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PVsites

Samples of crystalline silicon based photovoltaic glazing products for indoor validation tests

Project report

ONYX SOLAR

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Summary

This document is associated to the task “T3.7: Performance validation testing” within “WP3: BIPV modules based on crystalline silicon technology” of the PVSITES project.

This document describes all the manufactured samples which will be tested under what is specified in Task 3.7: *Performance Validation Testing*. Final prototypes have been developed in accordance to the analyses undertaken under the project tasks corresponding to each c-Si based product (Tasks 3.1 to 3.5).

Acknowledgements

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The present report was prepared by PVSITES project partner ONYX SOLAR. The report was originally submitted to the European Commission as Project Deliverable D3.8 in March 2017.

Disclaimer

About the PVSITES project

PVSITES is an international collaboration co-funded by the European Union under the Horizon 2020 Research and Innovation program. It originated from the realisation that although building-integrated photovoltaics (BIPV) should have a major role to play in the ongoing transition towards nearly zero energy buildings (nZEBs) in Europe, the technology in new constructions has not yet happened. The cause of this limited deployment can be summarised as a mismatch between the BIPV products on offer and prevailing market demands and regulations.

The main objective of the PVSITES project is therefore to drive BIPV technology to a large market deployment by demonstrating an ambitious portfolio of building integrated solar technologies and systems, giving a forceful, reliable answer to the market requirements identified by the industrial members of the consortium in their day-to-day activity.

Coordinated by project partner Tecnalia, the PVSITES consortium started work in January 2016 and will be active for 3.5 years, until June 2019. This document is part of a series of public reports summarising the consortium's activities and findings, available for download on the project's website at www.pvsites.eu.

The PVSITES consortium:

Tecnalia Research & Innovation	CTCV	FormatD2
Onyx Solar	Flisom	Vilogia
BEAR-iD	Cricursa	R2M Solution Research to Market
Nobatek	CEA	CADCAMation
Film Optics	Acciona Infraestructuras	WIP - Renewable Energies

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1 EXECUTIVE SUMMARY

1.1 Description of the deliverable content and purpose

PVSITES Work Package 3 focuses on providing a multiple answer to the market needs defined in Task 1.1: *Market and Stakeholder Needs* by taking to a pre-industrial stage a set of c-Si technology-based products, specially designed to cope with these needs. Families of c-Si based products have been developed under Tasks 3.1 to 3.5 for different implementations within the building (skylights, curtain walls, ventilated façades, shading elements). This document describes all the manufactured samples which will be tested under what is specified in Task 3.7: *Prototypes for Indoor Validation Testing* in order to guarantee that the new families of products comply with applicable standards. The test sequence for each product defined by the involved partners is detailed.

Final prototypes have been developed in accordance to the analysis carried out under the project tasks corresponding to each c-Si based product (Tasks 3.1 to 3.5). In this sense, in Deliverables 3.1 to 3.6, all the details regarding the current state of the art, technologies, materials, processes, cost analysis and conclusions regarding these products can be consulted.

1.2 Relation with other activities in the project

Table 1.1 depicts the main links of this deliverable to other activities 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
Task 1.1	Market and stakeholder analysis and present and future stakeholder´s needs are considered as basis for the development of prototypes of different product families for Indoor Validation Testing. These analyses are detailed in D1.1.
Task 1.3	Standardization needs and testing sequences to be considered in T3.7 are shown in D1.3 as a result of an exhaustive analysis of current applicable standards.
Task 2.1	This task includes the definition of the technical specifications for the PV modules and their manufacturing processes. The basis of PVSITES product design is established in this task.
Task 2.3	All the products resulting from the PVSITES project will be part of a BIPV product portfolio developed under this task.
Task 3.6	Through this task a complete simulation of the BIPV modules at element and building level will be done. The task also provides direct feedback to task 2.3 and the generation of information for dissemination materials.
Tasks 3.1, 3.2, 3.3, 3.4, 3.5	Through these tasks, the product families to be tested within T3.7 will be developed: semitransparent and low concentration BIPV solutions, opaque BIPV solutions with hidden busbars and L-interconnections, back-contact solar cells implemented as See-Thru glazing/glazing BIPV solution, framing systems for XL BIPV formats and BIPV units including glazing treatments for improved passive properties.

Task 3.7 and 3.8	Results of the testing of prototypes described in this deliverable will be shown in D3.9. These results will serve as a basis for the prototypes to be developed for demonstration in outdoor test benches. D3.10 (M21) will define prototypes for outdoor testing and results will be shown in D3.11 (M30)

The following figure schematizes the relation between the mentioned tasks.

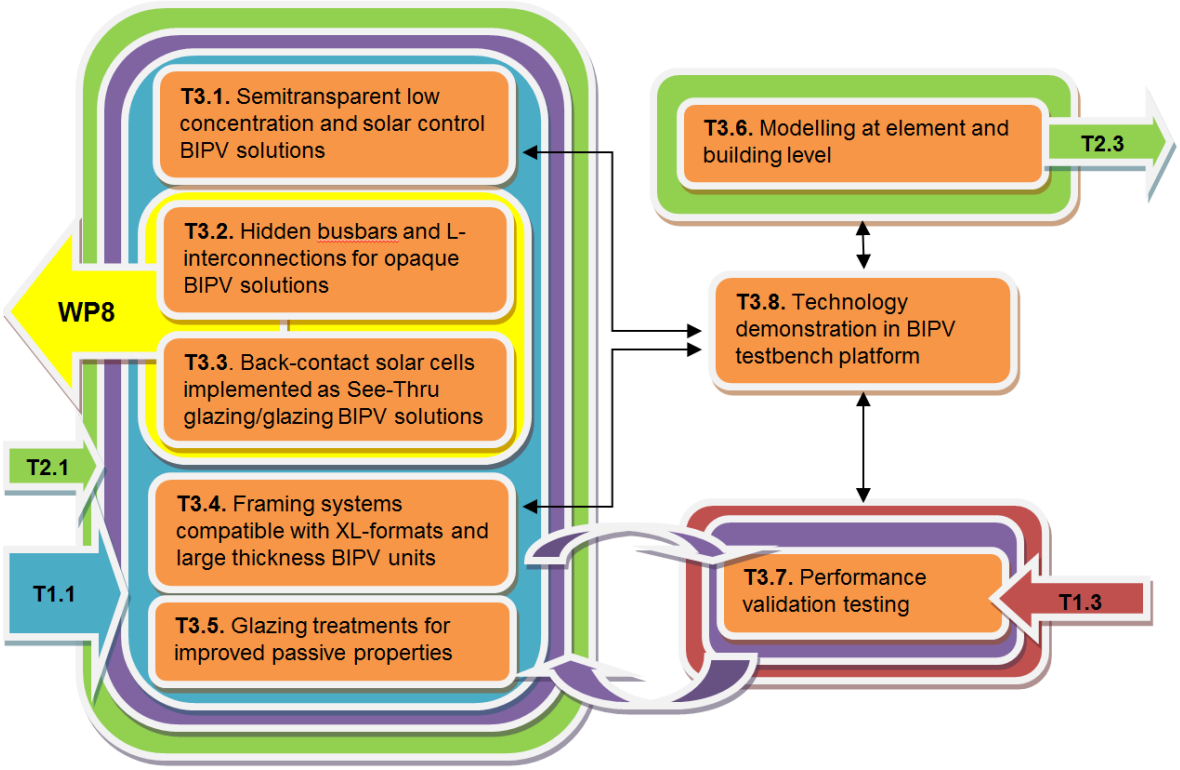

Figure 1.1 Relationship between T3.7 and other tasks

1.3 Reference material

This deliverable has used some data from PVSITES deliverable 2.1: Technical specifications for BIPV modules.

1.4 Abbreviation list

BIPV: Building Integrated Photovoltaics

c-Si: Crystalline Silicon

EU: European Union

H2020: Horizon 2020

Low-E: Low Emissivity

M: Month

PV: Photovoltaic

WP: Work Package

X5: t“C-Si glazed products with hidden bus bars and L interconnections” product

X6: “Glass-glass products with back contact c-Si cells” product

X8: “Framing system for c-Si large area glass” product

X9: “C-Si semitransparent low concentration and Solar control BIPV system – skylight configuration” product

X10: “C-Si semitransparent low concentration and Solar control BIPV system – facade configuration” product

X11: “C-Si semitransparent low concentration and Solar control BIPV system – shading element configuration” product

X12: “Glazed modules treated for improved passive properties” product

2 SAMPLES DEVELOPMENT

This chapter is divided in several subsections for each product developed within WP3: X9, X10, X11 (low concentrator and solar control BIPV systems developed by TECNALIA) and X5, X6, X8, X12 (BIPV products developed by ONYX). Subsections corresponding to each product are divided at the same time in several parts:

- The first part shows the sample needs according to the test requirements defined by the involved partners. The results of these tests will be included in D3.9: *Report on indoor validation tests*. Each section includes a table where the characteristics of manufactured samples to be tested under the respective standards within Task 3.7: *Performance validation testing* are shown. Each table contains different **References** in order to identify each product developed for testing. The references in the tables are associated with their **final appearance pictures**, **manufacturing drawings**, product description, dimensions, number of samples manufactured, tests description and standards.
- The second part shows some **final appearance pictures** of the manufactured samples.
- The third part shows some **final manufacturing drawings** of the samples.

2.1 C-Si semi-transparent low concentrator and solar control BIPV system, skylight configuration

This section will be updated once the corresponding samples are manufactured. More information of this product can be consulted in D3.1: *Low-concentration, solar control system: report on lens and module designs and validity ranges* and D3.2: *Low-concentration, solar control system: report on architectural integration*.

2.1.1 Samples for indoor validation tests

The following table includes the sample needs for laboratory testing of this product, as defined by the corresponding partners in D1.3. and T3.7, and according to the latest skylight concept.

Table 2.1 Samples for indoor validation testing of product X9

Reference	Standard	Test description	Number of samples	Dimensions (mm)	Sample description
X9	IEC 62108	Test sequences in standard	8	1600 x 1000	PV modules including structure and lenses
X9	EN 12543 – Part 4	Radiation	3	300 x 300	Lenses composed by 4mm extra clear tempered glass with glued 200 microns PMMA film
X9	EN 12543 – Part 4	Humidity and high temperature	6	100 x 300	Lenses composed by 4mm extra clear tempered glass with glued 200 microns PMMA film
X9	CWCT note 67	Impact due to maintenance activities	3	1500x950	PV modules including structure and lenses

2.1.2 Results

While the original scope of this deliverable includes all products under WP3, the manufacturing process of task 3.1 products (low-concentration system for skylights and façades), under TECNALIA's responsibility, is not finalized yet. A larger set of configurations than initially expected have been explored during the design phase in order to optimize the system performance and the manufacturing of the Fresnel lenses has not been launched until M15. Given that the foreseen manufacturing period for the lenses is 8-12 weeks, a 3 month delay is expected for the physical samples to be manufactured (M18). Overall in the project, this delay can be recovered, as the laboratory testing task will be active until M24, which gives 6 months for the testing of the product. Regarding the outdoor exposure, samples are foreseen for M21 and therefore no delays are expected. These products do not form part of demonstration activities in real buildings.

An update of this deliverable will be issued once the corresponding samples are manufactured.

2.1.3 Manufacturing drawings

Figure 2.1 shows a general manufacturing sketch of the skylight module.

