIGS technology

DEFINITION AND LOCATION	
Definition	Opaque curved glass-glass CIGS PV module (X7-E design)
Construction unit	Ventilated façade
Location	Due to their curved shape, it can be used in designs with non-linear shapes (irregular roofings, curved canopies, etc). This product was installed in a test bench platform in France
Architectural location	Façade

CONSTRUCTION UNIT FEATURES						
Physical properties	Length	Unit 1	Width	Unit 2	Thickness	Unit 3
Shape	Rectangular/ curved					
Dimensions	900	mm	450	mm	11	mm
Weight			21.32	kg/m^2		
Materials and devices	PV glazing. Includes junction box at the back					
Configuration	Simple laminated					
Frame structure	Frameless					
PV technology	Thin film (CIGS)					
Location of pipes, diameters	Each PV glazing will have two cables. Cables can be housed in the structure.					
Thermal insulation	Common glazing thermal insulation strategies can be used, taking into account the curvature of the glass					
Thermal bridge	Determined by structure					
Aesthetical features	Appearance can be customised					
Opacity	Opaque					
Colours of sub-modules	Black (Front), Gold (rear)					
Background colour	Customisable					
Frame colour	Customisable					

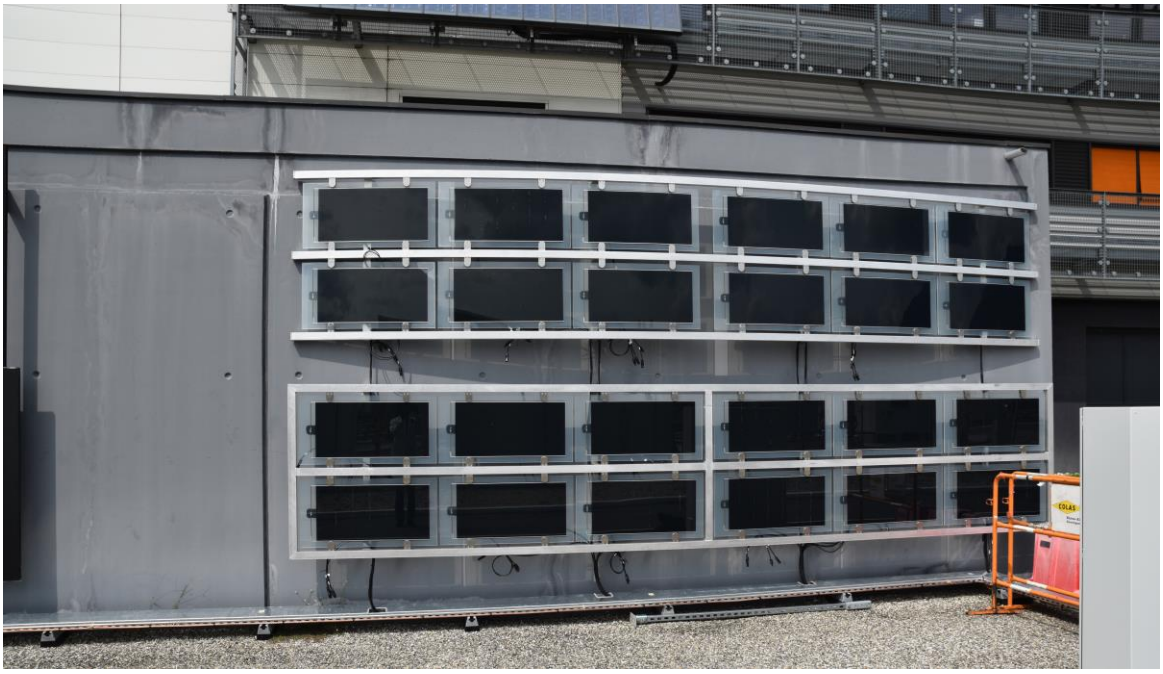
Surface treatments	Colour or surface technologies for glass can be used

INTEGRATION AND MAINTENANCE MEASURES	
Mounting system	Common façade systems applied for curved systems
Maintenance	Cleaning periodic activities, in order to avoid performance losses
Inspection	Remote monitoring
Sequence of inspection	N/A
Maintenance for the system	N/A
Sequence of maintenance	Cleaning frequency depends on environmental conditions
Accessibility of system	PV modules are accessible from the exterior
Safety procedure	Glazing system should comply with standards (f.i. CWCT note 67 or ETAG 034) in order to guarantee safety accessibility
Removal	Same removal process than normally applied in skylight or façade elements, taken care of disconnecting cables.

INTEGRATION AND MAINTENANCE MEASURES	
Construction	Facade
Mounting system	Common ventilated façade/curtain wall systems
Secondary construction	n.a.
Procedure	
New construction permits needed	Based on local regulations
Retrofitting permits needed	Based on local regulations
Maintenance	Cleaning periodic activities, in order to avoid performance losses
Inspection	Remote monitoring / Physical inspection
Sequence of inspection	At least twice a year
Maintenance for the system	Yes
Sequence of maintenance	Cleaning activities depending on the environmental conditions
Accessibility of system	PV modules are accessible from the exterior.
Safety procedure	Description of safety procedure needed
Removal	Same removal process than normally façade elements, take care of disconnecting cables
Accessibility for removal	PV modules are accessible from the exterior.
Ease of removal	Same removal process than normally façade elements, take care of disconnecting cables

Safety procedure needed	Glazing system should comply with standards (f.i. CWCT note 67 or ETAG 034) in order to guarantee safety accessibility

PHOTO



10.4 Electrical Performance – X7

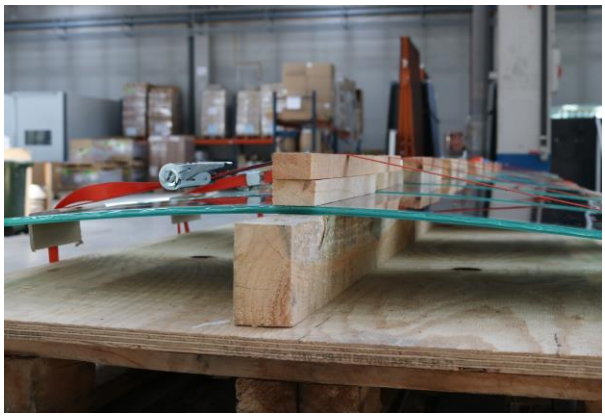
TECHNICAL TEMPLATE REFERENCE	
Technical subject	Electrical performance of BIPV modules
Partner	Tecnalia
Author	Daniel Valencia / Elena Rico

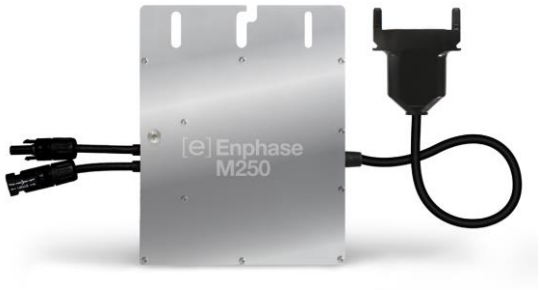
PRODUCT CODE	
Denomination	X7 - Curved glass-glass, CIGS technology

DESIGN/DATASHEET VALUES						
PHOTOVOLTAIC CELL/ ARRAY						
General characteristics	Opaque curved glass-glass CIGS PV module					
Manufacturer	FLISOM					
Cell type	CIGS pre encapsulated sub-module					
Shape	Rectangular/customisable					
Colour	Black PV active surface. Transparent non-coloured glazing					
Front layer	Clear tempered glass					
Frame	Frameless PV glass					
Connection Box	Non specific					
Cables	4 mm^2 up to 1000V					
Connectors	MC4					
Series-parallel connection						
Physical characteristics	Value 1	Unit 1	Value 2	Unit 2	Value 3	Unit 3
Height/ Length/ Thickness (glazing)	900	mm	450	mm	11	mm
Height/ Length/ Thickness (CIGS submodule)	742	mm	372	mm	-	mm
Electrical characteristics	Value 1	Unit 1	Value 2	Unit 2	Value 3	Unit 3
Rated power	30	Wp	108.6	Wp/m^2		-
Efficiency	11	%		-		-
Tolerance	±10	%		-		-
Vmp	34	V		-		-
Imp	0.88	A		-		-
Voc	46	V		-		-
Isc	0.97	A		-		-

Thermal parameters	Value 1	Unit 1	Value 2	Unit 2	Value 3	Unit 3
Isc (α) Temp. coefficient	0.01	%/ºC				-
Voc (β) Temp. coefficient	-0.3	%/ºC				-
P (γ) Temp. coefficient	-0.35	%/ºC				-
Operating range						
Temperature	-40 - +90	ºC				
Maximum System Voltage	1000	V				
Protection	IP65					
Maximum Wind /Snow Load	2400	Pa				
Max. Reverse Current (IR)	N/A	A				

POWER MANAGEMENT SYSTEM (demos)						
General characteristics	Integration of curved and planar glass-glass CIGS modules in façade configuration in a test bench platform					
Manufacturer	Onyx					
Model	Opaque curved glass-glass CIGS PV module					
Physical characteristics	Value 1	Unit 1	Value 2	Unit 2	Value 3	Unit 3
Module Height/ Length/ Thickness	900	mm	450	mm	11	mm
Module curvature (Façade 1 / Façade 2)	12.5	mm	0	mm		
Module Weight	21.32	Kg/m^2		-		-
Number of modules	12 per façade					
PV façade area	4.86	m2				
Number of façades	2					
Electrical characteristics	Value 1	Unit 1	Value 2	Unit 2	Value 3	Unit 3
DC Power (Fac 1 / Fac 2)	373.2	W	359.6	W		-
Inverters	2 microinverters Enphase M250 (60V)					-
Strings	12 PV modules in parallel					-
Observations:						

PICTURE
CONFIGURATION AND MATERIALS
   
Observations: Pictures of X7-E CIGS samples (Front and rear views of one X7-E sample, X7-E laminated standard samples and closer view of the bending system of X7-E samples)

POWER MANAGEMENT SYSTEM

Observations: Enphase M250 inverter

10.5 Optical Performance – X7

TECHNICAL TEMPLATE REFERENCE	
Technical subject	Optical performance of BIPV modules
Partner	Tecnalia
Author	Maider Machado / Daniel Valencia

PRODUCT CODE	
Denomination	X7 - Curved glass-glass, CIGS technology

DESIGN / DATASHEET VALUES

BIPV UNIT						
General characteristics	Opaque curved glass-glass CIGS PV module					
Manufacturer	Flisom - Onyx Solar					
Model	Curved CIGS glass elements					
Shape	Curved - Rectangular					
Physical characteristics	Value 1	Unit 1	Value 2	Unit 2	Value 3	Unit 3
Height/ Length/ Thickness	500	mm	1500	mm	11	mm
Weight			21.32	kg/m^2	-	-
Optical characteristics	Value 1	Unit 1	Value 2	Unit 2	Value 3	Unit 3
Visible transmittance	0	%	-	-	-	-
Solar transmittance	0	%	-	-	-	-
Visible reflectance (tz)	-	%	-	-	-	-
Solar reflectance (tz)	-	%	-	-	-	-
Visible reflectance (cz)	5	%	-	-	-	-
Solar reflectance (cz)	8.9	%	-	-	-	-
Visible absorptance (tz)	-	%	-	-	-	-
Solar absorptance (tz)	-	%	-	-	-	-
Visible absorptance (cz)	95	%	-	-	-	-
Solar absorptance (cz)	91.1	%	-	-	-	-
Emissivity	83.7	%	-	-	-	-
Observations: Absorptance is calculated from transmittance and reflectance values. Acronym (tz): transparent zone. Acronym (cz): cell zone.						

10.6 Maintenance and Dismantling – X7

TECHNICAL TEMPLATE REFERENCE	
Technical subject	Maintenance and dismantling of products and installations
Partner	Onyx Solar
Author	Elena Rico

PRODUCT CODE	
Denomination	Opaque curved glass-glass CIGS PV module-X7

MAINTENANCE		
BY THE USER	Periodicity (months)	Description
Action 1	Depending on the environmental conditions, Similar as conventional glazing	Cleaning periodic activities, in order to avoid performance losses
Action 2	Twice per year	Checking system connections
Action 3	Twice per year	Checking cable system
Action 4	Twice per year	Checking the sealing of the junction boxes
Action 5	Twice per year	Checking the structural pieces in the structure that supports the photovoltaic modules
Action 6	Twice per year	Checking if any glass may be fractured
Action 7	Twice per year	Checking all segments of the BOS
Action 8	Twice per year	Checking all the earth connections
Observations.		

DISMANTLING
Description of dismantling Similar than other conventional glass solutions, take care of disconnecting cables

10.7 Economic Evaluation – X7

TECHNICAL TEMPLATE REFERENCE	
Technical subject	Economic evaluation and benefits of BIPV modules
Partner	Onyx Solar
Author	Elena Rico

PRODUCT CODE	
Denomination	X7 - Curved glass-glass, CIGS technology

ECONOMIC BALANCE						
General assumptions taking into account in the economic study	**Value 1**	**Unit 1**				
Total building area	767.31	m^2				
Net conditioned building area	767.31	m^2				
Curtain wall or ventilated facade surface area	200	m^2				
Peak power of glass-glass CIGS module	75	W/m^2				
Local electricity cost	0.2367	€/kWh				
Variation in electricity cost until 2020	8.18	%				
Variation in electricity cost from 2020	1.00	%				
Costs estimation of ventilated façade system	**Value 1**	**Unit 1**	**Value 2**	**Unit 2**	**Value 3**	**Unit 3**
Conventional equivalent glass Cladding material/ Fixation system/BOS	115	$€/m^2$	70	$€/m^2$	0	$€/m^2$
CIGS glass-glass module Cladding material/ Fixation system/BOS	245	$€/m^2$	70	$€/m^2$	50.55	$€/m^2$
Energy behavior of a building with ventilated façade systems	**Value 1**	**Unit 1**	**Value 2**	**Unit 2**	**Value 3**	**Unit 3**
Wall + conventional ventilated façade: HVAC energy consumption / Renewable energy production	50829.31	kWh/year	0	kWh/year		
Wall + PV ventilated façade: HVAC energy consumption / Renewable energy production	50829.31	kWh/year	14420.59	kWh/year		
Total reduction of energy demand with opaque glass-glass PV CIGS ventilated façade (PV VENTILATED FAÇADE versus	**Value 1**	**Unit 1**	**Value 2**	**Unit 2**	**Value 3**	**Unit 3**

CONVENTIONAL VENTILATED FACADES)						
ENERGY SAVINGS INDUCED BY THERMAL ENVELOPE IN 30 YEARS (A)	0	euro	0	kWh	…	
PV ENERGY PRODUCTION IN 30 YEARS (B)	146637	euro	389355	kWh	…	
TOTAL REDUCTION OF ENERGY DEMAND IN 30 YEARS (A+B)	146637	euro	389355	kWh	16.9	%
Economic metrics with PV opaque glass-glass CIGS ventilated facade (PV versus CONVENTIONAL GLASS VENTILATED FAÇADE)	**Value 1**	**Unit 1**	**Value 2**	**Unit 2**	**Value 3**	**Unit 3**
Average reduction of energy demand	733.19	€/m^2				
Amount to invest	180.55	€/m^2				
Amount to invest after incentives	180.55	€/m^2				
ROI	307	%				
Payback period	< 8	years				
IRR	14	%				
Times the investment	4.07	time				

Observations:
The economic study has been conducted considering the energy savings by the BIPV products under different scenarios.

With the aim of having results of the reduction in the energy demand of a whole building due to opaque glass-glass CIGS product (which exhibits a black finish on the front side due to the homogeneous and linear aspect of the CIGS sub-modules), different models have been simulated with Design Builder software. An office building type has been chosen to simulate the energetic behavior under different scenarios. The south façade building is a conventional opaque wall and the idea is to analyze the implementation of different types of ventilated facades as an energy retrofit measure.

Ventilated façade is the selected system because it is the most appropriate to integrate the opaque CIGS photovoltaic product in order to maximize the saving costs. A canopy could be also a good integration choice, but in this case the additional energy savings as consequence of the passive properties of the material is lower than in ventilated façade configuration. The ventilated façade system is composed of an insulation material in the inner part, an air gap and a cladding material in the outer layer. The cladding layer can be made of different materials: wood, stone, composite, glass, photovoltaic glass…This system is implemented to reduce thermal exchanges and to avoid thermal bridges. Thanks to the ventilated air chamber and the application of insulating material, this system increases the acoustic absorption and reduces the amount of heat that buildings absorb in hot weather conditions. The difference between the density of hot and cold air within the air space creates natural ventilation through a chimney effect. This

helps in eliminating heat and moisture, enhancing the comfort level of the occupants. By using a photovoltaic cladding material, the façade also produces clean electricity.

Therefore, the economic analysis is performed by comparing between the opaque existing conventional wall and the same wall with different ventilated façade systems. Also, an economic analysis comparing the different conventional ventilated facades with the opaque (glass-glass CIGS) modules is made to present the economic advantages of this innovative system with respect to other more conventional systems. In other words, the objective is to compare the product developed with other similar non-photovoltaic solutions. The selected conventional ventilated façade systems are the following:

- Composite panel consisting of two aluminum cover sheets and a mineral-filled polymer core.
- Porcelain tiles.
- Conventional equivalent black glass (non-photovoltaic).

In this document, only the third scenario is presented (conventional equivalent black glass (non-photovoltaic) ventilated façade versus fully opaque PV façade based on CIGS glass-glass modules). Ventilated façade solution in the south façade in the city of Madrid has been used as case study. The level of irradiation in Madrid is 1663 kWh/m^{2}year.

11 X8 - Framing system for c-Si large area glas

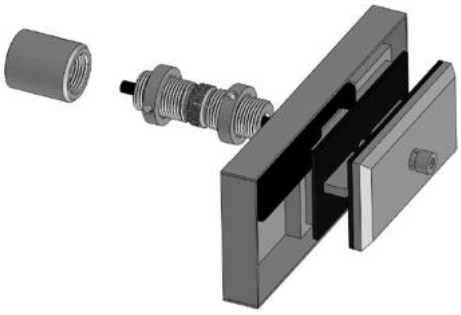
11.1 General Description, Design and Materials – X8

TECHNICAL TEMPLATE REFERENCE	
Technical subject	General description, design and materials of BIPV modules.
Partner	Onyx Solar
Author	Léo Staccioli, Héctor Zamora

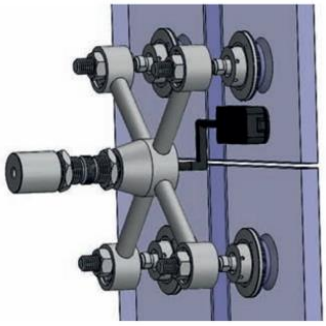
PRODUCT CODE	
Project	PVSITES. Task 2.3. BIPV products portfolio
Category	Ventilated façade/ Curtain wall/ Skylight/ Roofing shingle/ Shading system
Denomination	X8 - Framing system for c-Si large area glass

PICTURES

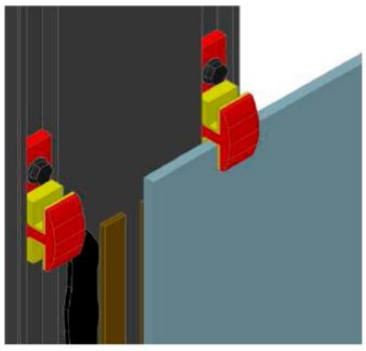
EXPLODED DRAWING / ARTIST IMPRESSION



1.Mounting system for ventilated façades



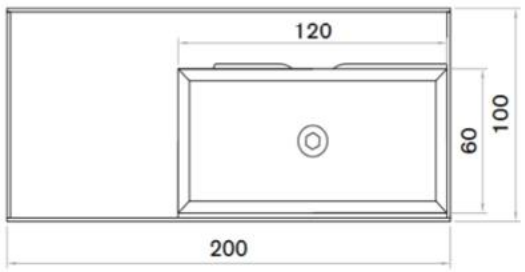
2.Mounting system for PV skylights and curtain walls

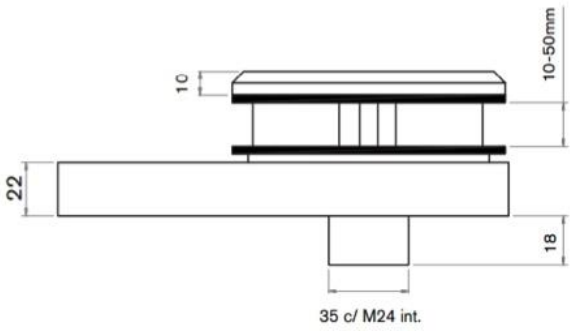


3.Mounting system for ventilated façades

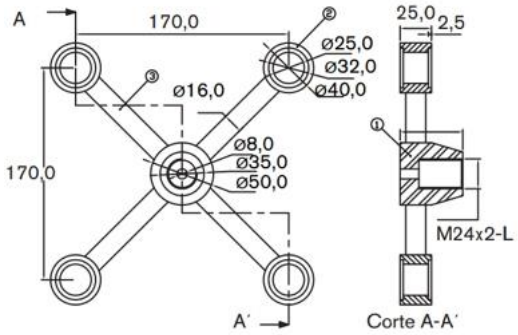
4.Mounting system for ventilated façade

DESIGN DRAWINGS

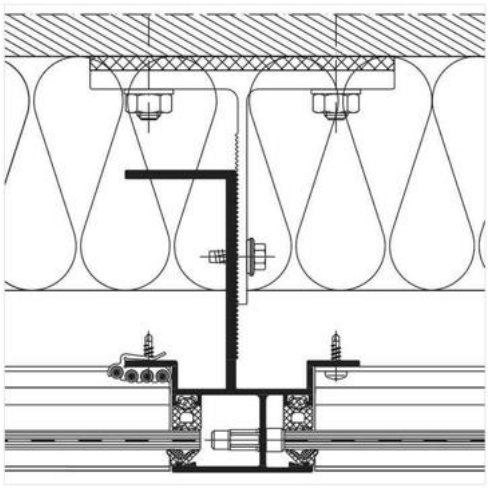




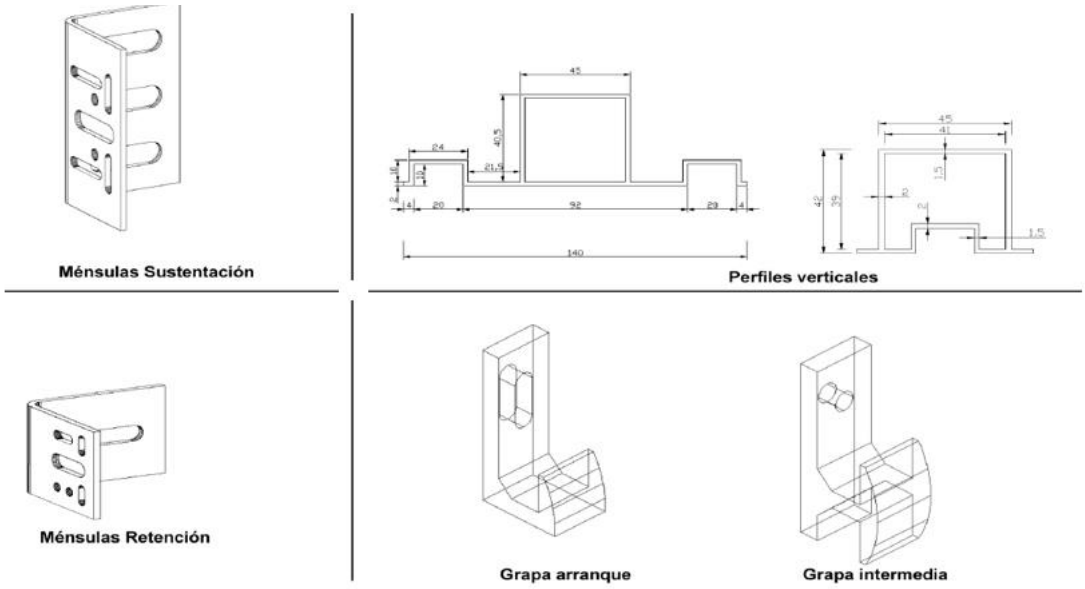
Mounting system for ventilated façades



2.Mounting system for PV skylights and curtain walls



4.Mounting system for ventilated façade



3.Mounting system for ventilated façades

DETAILED DESCRIPTION	
Definition	Framing system for c-Si large area glass
Construction unit	Ventilated façade/ Curtain wall/ Skylight
Architectural location	Façade/ Roof
Geometrical design	Depends on the glazing
Dimensions	Height: up to 2400 mm, Length: up to 5100 mm (dimensions of the glazing)
Geometrical shape	Depends on the glazing
Materials	Aluminium/ Stainless steel/ PV glazing
Frame structure	1. Mounting system for ventilated façades 2. Mounting system for PV skylights and curtain walls 3. Mounting system for ventilated façades 4. Mounting system for ventilated façade
PV technology	c-Si large area glass
Encapsulation material	EVA
Weight	Total weight will depend on the glazing
Rigidity	Rigid
Opacity	Depends on the glazing
Mobility	No mobile parts
Active energy features	Photovoltaic glazing that generates electricity with Sun radiation
Photovoltaic power	Depends on the glazing
Optical transmittance	Depends on the glazing
Thermal transmittance (U value)	Defined by glazing system used

11.2 Mechanical Performance – X8

TECHNICAL TEMPLATE REFERENCE	
Technical subject	Mechanical performance of BIPV modules
Partner	Onyx Solar
Author	Léo STACCIOLI

PRODUCT CODE	
Denomination	X8 - Framing system for c-Si large area glass

DESIGN/DATASHEET VALUES		
BIPV UNIT		
General characteristics	Framing system for c-Si large area glass	
Physical characteristics	1. Mounting system for ventilated façades (Example)	Unit 1
Height/ Length/ Thickness	Depends on the glazing	mm
Weight	Depends on the glazing	kg
Others	-	-
Mechanical characteristics (Framing system)	Value 1	Unit 1
Ø	12-100	mm
Elastic Limit: Rp 0,2 min	200	N/mm^2
Elastic Limit: Rp 1,0 min	275	N/mm^2
Tensile strength: Rp min	500-700	N/mm^2
Elongation: AMin(Long/Trans)	40-30	**%**
HB (Brinel) max hardness	215	-

11.3 Architectural Integration – X8

TECHNICAL TEMPLATE REFERENCE	
Technical subject	Architectural integration of BIPV products
Partner	Onyx Solar
Author	Léo Staccioli/ Elena Rico

PRODUCT CODE	
Denomination	X8 - Framing system for c-Si large area glass

DEFINITION AND LOCATION	
Definition	Framing system for c-Si large area glass
Construction unit	Ventilated façade/ Curtain wall/ Skylight
Location	Demonstrator test bench in Chambery (France)
Architectural location	Façade

CONSTRUCTION UNIT FEATURES						
Physical properties	Length	Unit 1	Width	Unit 2	Thickness	Unit 3
Shape	Rectangular/Customizable					
Dimensions (glazing)	3036	mm	1368	mm		mm
Materials and devices	Aluminium/Stainless steel + XL c-Si PV glazing					
Configuration	Ventilated facade					
Frame structure	Aluminium/Stainless steel					
PV technology	6” monocrystalline Si cells					
Location of pipes, diameters	Depends on the glazing					
Thermal insulation	Common glazing thermal insulation strategies can be used					
Thermal bridge	Determined by structure					
Opacity	62%					
Cell colour	Dark blue/Blue					
Background colour	Full black					
Frame colour	Grey (aluminium/stainless steel)					
Surface treatments	Colour or surface technologies for glass can be used. The module used is composed by an anti-slip front glass and a rear black glass.					