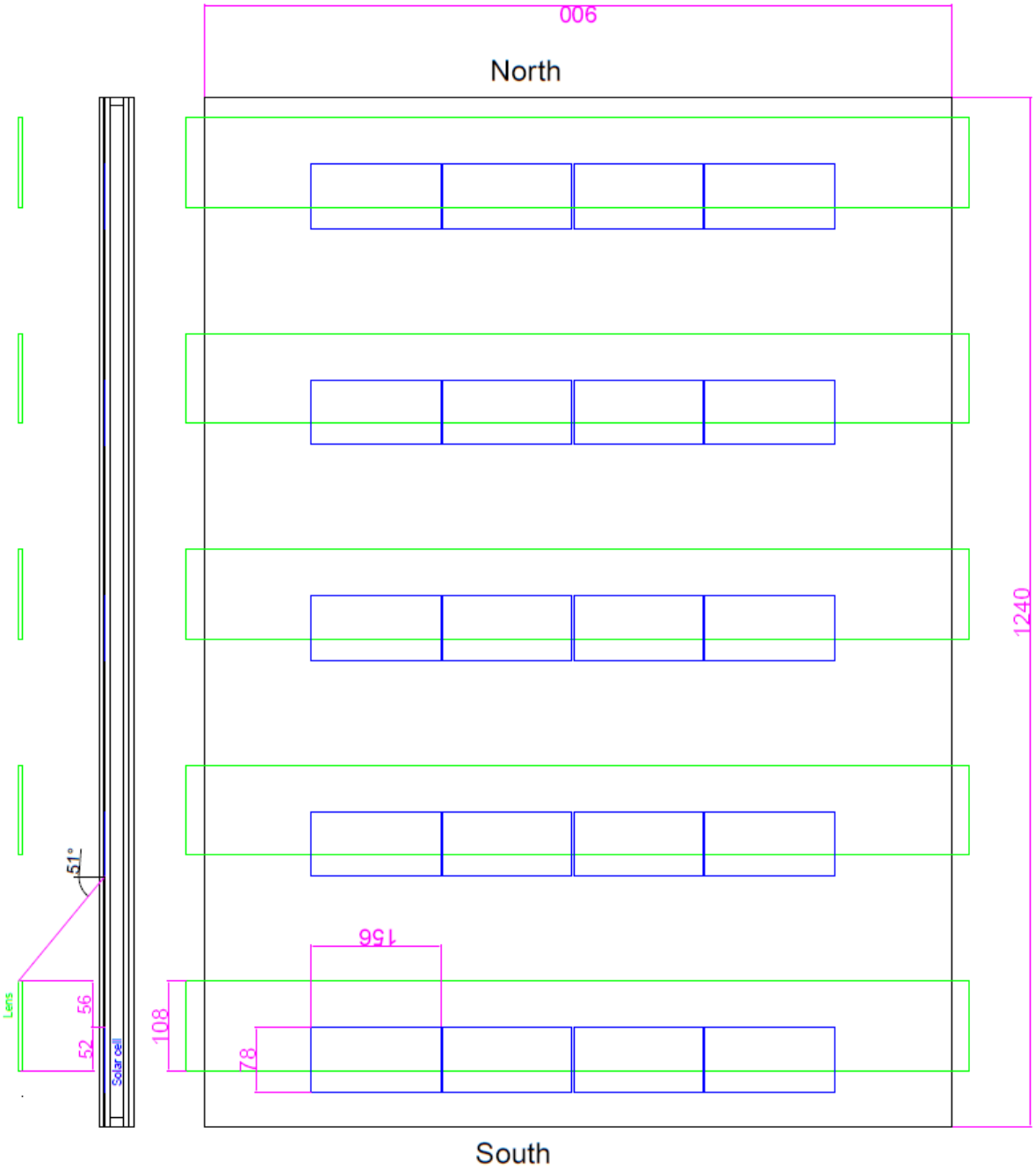

Figure 2.1: Sketch of X9 module

2.2 C-Si semi-transparent low concentrator and solar control BIPV system, façade configuration

As explained in D3.1, this product displayed a lower performance than the shading element configuration, so both the laboratory and outdoor testing will be performed on the shading element for façades.

2.3 C-Si semi-transparent low concentrator and solar control BIPV system, shading element configuration

This section will be updated once the corresponding samples are manufactured. More information of this product can be consulted in D3.1: *Low-concentration, solar control system: report on lens and module designs and validity ranges* and D3.2: *Low-concentration, solar control system: report on architectural integration*.

2.3.1 Samples for indoor validation tests

The following table includes the sample needs for laboratory testing of this product, as defined by the corresponding partners in D1.3. and T3.7.

Table 2.2 Samples for indoor validation testing of product X11

Reference	Standard	Test description	Number of samples	Dimensions (mm)	Sample description
X11	IEC 62108	Test sequences in standard	8	1008 x 920	PV modules including structure and lenses
X11	EN 12543 – Part 4	Radiation	3	300 x 300	Lenses composed by 4mm extra clear tempered glass with glued 200 microns PMMA film
X11	EN 12543 – Part 4	Humidity and high temperature	6	100 x 300	Lenses composed by 4mm extra clear tempered glass with glued 200 microns PMMA film
X11	EAD 220025-000401	Impact resistance, pull-out test, residual load capacity	TBD	TBD	Tests should be adapted to shading system specificities
X11	EN 1716	Reaction to fire	5	100 gr	PMMA film combustion

2.3.2 Results

See section 2.1.2

2.3.3 Manufacturing drawings

Following figures show general manufacturing sketches of the façade module.

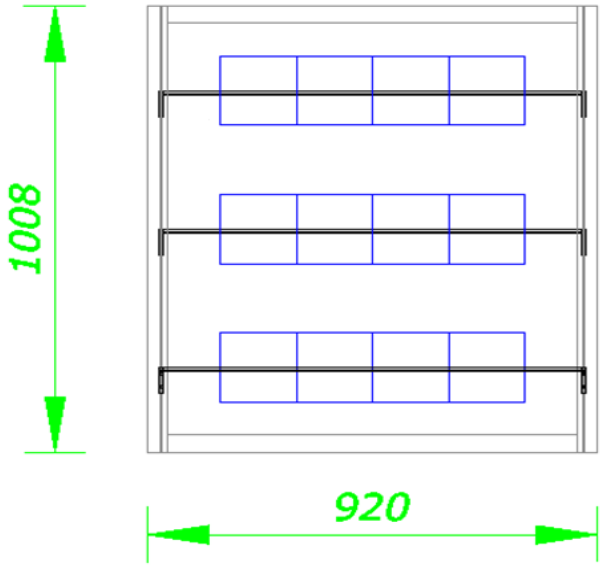

Figure 2.2 2D sketch of X11 module

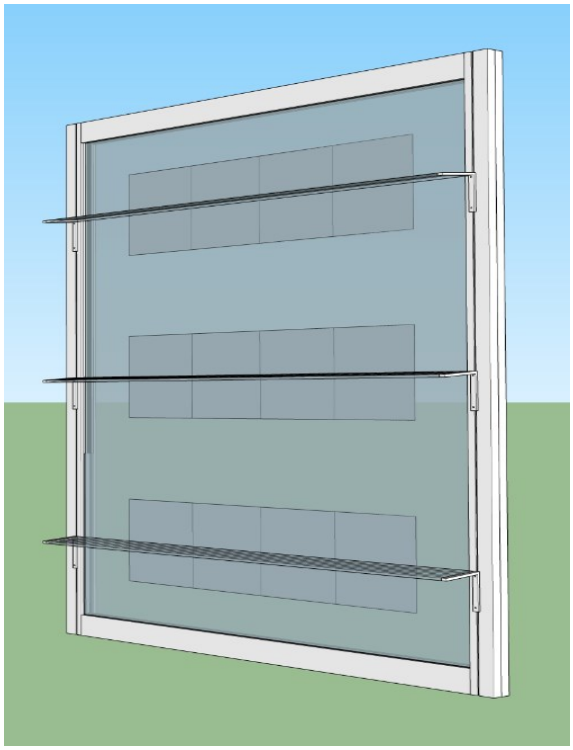

Figure 2.3 3D sketch of X11 module

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

All the information related to this product can be consulted in D3.3: *Operational prototypes with hidden busbars and L-interconnections.*

2.4.1 Samples for indoor validation tests

The following table describes the sample needs and its characteristics according to the test requirements defined by the involved partners. The table contains different References in order to identify each product developed for testing. Each reference in Table 2.3 is associated with two pictures or figures (final appearance picture and manufacturing drawing), product description, dimensions, number of samples manufactured, test description and standards. In this case, Figure 2.4 to Figure 2.11 (shown in section 0) are related to the final appearance of the samples and Figure 2.12 to Figure 2.19 (shown in section 2.4.3) to manufacturing drawings.

Table 2.3 Samples for indoor validation testing of product X5

Reference	Standard	Test description	Number of samples	Dimensions (mm)	Product description	Related figures
X5-1	IEC 61215	Damp heat test, thermal cycling	3	1700 x 1000	1st generation: Standard ribbon Black backsheet Black rear glass	Figure 2.4 Figure 2.12
X5-2	IEC 61215	Damp heat test, thermal cycling	3	1700 x 1000	2nd generation: Black ribbon Black rear glass	Figure 2.5 Figure 2.13
X5-3	ISO 12543 Part 4	Radiation, humidity and high temperature tests	7	360 x 360	Standard ribbon Black backsheet Black rear glass	Figure 2.6 Figure 2.14
X5-4	EN 12600	Impact resistance	4	1938 x 876	Standard ribbon Black backsheet	Figure 2.7 Figure 2.15
X5-5	EN 356	Manual attack	3	1100 x 900	Standard ribbon Black backsheet	Figure 2.8 Figure 2.16
X5-6	EN 13823	Reaction to fire	3	1500 x 1000	Standard ribbon Black backsheet	Figure 2.9 Figure 2.17
X5-7	EN 13823	Reaction to fire:	3	1500 x 500	Standard ribbon Black backsheet	Figure 2.10 Figure 2.18
X5-8	EN 11925-2	Ignitability of products (direct impingement of flame)	6	250 x 90	Standard ribbon Black backsheet	Figure 2.11 Figure 2.19
X5-9	EN 410	Determination of glazing optical properties	1	various	Piece of glass from X5-7 sample	Figure 2.11, Figure 2.19

2.4.2 Results

Figure 2.4 to Figure 2.11 show **final appearance pictures** of the samples described in Table 2.3.

Figure 2.4 Final appearance of sample X5-1 (front and back views)

Figure 2.5 Final appearance of sample X5-2 (front and back views)

Figure 2.6 Final appearance of sample X5-3 (front view)

Figure 2.7 Final appearance of sample X5-4 (front view)

Figure 2.8 Final appearance of sample X5-5 (front view)

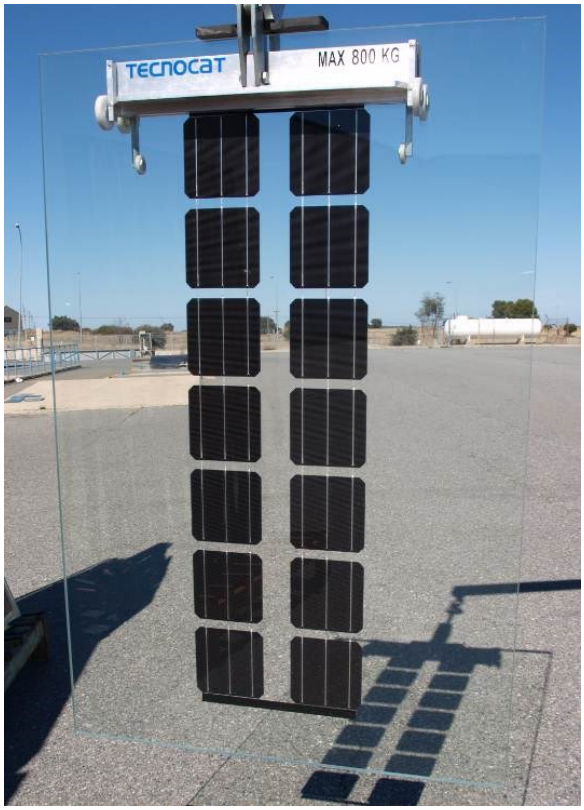

Figure 2.9 Final appearance of sample X5-6 (front view)

Figure 2.10 Final appearance of sample X5-7 (front view)

Figure 2.11 Final appearance of samples X5-8 and X5-9 (front view). Samples will be cut to obtain the indicated dimensions.