INTEGRATION AND MAINTENANCE MEASURES	
Construction	Ventilated facade
Mounting system	Façade
Secondary construction	n.a.
Procedure	
New construction permits needed	N/A
Retrofitting permits needed	N/A
Maintenance	Cleaning periodic activities, in order to avoid performance losses
Inspection	Remote monitoring
Sequence of inspection	
Maintenance for the system	Cleaning periodic activities, in order to avoid performance losses
Sequence of maintenance	Cleaning frequency depends on environmental conditions
Accessibility of system	PV modules are accessible from the exterior
Safety procedure	Framing system should comply with standards ETAG 034 (Wind suction resistance) and CWCT note 67 (Impact due to maintenance activities)

Removal	Same removal process than normally façade, curtain wall and skylight elements, taken care of disconnecting cables
Accessibility for removal	Description
Ease of removal	Description

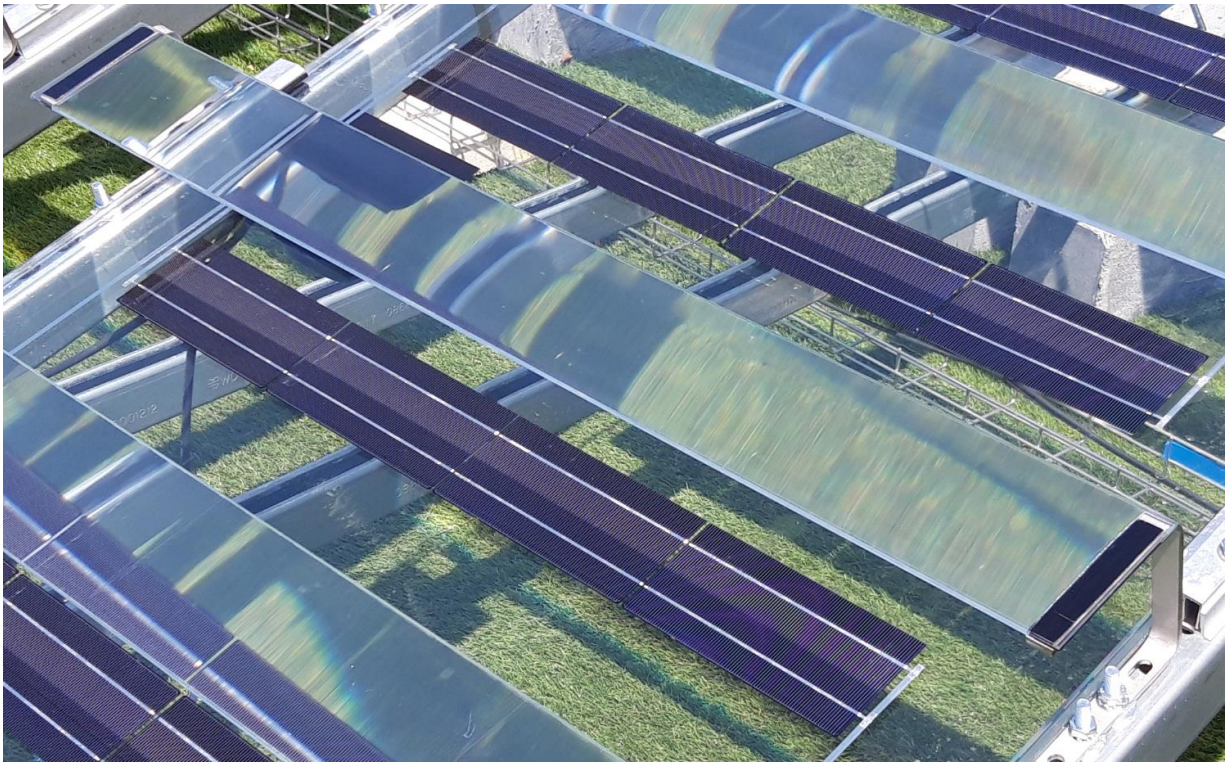
12 X9 - C-Si semi-transparent low concentration and solar control BIPV system – skylight configuration

12.1 General Description, Design and Materials – X9

TECHNICAL TEMPLATE REFERENCE	
Technical subject	General description, design and materials of BIPV modules
Partner	Tecnalia
Author	Daniel Valencia

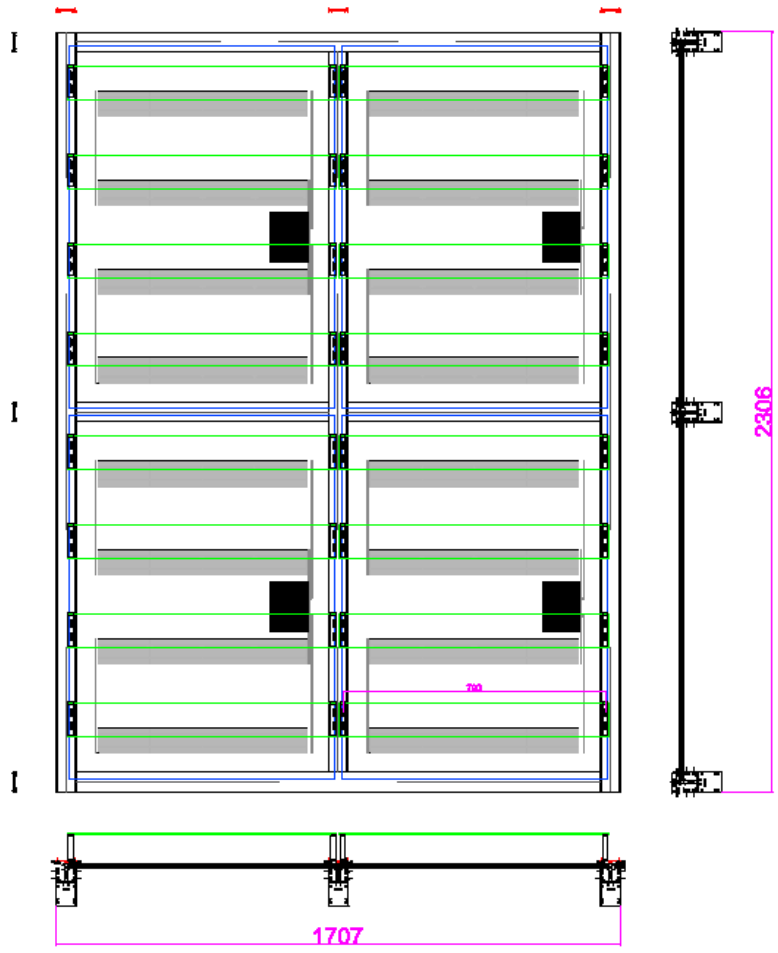
PRODUCT CODE	
Project	PVSITES. Task 2.3. BIPV products portfolio
Category	Skylight
Denomination	X9 - C-Si semitransparent low concentration and Solar control BIPV system – skylight configuration (LCSK)
Partner/s	Tecnalia, Film Optics, Bear, Nobatek, Onyx

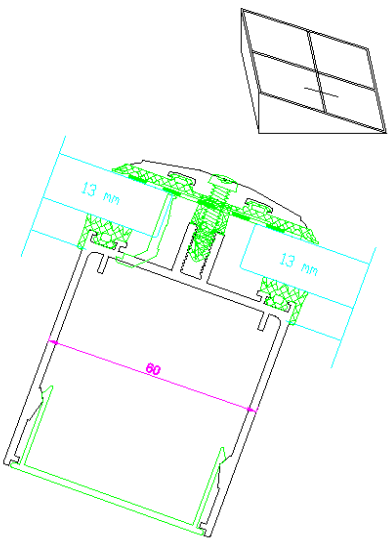
PICTURES
PHOTOS



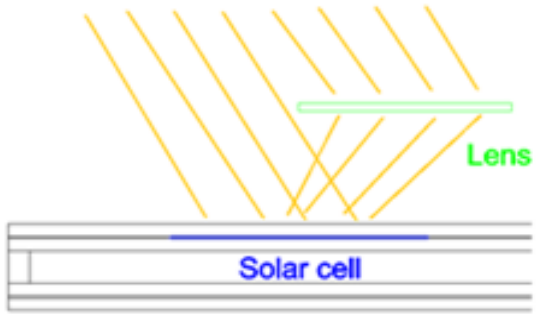
Observations:
Photovoltaic skylight system including lenses to concentrate solar radiation onto the solar cells during the central part of the year and allow light passing towards the interior of the building during the winter.

DESIGN PLANS

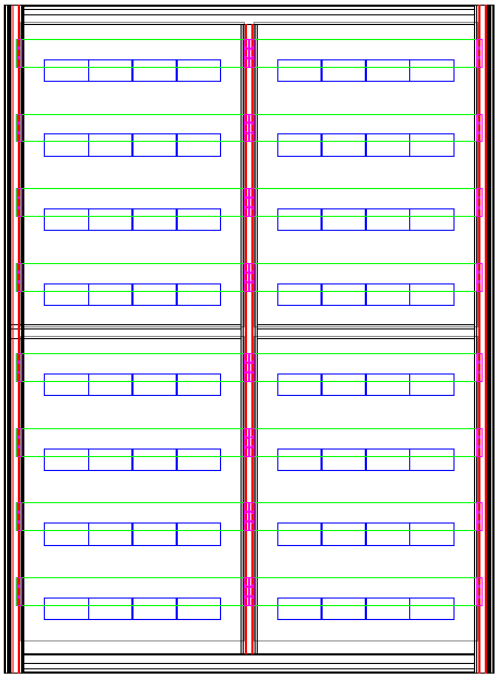




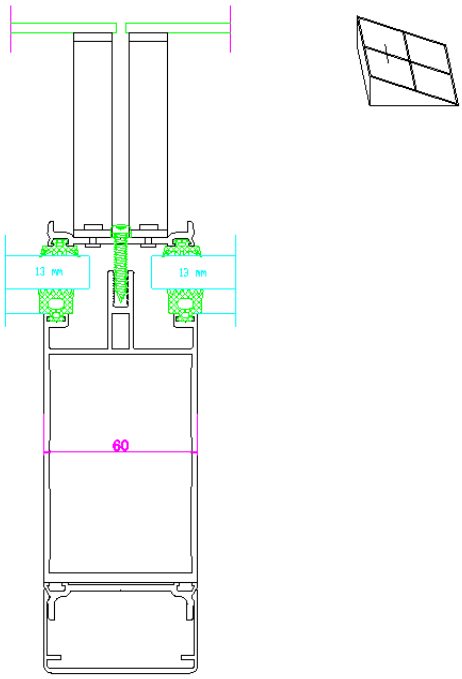
Horizontal section



Working principle (spring-summer)



Front view



Vertical section with single glazing

DETAILED DESCRIPTION	
Definition	PV rectangular glazing combined with optical system anchored to the skylight structure
Construction unit	Skylight
Architectural location	Roof
Geometrical design	Rectangular glazing combined with optical systems
Dimensions	Height: 700-3000 mm, Length: 350-1000 mm.
Geometrical shape	Rectangular
Materials	PV glazing (glass, EVA, silicon solar cells) + Optical system (glass, PMMA), structural system (aluminium, steel)
Configuration	Simple or double glazing
Layers	From top to bottom: Optical system: Extraclear glass, PMMA; PV glazing: Extraclear glass glass, EVA, Solar cells, EVA, glass, junction box Additional layers maybe added in case of double glazing Glass layers may be tempered depending on safety requirements
Frame structure	Aluminium. Others may be used
PV technology	Si-polycrystalline
Encapsulation material	EVA

Surface treatments	May be included on PV glazing back side
Thermal insulation	Common glazing technologies can be used (double/triple glazing, low-E coatings, etc)
Acoustic insulation	Double/triple glazing can be used. Especial encapsulants should be studied
Physical features	Similar to other glazing skylights
Weight	20 to 60 kg/m^2 (glazing) + 5 kg/m^2 (optical system) + 8 kg/m^2 (extra aluminium structure)
Rigidity	Rigid
Opacity	Transparent, with opaque solar cells
Mobility	No mobile parts
Active energy features	Photovoltaic glazing that generates electricity with Sun radiation
Photovoltaic power	40 Wp/m^2 with standard config. It can be customized
Additional gain	Peak power may be multiplied up to 1.8X due to concentration effects
Passive energy features	Variable optical properties depending on the season
Optical transmittance	~39% in summer and ~47% in winter (for simple PV glazing, Latitude 45º, 20º tilted)
Thermal transmittance (U value)	Defined by glazing system

12.2 Mechanical Performance – X9

TECHNICAL TEMPLATE REFERENCE	
Technical subject	Mechanical performance of BIPV modules
Partner	Tecnalia
Author	Daniel Valencia

PRODUCT CODE	
Denomination	X9 - C-Si semitransparent low concentration and Solar control BIPV system – skylight configuration (LCSK)

DESIGN/DATASHEET VALUES	
BIPV UNIT	
General characteristics	PV rectangular glazing combined with optical system anchored to the skylight structure
Manufacturer	Onyx Solar
Model	Low-C Skylight

Shape	Rectangular			
Physical characteristics	PV glazing	Unit	Optical system	Unit
Height/ Length/ Thickness	700-3000/ 350-1000/ 8-40	mm	100/ 360-1020/ 4	mm
Weight	20 - 60	kg/m^2	~ 0.36-1	kg/lens
Mechanical characteristics	Glass mechanical properties			
Breakage distributed load of lenses	8	kPa		
Tensile strength	120-200 (tempered); 40 (float)	MPa	120-200 (tempered); 40 (float)	MPa
Tensile modulus	~70	GPa	~70	GPa
Poisson coefficients	0.22	-	0.22	-

Observations:

Mechanical characteristics are the ones from the glass layers, which are the main mechanical material of the PV glazing and the optical system

12.3 Architectural Integration – X9

TECHNICAL TEMPLATE REFERENCE	
Technical subject	Architectural integration of BIPV products
Partner	Tecnalia
Author	Daniel Valencia

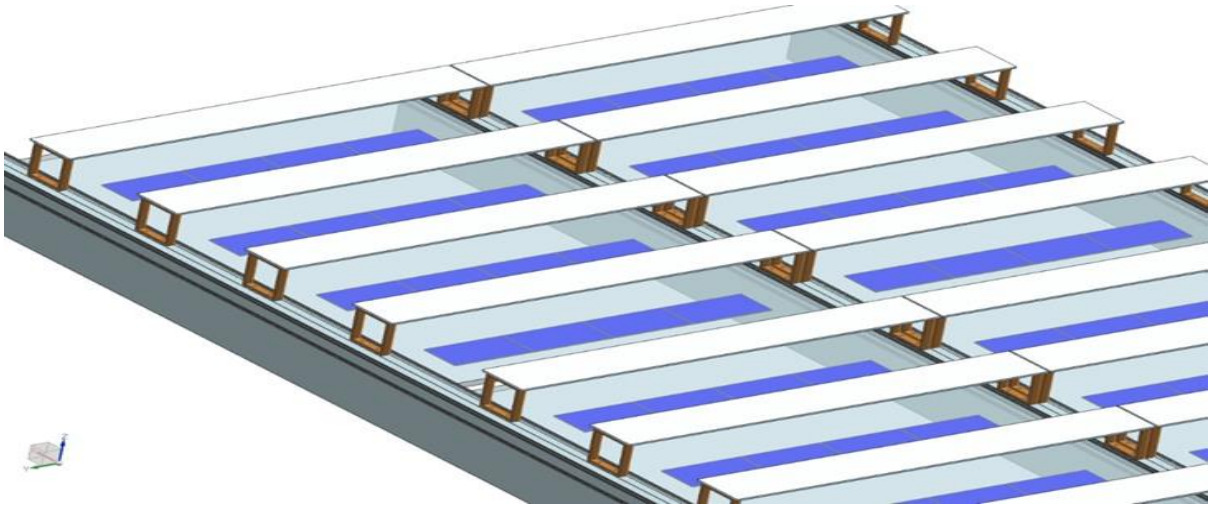
PRODUCT CODE	
Denomination	X9 - C-Si semitransparent low concentration and Solar control BIPV system – skylight configuration (LCSK)

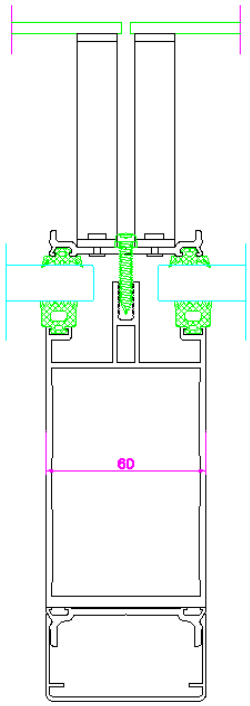
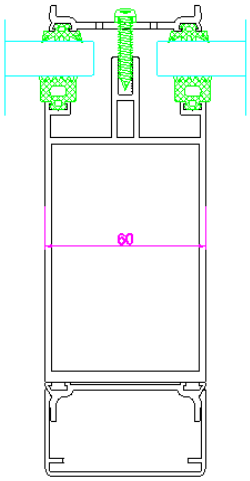
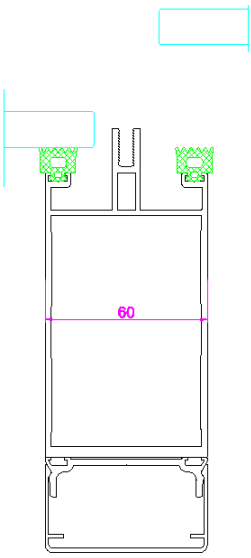
DEFINITION AND LOCATION	
Definition	PV rectangular glazing combined with optical system anchored to the skylight structure
Construction unit	Skylight
Location	Especially useful in latitudes range +/-20º - +/- 50º. Better in locations with high direct radiation
Architectural location	Roof

CONSTRUCTION UNIT FEATURES						
Physical properties	Height	Unit 1	Length	Unit 2	Thickness	Unit 3
Shape	Rectangular					
Dimensions	700-3000	mm	350-1000	mm	200-256*	mm
Standardized variations	312	mm	156	mm	1-2	mm
Weight	33-73*	kg/m^2	Depend on glazing configuration			
	** Including structure, PV glazing and optical system*					
Materials and devices	PV glazing (double or simple). Includes junction box at the back and optical system above glazing, anchored to the skylight structure					
Configuration	Double glazing (IGU) or simple laminated					
Frame structure	Aluminium/ steel skylight structure (others materials can be possible)					
PV technology	78x156 mm crystalline silicon solar cells (half cells)					
Location of pipes, diameters	Each PV glazing will have two cables. Cables can be housed in the structure					
Thermal insulation	Common glazing thermal insulation strategies can be used					
Thermal bridge	Determined by structure					
Aesthetical features	Structure appearance can be customized					
Opacity	Transparent glazing with opaque PV cells covering 20-30% of the area					
Cell colour	Dark blue (front), grey (back)					
Background colour	Customizable					
Frame colour	Customizable					
Surface treatments	Colour or surface technologies for glass can be used					

INTEGRATION AND MAINTENANCE MEASURES	
Construction	
Mounting system	Common skylight structural system. Structure pressure plate geometry should be studied
Secondary construction	Additional supports for optical system are required. Specific holes in skylight structure are needed
Procedure for lenses installation	1) Drill threaded holes on the pressure plate of the skylight structure 2) screw the lenses supports 3) Stick the lenses to the supports
New construction permits needed	N/A
Retrofitting permits needed	N/A
Maintenance	Clean the lenses at the beginning of spring if it has not rained
Inspection	Remote monitoring

Sequence of inspection	N/A
Maintenance for the system	N/A
Accessibility of system	Optical elements can be easily removed to access any area of the system
Safety procedure	Glazing system (and skylight system in general) should comply with standards (f.i. CWCT note 67) in order to guarantee safety accessibility
Removal	1) Remove optical elements (lenses) 2) Remove structure pressure plate 3) Remove glass as normally done in skylight, taken care of disconnecting cables
Accessibility for removal	If required, lenses can be removed to reach the working area. They can be easily dismounted by removing bolts
Ease of removal	Description

PICTURES
Integration method


		
Initial	*Remove optical elements*	*Remove structure pressure plate and glass*

12.4 Electrical Performance– X9

TECHNICAL TEMPLATE REFERENCE	
Technical subject	Electrical performance of BIPV modules
Partner	Tecnalia
Author	Daniel Valencia

PRODUCT CODE	
Denomination	X9 - C-Si semitransparent low concentration and Solar control BIPV system – skylight configuration (LCSK)

EXAMPLE OF MODULE DATASHEET						
MODULE						
General characteristics	Simple laminated semitransparent PV module					
Manufacturer	Not specific cell provider required					
Cell type	78x156 mm crystalline silicon solar cells (half cells) with 2BB					
Module Shape	Rectangular					
Module Colour	Dark blue solar cells. Transparent non-coloured glazing					
Front layer	Extra-clear glass plate					
Frame	Frameless PV glass					
Junction Box (JB)	On module backside for simple glazing. Edge-JB for double glazing					
Cables	4 mm^2 up to 1000V					
Connectors	MC4					
Series-parallel connection	Non-parallel connection within one module					
Physical characteristics	Value 1	Unit 1	Value 2	Unit 2	Value 3	Unit 3
Height/ Length/ Thickness	1100	mm	800	mm	13	mm
Electrical characteristics	Value 1	Unit 1	Value 2	Unit 2	Value 3	Unit 3
Rated power [Wp – Wp/m^2]	32 - 40	Wp – Wp/m^2	Up to +60% aprox due to lens concentration			
Efficiency	16.4	%	Up to +60% aprox due to lens concentration			
Vmp: max. power voltage	8.10	V		-		-
Imp: max. power current	3.91	A	Up to +60% aprox due to lens concentration			
Voc: open circuit voltage	10.2	V		-		-
Isc: short circuit current	4.15	A	Up to +60% aprox due to lens concentration			
Thermal parameters	Value 1	Unit 1	Value 2	Unit 2	Value 3	Unit 3

Isc (α) Temp. coefficient	+0.08	%/ºC				-
Voc (β) Temp. coefficient	-0.361	%/ºC				-
P (γ) Temp. coefficient	-0.451	%/ºC				-
Operating range						
Temperature	-40 - +85	ºC				
Maximum System Voltage	600	V				

POWER MANAGEMENT SYSTEM (demos)						
General characteristics	Skylight composed by 4 semitransparent PV modules in 2x2 configuration					
Manufacturer	Onyx					
Model	X9 - C-Si semitransparent low concentration and Solar control BIPV system – skylight configuration (LCSK)					
Physical characteristics	Value 1	Unit 1	Value 2	Unit 2	Value 3	Unit 3
Height/ Length	2306	mm	1707	mm	-	mm
Electrical characteristics	Value 1	Unit 1	Value 2	Unit 2	Value 3	Unit 3
Voc / Isc / Pmp	40	V	4.25	A	127	W
Inverter characteristics	DC electronic loads with MPPT function are used instead of microinverter					

POWER MANAGEMENT SYSTEM
Observations: DC electronic loads with MPPT function are used instead of microinverter

12.5 Optical Performance – X9

TECHNICAL TEMPLATE REFERENCE	
Technical subject	Optical performance of BIPV modules
Partner	Tecnalia
Author	Daniel Valencia

PRODUCT CODE	
Denomination	X9 - C-Si semitransparent low concentration and Solar control BIPV system – skylight configuration (LCSK)

DESIGN/DATASHEET VALUES

BIPV UNIT						
General characteristics	PV laminated glass with rows of half solar cells every 270 mm					
Manufacturer	Onyx Solar					
Model	X9 – simple glazing 6+6 mm					
Shape	Rectangular					
Physical characteristics	Value 1	Unit 1	Value 2	Unit 2	Value 3	Unit 3
Height/ Length/ Thickness	1100	mm	800	mm	13	mm
Weight	27	kg	30.7	kg/m^2	-	-
PV ratio (PVR)	22.1	%				
Optical characteristics	Value 1	Unit 1	Value 2	Unit 2	Value 3	Unit 3
Visible transmittance (tz)	89.8	%	-	-	-	-
Solar transmittance (tz)	81.9	%	-	-	-	-
Visible reflectance (tz)	8.5	%	-	-	-	-
Solar reflectance (tz)	7.8	%	-	-	-	-
Visible reflectance (cz)	10.1	%	-	-	-	-
Solar reflectance (cz)	5.9	%	-	-	-	-
Visible absorptance (tz)	1.7	%	-	-	-	-
Solar absorptance (tz)	10.3	%	-	-	-	-
Visible absorptance (cz)	89.9	%	-	-	-	-
Solar absorptance (cz)	94.1	%	-	-	-	-
Emissivity	83.7	%	-	-	-	-

Observations:
Absorptance is calculated from transmittance and reflectance values. Acronym (tz): transparent zone. Acronym (cz): cell zone.
This data does not consider the effect of redirection of light by the optical system as it varies strongly with latitude, tilt, PV occupancy ratio of glazing and diffuse light ratio. This effect will affect to operational solar factor and light transmittance.

12.6 System PV production – X9

TECHNICAL TEMPLATE REFERENCE	
Technical subject	PV production of BIPV modules
Partner	Tecnalia
Author	Daniel Valencia

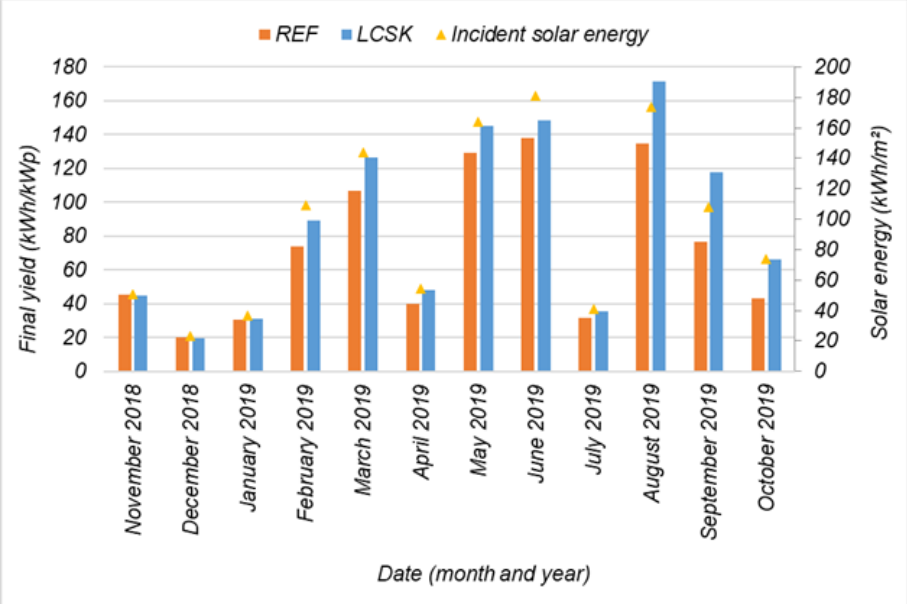
PRODUCT CODE	
Denomination	X9 - C-Si semitransparent low concentration and Solar control BIPV system – skylight configuration (LC-SK)

MEASURED PV PERFORMANCE (PV Ratio = 29%)						
Prototype at CEA-INES Chambery, France	LCSK with lenses	REF w/o lenses	LCSK vs REF			Unit
Irradiation Plane-of-Array	1159		-			kWh/m^2
PV production per m^2 – Yearly	170.3	141.9	+20.0%			kWh/m^2
PV production per kWp	1044	870.3				kWh/kWp
Average operating* temperature	24.8	23.9	+4.0%			ºC
Max operating* temperature	73.1	63.4	-			ºC
Min temperature	2.8	1.8	-			ºC
Heating Energy (>21ºC)	594	758	-21.6%			kWh
Cooling Energy (<26ºC)	1871	2421	-22.7%			kWh
Total thermal Energy	2478	3192	-22.4%			kWh
Average natural daylighting	598	586	+2.0%			Lux

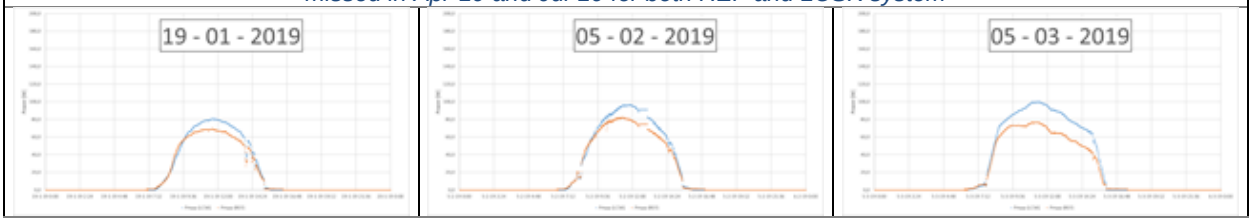
Observations:
Some data missing for some periods, thus absolute PV production and irradiation values are slightly lower than expected. However, it affects the same for both LCSK and REF cases.
Operating temperature means with irradiance > 100 W/m^2.
The heating system of the test cell was set to 21ºC.
The cooling system of the test cell was set to 26ºC.

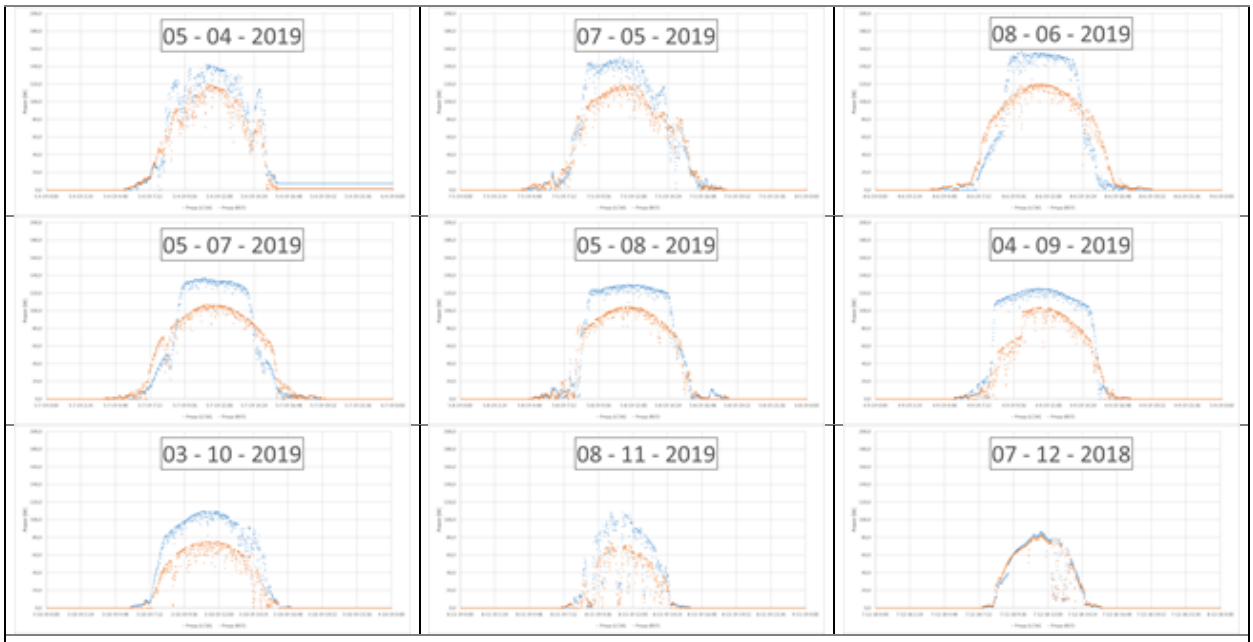
Two PV skylights installed in FACT experimental building at CEA-INES, Chambery, France.
Left : Reference PV skylight without lenses (REF) Right : New PV skylight with lenses (LCSK)

PV PRODUCTION – LCSK vs CONVENTIONAL PV



Measured monthly PV production of low-C skylight (LCSK) with 29% cell occupancy compared to equivalent PV skylight without low-concentration system (REF). Location: Chambery (FR), Inclination: 20º south. Significant data missed in Apr-19 and Jul-19 for both REF and LCSK system





Daily production profiles of REF and LCSK. The production increase occurs mainly during spring-summer, especially at noon hours.

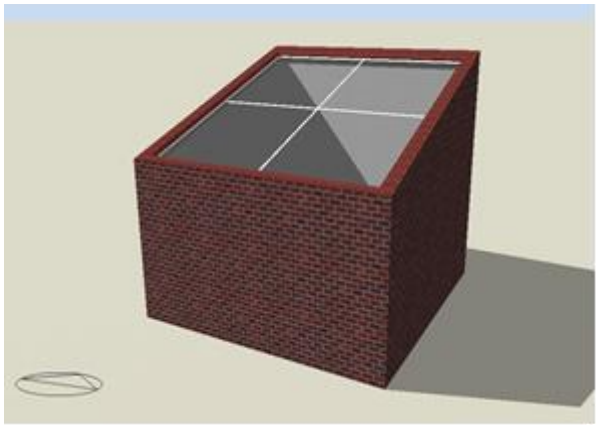
12.7 Simulation of Passive Performance – X9

TECHNICAL TEMPLATE REFERENCE	
Technical subject	Passive performance of BIPV modules
Partner	Tecnalia
Author	Daniel Valencia

PRODUCT CODE	
Denomination	X9 - C-Si semitransparent low concentration and Solar control BIPV system – skylight configuration (LCSK)

PILOT BUILDING	
Definition	Simple box building
Use	Office
Area	32 m^2
Orientation	South

DESIGN PLANS



Graphic picture from Design Builder

Observations.
Dimensions of buildings were set to 6x6x6 meters, and its use was defined assuming an office demand, which includes internal temperatures between 20-26 ºC during working hours from Monday to Friday and a minimum level of illuminance during those hours.

REFERENCE DEMAND OF THE PILOT BUILDING

Location	Lyon (lat 45º)			Sevilla (lat 38º)			Jerusalem (lat 32º)			
Energy demand	LC-SK	Ref	Variation	LC-SK	Ref	Variation	LC-SK	Ref	Variation	Units
Heating annual demand	70	69	1.4%	6	5	+20%	7	7	0%	kWh/m^2
Cooling annual demand	97	101	-4.0%	147	151	-2.6%	142	145	-2.1%	kWh/m^2
Lighting annual demand	3	3	0%	3	3	0%	3	3	0%	kWh/m^2
Total annual demand	170	173	-1.7%	155	159	-2.5%	152	155	-1.9%	kWh/m^2
PV production	68	60	13.3%	103	90	+14.4%	101	91	11.0%	kWh/m^2
Net annual energy consumption	102	113	-9.7%	52	69	-24.6%	51	64	-20.3%	kWh/m^2

Observations.
Low concentration skylight system (LC-SK) is compared with equivalent common PV skylight, both with 29% PV ratio. Skylight surface of 31m^2 in a simple building of 36 m^2.
Energy production and savings are based on simulation. Real measurements not available yet.

12.8 Maintenance and Dismantling – X9

TECHNICAL TEMPLATE REFERENCE	
Technical subject	Maintenance and dismantling of products and installations
Partner	Tecnalia
Author	Daniel Valencia

PRODUCT CODE	
Denomination	X9 - C-Si semitransparent low concentration and Solar control BIPV system – skylight configuration (LCSK)

MAINTENANCE		
BY THE USER	Periodicity (months)	Description
Action 1	3	Check monitored production data vs expectation
Action 2	12	Clean the lenses at the beginning of spring
Observations.		

DISMANTLING
Description of dismantling Lenses can be cleaned with water or with common glass cleaning products

12.9 Life Cycle Assessment – X9

TECHNICAL TEMPLATE REFERENCE	
Technical subject	Life cycle assessment of products and installations
Partner	CTCV
Author	Marisa Almeida

PRODUCT CODE	
Denomination	X9 - C-Si semitransparent low concentration and Solar control BIPV system – skylight configuration (LCSK)

LCA INDICATORS					
	Value 1	Unit 1			
Global warming	135	Kg CO2 eq/m^2			

Acidification	1,116	kg SO_2 eq/m^2			
Eutrophication	0,128	kg PO4-3 eq /m^2			
Photochemical oxidation formation	0,0496	kg C2H4 eq /m^2			
Abiotic depletion	1740	MJ /m^2			
Ozone layer depletion	2,07E-05	kg CFC-11 eq/m^2			
Human Toxicity	1,80E-05	CTUh /m			
Particulate matter	1,30E-01	kg PM2.5 eq/m^2			
Observations: Provisional data based on generic ACV for GIGs with similar properties. LCA methodology: ISO14040/ISO14044 with CML and ILCD methods.					

12.10 Economic Evaluation – X9

TECHNICAL TEMPLATE REFERENCE	
Technical subject	Economic evaluation and benefits of BIPV modules
Partner	Tecnalia
Author	Daniel Valencia

PRODUCT CODE	
Denomination	X9 - C-Si semitransparent low concentration and Solar control BIPV system – skylight configuration (LCSK)

ECONOMIC BALANCE						
Investment	Retail price (VAT exc)	Unit 1				
Investment LCSK system (glazing + structure)	571	€ / m^2				
Investment BOS	19	€ / m^2				
Mechanical installation costs	72	€ / m^2				
Electrical installation costs	10	€ / m^2				
Avoided cost for building materials (-)	455	€ / m^2				
Avoided installation cost for other materials (-)	88	€ / m^2				
Subtotal investment	129	€ / m^2				
Incentives (-)	0	%				

TOTAL INVESTMENT (A)	129	€ / m^2				
	Real Prototype	Simulation				
	Chambery (lat 45º)	Lyon (lat 45º)	Sevilla (lat 38º)	Jerusalem (lat 32º)	Units	
PV Overgeneration	+6.6	+8	+13	+10	kWh / m^2	
Energy savings (electricity)	39.67	1.5	2	1.5	kWh_e / m^2	
kWh_e cost	0.15				€	
Extra PV income	6.94	1.43	2.25	1.73	€ / m^2	
Simple payback (A/B)	18.6	90	57	74	year	
Observations: For energy savings, heat pump system with average COP=2 is assumed. Cost of electricity kWh = 15c€.						

13 X11 - C-Si semitransparent low concentration and solar control BIPV system – shading element configuration

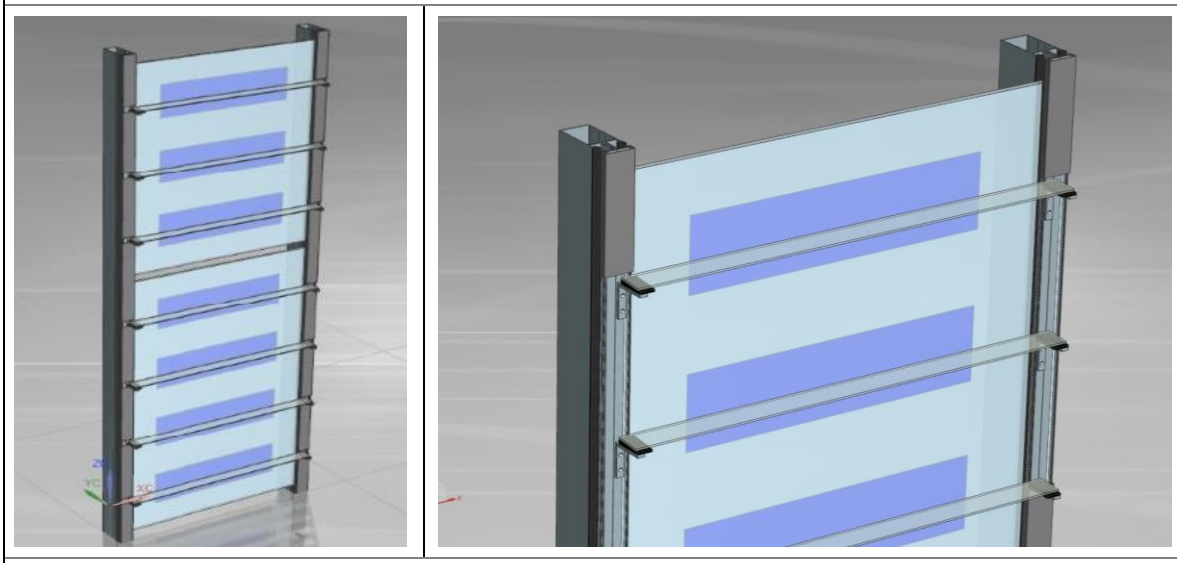
13.1 General Description, Design and Materials – X11

TECHNICAL TEMPLATE REFERENCE	
Technical subject	General description, design and materials of BIPV modules
Partner	Tecnalia
Author	Daniel Valencia

PRODUCT CODE	
Project	PVSITES. Task 2.3. BIPV products portfolio
Category	Facade
Denomination	X11 - C-Si semitransparent low concentration and Solar control BIPV system – façade configuration (LCFC)
Partner/s	Tecnalia, Film Optics, BEAR, Nobatek, Onyx

PICTURES

REALISTIC DRAWING / ARTIST IMPRESSION

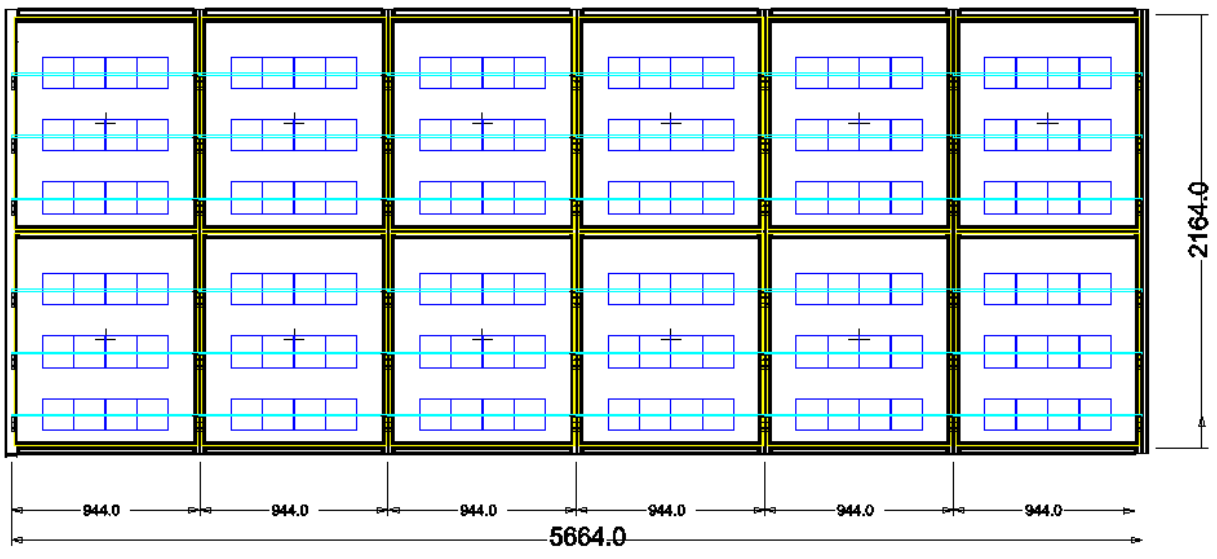


First design with 7 rows of cells

Real Prototype of LCFC

Observations:
Photovoltaic façade system including lenses to concentrate solar radiation onto the solar cells during the central part of the year and allow light passing towards the interior of the building during the winter.

DESIGN DRAWINGS



DETAILED DESCRIPTION	
Definition	PV rectangular glazing combined with optical system anchored to the façade structure
Construction unit	Curtain wall/ Shading system
Architectural location	Façade
Geometrical design	Rectangular glazing combined with optical systems
Dimensions	Height: 700-3000 mm, Length: 350-1000 mm.
Geometrical shape	Rectangular
Materials	PV glazing (glass, EVA, silicon solar cells) + Optical system (glass, PMMA), structural system (aluminium, EPDM)
Configuration	Double glazing or simple laminated glass
Layers	From exterior to interior: Optical system: Extraclear glass, PMMA; PV glazing: Extraclear glass glass, EVA, Solar cells, EVA, glass, junction box Additional layers maybe added in case of double glazing Glass layers maybe tempered depending on safety requirements
Frame structure	Aluminium / steel. Others may be used
PV technology	Crystalline silicon solar cells
Encapsulation material	EVA
Surface treatments	May be included on PV glazing back side
Thermal insulation	Common glazing technologies can be used (double/triple glazing, low-E coatings, etc)
Acoustic insulation	Double/triple glazing can be used. Special encapsulants should be studied
Physical features	Similar to other glazed façades
Weight	20 to 60 kg/m^2 (glazing) + 5 kg/m^2 (optical system) + 8 kg/m^2 (aluminium structure)
Rigidity	Rigid
Opacity	Transparent, with opaque solar cells
Mobility	No mobile parts
Active energy features	Photovoltaic glazing that generates electricity with Sun radiation
Photovoltaic power	40 Wp/m^2 with standard config. It can be customized
Additional gain	Generated power may be multiplied up to 2X due to concentration effects during spring-summer
Passive energy features	Variable optical properties depending on the season
Thermal transmittance (U value)	Defined by glazing system used

13.2 Mechanical Performance – X11

TECHNICAL TEMPLATE REFERENCE	
Technical subject	Mechanical performance of BIPV modules
Partner	Tecnalia
Author	Daniel Valencia

PRODUCT CODE	
Denomination	X11 - C-Si semitransparent low concentration and Solar control BIPV system – façade configuration (LCFC)

DESIGN/DATASHEET VALUES				
BIPV UNIT				
General characteristics	PV rectangular glazing combined with optical system anchored to the façade structure			
Manufacturer	Onyx Solar			
Model	Low-C Façade			
Shape	Rectangular			
Physical characteristics	PV glazing	Unit	Optical system	Unit
Height/ Length/ Thickness	700-3000/ 350-1000/ 8-40	mm	100/ 360-1020/ 4-6	mm
Weight	20 - 60	kg/m^2	~5	kg/m^2
Mechanical characteristics	Glass mechanical properties			
Breakage distributed load of lenses	8	kPa		
Tensile strength	120-200 (tempered); 40 (float)	MPa	120-200 (tempered); 40 (float)	MPa
Tensile modulus	~70	GPa	~70	GPa
Poisson coefficients	0.22	-	0.22	-
Observations: Mechanical characteristics are the ones from the glass layers, which are the main mechanical material of the PV glazing and the optical system				

13.3 Architectural Integration – X11

TECHNICAL TEMPLATE REFERENCE	
Technical subject	Architectural integration of BIPV products
Partner	Tecnalia
Author	Daniel Valencia

PRODUCT CODE	
Denomination	X11 - C-Si semitransparent low concentration and Solar control BIPV system – façade configuration (LCFC)

DEFINITION AND LOCATION	
Definition	PV rectangular glazing combined with optical system anchored to the façade structure
Construction unit	Façade/ Curtain wall glazing
Location	Especially useful in latitudes range +/-20º - +/- 50º. Better in locations with high direct radiation
Architectural location	Façade

CONSTRUCTION UNIT FEATURES						
Physical properties	Height	Unit 1	Length	Unit 2	Thickness	Unit 3
Shape	Rectangular					
Dimensions	700-3000	mm	350-1000	mm	200-256*	mm
Standardized variations	312	mm	156	mm	1-2	mm
Weight	33-73*	kg/m^2	Depend on glazing configuration			
	** Including structure, PV glazing and optical system*					
Materials and devices	PV glazing (double or simple). Includes junction box at the back and optical system above glazing anchored to the skylight structure					
Configuration	Double glazing or simple laminated					
Frame structure	Aluminium (others can be possible)					
PV technology	crystalline-Si. 156x156 mm solar cells					
Location of pipes, diameters	Each PV glazing will have two cables. Cables can be housed in the structure					
Thermal insulation	Common glazing thermal insulation strategies can be used					
Thermal bridge	Determined by structure					
Aesthetical features	Structure appearance can be customized					
Opacity	Transparent glazing with opaque PV cells covering 30-40% of the area					

Cell colour	Dark blue (front), grey (back)
Background colour	Customizable
Frame colour	Customizable
Surface treatments	Colour or surface technologies for glass can be used

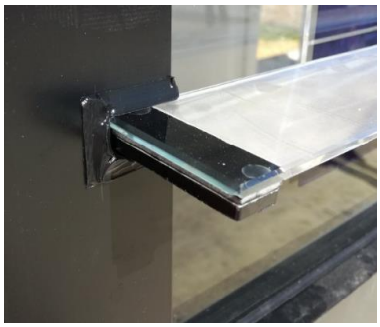
INTEGRATION AND MAINTENANCE MEASURES	
Construction	
Mounting system	Common curtain wall structural system. Structure pressure plate geometry should be studied
Secondary construction	Additional supports for optical system are required. Specific holes in structure are needed
Procedure for lenses installation	1) Drill threaded holes on the pressure plate of the skylight structure 2) screw the lenses supports 3) Stick the lenses to the supports
New construction permits needed	N/A
Retrofitting permits needed	N/A
Maintenance	Clean the lenses at the beginning of spring if it has not rained
Inspection	Remote monitoring
Sequence of inspection	N/A
Maintenance for the system	N/A
Sequence of maintenance	
Accessibility of system	Similar to other façade systems. Optical elements can be easily removed if required
Safety procedure	Glazing system should comply with standards in order to guarantee safety accessibility
Removal	1) Remove optical elements (lenses) and disconnect module cables 2) Remove structure pressure plate 3) Remove glass as in normal curtain walls
Accessibility for removal	If required, lenses can be removed to reach the working area. They can be easily dismounted by removing the screws
Ease of removal	Description

PICTURES

Integration method

Overview demo façade without lenses

Façade integration detail with lenses



Overview of details

13.4 Electrical Performance – X11

TECHNICAL TEMPLATE REFERENCE	
Technical subject	Electrical performance of BIPV modules
Partner	Tecnalia
Author	Daniel Valencia

PRODUCT CODE	
Denomination	X11 - C-Si semitransparent low concentration and Solar control BIPV system – façade configuration (LCFC)

EXAMPLE OF MODULE DATASHEET						
PHOTOVOLTAIC CELL/ ARRAY						
General characteristics	Simple laminated semitransparent PV module					
Manufacturer	Not specific cell provider required					
Cell type	Crystalline silicon. 156x156 mm solar cell					
Module Shape	Rectangular					
Module Colour	Dark blue solar cells. Transparent non-coloured glazing					
Front layer	Low-iron glass plate					
Frame	Frameless PV glass					
Connection Box	On module backside for simple glazing. Edge-JB for double glazing					
Cables	4 mm^2 up to 1000V					
Connectors	MC4					
Series-parallel connection	Non-parallel connection within one module					
Physical characteristics of demo module	Value 1	Unit 1	Value 2	Unit 2	Value 3	Unit 3
Height/ Length/ Thickness	1059	mm	922	mm	13	mm
Electrical characteristics of demo module	Value 1	Unit 1	Value 2	Unit 2	Value 3	Unit 3
Rated power	42	Wp	43	Wp/m^2		-
Efficiency	14.4	%	-	-		-
Vmp: max. power voltage	5.78	V		-		-
Imp: max. power current	7.37	A		-		-
Voc: open circuit voltage	7.49	V		-		-
Isc: short circuit current	7.89	A		-		-
Thermal parameters	Value 1	Unit 1	Value 2	Unit 2	Value 3	Unit 3
Isc (α) Temp. coefficient	+0.08	%/ºC				-
Voc (β) Temp. coefficient	-0.361	%/ºC				-
P (γ) Temp. coefficient	-0.451	%/ºC				-
Operating range						
Temperature	-40 - +85	ºC				
Maximum System Voltage	600	V				
Maximum Wind /Snow Load	N/A	Pa				

Max. Reverse Current (IR)	N/A	A				

POWER MANAGEMENT SYSTEM (demos)						
General characteristics	Façade composed by 12 semitransparent PV modules					
Manufacturer	Onyx					
Model	X9 - C-Si semitransparent low concentration and Solar control BIPV system – façade configuration (LCFC)					
Physical characteristics	Value 1	Unit 1	Value 2	Unit 2	Value 3	Unit 3
Height/ Length	2164	mm	1707	mm	-	mm
Electrical characteristics	Value 1	Unit 1	Value 2	Unit 2	Value 3	Unit 3
Number of strings	2					
String 1: Voc / Isc / Pmp	45	V	7.89	A	252	W
String 2: Voc / Isc / Pmp	45	V	7.89	A	252	W
Inverter characteristics	Value 1	Unit 1	Value 2	Unit 2	Value 3	Unit 3
Number MPPTs	2					
MPPT voltage range / operation range / Startup	22-45	V	16-52	V	22	V
Maximum Input Current	12 x 2	A				
Max continuous Output Power / Peak Output Power	500	W	548	W		
Efficiency (EN50530 EU)	95	%		-		-
Observations:						

13.5 Thermal Performance – X11

TECHNICAL TEMPLATE REFERENCE	
Technical subject	Thermal performance of BIPV modules
Partner	Tecnalia
Author	Daniel Valencia

13.6 Optical Performance – X11

TECHNICAL TEMPLATE REFERENCE	
Technical subject	Optical performance of BIPV modules

Partner	Tecnalia
Author	Daniel Valencia

PRODUCT CODE	
Denomination	X11 - C-Si semitransparent low concentration and Solar control BIPV system – façade configuration (LCFC)

DESIGN/DATASHEET VALUES						
BIPV UNIT						
General characteristics	PV laminated glass with rows of solar cells every 312 mm					
Manufacturer	Onyx Solar					
Model	X11 – simple glazing 6+6 mm					
Shape	Rectangular					
Physical characteristics	Value 1	Unit 1	Value 2	Unit 2	Value 3	Unit 3
Height/ Length/ Thickness	1059	mm	922	mm	13	mm
Weight	31	kg	35.2	kg/m^2		
PV ratio (PVR)	30	%				
Optical characteristics	Value 1	Unit 1	Value 2	Unit 2	Value 3	Unit 3
Visible transmittance (tz)	89.8	%	-	-	-	-
Solar transmittance (tz)	81.9	%	-	-	-	-
Visible reflectance (tz)	8.5	%	-	-	-	-
Solar reflectance (tz)	7.8	%	-	-	-	-
Visible reflectance (cz)	10.1	%	-	-	-	-
Solar reflectance (cz)	5.9	%	-	-	-	-
Visible absorptance (tz)	1.7	%	-	-	-	-
Solar absorptance (tz)	10.3	%	-	-	-	-
Visible absorptance (cz)	89.9	%	-	-	-	-
Solar absorptance (cz)	94.1	%	-	-	-	-
Emissivity	83.7	%	-	-	-	-
Observations: Absorptance is calculated from transmittance and reflectance values. Acronym (tz): transparent zone. Acronym (cz): cell zone.						