2.4.3 Manufacturing drawings

Figure 2.12 to Figure 2.19 show **manufacturing drawings of final modules** described in Table 2.3.

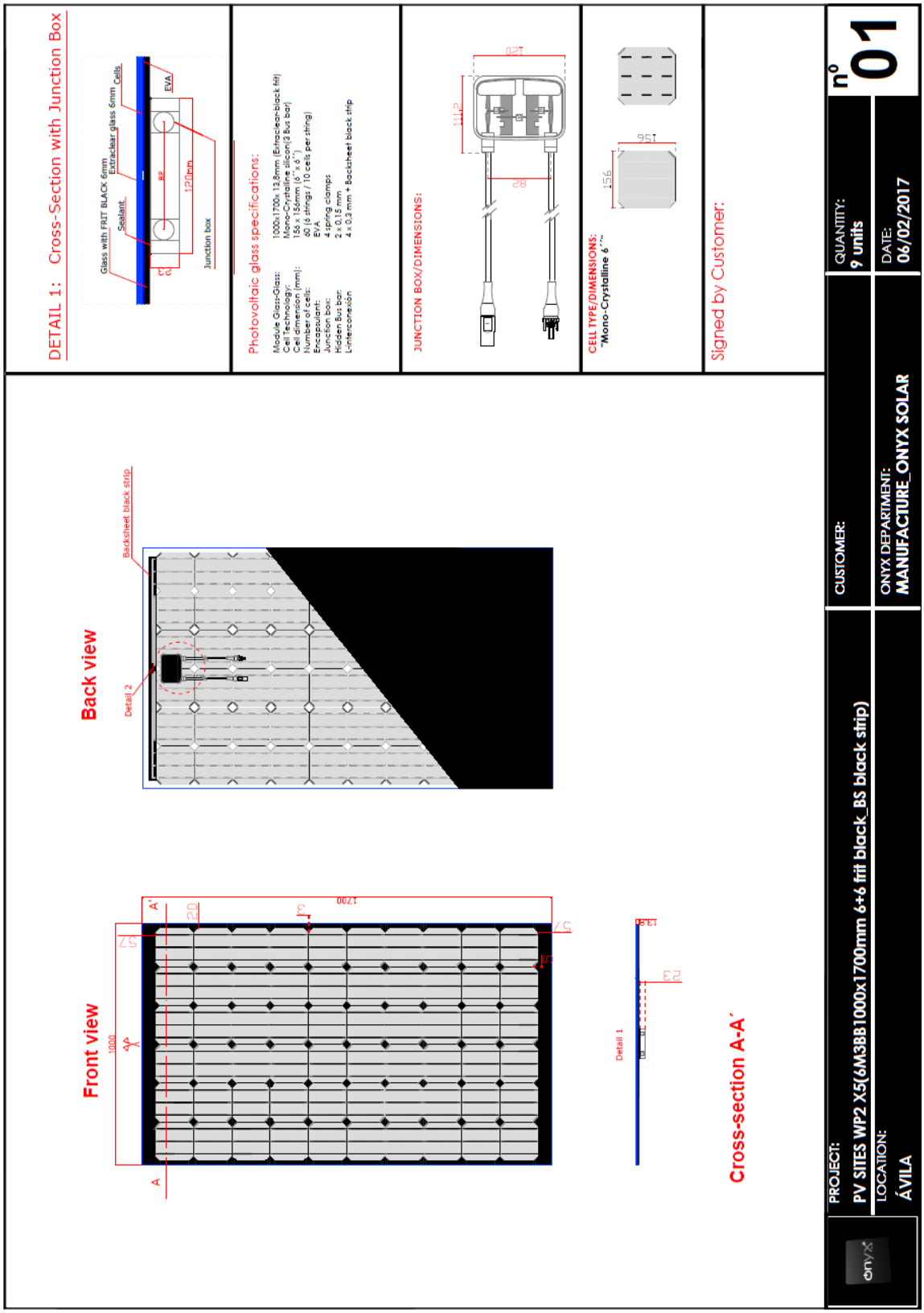

Figure 2.12 Manufacturing drawing of sample X5-1

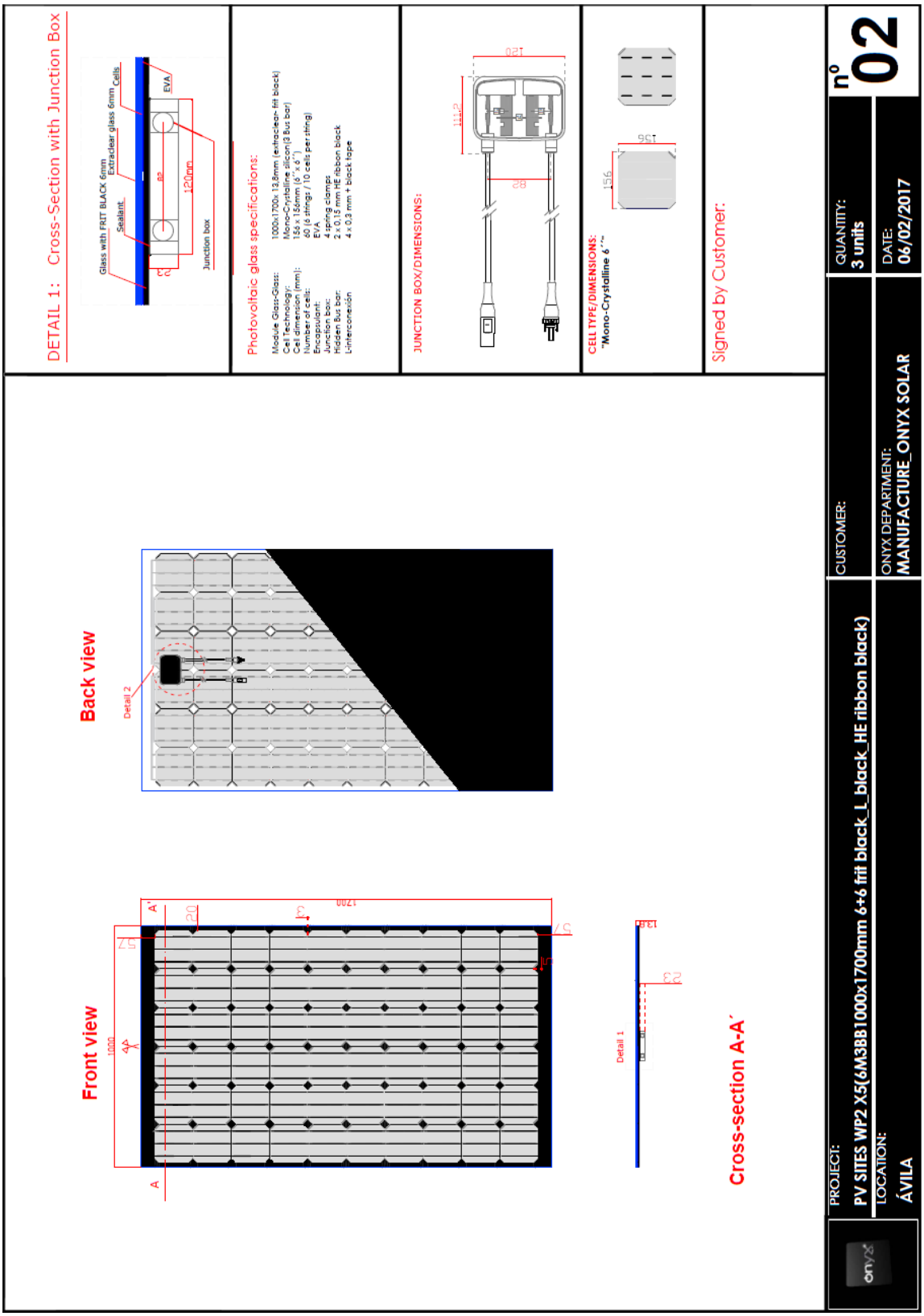

Figure 2.13 Manufacturing drawing of sample X5-2

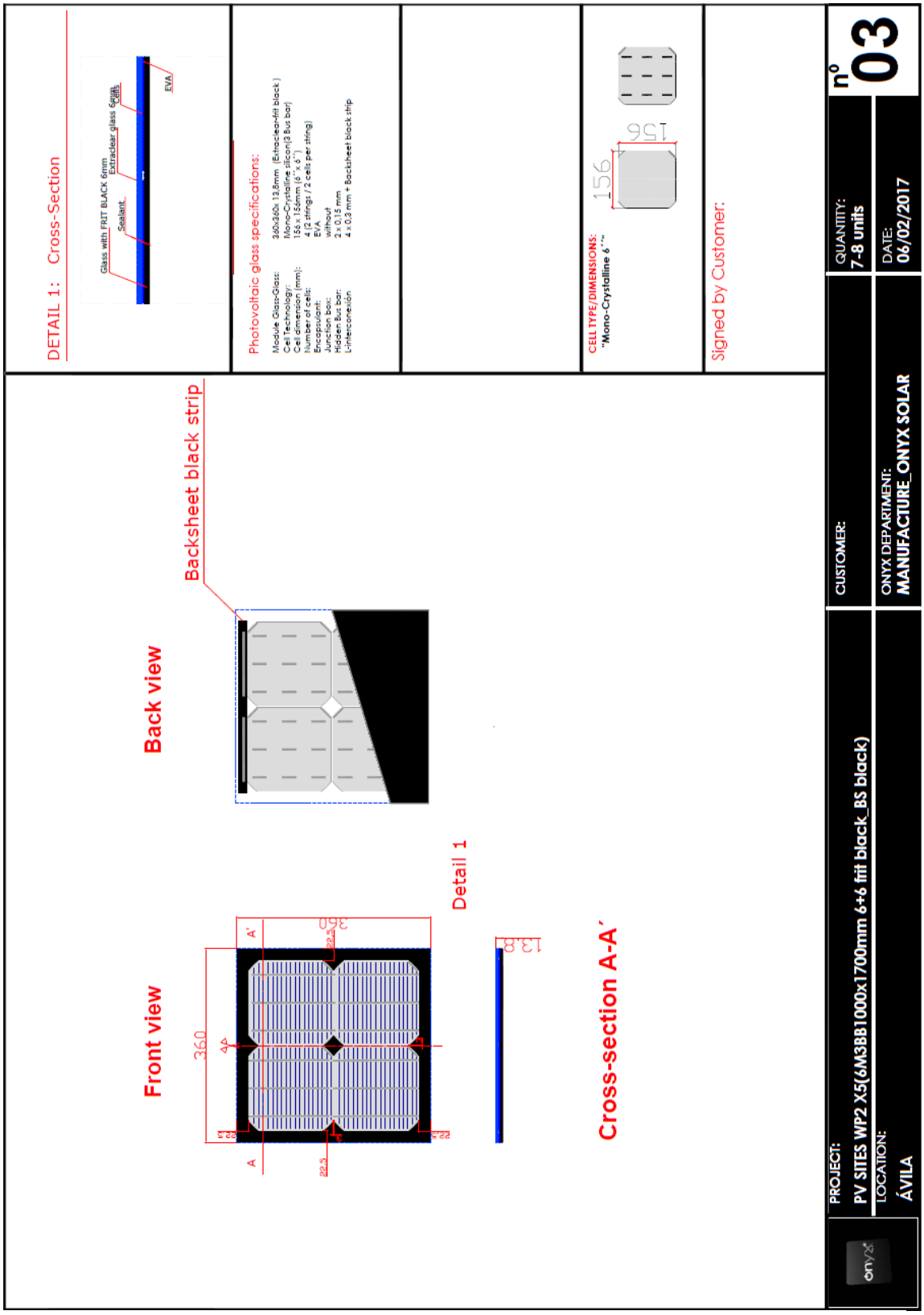

Figure 2.14 Manufacturing drawing of sample X5-3

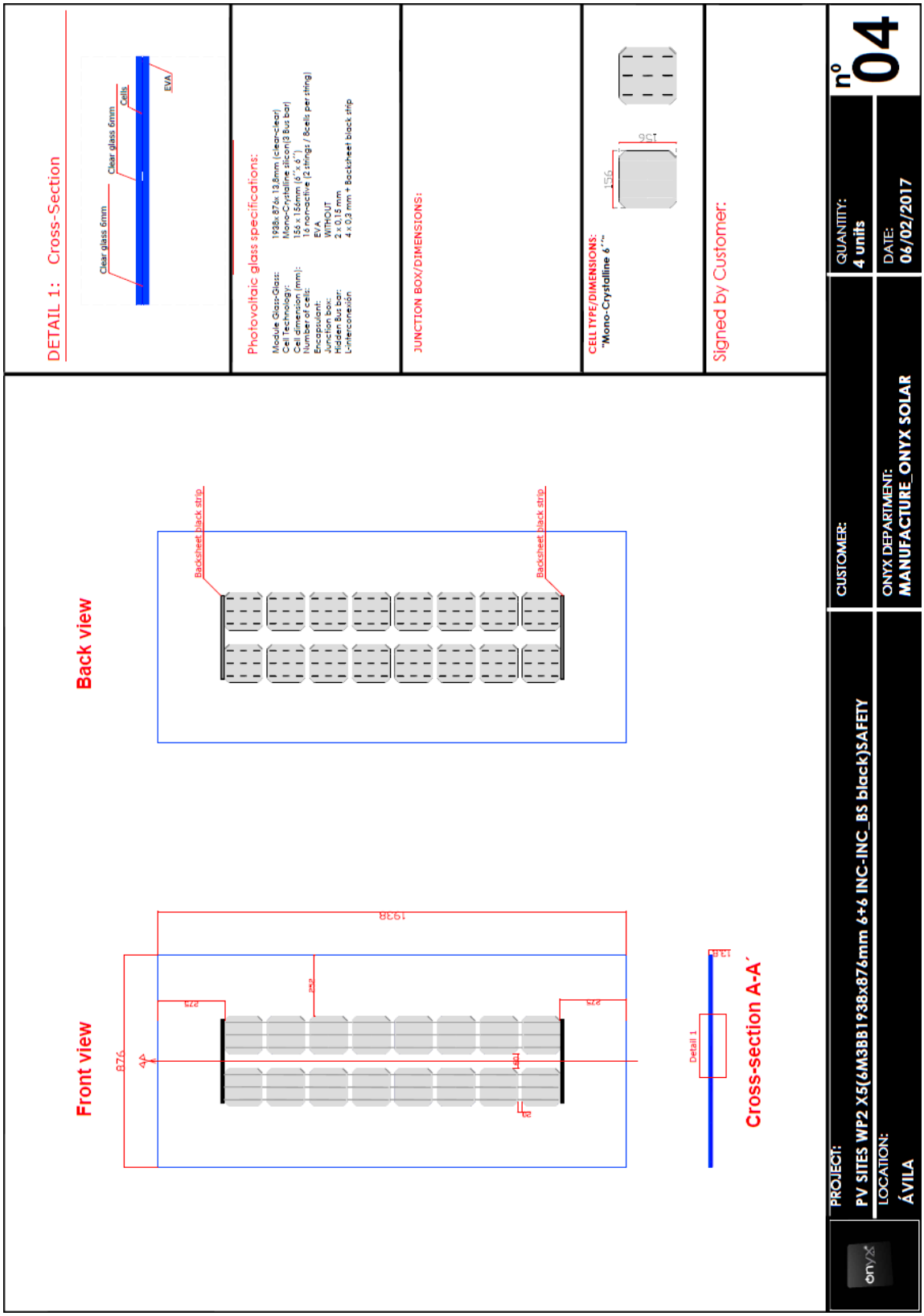

Figure 2.15 Manufacturing drawing of sample X5-4

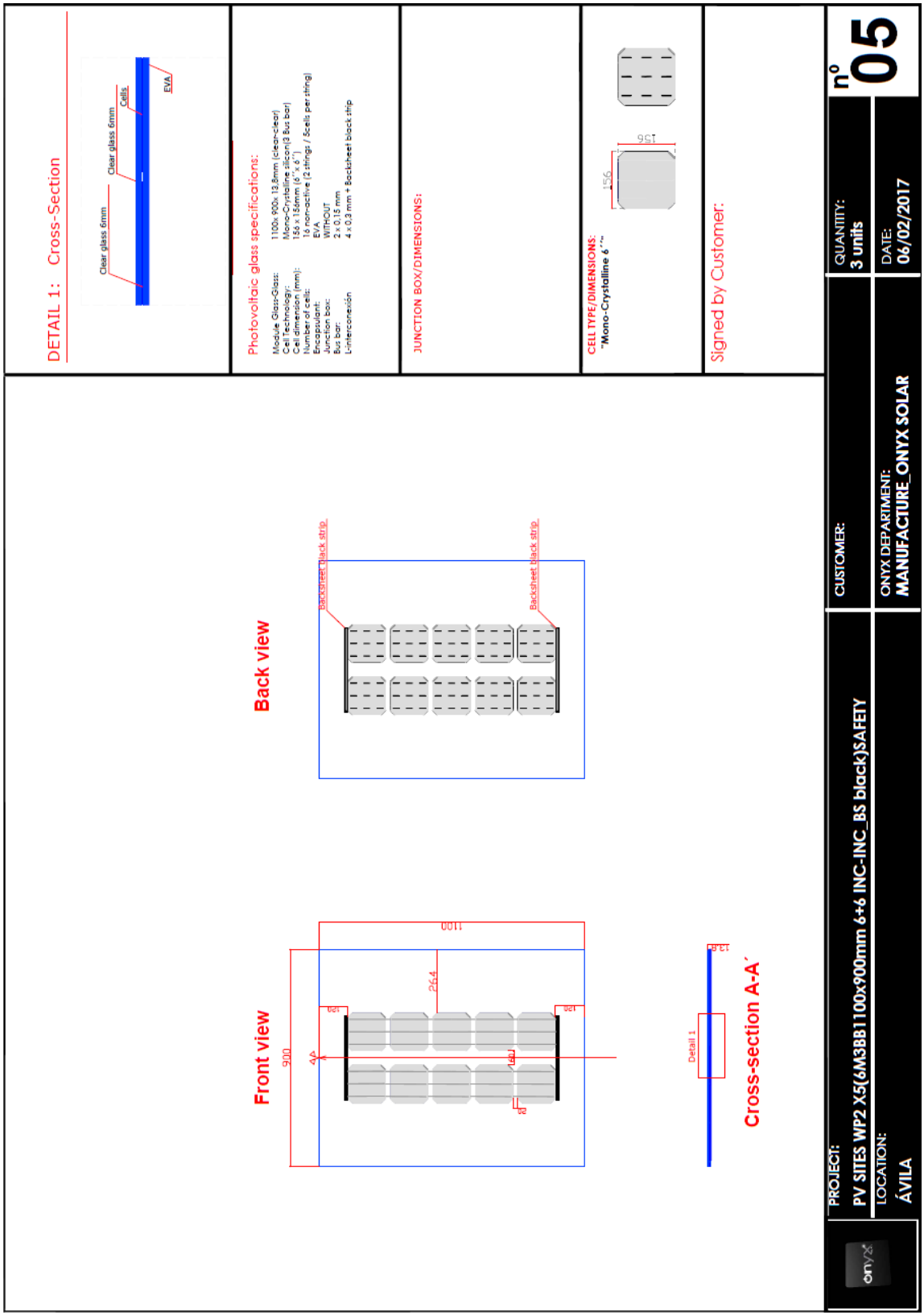

Figure 2.16 Manufacturing drawing of sample X5-5

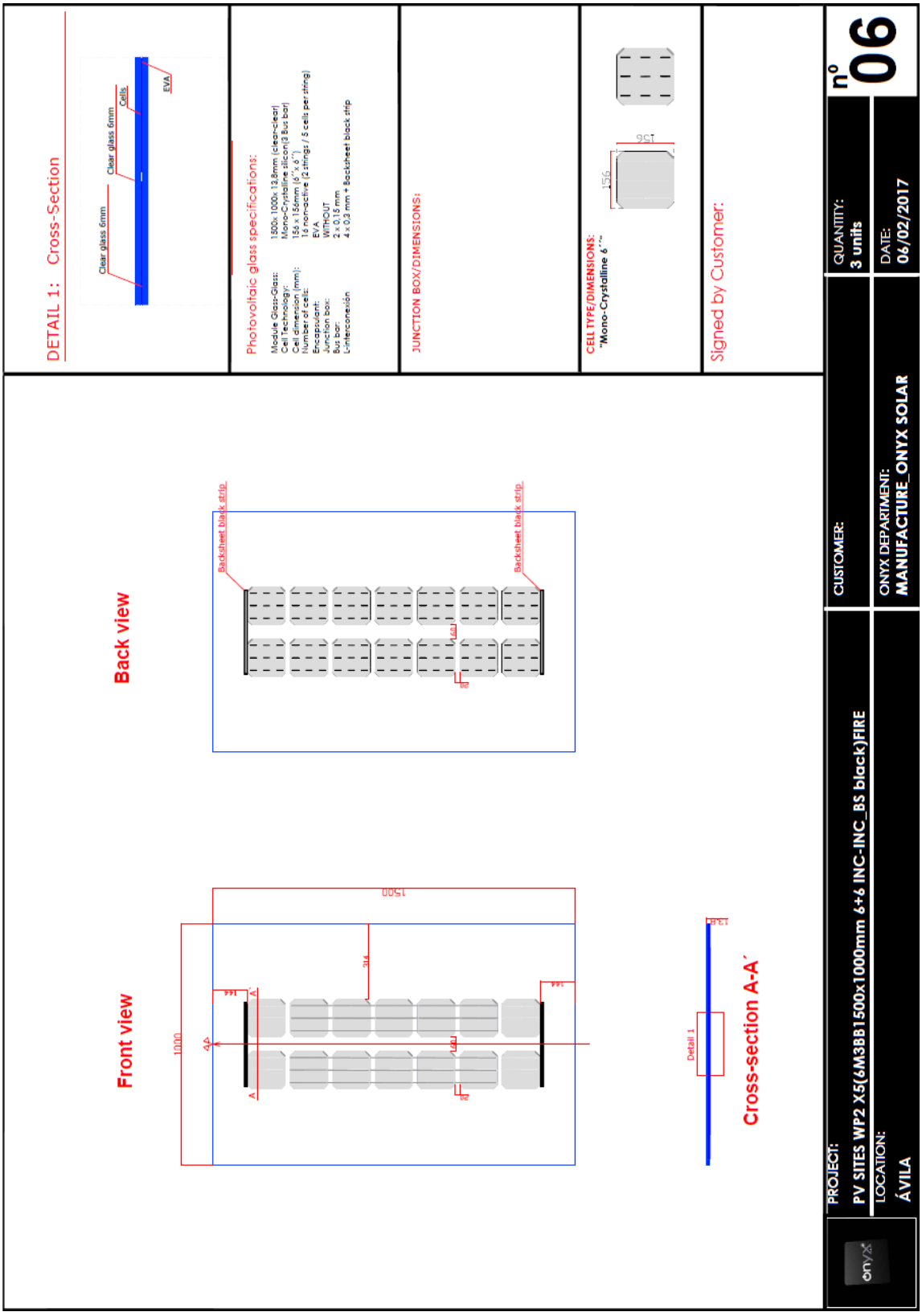

Figure 2.17 Manufacturing drawing of sample X5-6

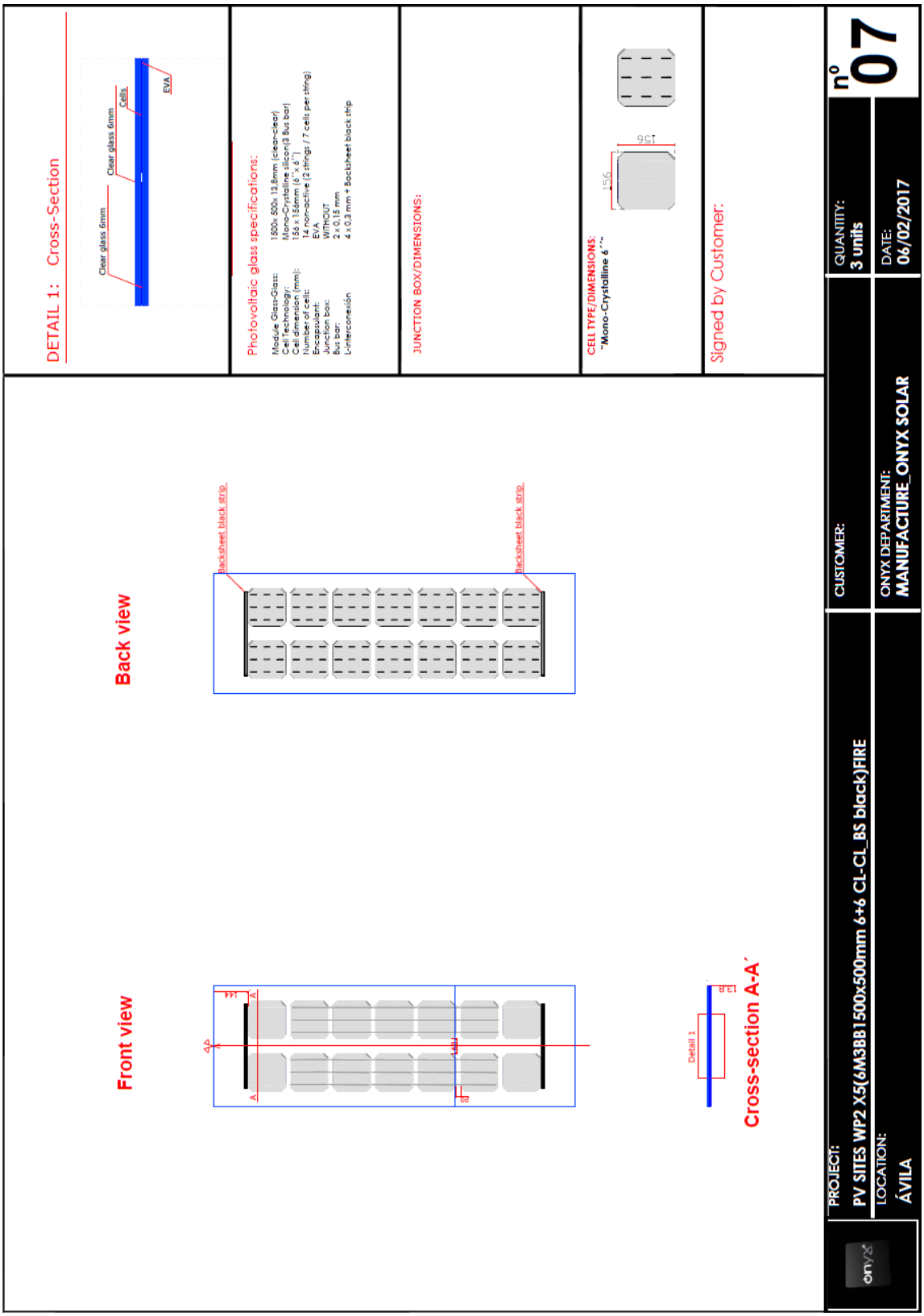

Figure 2.18 Manufacturing drawing of sample X5-7

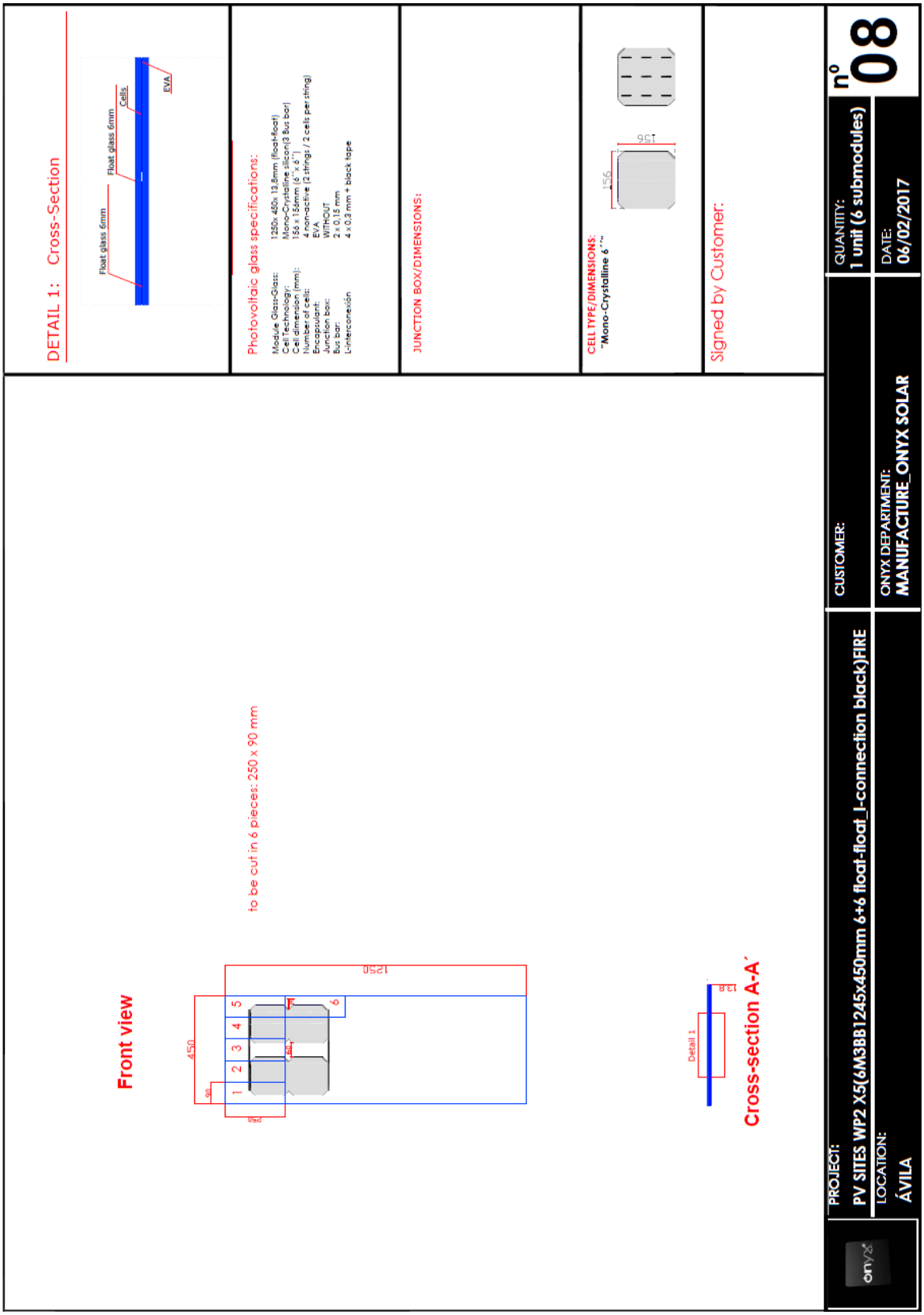

Figure 2.19 Manufacturing drawing of samples X5-8 and X5-9 (to be cut in 6 pieces)

2.5 Glass-glass products with back contact c-Si cells