This data does not consider the effect of redirection of light by the optical system as it varies strongly with latitude, tilt, PV occupancy ratio of glazing and diffuse light ratio. This effect will affect to operational solar factor and light transmittance.

13.7 System PV production – X11

TECHNICAL TEMPLATE REFERENCE	
Technical subject	PV production of BIPV modules
Partner	Tecnalia
Author	Daniel Valencia

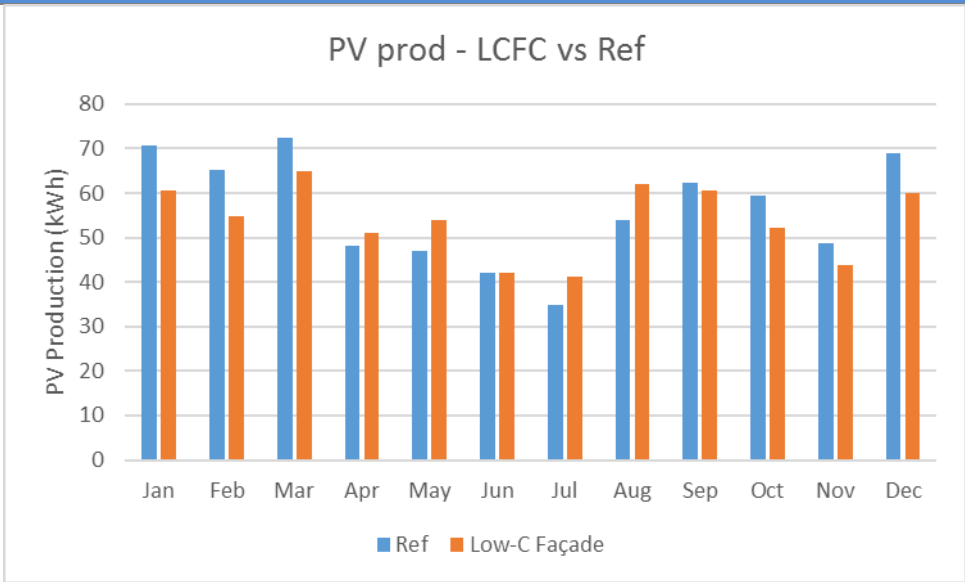
PRODUCT CODE	
Denomination	X11 - C-Si semitransparent low concentration and Solar control BIPV system – skylight configuration (LCFC)

MEASURED PV PERFORMANCE (PV Ratio = 29%)						
Prototype in Seville, Spain	LCFC with lenses	REF w/o lenses	LCFC vs REF			Unit
Irradiation Plane-of-Array	1351		-			kWh/m^2
PV production per m^2 – Yearly	174.1	177.3	-1.8%			kWh/m^2
PV production per kWp	1233	1211				kWh/kWp
Average operating* temperature	39.5	39.5	0%			ºC
Max operating* temperature	60.8	61.2	-			ºC
Min temperature	4.5	3.7	-			ºC

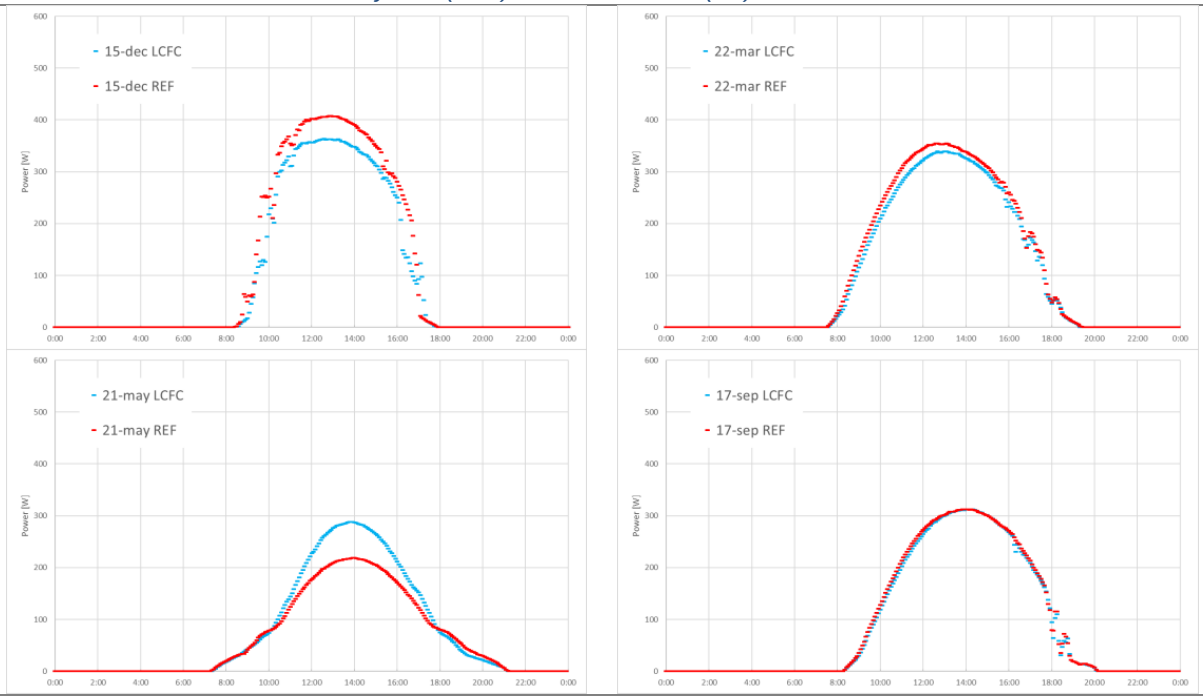
Observations:
Operating temperature means with irradiance > 100 W/m^2.

Two PV façades installed in Seville, Spain.
Left : Reference PV façade without lenses (REF) Right : New PV façade with lenses (LCFC)

PV PRODUCTION – LCFC vs CONVENTIONAL PV



Measured monthly PV production of low-C façade (LCFC) compared to equivalent PV façade without low-concentration system (REF). Location: Sevilla (SP), Inclination: 90º south.



Daily production profiles of REF and LCFC. The production increase occurs mainly during spring-summer, especially at noon hours.

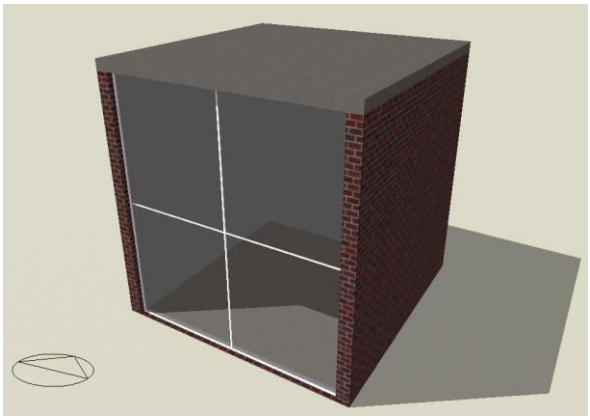
13.8 Simulation of Passive Performance – X11

TECHNICAL TEMPLATE REFERENCE

Technical subject	Passive performance of BIPV modules
Partner	Tecnalia
Author	Daniel Valencia

PRODUCT CODE	
Denomination	X11 - C-Si semitransparent low concentration and Solar control BIPV system – façade configuration (LC-FC)

PILOT BUILDING	
Definition	Simple box building
Use	Office
Area	32 m^2
Orientation	South
DESIGN PLANS	



Graphic picture from Design Builder

Observations.
Dimensions of buildings were set to 6x6x6 meters, and its use was defined assuming an office demand, which includes internal temperatures between 20-26 ºC during working hours from Monday to Friday and a minimum level of illuminance during those hours.

REFERENCE DEMAND OF THE PILOT BUILDING										
Location	Lyon (lat 45º)			Sevilla (lat 38º)			Jerusalem (lat 32º)			
Energy demand	LC-FC	Ref	Variation	LC-FC	Ref	Variation	LC-FC	Ref	Variation	Units
Heating annual demand				4	4	0%				kWh/m^2
Cooling annual demand				167	191	-12,6%				kWh/m^2

Lighting annual demand				4	3	+33%				kWh/m^2
Total annual demand				175	198	-11,6%				kWh/m^2
PV production				87	91	-4,4%				kWh/m^2
Net annual energy consumption				88	107	-17,8%				kWh/m^2
Observations. Low concentration façade system (LCFC) is compared with equivalent common PV skylight, both with 50% PV ratio. Skylight surface of 32m^2 in a simple building of 36 m^2. Energy demand data based on simulations.										

13.9 Maintenance and Dismantling – X11

TECHNICAL TEMPLATE REFERENCE	
Technical subject	Maintenance and dismantling of products and installations
Partner	Tecnalia
Author	Daniel Valencia

PRODUCT CODE	
Denomination	X11 - C-Si semitransparent low concentration and Solar control BIPV system – façade configuration (LCFC)

MAINTENANCE		
BY THE USER	Periodicity (months)	Description
Action 1	3	Check monitored production data vs expectation
Action 2	12	Clean the lenses at the beginning of spring if it has not rained
Observations.		

DISMANTLING
Description of dismantling Lenses can be cleaned with water or with common glass cleaning products

13.10 Life Cycle Assessment – X11

TECHNICAL TEMPLATE REFERENCE	
Technical subject	Life cycle assessment of products and installations
Partner	CTCV
Author	Marisa Almeida

PRODUCT CODE	
Denomination	X11 - C-Si semitransparent low concentration and Solar control BIPV system – façade configuration (LCFC)

LCA INDICATORS					
	Value 1	Unit 1			
Global warming	140	Kg CO2 eq/m^2			
Acidification	1,152	kg SO_2 eq/m^2			
Eutrophication	0,132	kg PO4-3 eq /m^2			
Photochemical oxidation formation	0,051	kg C2H4 eq /m^2			
Abiotic depletion	1880	MJ /m^2			
Ozone layer depletion	2,34E-05	kg CFC-11 eq/m^2			
Human Toxicity	2,16E-05	CTUh /m^2			
Particulate matter	1,43E-01	kg PM2.5 eq/m^2			
Observations: Provisional data based on generic ACV for GIGs with similar properties. LCA methodology: ISO14040/ISO14044 with CML and ILCD methods					

13.11 Economic Evaluation – X11

TECHNICAL TEMPLATE REFERENCE	
Technical subject	Economic evaluation and benefits of BIPV modules
Partner	Tecnalia
Author	Daniel Valencia

PRODUCT CODE	
Denomination	X11 - C-Si semitransparent low concentration and Solar control BIPV system – façade configuration (LC-FC)

ECONOMIC BALANCE						
Investment	Retail price (VAT exc)	Unit 1				
Investment LC-FC system (glazing + structure)	542	€ / m^2				
Investment BOS	19	€ / m^2				
Engineering costs	…	€ / m^2				
Mechanical installation costs	80	€ / m^2				
Electrical installation costs	10	€ / m^2				
Avoided cost for building materials (-)	459	€ / m^2				
Avoided installation cost for other materials (-)	95	€ / m^2				
Subtotal investment	97	€ / m^2				
Incentives (-)	0	%				
TOTAL INVESTMENT (A)	97	€ / m^2				
Annual costs	Value 1	Unit 1				
Maintenance cost	…	euro/year				
Financial cost	…	euro /year				
TOTAL ANNUAL COSTS	Lyon (lat 45º)	Sevilla (lat 38º)	Jerusalem (lat 32º)	Units		
PV Overgeneration	-	-4	-	kWh / m^2		
Energy savings (electricity)	-	23	-	kWh_e / m^2		
kWh_e cost	0.15			€		
Extra PV income	-	2,85	-	€ / m^2		
Simple payback (A/B)	-	34	-	year		

Observations: Energy production and savings are based on simulation. Real measurements not available yet. For energy savings, heat pump system with average COP=2 is assumed. Cost of electricity kWh = 15c€.

14 X12 - Glazed modules treated for improved passive properties (Light blue mass coloured glass)

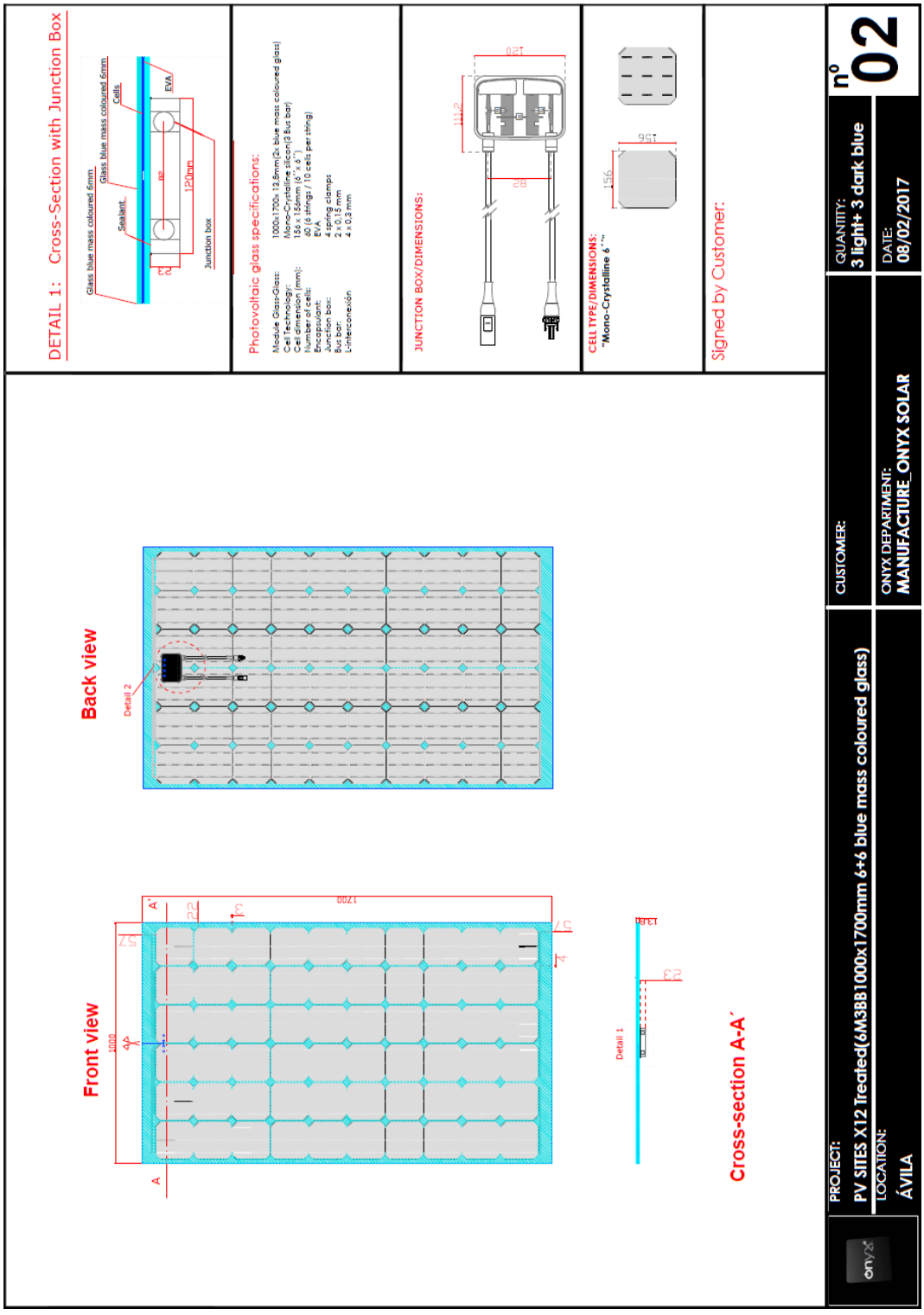
14.1 General Description, Design and Materials – X12

TECHNICAL TEMPLATE REFERENCE	
Technical subject	General description, design and materials of BIPV modules.
Partner	Onyx Solar
Author	Léo Staccioli, Héctor Zamora, Elena Rico

PRODUCT CODE	
Project	PVSITES. Task 2.3. BIPV products portfolio
Category	Ventilated façade/ Curtain wall/ Skylight/ Shading system
Denomination	X12 - Glazed modules treated for improved passive properties (Light blue mass coloured glass)
Partner/s	Onyx

PICTURES	
PHOTOS	
	
Observations: Final appearance of PV rectangular c-Si module with tempered light blue mass coloured glass	

DESIGN DRAWING



Observations:
Manufacturing drawings of sample X12 (front and back views)

DETAILED DESCRIPTION	
Definition	PV rectangular c-Si modules with tempered light blue mass coloured glass
Construction unit	Ventilated façade/ Curtain wall/ Skylight
Architectural location	Façade/Roof
Geometrical design	Rectangular module / Customizable
Dimensions	Length: 1700 mm, Width: 1000 mm, Thickness: 13.8
Geometrical shape	Rectangular/Customizable
Materials	PV glazing (Light blue mass coloured glass, EVA, c-Si cells)
Configuration	Double glazing or simple laminated glass
Layers	From top to bottom: Tempered light blue mass coloured glass EVA, c-Si solar cells, EVA Tempered light blue mass coloured glass
Frame structure	Frameless
PV technology	Si-monocrystalline
Encapsulation material	EVA
Surface treatments	May be included
Thermal insulation	Common glazing technologies can be used (double/triple glazing, low-E coatings, etc)
Acoustic insulation	Double/triple glazing can be used.
Physical features	Similar to classic c-Si modules
Weight	30 kg/m^2 (glazing)
Rigidity	Rigid
Opacity	81% (opaque)
Mobility	No mobile parts
Active energy features	Photovoltaic glazing that generates electricity with Sun radiation
Photovoltaic power	82 Wp/m^2
Thermal transmittance (U value)	Defined by glazing system used

14.2 Mechanical Performance – X12

TECHNICAL TEMPLATE REFERENCE	
Technical subject	Mechanical performance of BIPV modules
Partner	Onyx Solar
Author	Léo Staccioli, Héctor Zamora, Elena Rico

PRODUCT CODE	
Denomination	X12 - Glazed modules treated for improved passive properties

DESIGN/DATASHEET VALUES		
BIPV UNIT		
General characteristics	PV rectangular c-Si modules with tempered light blue mass coloured glass	
Manufacturer	Onyx Solar	
Model	c-Si modules with light blue mass coloured glass	
Shape	Rectangular	
Physical characteristics	PV glazing	Unit
Width/ Length/ Thickness	1000/1700/13.8	mm
Weight	30	Kg/ m^2
Mechanical characteristics	Glass mechanical properties	
Tensile strength	120-200 (tempered); 40 (float)	MPa
Tensile modulus	~70	GPa
Poisson coefficients	0.22	-
Observations: Mechanical characteristics are the ones from the glass layers, which are the main mechanical material of the PV glazing		

14.3 Architectural Integration – X12

TECHNICAL TEMPLATE REFERENCE	
Technical subject	Architectural integration of BIPV products
Partner	Onyx Solar
Author	Léo Staccioli, Elena Rico

PRODUCT CODE	
Denomination	X12 - Glazed modules treated for improved passive properties

DEFINITION AND LOCATION	
Definition	PV rectangular C-Si opaque modules with light blue mass coloured glass
Construction unit	Ventilated façade/ Curtain wall/ Skylight
Location	Better performance in locations with high direct radiation

Architectural location	Façade/Roof

CONSTRUCTION UNIT FEATURES						
Physical properties	Length	Unit 1	Width	Unit 2	Thickness	Unit 3
Shape	Rectangular					
Dimensions	1700	mm	1000	mm	13.8	mm
Weight	51	kg	30	kg/m^2		
Materials and devices	PV glazing (double or simple). Includes junction box at the back					
Configuration	Double glazing or simple laminated					
Frame structure	Frameless					
PV technology	Si-mono-crystalline 156x156mm solar cells					
Location of pipes, diameters	Each PV glazing will have two cables. Cables can be housed in the structure					
Thermal insulation	Common glazing thermal insulation strategies can be used					
Thermal bridge	Determined by structure					
Aesthetical features	Light blue aspect					
Opacity	81%					
Cell colour	Dark blue					
Background colour	Light blue					
Surface treatments	Surface technologies for glass can be used					

INTEGRATION AND MAINTENANCE MEASURES	
Mounting system	Common façade/Curtain wall/ Skylight systems
Maintenance	N/A
Inspection	Remote monitoring
Accessibility of system	PV modules are accessible from the exterior.
Safety procedure	Glazing system should comply with standards (f.i. CWCT note 67) in order to guarantee safety accessibility
Removal	Same removal process than normally used in façade elements, taking care of disconnecting cables

14.4 Electrical Performance – X12

TECHNICAL TEMPLATE REFERENCE	
Technical subject	Electrical performance of BIPV modules
Partner	Onyx Solar
Author	Léo Staccioli, Héctor Zamora, Elena Rico

PRODUCT CODE	
Denomination	X12 - Glazed modules treated for improved passive properties

DESIGN/DATASHEET VALUES						
PHOTOVOLTAIC CELL/ ARRAY						
General characteristics	Si-mono-crystalline PV glazing					
Manufacturer	Not specific cell provider required					
Cell type	Mono-crystalline silicon. 156x156 mm solar cell with three BB					
Shape	Rectangular					
Colour	Dark blue					
Front layer	Tempered light blue mass coloured glass					
Frame	Frameless PV glass					
Connection Box	Non specific					
Cables	4 mm^2 up to 1000V					
Connectors	MC4					
Series-parallel connection	Non-parallel connection within one module					
Physical characteristics	Value 1	Unit 1	Value 2	Unit 2	Value 3	Unit 3
Width/ Length/ Thickness	1000	mm	1700	mm	13.8	mm
Electrical characteristics	Value 1	Unit 1	Value 2	Unit 2	Value 3	Unit 3
Rated power	140	Wp	82	Wp/m^2		-
Efficiency	8	%		-		-
Vpm: max. power voltage	31.50	V		-		-
Ipm: max. power current	4.45	A		-		-
Voc: open circuit voltage	42.50	V		-		-
Isc: short circuit current	4.65	A		-		-
Thermal parameters	Value 1	Unit 1	Value 2	Unit 2	Value 3	Unit 3

Isc (α) Temp. coefficient	0.07	%/ºC				-
Voc (β) Temp. coefficient	-0.31	%/ºC				-
P (γ) Temp. coefficient	-0.41	%/ºC				-
Operating range						
Temperature	-40 - +85	ºC				
Maximum System Voltage	1000	V				
Maximum Wind /Snow Load	N/A	Pa				
Max. Reverse Current (IR)	N/A	A				
Observations:						

14.5 Optical Performance – X12

TECHNICAL TEMPLATE REFERENCE	
Technical subject	Optical performance of BIPV modules
Partner	Tecnalia
Author	Maider Machado/ Daniel Valencia (CONFIDENTIAL INFO)

14.6 Economic Evaluation – X12

TECHNICAL TEMPLATE REFERENCE	
Technical subject	Economic evaluation and benefits of BIPV modules
Partner	Onyx Solar
Author	Elena Rico

PRODUCT CODE	
Denomination	X12 - Glazed modules treated for improved passive properties

ECONOMIC BALANCE						
General assumptions taking into account in the economic study	Value 1	Unit 1				
Location	Madrid					
Total building area	767.31	m^2				
Net conditioned building area	767.31	m^2				
Curtain wall surface area	200	m^2				

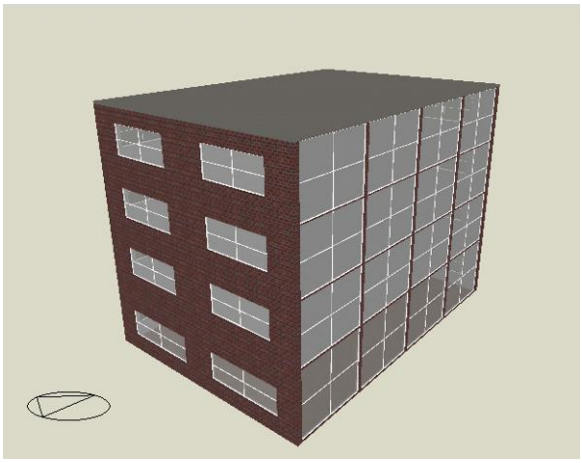
Peak power of PV mass blue colored glass	82	W/m²				
Local electricity cost (€/kWh)	0.2367	euro				
Variation in electricity cost until 2020	8.18	%				
Variation in electricity cost from 2020	1.00	%				
Costs estimation of curtain wall systems	Value 1	Unit 1	Value 2	Unit 2	Value 3	Unit 3
Mass coloured glass: conventional glazing/Fixation system/BOS	95	€/m²	=	€/m²	0	€/m²
Mass coloured glass: PV glazing/Fixation system/BOS	205,00	€/m²	=	€/m²	57.40	€/m²
OVERCOST (PV-Conventional glazing)	**167,40**	€/m²				
Energy behavior with blue mass coloured glass curtain wall (200 m²)	Value 1	Unit 1	Value 2	Unit 2		
Conventional glazing: HVAC energy consumption/ Renewable energy production	58900.55	kWh/year	0	kWh/year		
PV glazing: HVAC energy consumption/ Renewable energy production	56065.49	kWh/year	15767.00	kWh/year		
Total reduction of energy demand with blue mass coloured glass curtain wall (200 m²)	Value 1	Unit 1	Value 2	Unit 2	Value 3	Unit 3
ENERGY SAVINGS INDUCED BY THERMAL ENVELOPE IN 30 YEARS (A)	32032	€	85052	kWh		
PV ENERGY PRODUCTION IN 30 YEARS (B)	160328	€	425709	kWh		
TOTAL REDUCTION OF ENERGY DEMAND IN 30 YEARS (A+B)	192360	€	510761	kWh	29	%
Economic metrics with blue mass coloured glass curtain wall (200 m²)	Value 1	Unit 1	Value 1	Unit 1	Value 1	Unit 1
Average reduction of energy demand	961.80	€/m²				
Amount to invest	167.40	€/m²				

Amount to invest after incentives	167.40	€/m^2				
ROI	475	%				
Payback period	< 7	years				
IRR	17	%				
Times the investment	5,75	times				

Observations:
The economic study has been conducted considering the energy savings by the BIPV products under different scenarios.