All the information related to this product can be consulted in D3.4: *Operational prototypes, see-thru back contact solar cells.*

2.5.1 Samples for indoor validation tests

The following table describes the sample needs and its characteristics according to the test requirements defined by the involved partners. The table contains different References in order to identify each product developed for testing. References in Table 2.4 are associated with pictures or figures (final appearance pictures and/or manufacturing drawings), product description, dimensions, number of samples manufactured, test description and standards. In this case, Figure 2.20 to Figure 2.22 (shown in section 2.5.2) are related to the final appearance of the samples and Figure 2.23 and Figure 2.24 (shown in section 2.5.3) to manufacturing drawings.

Table 2.4 Samples for indoor validation testing of product X6

Reference	Standard	Test description	Number of samples	Dimensions (mm)	Product description	Related figures
X6-1	IEC 61215	Damp heat test, thermal cycling	6	1700 x 1000	Back contact cells Standard ribbon	Figure 2.20 Figure 2.23
X6-2	ISO 12543 Part 4	Radiation, humididy and high temperature tests	9	360 x 360	Back contact cells Standard ribbon	Figure 2.21 Figure 2.24
X6-3	EN 410	Light properties	5	5´	Samples of back contact solar cells	Figure 2.22
	EN 673	Thermal properties				

2.5.2 Results

Figure 2.20 to Figure 2.22 show the final appearance pictures of the modules described in Table 2.4.

Figure 2.20 Final appearance of sample X6-1 (front and back views)

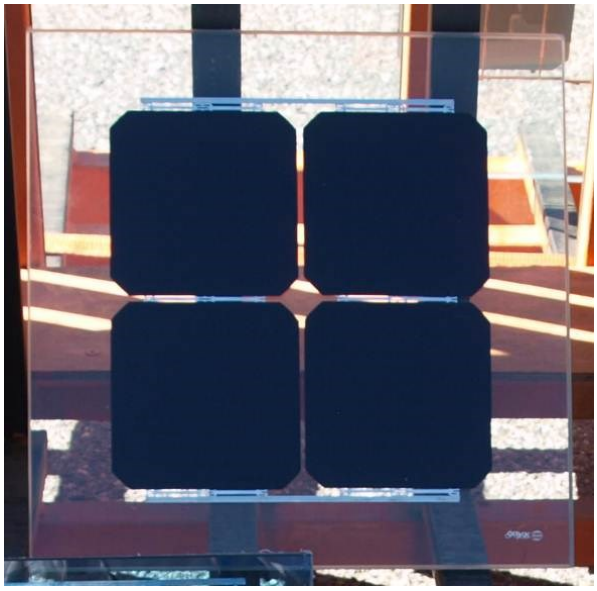

Figure 2.21 Final appearance of sample X6-2 (front view)

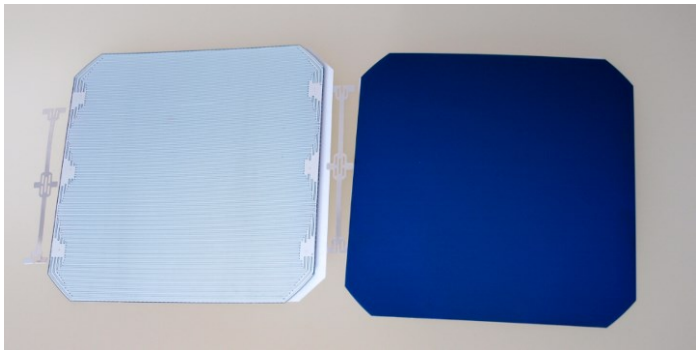

Figure 2.22 Final appearance of sample X6-3 (front and back views)

2.5.3 Manufacturing drawings

Figure 2.23 and Figure 2.24 show manufacturing drawings of final modules described in Table 2.4.

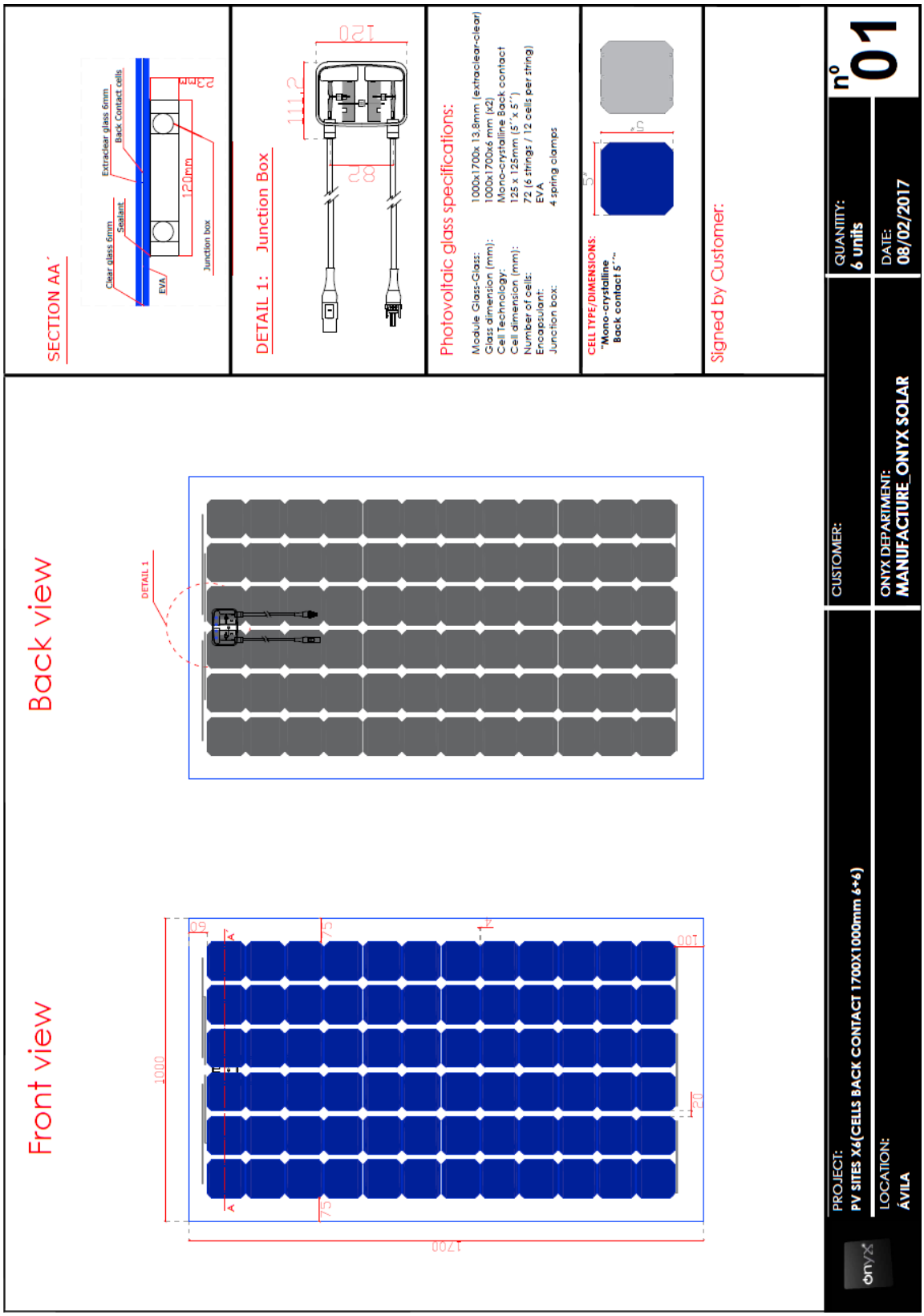

Figure 2.23 Manufacturing drawing of sample X6-1

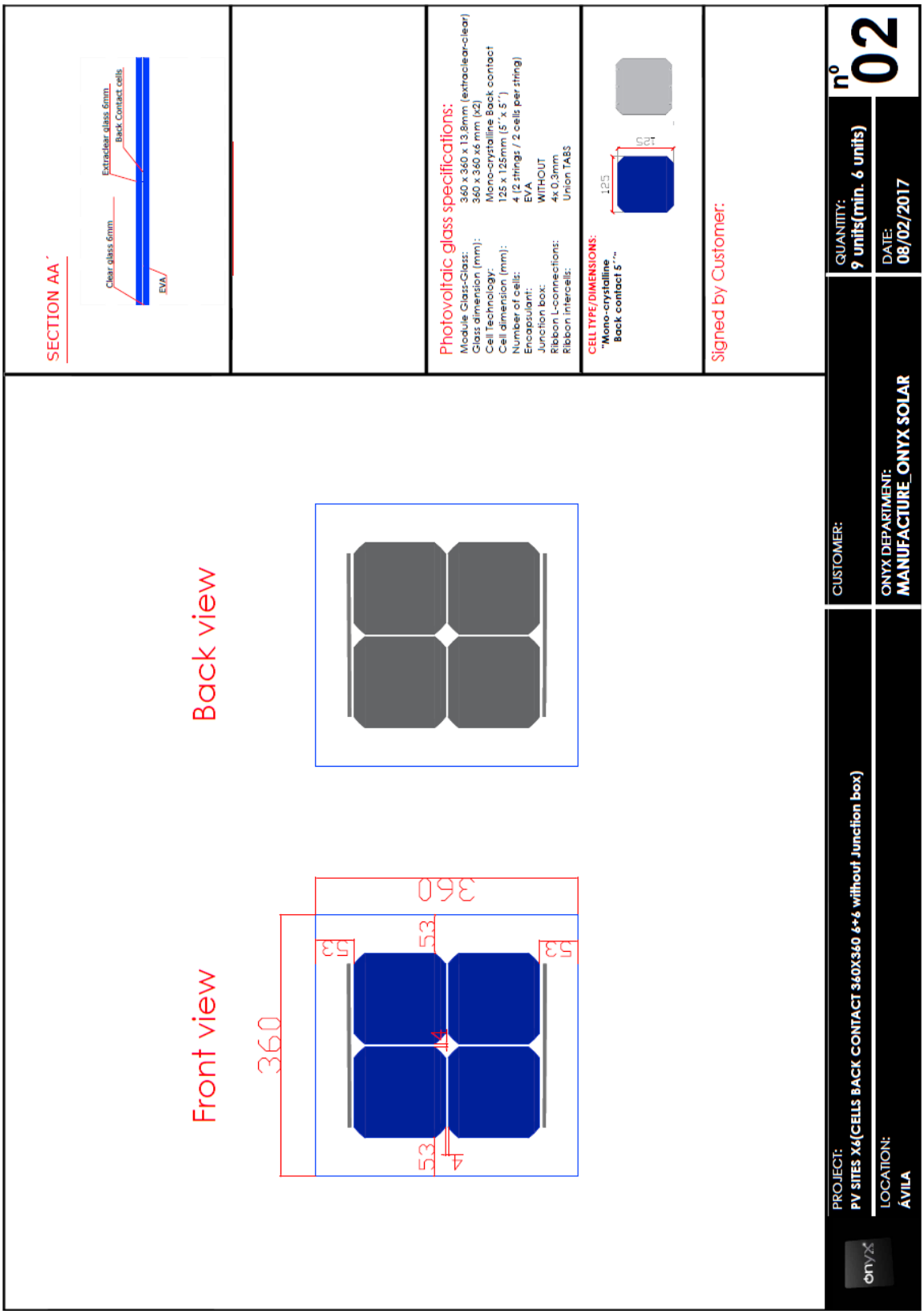

Figure 2.24 Manufacturing drawing of sample X6-2

2.6 Framing systems for c-Si large area glass

All the information related to this product can be consulted in D3.5: *Prototypes of framing systems compatible with XL-formats and large thickness BIPV units*

2.6.1 Samples for indoor validation tests

The following table describes the sample needs and its characteristics according to the test requirements defined by the involved partners. The table contains different References in order to identify each product developed for testing. References in Table 2.7 are associated with pictures or figures (materials for prototypes and manufacturing drawings), product description, dimensions, number of samples manufactured, test description and standards. In this case, Figure 2.25 and Figure 2.26 (shown in section 2.6.2) are related to the material needed for the prototypes and Figure 2.27 and Figure 2.25 (shown in section 2.6.3) drawings and schemes of the samples configuration.

Table 2.5 Samples for indoor validation testing of product X8

Reference	Standard	Test description	Number of samples	Dimensions (mm)	Product description	Related figures
X8-1	CWCT note 67. Class 2	Impact due to maintenance activities	3	Indicated in Figure 2.24 PV glass thickness: 5+1,8+5 mm Structural profile height: 150mm	Modules + structure: skylight configuration	Figure 2.25 Figure 2.27
X8-2	ETAG 034	Wind resistance Impact	1	Indicated in Figure 2.25	4 modules assembled in 2x2 ventilated façade configuration	Figure 2.26 Figure 2.28

2.6.2 Materials for prototypes

Onyx has manufactured the necessary PV glasses to test within ventilated façade and skylight/curtain wall framing systems. Structural systems and components are ready and the prototypes will be mounted and tested by Tecnalia (task 3.7). Figure 2.25 and Figure 2.26 show the necessary materials for prototypes described in Table 2.5.

Figure 2.25 Materials for prototype X8-1

Figure 2.26 Materials for prototype X8-2 (left and center) and support frame containing the PV glass for X8.1 and x8.2

2.6.3 Assembly schemes

Figure 2.27 and Figure 2.27 show drawings and schemes of the configuration (structure+modules) to be used for the tests described in Table 2.5.