With the aim of having results of the reduction in the energy demand of a whole building due to the developed innovative photovoltaic glass, in the current report different models have been simulated with Design Builder software. An office building type in the city of Madrid has been chosen to simulate its energetic behavior under different scenarios and in this report curtain wall in the south façade as constructive solution has been selected to compare the results. The idea is to compare between a building with treated glass in the envelope and a building with the same glass including photovoltaic technology in order to elaborate the corresponding economic study. In other words, to compare the products developed within PVSITES project (as an example PV glazing with light blue mass glass) with other similar non photovoltaic products (Mass coloured BIPV glass versus equivalent blue mass coloured glass).

The following picture represents 3D Design Builder model of a building with a curtain wall in the south façade and conventional windows in the other ones.

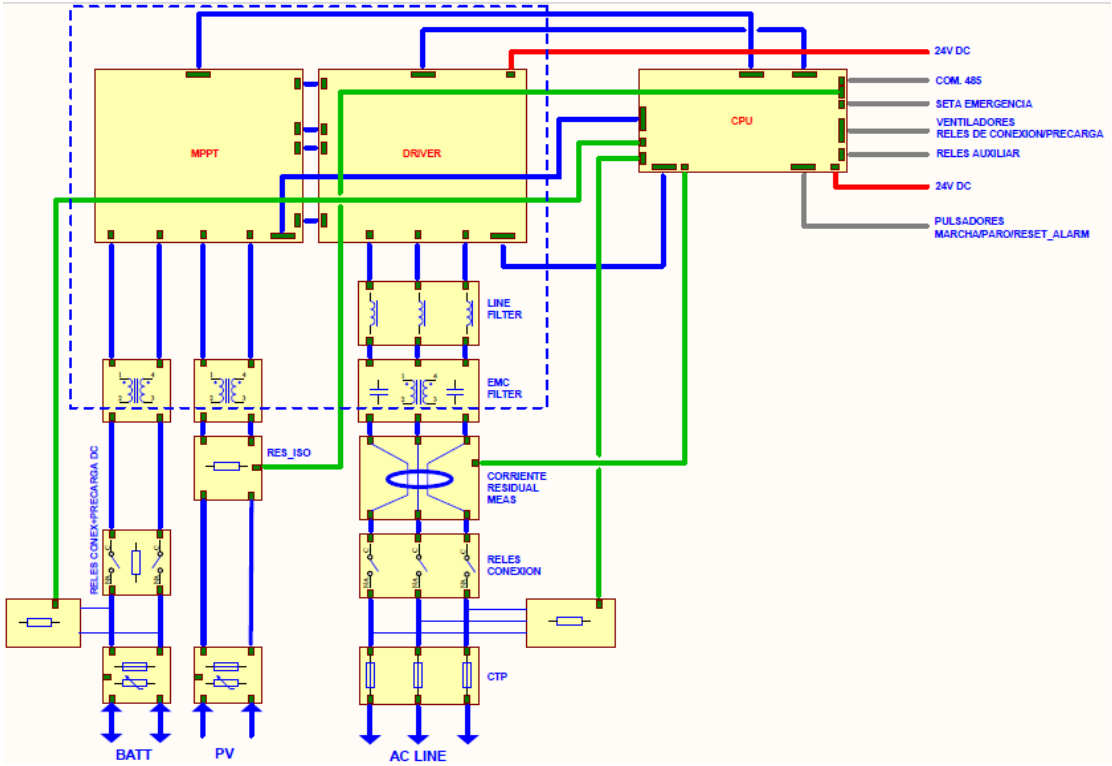


15 X13 - DC-Coupled PV Storage Inverter

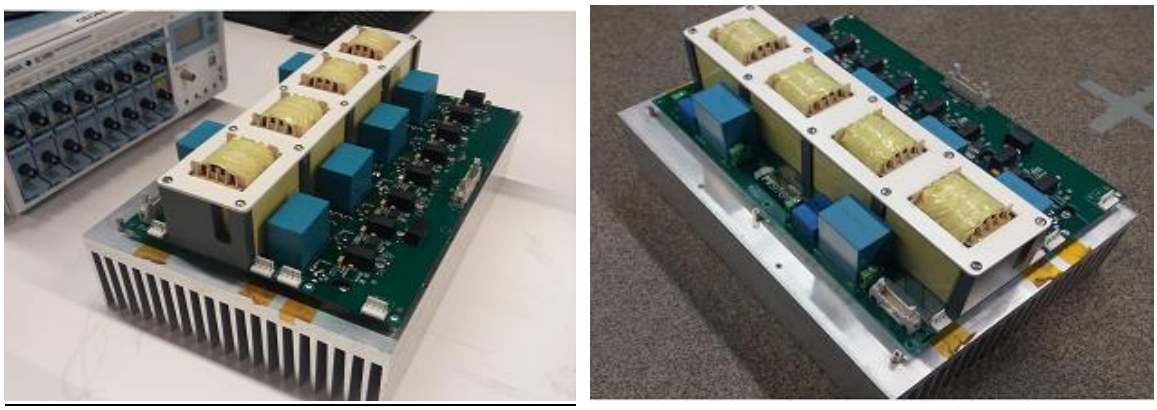
15.1 General Description and Design – X13

TECHNICAL TEMPLATE REFERENCE	
Technical subject	General description and design of inverters
Partner	Tecnalia
Author	Iñigo Vidaurrazaga

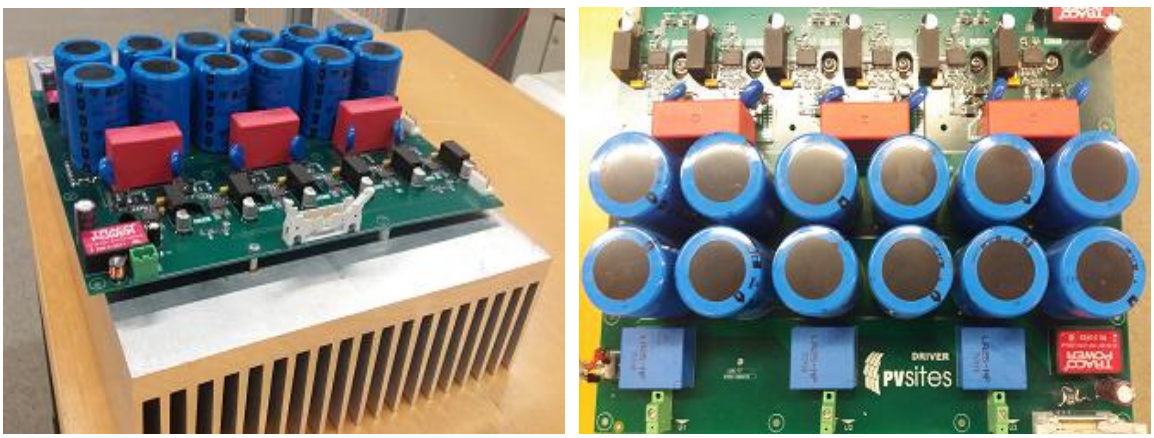
PRODUCT CODE	
Project	PVSITES. Task 2.6. BIPV products portfolio
Denomination	X13 - DC-Coupled PV Storage Inverter
Partner/s	Tecnalia
Author/s	Ricardo Alonso

PICTURES
REALISTIC DRAWING
Brief Scheme of the PV Storage Inverter

Complete system

DC/DC Converter



DC/AC Converter



DC/AC Converter
Observations: According to the scheme showed above, the PV Inverter is composed of the following elements: 1. DC-DC Converter (MPPT and Battery Converters). 2. DC-AC Converter 3. Control Board 4. DC EMI Filters 5. PV Array Insulation Meter 6. DC Relays for Battery Connection and DC precharging 7. Battery Voltage Meter 8. DC Overvoltage and Overcurrent protection (Voltage Suppressors, fuses…) 9. Voltage Surge Protection Device (PSM3-20/400 TNC) 10. AC Voltage Meter 11. AC Connection Relay 12. Residual Current Meter 13. AC EMI Filter 14. Line Filter
Apart from these elements, the PV Inverter also contains a power source (which can be powered from PV, Battery or Grid) for providing 24V to the entire circuit. The scheme also shows signal connection between power converters and control board, to provide analog measurement or PWM driving signals among others.

DETAILED DESCRIPTION	
Functionality description	High efficiency, low cost and flexible 10kW three-phase DC-coupled PV storage inverter. It can be easily parallelized to make larger systems up to hundreds of kW and offers a wide DC input range to cope with different BIPV generators (even affected by mismatching effects) and battery packs. It communicates with the BEMS in order to provide monitoring data about PV storage inverter performance and receive the required commands to implement required energy management strategies.
Technology description	Multilevel symmetrical topology is used for the DC-DC Converter for battery and PV source management. Both converters and the Three-Phase DC-AC Converter are coupled in a high-voltage DC link. The control unit is composed of a DSP controller (TMS320F28335) and FPGA for managing the power transfer inside the converter and provide external communication.
Number of PV inputs	1
Number of MPP trackers	1

Battery regulator	YES
Nominal AC Power	10 kW
Maximum PV power	10 kW
Maximum Battery power	10 kW
Dimensions	840x740x280 (mm)
Weight	75 Kg
Enclosure	Metallic cabinet
Protection degree	IP65
HMI	LEDs for indicating Inverter errors/status
Communication	Serial. RS485 Communication. The Inverter provides Modbus RTU communication in slave mode to exchange data operating with the BEMS or other SW interfaces
CAPEX	2000€
OPEX	0€/year
Lifetime	10 years

15.2 Installation – X13

TECHNICAL TEMPLATE REFERENCE	
Technical subject	Installation of PV inverters
Partner	Tecnalia
Author	Iñigo Vidaurrazaga

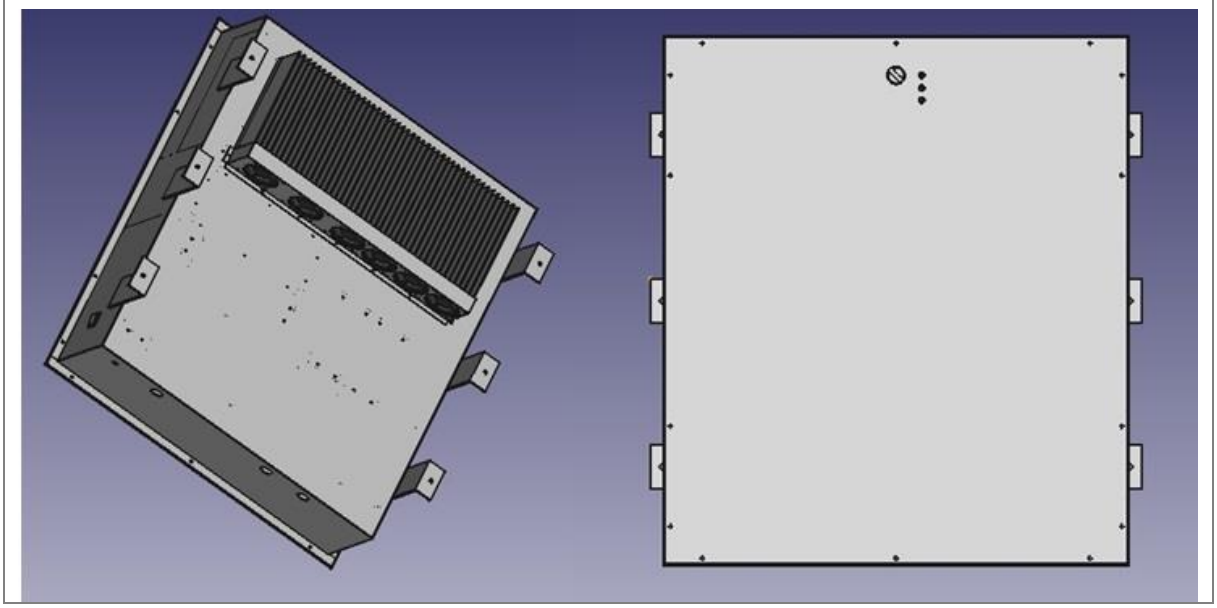
PRODUCT CODE	
Denomination	DC-Coupled PV Storage Inverter

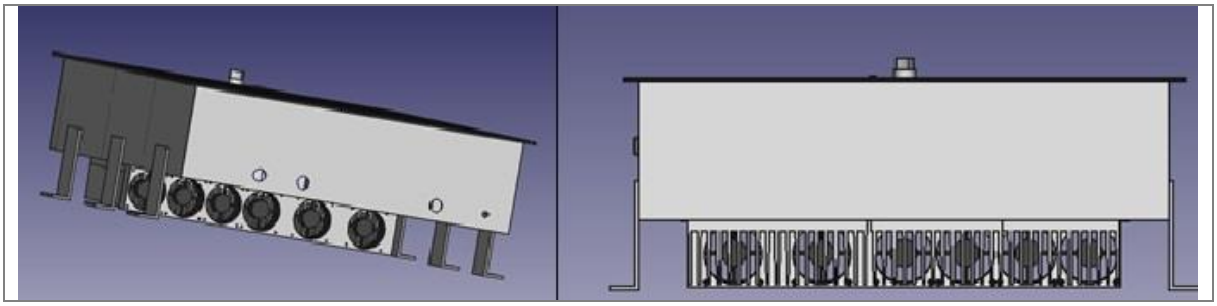
INSTALLATION AND MAINTENANCE MEASUREMENTS	
Dimensions	840x740x280 (mm)
Weight	75kg
Enclosure	Metallic cabinet
Protection degree (IEC 60529)	IP65
Refrigeration	Forced ventilation

Climatic class (IEC 60721-3-4)	-
Mounting system	Wall mounting
Acoustic emission	-
Operating temperature	0 – 40 ºC
Relative humidity	0-90%
General protections	Residual Current Detector, DC Reverse Polarity Protection, AC-DC Short Circuit Protection, AC-DC Over Voltage Protection, Grid Interface Protecction (Voltage&Frequency range), PV Array Insulation Protection.
Installation procedure	See below
Safety procedure	-
PV connectors	Terminal wire connectors
Battery connectors	Terminal wire connectors
AC connectors	Terminal wire connectors
Communication connectors	Terminal wire connectors
HMI	LEDs for indicating errors/status

PICTURES

INSTALLATION METHOD





Observations:
Mount vertically on the wall or on a solid surface with tilted backwards by max 15ºC.
The mounting location must be clear and safely accessible at all times without the use of additional aids such as scaffolding or lifting platforms.
The ambient temperature should be below 40°C to ensure proper operation. Do not expose the inverter to direct solar irradiation.

Respect at least the following clearance to the walls or other objects:

- Floor: 50cm
- Sides: 30cm each side
- Ceiling: 30cm
- Front: 10cm

15.3 Electrical Performance – X13

TECHNICAL TEMPLATE REFERENCE	
Technical subject	Electrical performance of inverters
Partner	Tecnalia
Author	Iñigo Vidaurrazaga

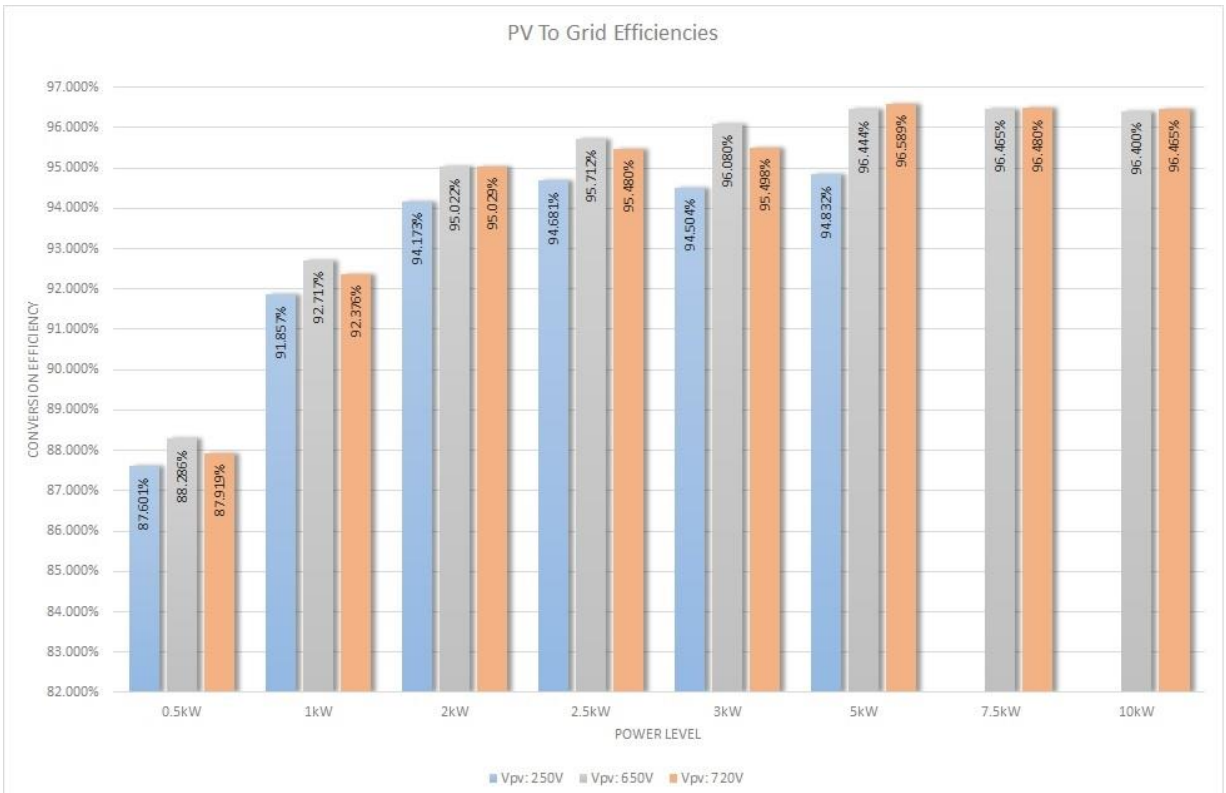
PRODUCT CODE	
Denomination	DC-Coupled PV Storage Inverter

DESIGN/DATASHEET VALUES		
Maximum Efficiency (PV to Grid)	96.589% (@V_{PV}: 720V,P: 5kW)	
Overall efficiency (50530) (PV to Grid)	European	94.318% (@V_{PV}: 250V) 95.746% (@V_{PV}: 650V) 95.739% (@V_{PV}: 720V)
	CEC	94.640% (@V_{PV}: 250V) 96.189% (@V_{PV}: 650V) 96.147% (@V_{PV}: 720V)
Maximum Efficiency (Battery to Grid)	96.249% (@V_{BAT}: 650V, P: 5kW)	

Maximum Efficiency (PV to Battery)	97.229% (@V_{BAT}: 550V,V_{PV}: 650V,P: 3kW)
PV voltage Range	200-1000V
PV MPPT voltage Range	200-800V
Max PV Input Power	10kW
Min PV Input Power	50W
Max PV Input Current	20A
Bat voltage Range	250V-700V
Max Bat Power	10kW
Min Bat Power	50W
Max Bat Current	20A
Max AC Output Power	10kW
Power factor (PF)	>0.9998 at Rated Power
Nominal AC Voltage	230V/400V
Max AC Output Current	15.9A / 27.6A
Number of Phases	3
Frequency	50Hz
Reactive power control	33%
Stand-by consumption	15W
Night consumption	15W
Residual Current Detector (RCD)	YES
Low Voltage Ride through (LVRT)	YES (IEC 62910)
Anti-islanding protection	YES (UNE EN 62116)
Intended islanding operation	No Islanding Operation
Grid current distortion (THD)	Ideal Strong Grid. 0.6% (@33%Pn), 0.35%(@66%Pn), 0.32%(@100%Pn).
Direct current injection	<72mA (<0.5%In)
PV array insulation resistance detection	YES
CE conformity	**Pre-Certified:** Yes

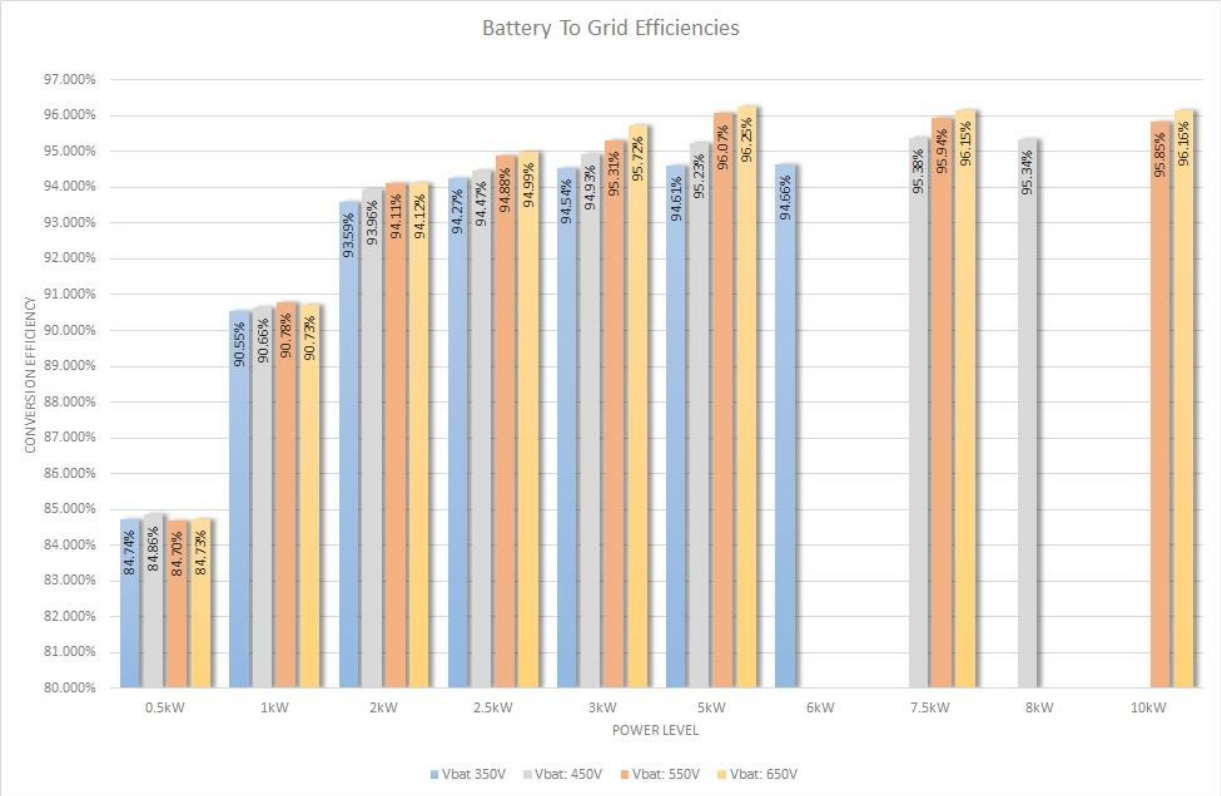
PV to Grid Efficiencies

PV To Grid		Power Level								GLOBAL	
		0.5kW	1kW	2kW	2.5kW	3kW	5kW	7.5kW	10kW	EUROPEAN	CEC
VPV	250V	87.601%	91.857%	94.173%	94.681%	94.504%	94.832%			94.318%	94.640%
	650V	88.286%	92.717%	95.022%	95.712%	96.080%	96.444%	96.465%	96.400%	95.746%	96.189%
	720V	87.919%	92.376%	95.029%	95.480%	95.498%	96.589%	96.480%	96.465%	95.739%	96.147%



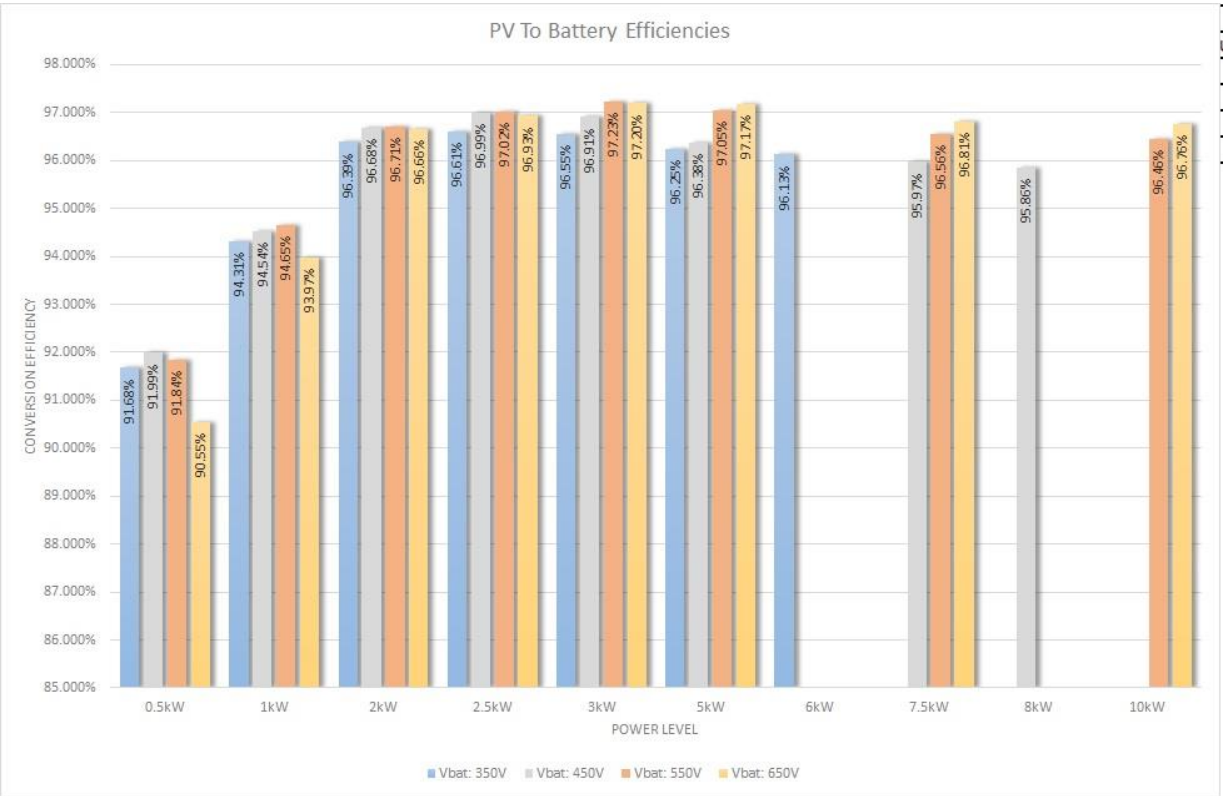
Battery to Grid Efficiencies

BatTo Grid		Power Level										GLOBAL	
		0.5kW	1kW	2kW	2.5kW	3kW	5kW	6.5kW	7.5kW	8.5kW	10kW	EUROPEAN	CEC
VBAT	320V	84.742%	90.552%	93.593%	94.265%	94.540%	94.610%	94.658%				93.941%	94.416%
	430V	84.856%	90.662%	93.959%	94.465%	94.930%	95.234%		95.384%	95.345%		94.475%	95.036%
	540V	84.700%	90.780%	94.115%	94.877%	95.314%	96.069%		95.942%		95.851%	95.037%	95.591%
	650V	84.728%	90.729%	94.122%	94.988%	95.720%	96.249%		96.154%		96.165%	95.226%	95.804%



PV to Battery Efficiencies

PvtoBat		Power Level										GLOBAL	
		0.5kW	1kW	2kW	2.5kW	3kW	5kW	6.5kW	7.5kW	8.5kW	10kW	EUROPEAN	CEC
VBAT	320V	91.680%	94.312%	96.387%	96.612%	96.550%	96.249%	96.130%				96.020%	96.146%
	430V	91.987%	94.536%	96.678%	96.992%	96.910%	96.380%		95.971%	95.858%		96.125%	96.142%
	540V	91.837%	94.653%	96.710%	97.025%	97.229%	97.050%		96.564%		96.459%	96.605%	96.672%
	650V	90.550%	93.974%	96.660%	96.933%	97.195%	97.173%		96.811%		96.765%	96.636%	96.810%



Observations:
At low Battery and PV voltages power level is saturated when maximum current is reached (around 20A). When computing the overall efficiency (European and CEC according to EN50530), this saturated power is considered for higher power levels. The power conversion results for transfers from PV to Battery are tested at the nominal PV Voltage (650V)

15.4 Monitoring and control – X13

TECHNICAL TEMPLATE REFERENCE	
Technical subject	Monitoring and control of inverters
Partner	Tecnalia
Author	Iñigo Vidaurrazaga

PRODUCT CODE	
Denomination	DC-Coupled PV Storage Inverter

DESIGN/DATASHEET VALUES	
Communication protocol	Modbus-RTU
OUTPUT MONITORING DATA	
AC Active Power	Data Type: IQ15 (32 bits), Unit: W
AC Reactive Power	Data Type: IQ15 (32 bits), Unit: VAr
AC Grid Voltage	Data Type: IQ21 (32 bits), Unit: V
Grid Frequency	Data Type: IQ21 (32 bits), Unit: Hz
Inverter Status	Data Type: Unsigned Integer (16 bits), Values: 0-Stop 1- Starting 2-Operating 3- Alarm 4- Sleep Mode
Alarm Status	Data Type: Unsigned Integer (16 bits), Values: 1-OFF 2- Warning 3-ON 4-ACK
Alarm ACK Status	Data Type: Unsigned Integer (16 bits). Values: Boolean. 0- NO ACK, 1-ACK
Alarm Type	Data Type: Unsigned Integer (16 bits). Values: 0 - No Alarm, 1-DC Overvoltage, 2- Grid Overcurrent, 4- Unused, 8- DC Overcurrent, 16-HW Error, 32- DC/AC Driver Error, 64- DC/DC Driver Error, 128- Unused, 256- DC/AC- Overheat, 512- DC/DC Overheat, 1024- Battery Over/Under Voltage 2048- PV Array Insulation Failure 4096- Ground Fault
Grid Switch Status	Data Type: Unsigned Integer (16 bits). Values: 0- Disconnected, 2-Waiting, 4 Connected -8 OverFrequency 16- Under Frequency 32-Over Voltage 64- Under Voltage 128 - DC Precharging 256- PV Array Insulation Testing
Frequency Mode	Data Type: Unsigned Integer (16 bits). Values: 0-No Frequency Control 1- FSM Mode 2-LFSM Mode
Reactive Power Control Mode	Data Type: Unsigned Integer (16 bits). Values: 0- Reactive Power Set Point 1- Power Factor Control 2- AC Voltage Control 3- LVRT Mode
Start Bottom Status	Data Type: Unsigned Integer (16 bits). Values: Boolean 0- OFF, 1- ON
Stop Bottom Status	Data Type: Unsigned Integer (16 bits). Values: Boolean 0- OFF, 1- ON
Inverter Mode	Data Type: Unsigned Integer (16 bits), Values: 0- PV/Storage/Grid Mode 1- PV/Grid Mode 2- Storage/Grid Mode 3- PV/Storage Mode

PV Source Status	Data Type: Unsigned Integer (16 bits), Values: 0-Disabled 1- No PV 2- Low Power 3- Normal
PV Operating Mode	Data Type: Unsigned Integer (16 bits), Values: 0-Disabled 1- Low Power Mode 2- MPPT Mode 3- Limited Power Mode 4- Constant Voltage Mode
GMPPT Execution	Data Type: Unsigned Integer (16 bits), Values: 0- OFF 1- ON
MPPT Mode	Data Type: Unsigned Integer (16 bits), Values: 0-MPPT 1-MPRT
Grid Voltage Status	Data Type: Unsigned Integer (16 bits), Values: 0- Permanent 1- LVRT 2- LVRT (trans) 3- HVRT
DC Link Voltage	Data Type: IQ21 (32 bits), Unit: V
Battery Power	Data Type: IQ15 (32 bits), Unit: W
PV Power	Data Type: IQ15 (32 bits), Unit: W
Battery Voltage	Data Type: IQ21 (32 bits), Unit: V
PV Voltage	Data Type: IQ21 (32 bits), Unit: V
DC-AC Temperature	Data Type: IQ21 (32 bits), Unit: ºC
DC-DC Temperature	Data Type: IQ21 (32 bits), Unit: ºC
INPUT COMMANDS	
Modbus Address	Data Type: Unsigned Integer (16 bits). Values: 1-255
Alarm ACK	Data Type: Unsigned Integer (16 bits). Values: 4-ACK
Enable Frequency Sensitive Mode (FSM)	Data Type: Unsigned Integer (16 bits). Values: Boolean 0-DISABLE 1-ENABLE
Set Reactive Power Control	Data Type: Unsigned Integer (16 bits). Values: 0- Reactive Power Set Point 1- Power Factor Control 2- AC Voltage Control
Set/Clear Start Bottom	Data Type: Unsigned Integer (16 bits). Values: Boolean 0- OFF, 1- ON
Set/Clear Stop Bottom	Data Type: Unsigned Integer (16 bits). Values: Boolean 0- OFF, 1- ON
Nominal Power	Data Type: IQ15 (32 bits), Range/Unit: 0-10000W
Max. Power Gradient	Data Type: IQ7 (16 bits), Range/Unit: (0-1Pn)/min
Power Limited/Constant Set Point	Data Type: IQ15 (32 bits), Range/Unit: (0-10000)W

K_FSM (Constant for Frequency Sensitive Mode)	Data Type: IQ21 (32 bits), Range/Unit: (0-1)Pn/Hz
K_VAC (AC Voltage Control)	Data Type: IQ21 (32 bits), Range/Unit: (0-0.33)Pn/V
Grid Power Set Point	Data Type: IQ15 (32 bits), Range/Unit: 0 - Nominal Power, W
Reactive Power Set Point	Data Type: IQ15 (32 bits), Range/Unit : (±3330W)
Power Factor Set Point	Data Type: IQ21 (32 bits), Range: ±0.95
Set Inverter Mode	Data Type: Unsigned Integer (16 bits), Values: 0- PV/Storage/Grid Mode 1- PV/Grid Mode 2- Storage/Grid Mode 3- PV/Storage Mode
Set MPPT Mode	Data Type: Unsigned Integer (16 bits), Values: 0-MPPT 1-MPRT
GMPPT Frequency	Data Type: Unsigned Integer (16 bits), Values: 0- DISABLED 1- LOW 2- STANDARD 3- HIGH
D_MIN	Data Type: IQ21 (32 bits), Unit: V. Minimum distance between 2MPPs
Max Battery Voltage	Data Type: IQ21 (32 bits), Range/Unit: (250-700) V
Min Battery Voltage	Data Type: IQ21 (32 bits), Range/Unit: (250-700) V
Battery Nominal Capacity	Data Type: IQ21 (32 bits), Range/Unit: 0-200Ah
SoC	Data Type: IQ21 (32 bits), Range/Unit: (0-100%)
Float Discharging Voltage	Data Type: IQ21 (32 bits), Range/Unit: (250-700) V
Float Charging Voltage	Data Type: IQ21 (32 bits), Range/Unit: (250-700) V

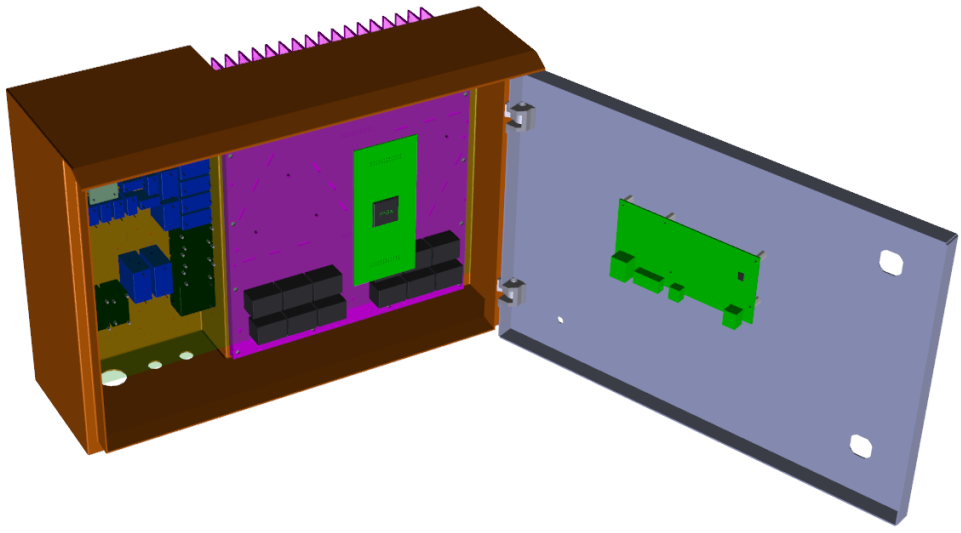
17 X14 - SiC based inverter

17.1 General Description and Design – X14

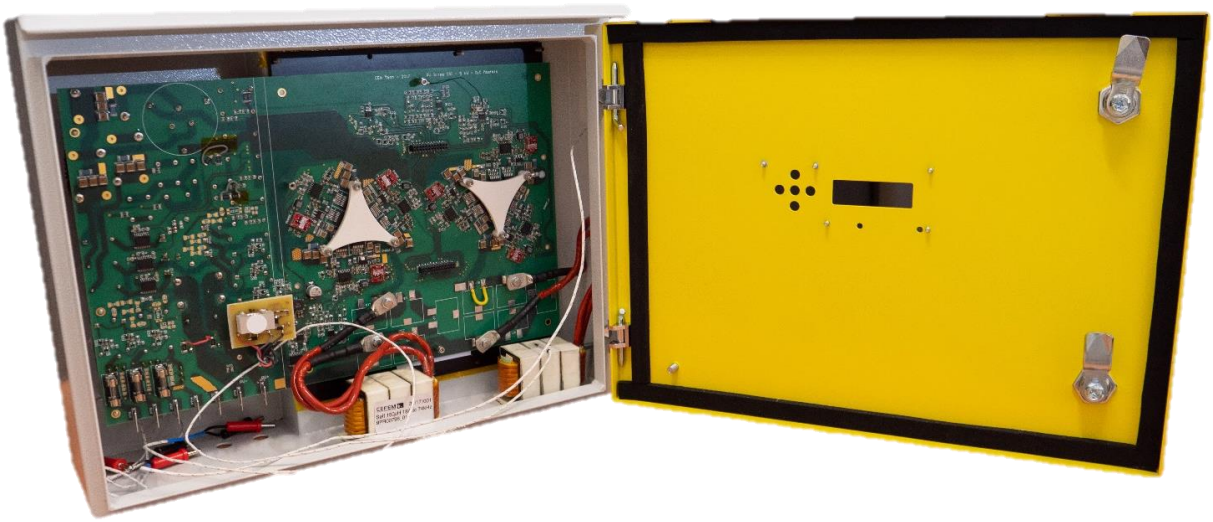
TECHNICAL TEMPLATE REFERENCE	
Technical subject	General description and design of inverters
Partner	CEA
Author	Anthony BIER

PRODUCT CODE	
Project	PVSITES. Task 5.3. BIPV products portfolio
Denomination	X14 - SiC based inverter
Partner/s	CEA
Author/s	Anthony BIER

PICTURES
REALISTIC DRAWING



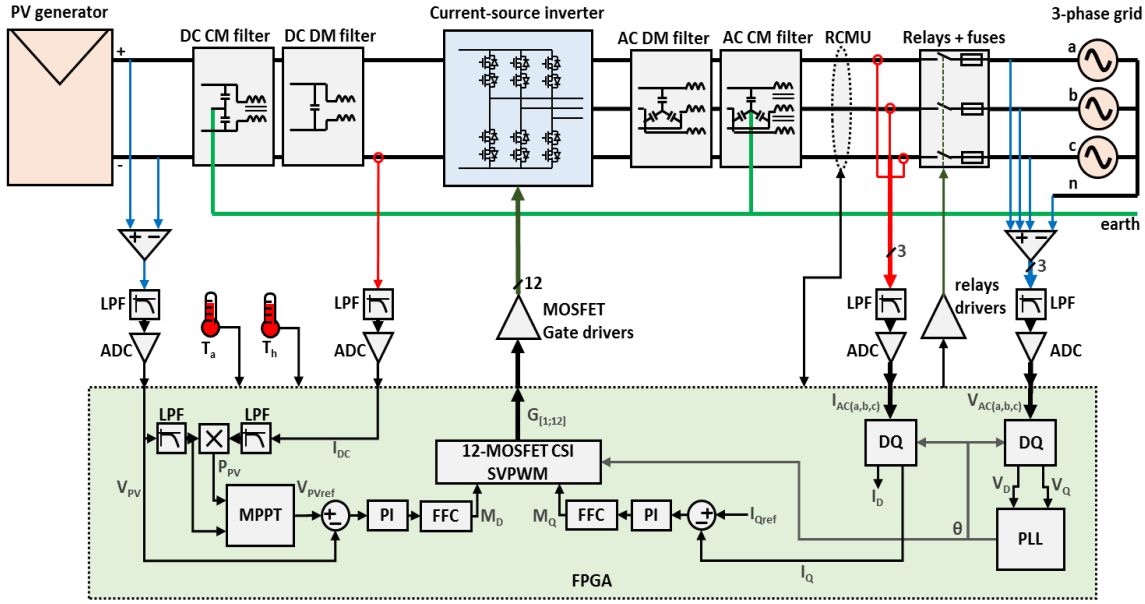
PHOTOS



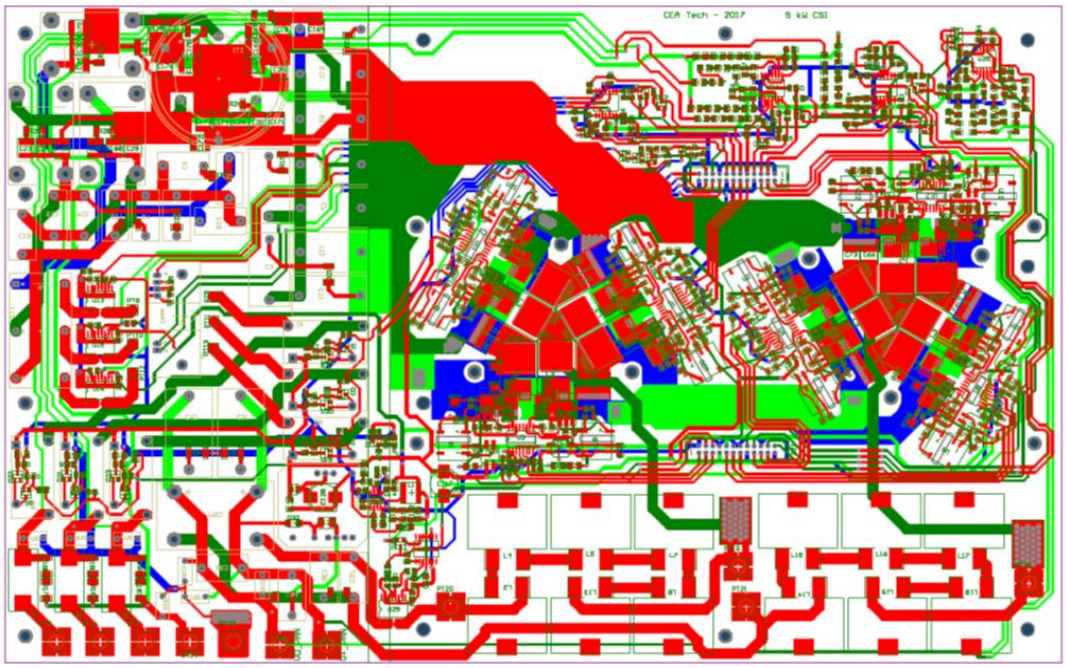
Observations:

3D View and real picture of the 5kW three-phase PV current-source inverter packaged in a metallic box with front door.

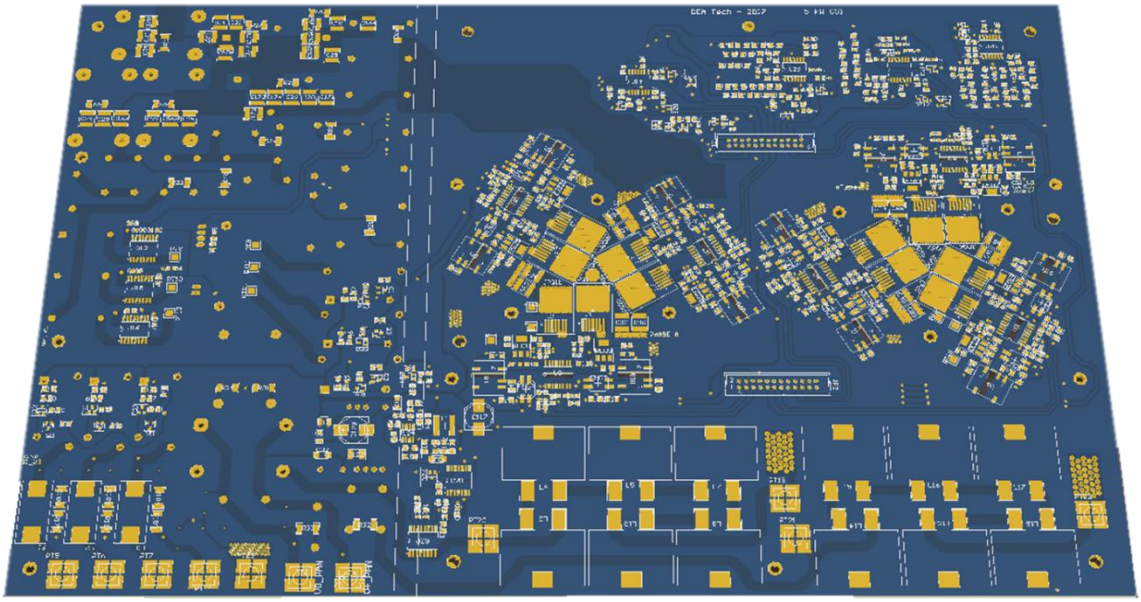
SCHEMATICS AND LAYOUT



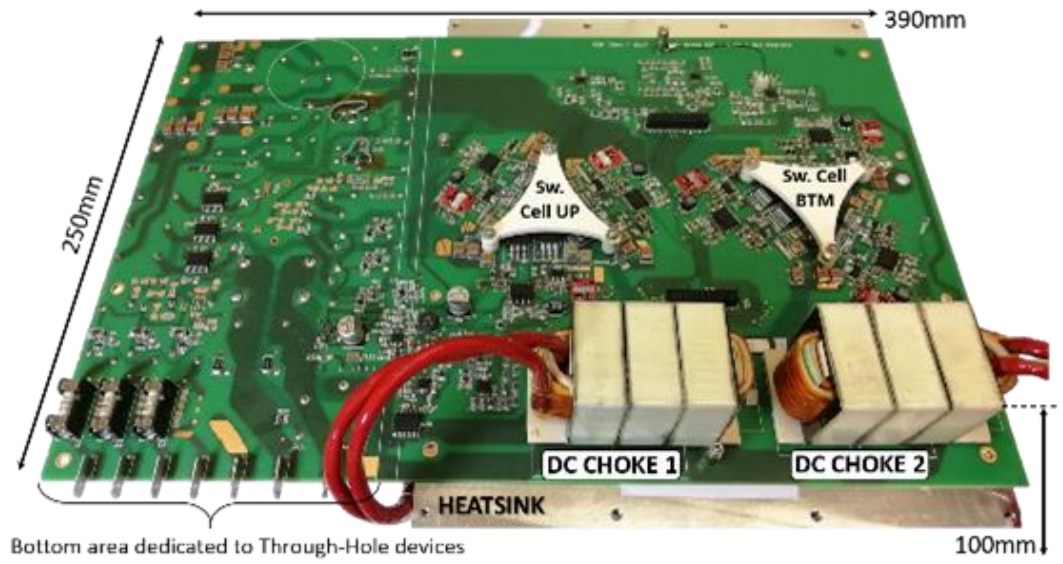
General electrical schematics of the power and control stages



4-layers printed circuit board (PCB) layout



3D rendered solid image of the PCB



Photograph of the top of the PCB with all the mounted components

DETAILED DESCRIPTION	
Functionality description	5 kW/5kVA, three-phase grid-tied, photovoltaic inverter
Technology description	Current-source topology (CSI) based on silicon carbide (SiC) semiconductors
Number of PV inputs	1
Number of MPP trackers	1
Battery regulator	no
Nominal AC Power	5 (kVA)
Maximum PV power	5 (kW)
Dimensions	410x160x290 (mm)
Weight	13 (kg)
Enclosure	Metallic box with front door and back-side wall-mounting bracket
Protection degree	IP65
HMI	Front LCD screen and push buttons
Communication	Modbus RS485
CAPEX	515€

17.2 Installation – X14

TECHNICAL TEMPLATE REFERENCE	
Technical subject	Installation of PV inverters
Partner	CEA
Author	Anthony BIER

PRODUCT CODE	
Denomination	5 kW SiC based PV CSI

INSTALLATION AND MAINTENANCE MEASUREMENTS	
Dimensions	410x160x290 (mm)
Weight	13 (kg)
Enclosure	Metallic box with front door and back-side wall-mounting bracket
Protection degree (IEC 60529)	IP65
Refrigeration	Natural air-cooling heatsink
Climatic class (IEC 60721-3-4)	-
Mounting system	Wall mounting with brackets and screws
Acoustic emission	-
Operating temperature	80 ºC maximum (heatsink)
Relative humidity	-
General protections	Closed metallic box preventing electric shocks/projections
Installation procedure	With cables disconnected, mounting on wall using dedicated brackets
Safety procedure	Before any intervention on the inverter (uninstallation, opening): 1) AC-side electrical separation 2) PV cable disconnection
PV connectors	MC4 PV connectors
Battery connectors	N/A
AC connectors	Screw terminal blocks
Communication connectors	RJ45 connector and RS485 terminal
HMI	Front LCD screen and push buttons

PICTURES
INSTALLATION METHOD

Back side of the inverter
Observations: The upper mounting brackets are used to be hooked to a wall

17.3 Electrical Performance – X14

TECHNICAL TEMPLATE REFERENCE	
Technical subject	Electrical performance of inverters
Partner	CEA
Author	Anthony BIER

PRODUCT CODE	
Denomination	5 kW SiC based PV CSI

DESIGN/DATASHEET VALUES	
Maximum Efficiency	98%
Overall efficiency (50530)	97.5% (CEC), 97.1% (EU)
Input voltage Range	140V – 500V
MPPT voltage Range	280V - 400V (at full rated power)
Max DC Input Power	5 kW

Min DC Input Power	0 W
Max Input Current	18 A
Maximum Output Power	5 kVA
Power factor (PF)	>0.90
Nominal Output Voltage	230 V_{RMS}
Max Output Current	9 A_{RMS}
Frequency	50 Hz
Reactive power control	no
Stand-by consumption	15 W
Night consumption	0 W
Residual Current Detector (RCD)	yes
Low Voltage Ride through (LVRT)	yes
Anti-islanding protection	Detection based on active method
PV array insulation resistance detection	yes
CE conformity	yes

17.4 Monitoring and control – X14

TECHNICAL TEMPLATE REFERENCE	
Technical subject	Monitoring and control of inverters
Partner	CEA
Author	Anthony BIER

DESIGN/DATASHEET VALUES	
Communication protocol	Modbus
OUTPUT MONITORING DATA	
Parameter 1	AC Active Power
Parameter 2	AC Reactive Power
Parameter 3	AC RMS voltage (line to neutral)
Parameter 4	AC RMS current / phase

Parameter 5	AC Frequency
Parameter 6	PV Power
Parameter 7	PV Voltage
Parameter 8	PV Current
Parameter 9	RCMU RMS Current
Parameter 10	PV Insulation Resistance
Parameter 11	Heatsink Temperature
Parameter 12	Internal ambient Temperature
Parameter 13	Inverter mode
Parameter 14	Inverter Status
Parameter 15	Alarms
Parameter 16	HW Version
Parameter 17	FW Version
Parameter 18	Serial Number

17.5 Maintenance and Dismantling – X14

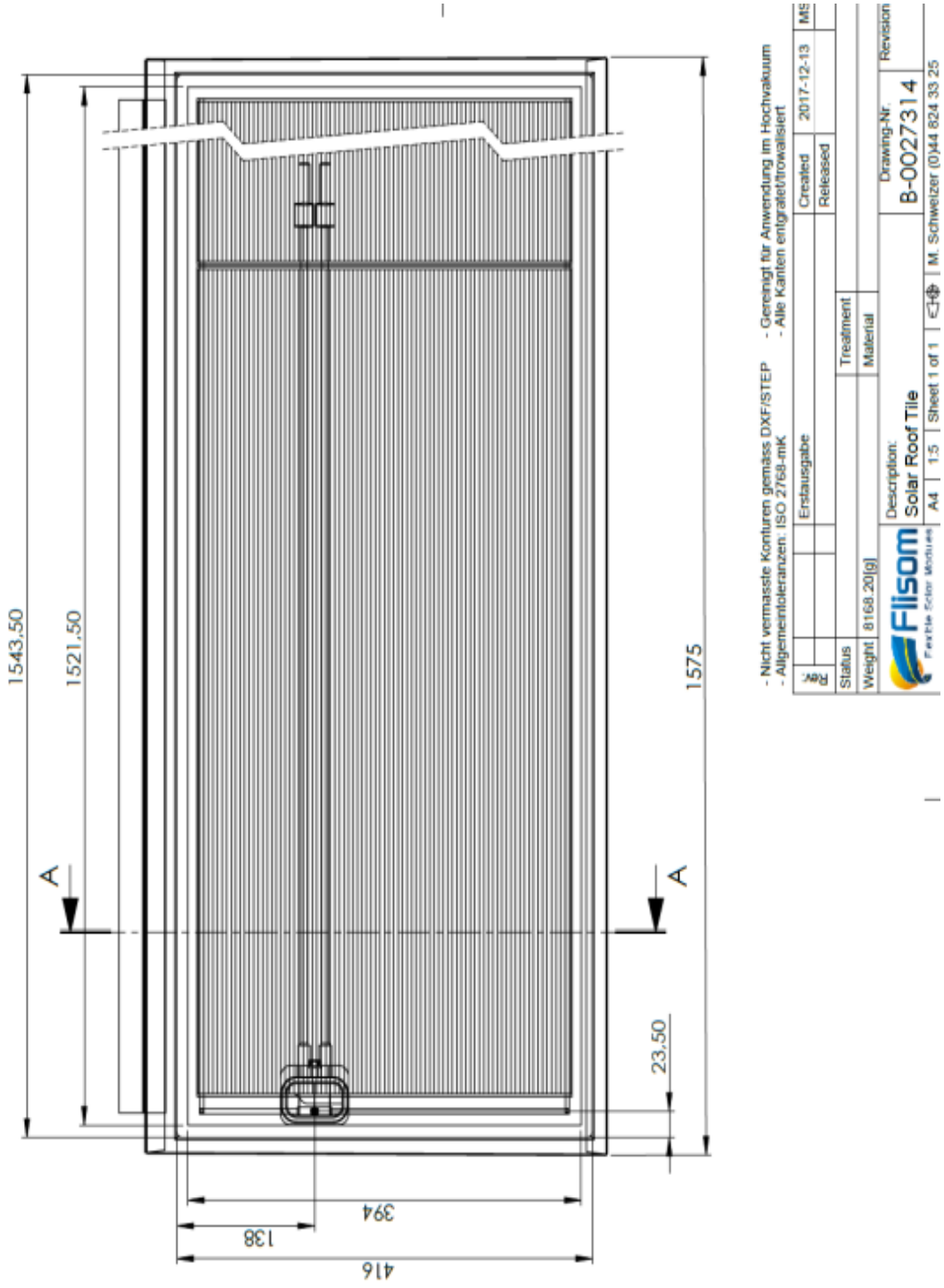
TECHNICAL TEMPLATE REFERENCE	
Technical subject	Maintenance and dismantling of products and installations
Partner	CEA
Author	Anthony BIER

PRODUCT CODE	
Denomination	5 kW SiC based PV CSI

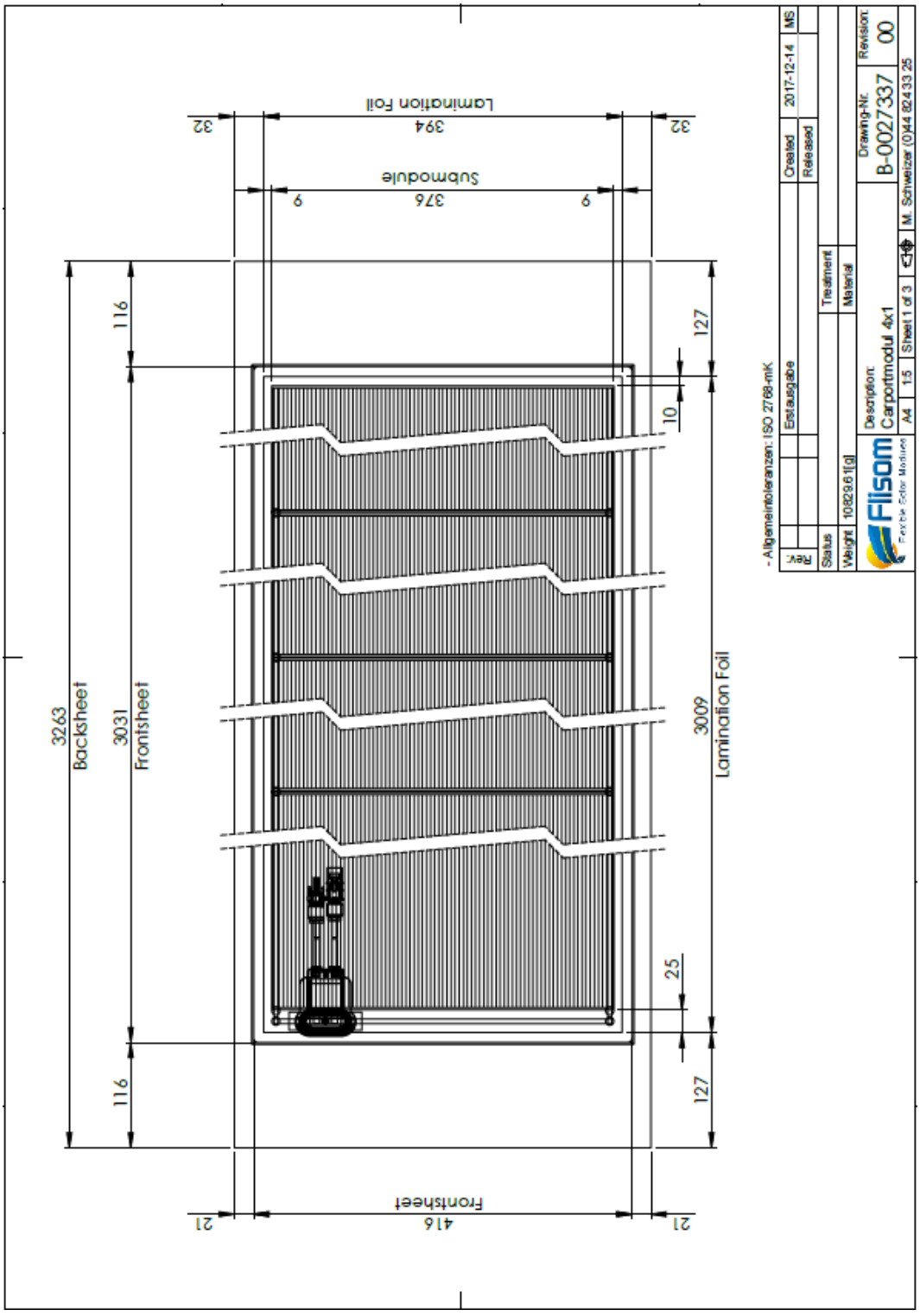
MAINTENANCE		
BY THE USER	Periodicity (months)	Description
Action 1	-	-
Observations. No periodical maintenance is needed		

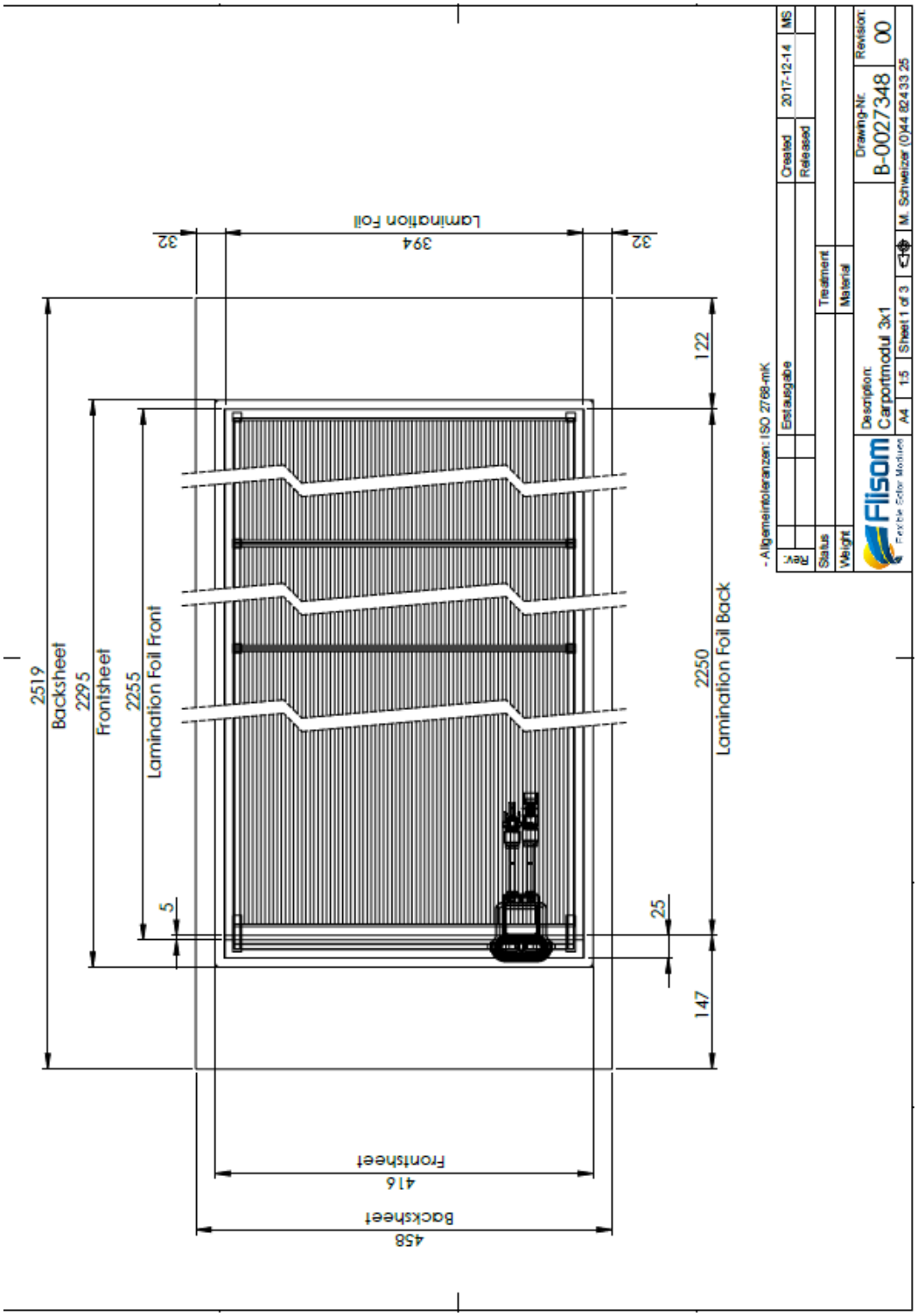
18 Appendix

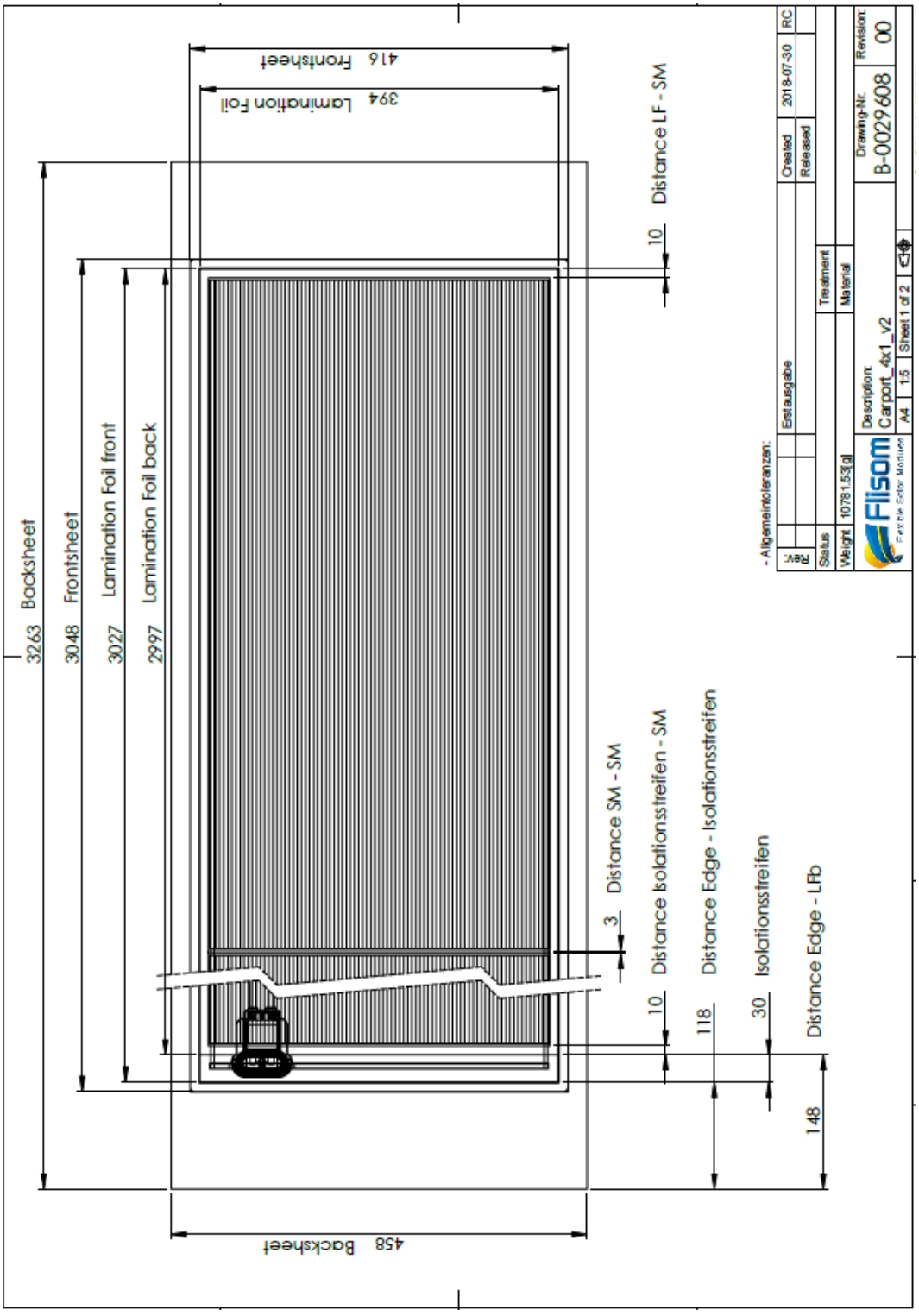
18.1 X1a



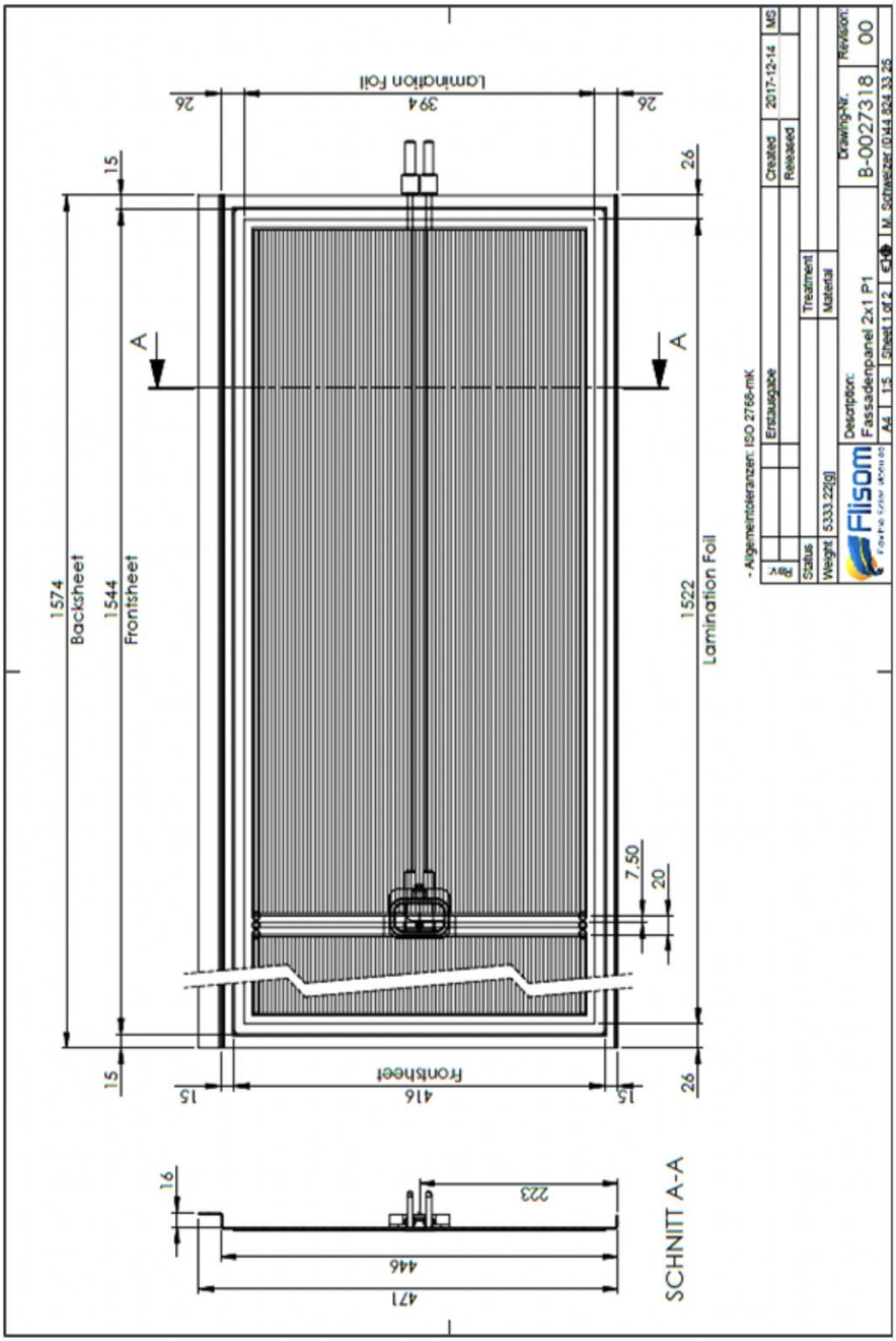
18.2 **X1b**


Laminationfoil
394
32
32
Submodule
376
9
9
116
127
10
3263
Backsheet
3031
Frontsheet
3009
Lamination Foil
25
116
127
Frontsheet
416
21
21
- Allgemeintoleranzen: ISO 2768-mK
Rev.
Erstausgabe
Created
2017-12-14
MS
Released
Treatment
Material
Status
Weight
10829.61[g]
Description:
Carportmodul 4x1
Drawing-Nr.
B-0027337
Revision:
00
A4
1:5
Sheet 1 of 3
M. Schweizer (0)44 824 33 25

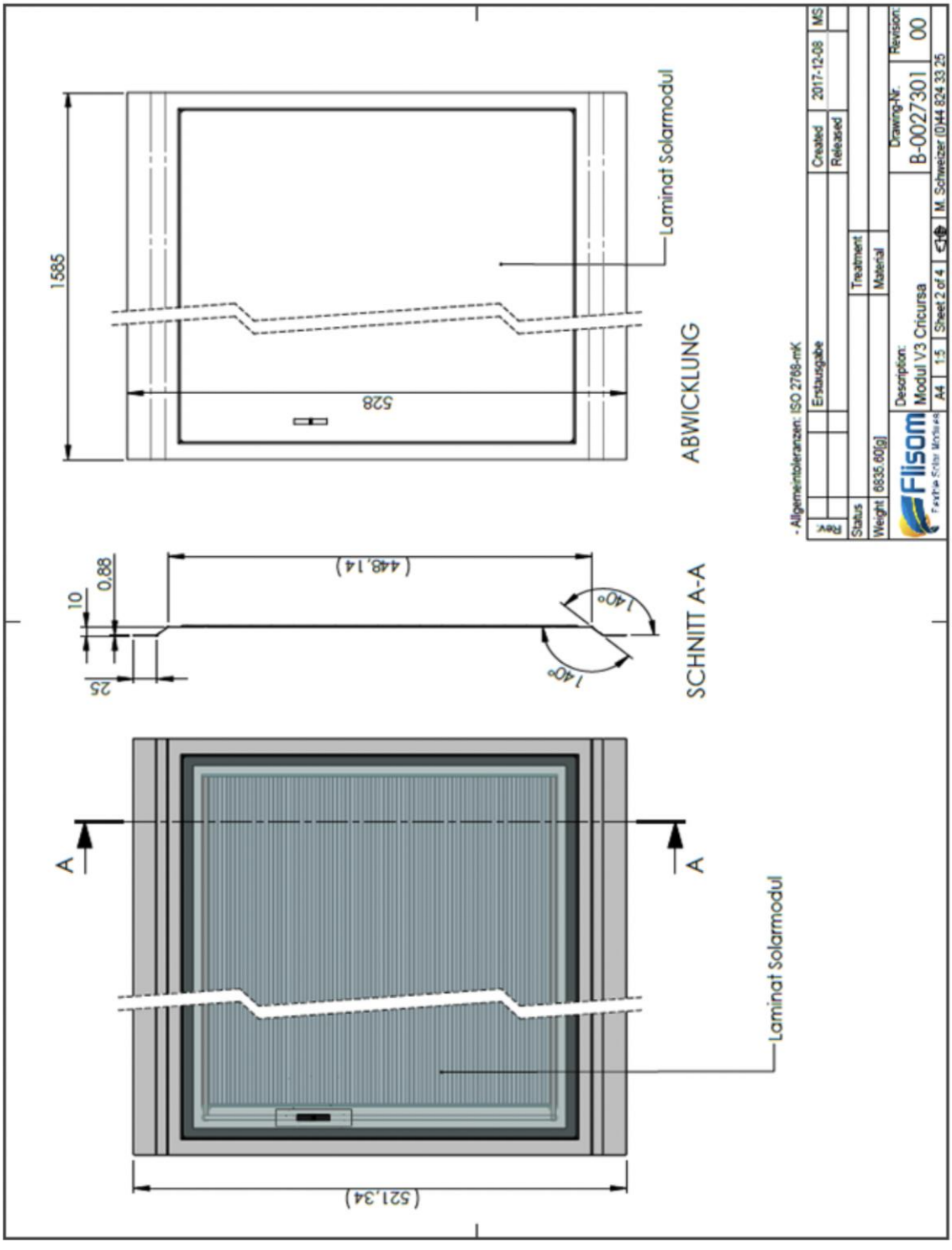

Laminationfoil
394
32
32
122
2519
Backsheet
2295
Frontsheet
2255
Lamination Foil Front
5
2250
Lamination Foil Back
25
147
Frontsheet
416
Backsheet
458
- Allgemeintoleranzen: ISO 2768-mK
Rev:
Status
Weight:
Estlausgabe
Released
Treatment
Material
Created
2017-12-14
MS
Description:
Carportmodul 3x1
Drawing-Nr.
B-0027348
Revision:
00
A4
1:5
Sheet 1 of 3
M. Schweizer (0)44 82433 25
Flisom
Flexible Solar Modules

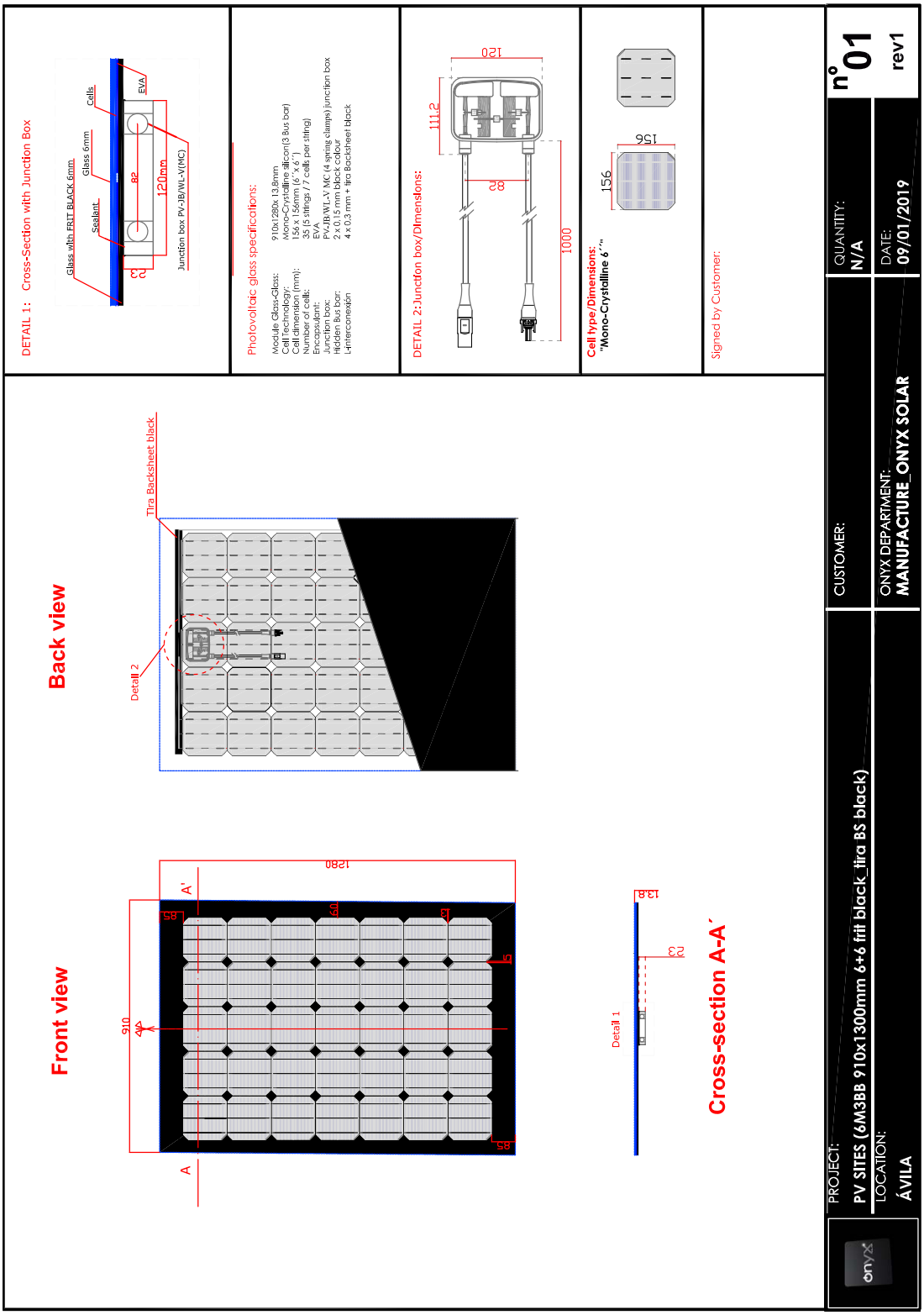

Backsheet
3263
Frontsheet
3048
Lamination Foil front
3027
Lamination Foil back
2997
Backsheet 458
Laminationfoil 394
Frontsheet 416
Distance LF - SM
10
Distance SM - SM
3
Distance Isolationsstreifen - SM
10
Distance Edge - Isolationsstreifen
118
Isolationsstreifen
30
Distance Edge - LRb
148
- Allgemeintoleranzen:
Rev.
Status
Weight 10781.53[g]
Material
Treatment
Estausgabe
Created 2018-07-30 RC
Released
Description: Carport_4x1_v2
Drawing-Nr. B-0029608
Revision 00
A4 1:5 Sheet 1 of 2
Flisom
Flexible Solar Modules

18.3**X2**

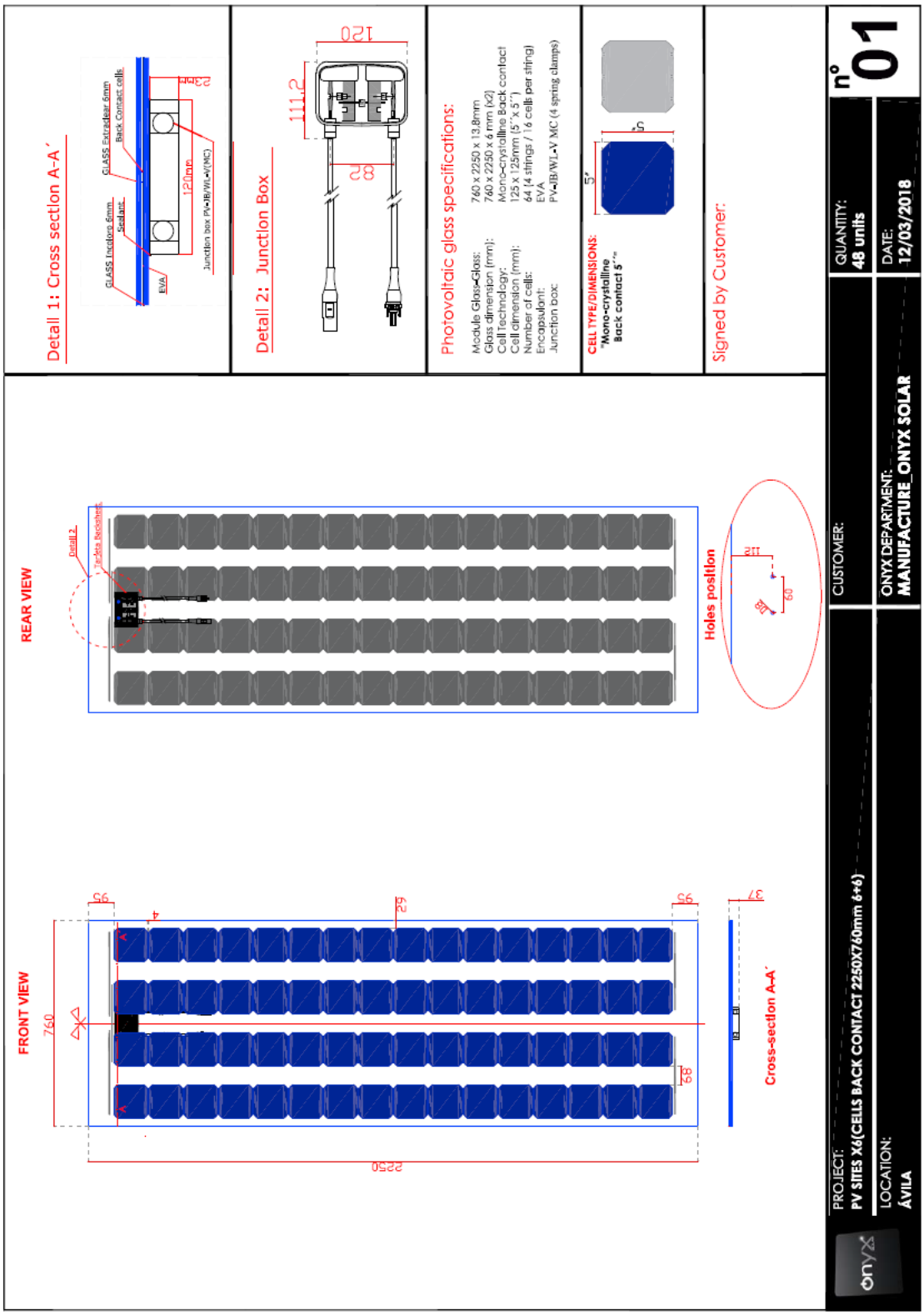

Lamination Foil
394
26
26
15
26
A
A
1574
Backsheet
1544
Frontsheet
1522
Lamination Foil
7.50
20
Frontsheet
416
15
15
15
26
16
223
446
471
SCHNITT A-A
Allgemeintoleranzen: ISO 2768-mK
Ersatzgabe
Created
2017-12-14
MS
Released
Treatment
Material
Status
Weight 5333.22[g]
Description:
Fassadenpanel 2x1 P1
Drawing-Nr.
B-0027318
Revision:
00
A4
1:5
Sheet 1 of 2
M. Schweizer / 044 824 33 25

18.4**X4**

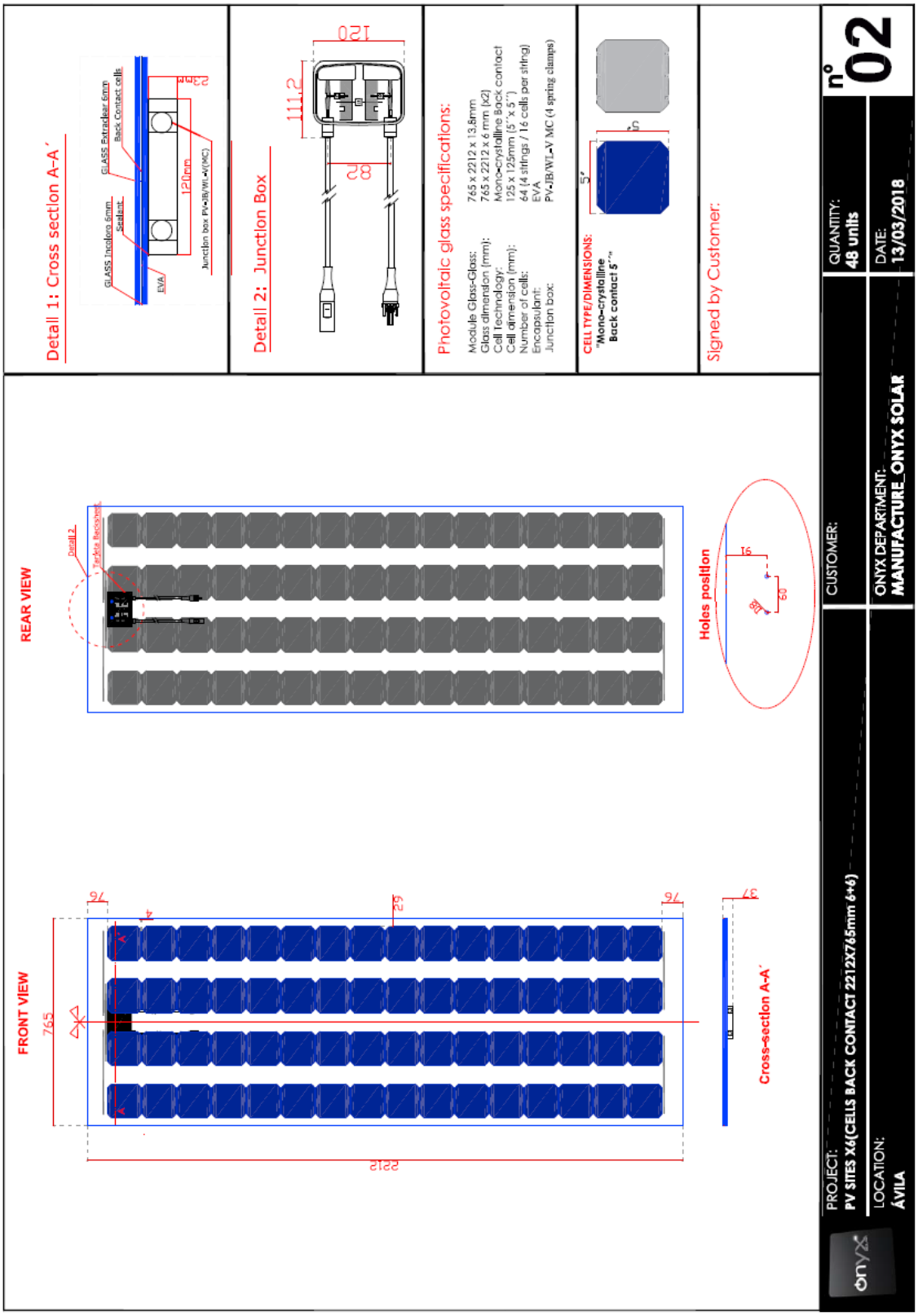

Laminat Solarmodul
1585
528
ABWICKLUNG
(448,14)
10
0,88
25
140°
140°
SCHNITT A-A
A
A
Laminat Solarmodul
(521,34)
Allgemeintoleranzen: ISO 2768-mK
Erstausgabe
Created
2017-12-08
MS
Released
Rev.
Status
Treatment
Weight 8835.60[g]
Material
Description:
Modul V3 Cricursa
Drawing-Nr.
B-0027301
Revision:
00
Flisom
A4
1:5
Sheet 2 of 4
M. Schweizer (0)44 824 33 25


DETAIL 1: Cross-Section with Junction Box
Glass with FRIT BLACK 6mm
Sealant
Glass 6mm
Cells
EVA
82
120mm
Junction box PV-JB/WL-V(MC)
Photovoltaic glass specifications:
Module Glass-Glass: 910x1280x 13.8mm
Cell Technology: Mono-Crystalline silicon(3 Bus bar)
Cell dimension (mm): 156 x 156mm (6 "x 6 ")
Number of cells: 35 (5 strings / 7 cells per string)
Encapsulant: EVA
Junction box: PV-JB/WL-3 / MC (4 spring clamps) junction box
Hidden Bus bar: 2 x 0.15 mm black colour
Interconexión: 4 x 0.3 mm + tira Backsheet black
DETAIL 2: Junction box/Dimensions:
120
111.2
82
1000
Cell type/Dimensions:
"Mono-Crystalline 6 ""
156
156
Signed by Customer:
Back view
Tira Backsheet black
Detail 2
Front view
1280
910
A
A'
85
85
5
Detail 1
13.8
2.3
Cross-section A-A´
PROJECT:
PV SITES (6M3BB 910x1300mm 6+6 frit black_tira BS black)
LOCATION:
ÁVILA
CUSTOMER:
QUANTITY:
N/A
ONYX DEPARTMENT:
MANUFACTURE_ONYX SOLAR
DATE:
09/01/2019
n°01
rev1

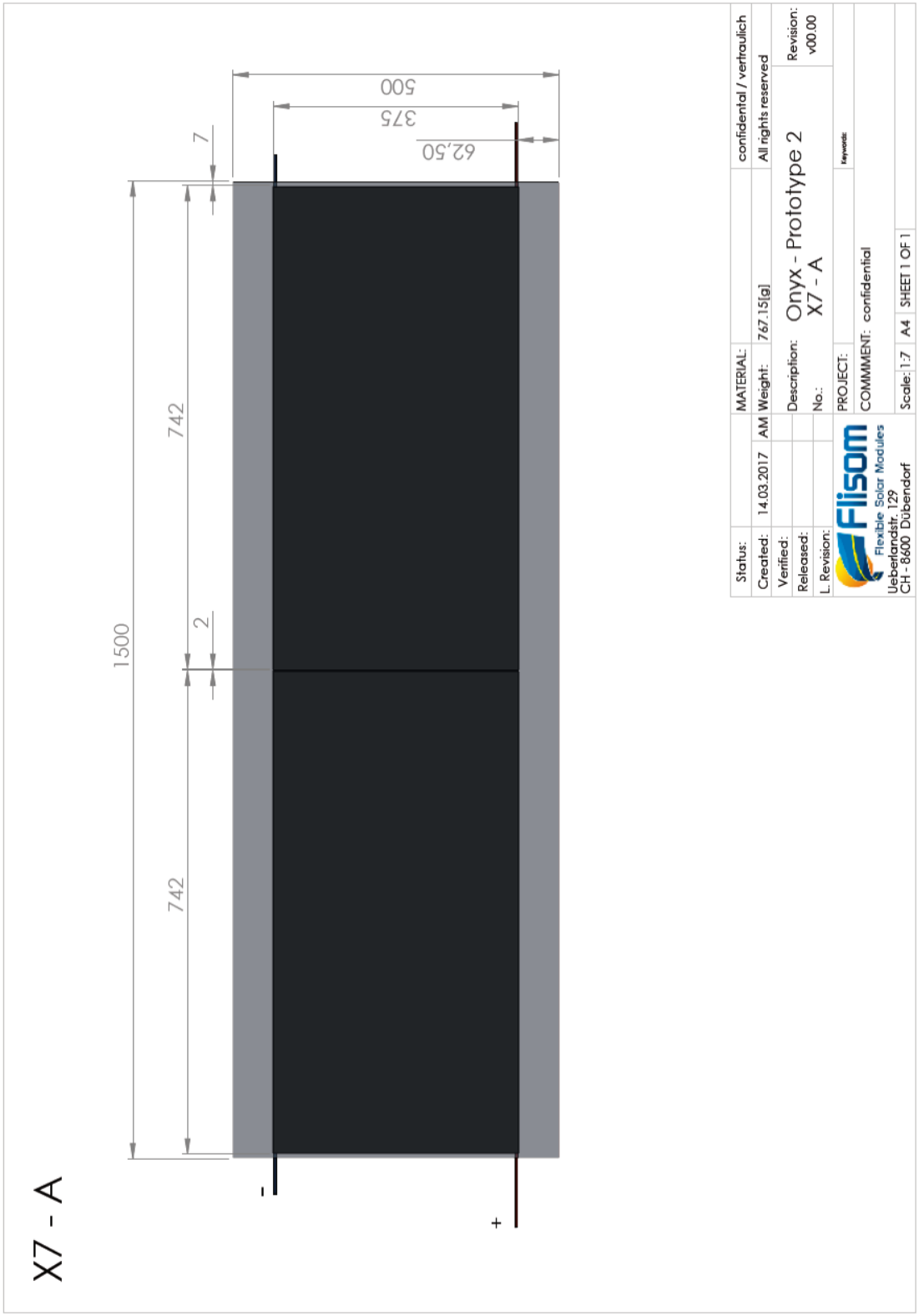
18.6 **X6a**


Detail 1: Cross section A-A´
GLASS Extra clear 6mm
Back Contact cells
GLASS Incoloro 6mm
Sealant
EVA
Junction box PV+JB/WI-V(MC)
Detail 2: Junction Box
Photovoltaic glass specifications:
Module Glass-Glass: 760 x 2250 x 13,8mm
Glass dimension (mm): 760 x 2250 x 6 mm (x2)
Cell Technology: Mono-crystalline Back contact
Cell dimension (mm): 125 x 125mm (5" x 5")
Number of cells: 64 [4 strings / 16 cells per string]
Encapsulant: EVA
Junction box: PV+JB/WI-V MC (4 spring clamps)
CELL TYPE/DIMENSIONS:
"Mono-crystalline
Back contact 5""
Signed by Customer:
REAR VIEW
Detail 2
Holes position
FRONT VIEW
760
2250
Cross-section A-A´
PROJECT:
PV SITES X6(CELLS BACK CONTACT 2250X760mm 6+6)
LOCATION:
ÁVILA
CUSTOMER:
ONYX DEPARTMENT:
MANUFACTURE_ONYX SOLAR
QUANTITY:
48 units
DATE:
12/03/2018
nº 01

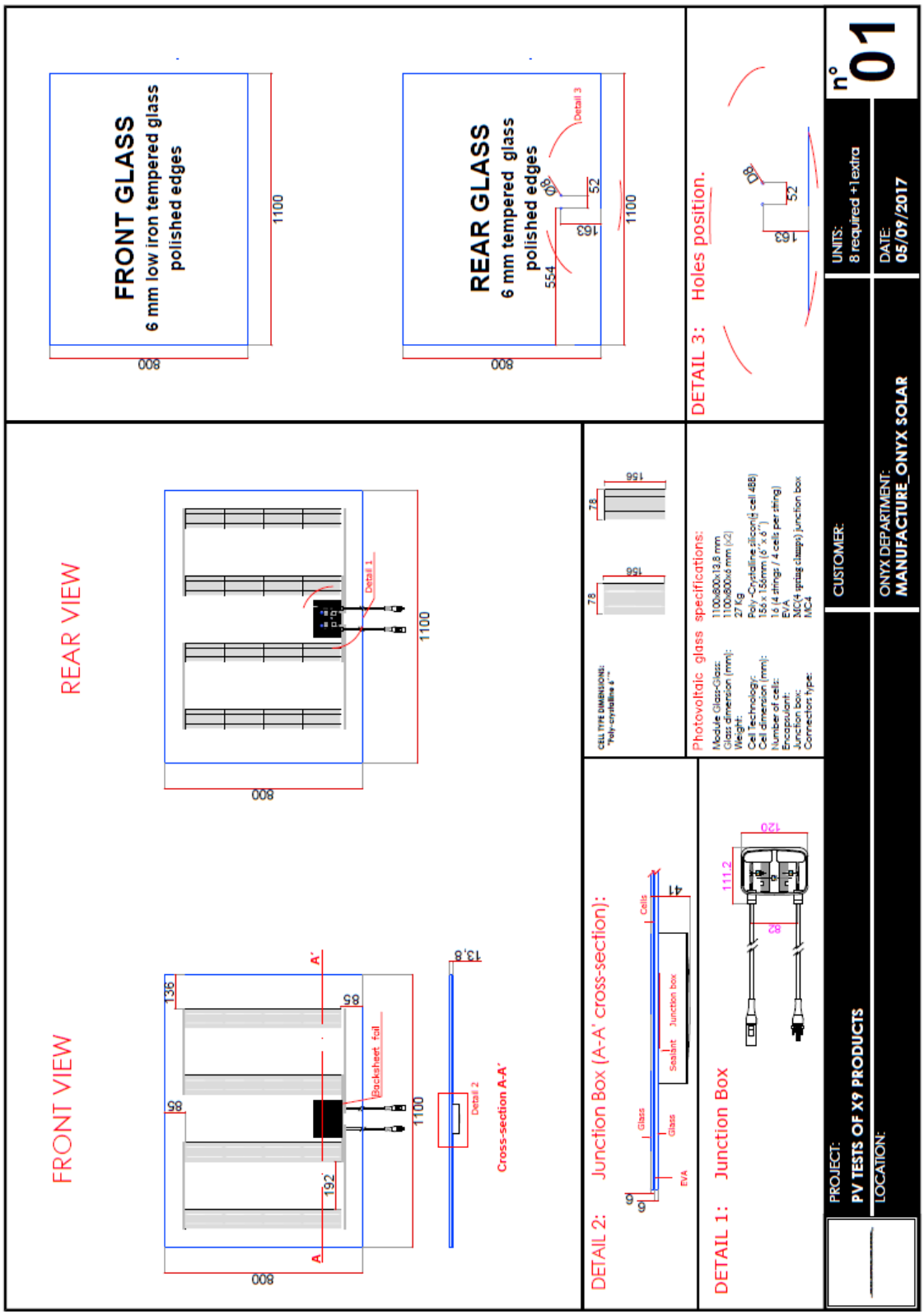
18.7 **X6b**

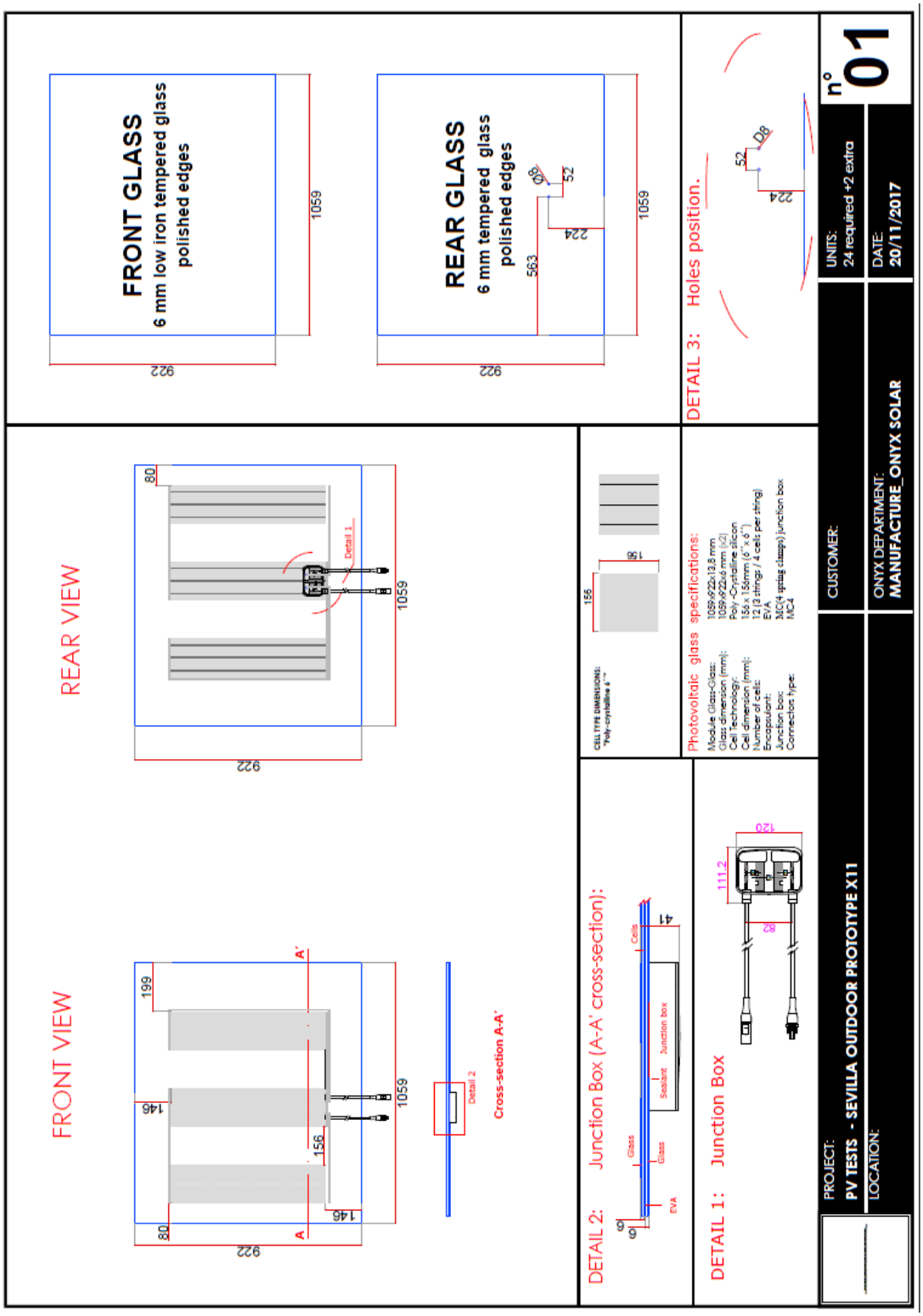

Detail 1: Cross section A-A´
GLASS Extraclear 6mm
Back Contact cells
GLASS Incolora 6mm
Sealant
EVA
120mm
Junction box PV-JB/WL-V(MC)
Detail 2: Junction Box
120
111.2
80
Photovoltaic glass specifications:
Module Glass-Glass: 765 x 2212 x 13.8mm
Glass dimension (mm): 765 x 2212 x 6 mm (x2)
Cell technology: Mono-crystalline Back contact
Cell dimension (mm): 125 x 125mm (5" x 5")
Number of cells: 64 (4 strings / 16 cells per string)
Encapsulant: EVA
Junction box: PV-JB/WL-V MC (4 spring clamps)
CELL TYPE/DIMENSIONS:
"Mono-crystalline
Back contact 5""
5"
5"
Signed by Customer:
REAR VIEW
Detail 2
Holes position
FRONT VIEW
765
2212
Cross-section A-A´
PROJECT:
PV SITES X6(CELLS BACK CONTACT 2212X765mm 6+6)
LOCATION:
ÁVILA
CUSTOMER:
ONYX DEPARTMENT:
MANUFACTURE_ONYX SOLAR
QUANTITY:
48 units
DATE:
13/03/2018
n° 02

18.8 X7


X7 - A
500
375
62,50
7
742
2
742
1500
-
+
confidential / vertraulich
All rights reserved
Revision:
v00.00
MATERIAL:
AM Weight:
767.15[g]
Description:
Onyx - Prototype 2
No.:
X7 - A
PROJECT:
COMMMENT: confidential
Status:
Created: 14.03.2017
Verified:
Released:
L. Revision:
Flisom
Flexible Solar Modules
Ueberlandstr. 129
CH - 8600 Dübendorf
Scale: 1:7
A4
SHEET 1 OF 1

18.9 X9


FRONT GLASS
6 mm low iron tempered glass
polished edges
1100
800
REAR GLASS
6 mm tempered glass
polished edges
Detail 3
Ø8
52
163
554
1100
800
DETAIL 3: Holes position.
Ø8
52
163
REAR VIEW
Detail 1
1100
800
FRONT VIEW
A'
136
85
85
Backsheet_foil
192
1100
A
800
13,8
Detail 2
Cross-section A-A'
CELL TYPE DIMENSIONS:
"Poly-crystalline 6 "
156
78
156
78
Photovoltaic glass specifications:
Module Glass-Glass: 1100x800x13.8 mm
Glass dimension (mm): 1100x800x3 mm (x2)
Weight: 27 kg
Cell Technology: Poly-Crystalline silicon(6 cell 488)
Cell dimension (mm): 156 x 156mm (6" x 6")
Number of cells: 16 (4 strings / 4 cells per string)
Encapsulant: EVA
Junction box: IP67(4 spring clamps) junction box
Connectors type: MC4
DETAIL 2: Junction Box (A-A' cross-section):
Cells
41
6
Glass
Glass
EVA
Sealant
Junction box
DETAIL 1: Junction Box
111,2
120
82
PROJECT:
PV TESTS OF X9 PRODUCTS
LOCATION:
CUSTOMER:
ONYX DEPARTMENT:
MANUFACTURE_ONYX SOLAR
UNITS:
8 required +1extra
DATE:
05/09/2017
n° 01


FRONT GLASS
6 mm low iron tempered glass
polished edges
REAR GLASS
6 mm tempered glass
polished edges
DETAIL 3: Holes position.
REAR VIEW
FRONT VIEW
Cross-section A-A'
DETAIL 2: Junction Box (A-A' cross-section):
DETAIL 1: Junction Box
Photovoltaic glass specifications:
PROJECT:
PV TESTS - SEVILLA OUTDOOR PROTOTYPE X11
LOCATION:
CUSTOMER:
ONYX DEPARTMENT:
MANUFACTURE_ONYX SOLAR
UNITS:
24 required +2 extra
DATE:
20/11/2017
n° 01