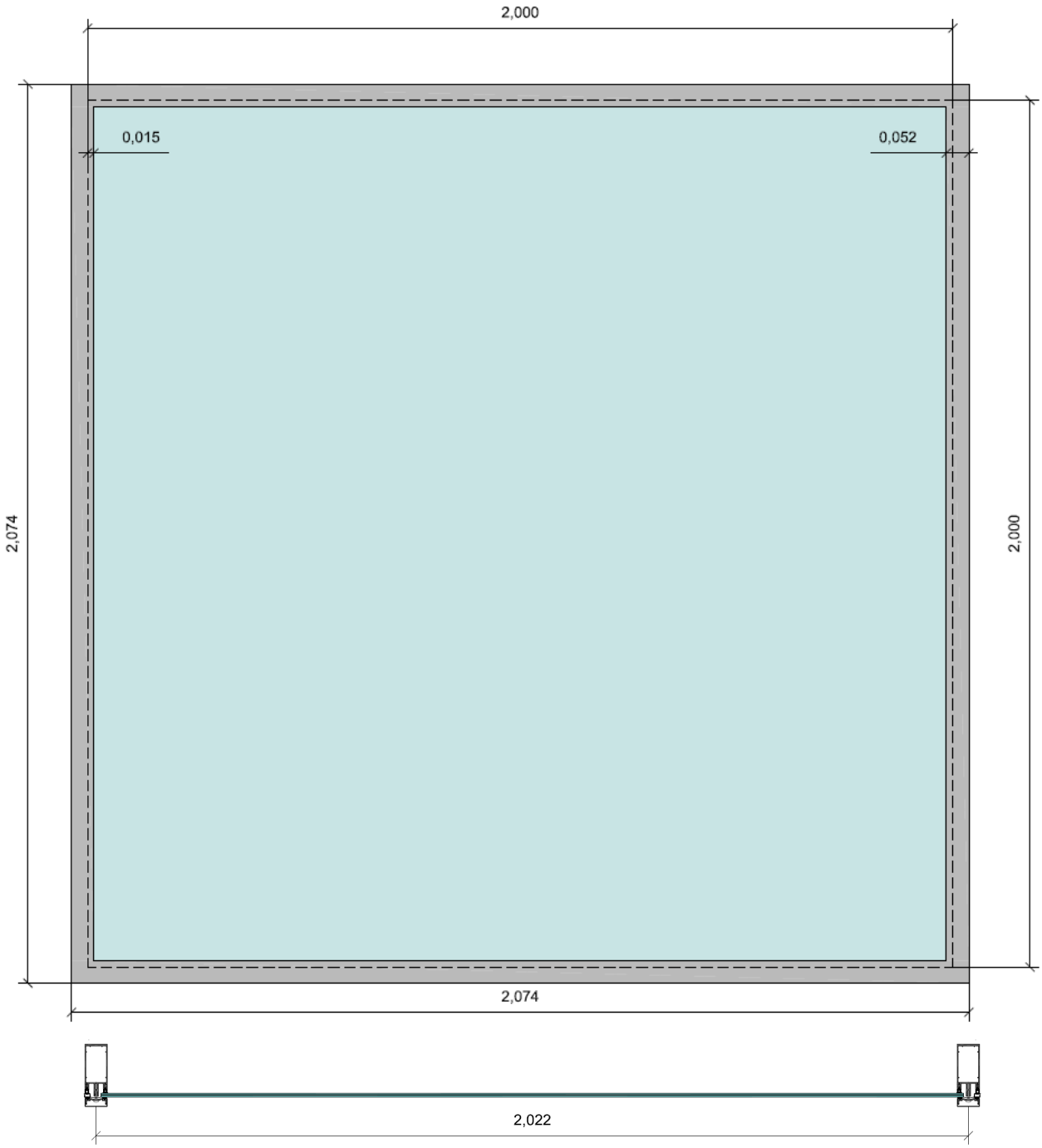

Figure 2.27 Assembly scheme of prototype X8-1

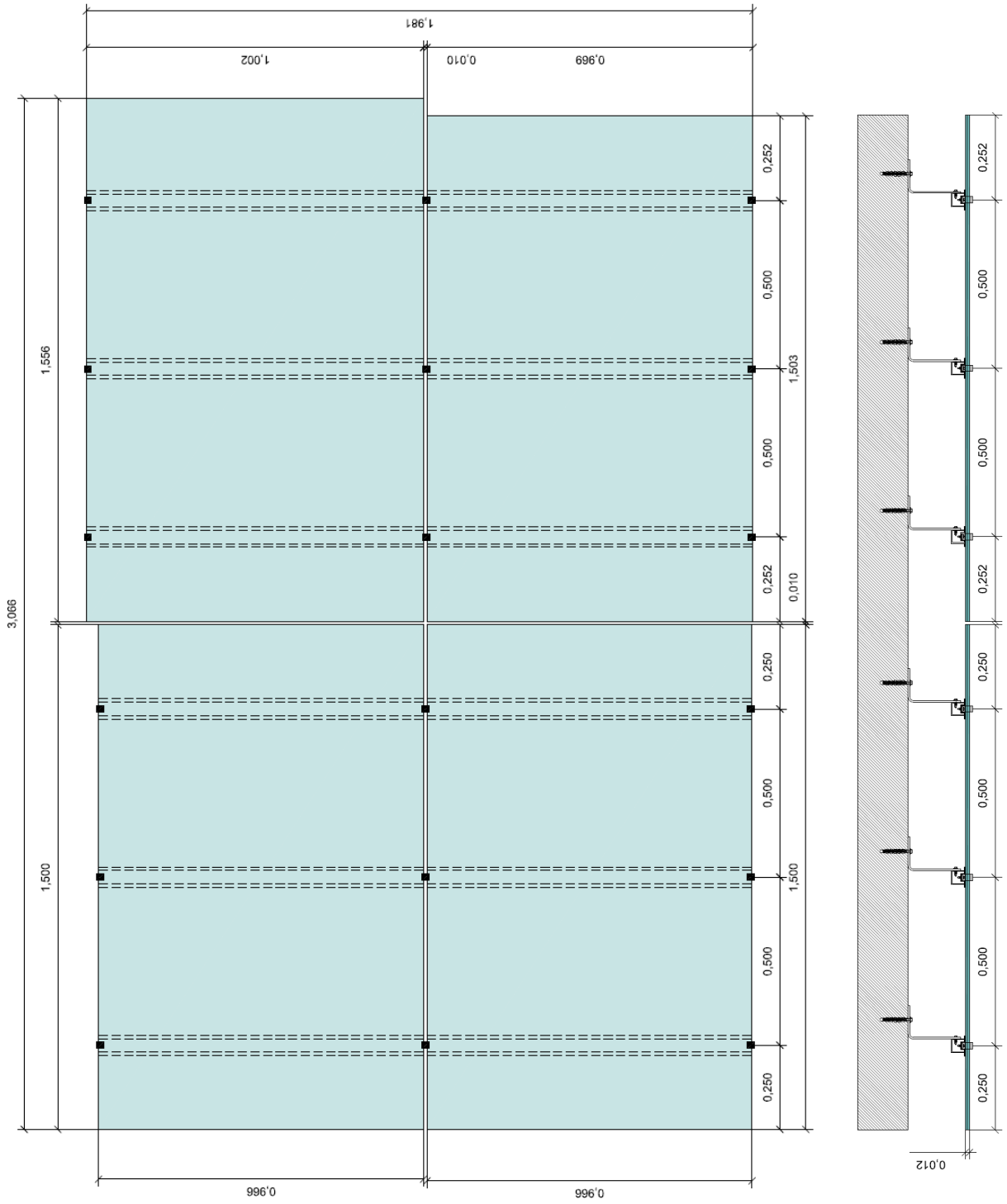

Figure 2.28 Assembly scheme of prototype X8-2 (horizontally oriented)

2.7 Glazed modules treated for improved passive properties

All the information related to these products can be consulted in D3.5: *Glazing treatments for improved passive properties, report on materials and processes*

2.7.1 Samples for indoor validation tests

The following table describes the sample needs and its characteristics according to the test requirements defined by the involved partners. The table contains different References in order to identify each product developed for testing. References in Table 2.9 are associated with pictures or figures (final appearance pictures and/or manufacturing drawings), [1] product description, dimensions, number of samples manufactured, test description and standards. In this case, Figure 2.29 to Figure 2.36 (shown in section 2.7.2) are related to the final appearance of the samples and Figure 2.37 to Figure 2.40 (shown in section 2.7.3) to manufacturing drawings.

Table 2.6 Samples for indoor validation testing of product X12

Reference	Standard	Test description	Nº of samples	Dimensions (mm)	Product description	Related figures
X12-1 (grey) X12-2 (green) X12-3 (blue) X12-4 (yellow)	IEC 61215	Damp heat test, thermal cycling	4	1700 x 1000	Color/reflective treatments in front glass	Figure 2.29 Figure 2.30 Figure 2.31 Figure 2.32 Figure 2.37
X12-5 (clear blue) X12-6 (dark blue)	IEC 61215	Damp heat test, thermal cycling	6 (3+3)	1700 x 1000	Blue mass coloured glass as front glass. Blue mass coloured glass as rear glass.	Figure 2.33 Figure 2.34 Figure 2.38
X12-7	IEC 61215	Damp heat test, thermal cycling	2	1700 x 1000	Low-E in #4	Figure 2.35 Figure 2.39
X12-8 (clear blue) X12-9 (dark blue)	ISO 12543 Part 4	Radiation, humidity and high temperature tests	6	360 x 360	Mass coloured glass as front glass. Mass coloured glass as rear glass.	Figure 2.36 Figure 2.40
X12-10	ISO 12543 Part 4	Radiation, humidity and high temperature tests	6	360 x 360	Colour/reflective treatments in front glass	To be provided
X12-11	EN410	Light properties	1	360 x 360	Float glass with treatment	To be provided

2.7.2 Results

Figure 2.29 to Figure 2.36 show the final appearance of the modules described in Table 2.6:

Figure 2.29 Final appearance of sample X12-1 (front and back views)

Figure 2.30 Final appearance of sample X12-2 (front and back views)

Figure 2.31 Final appearance of sample X12-3 (front and back views)

Figure 2.32 Final appearance of sample X12-4 (front and back views)

Figure 2.33 Final appearance of sample X12-5 (front and back views)

Figure 2.34 Final appearance of sample X12-6 (front and back views)

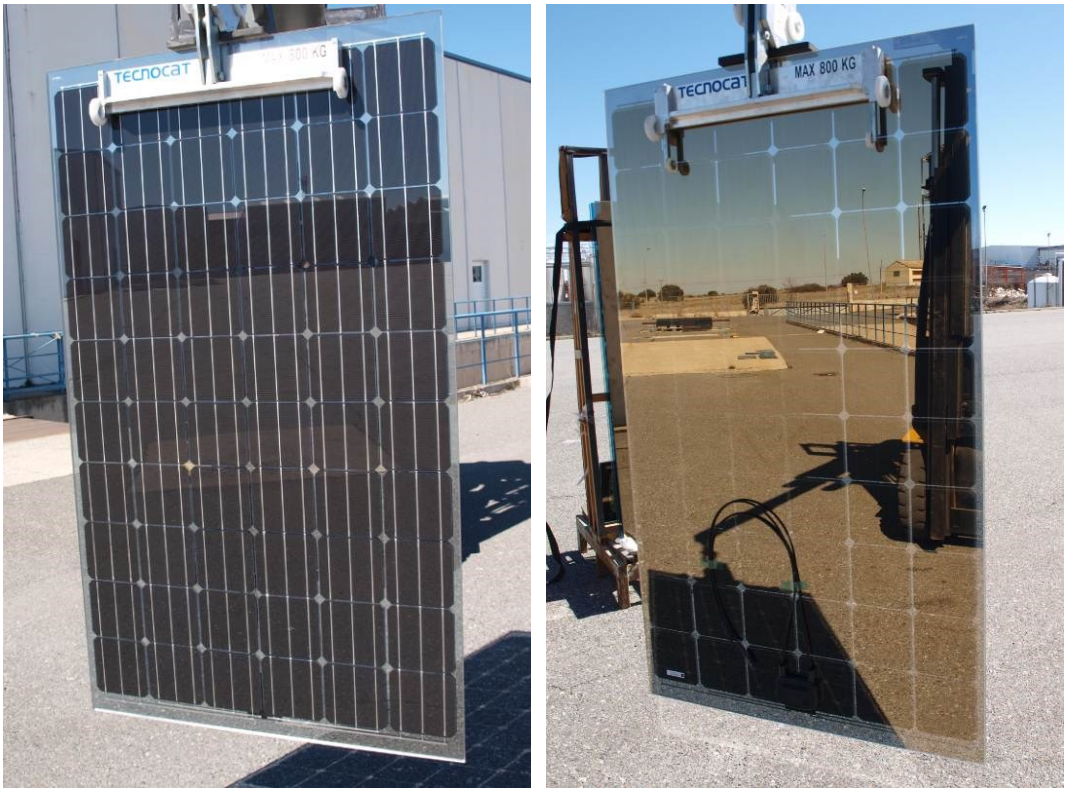

Figure 2.35 Final appearance of sample X12-7 (front and back views)

Figure 2.36 Final appearance of samples X12-8 and X12-9 (front views)

2.7.3 Manufacturing drawings

Figure 2.37 to Figure 2.40 show manufacturing drawings of final modules described in Table 2.6:

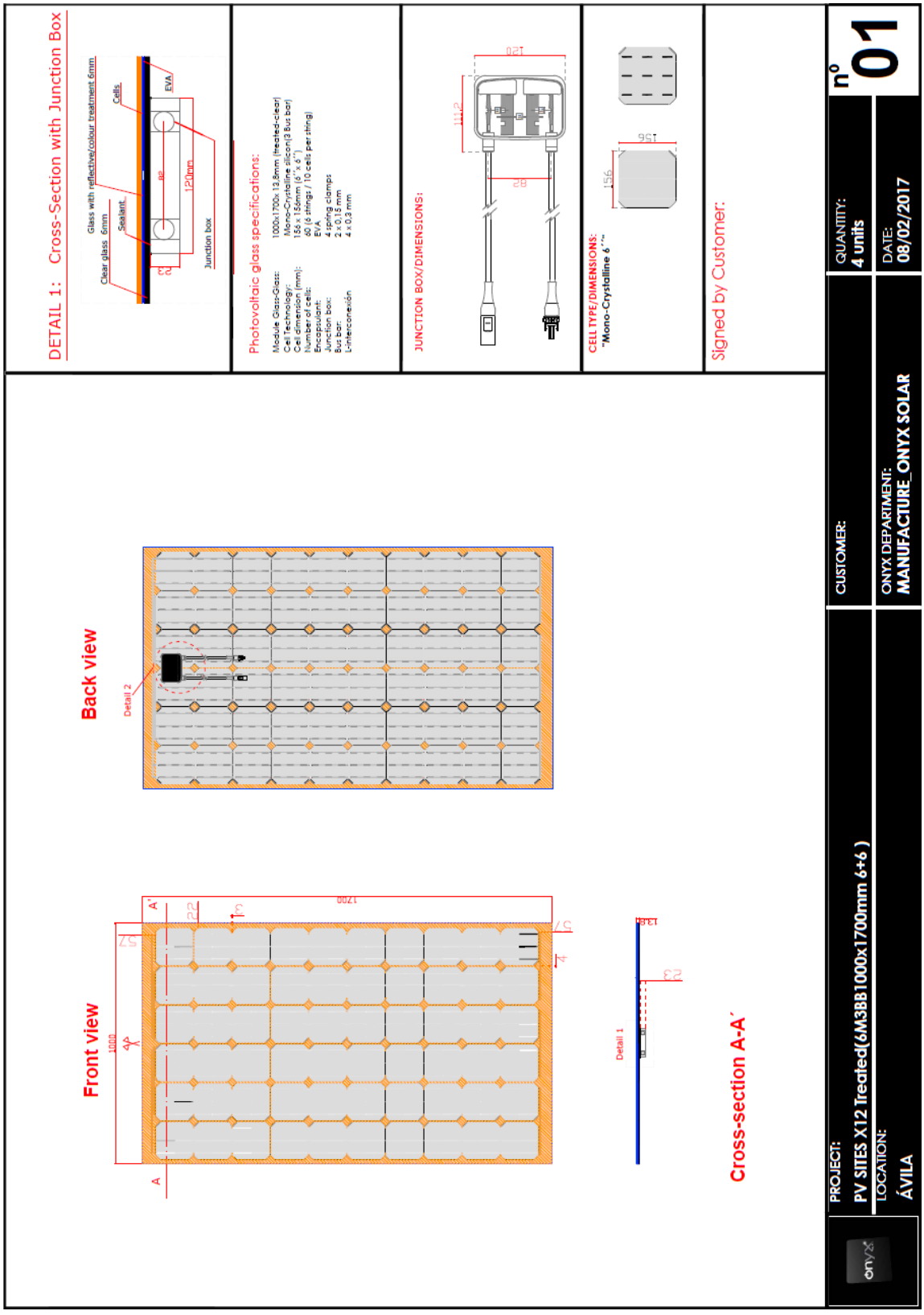

Figure 2.37 Manufacturing drawing of samples X12-1, X12-2, X12-3 and X12-4

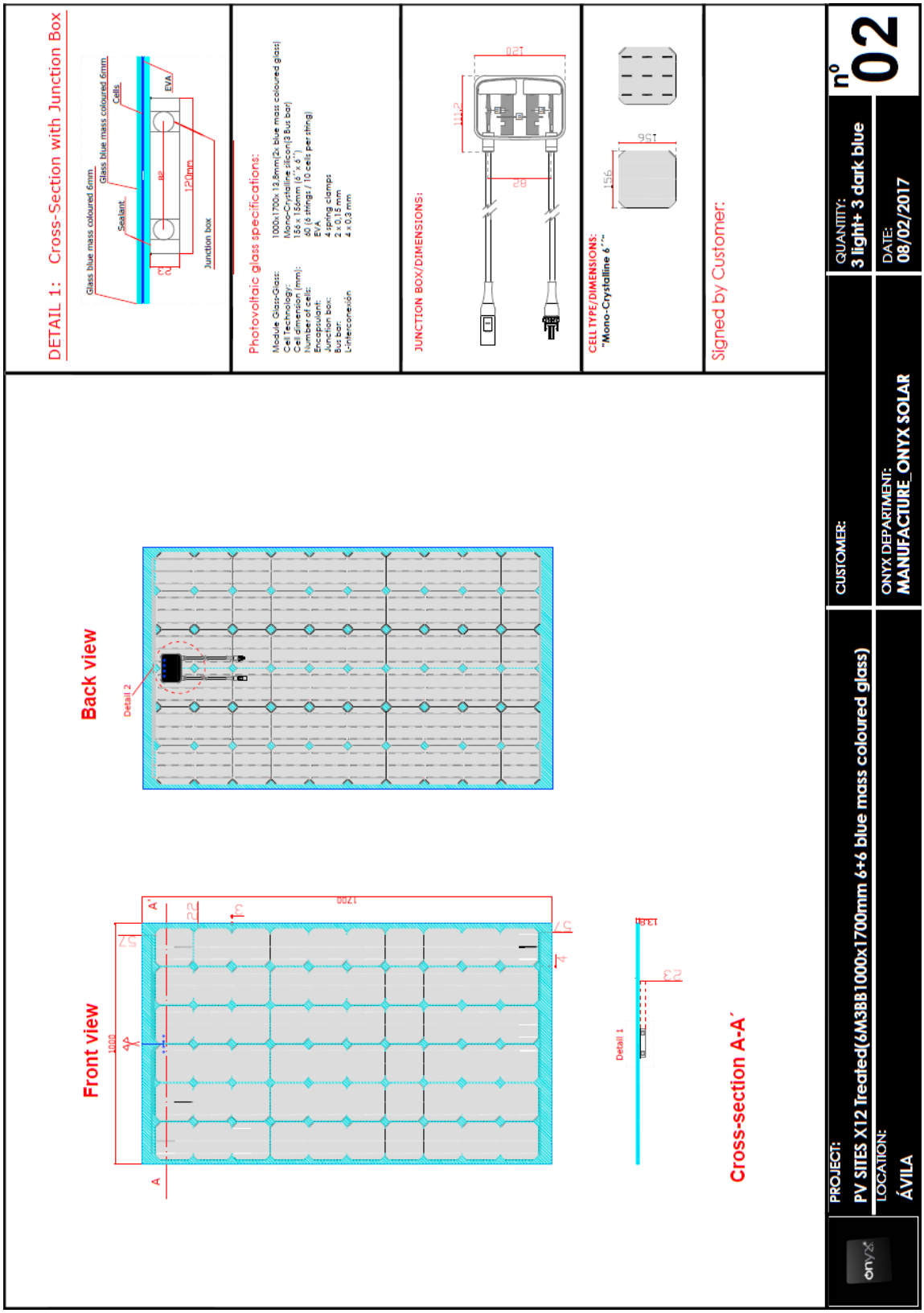

Figure 2.38 Manufacturing drawing of samples X12-5 and X12-6

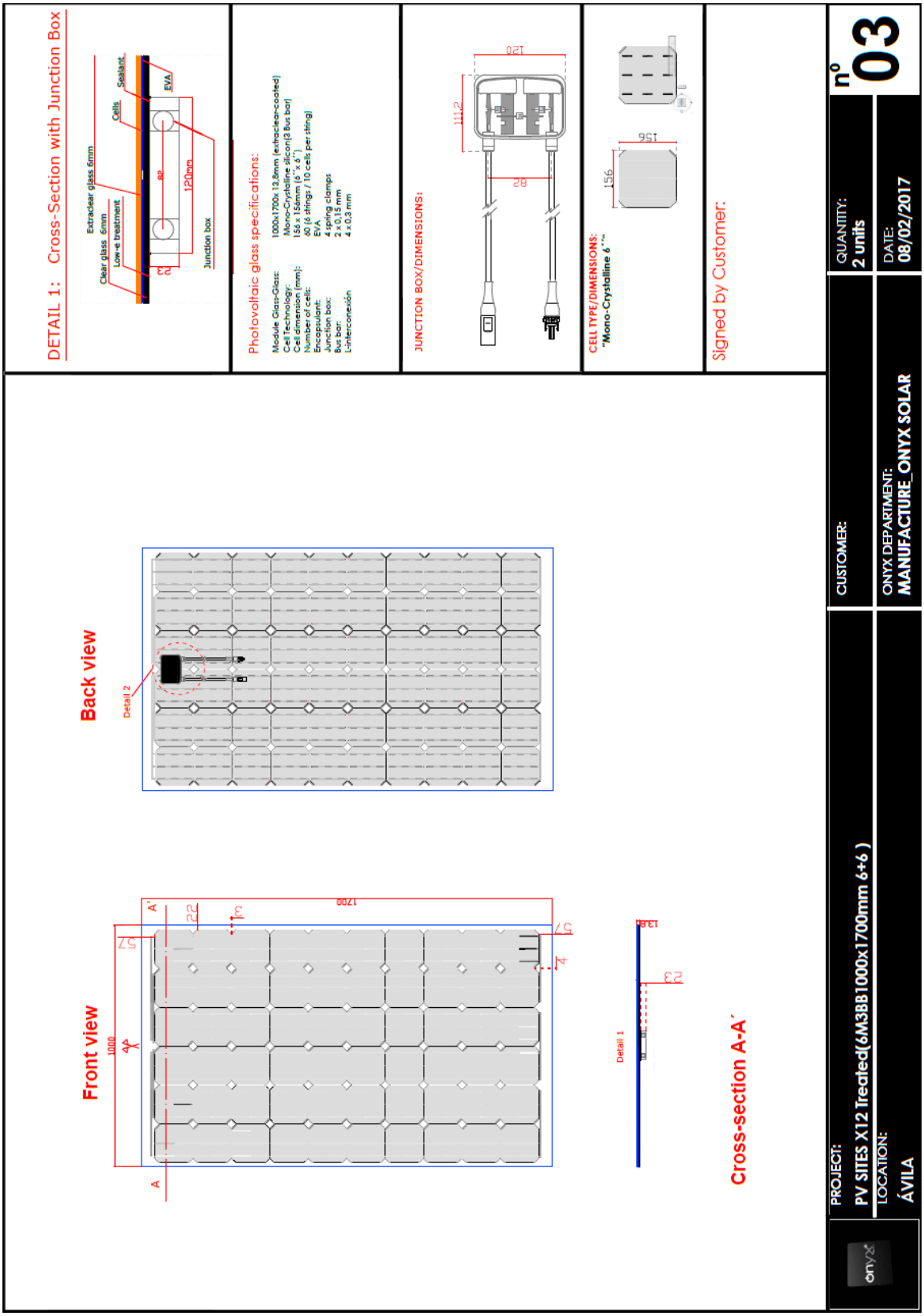

Figure 2.39 Manufacturing drawing of sample X12-7

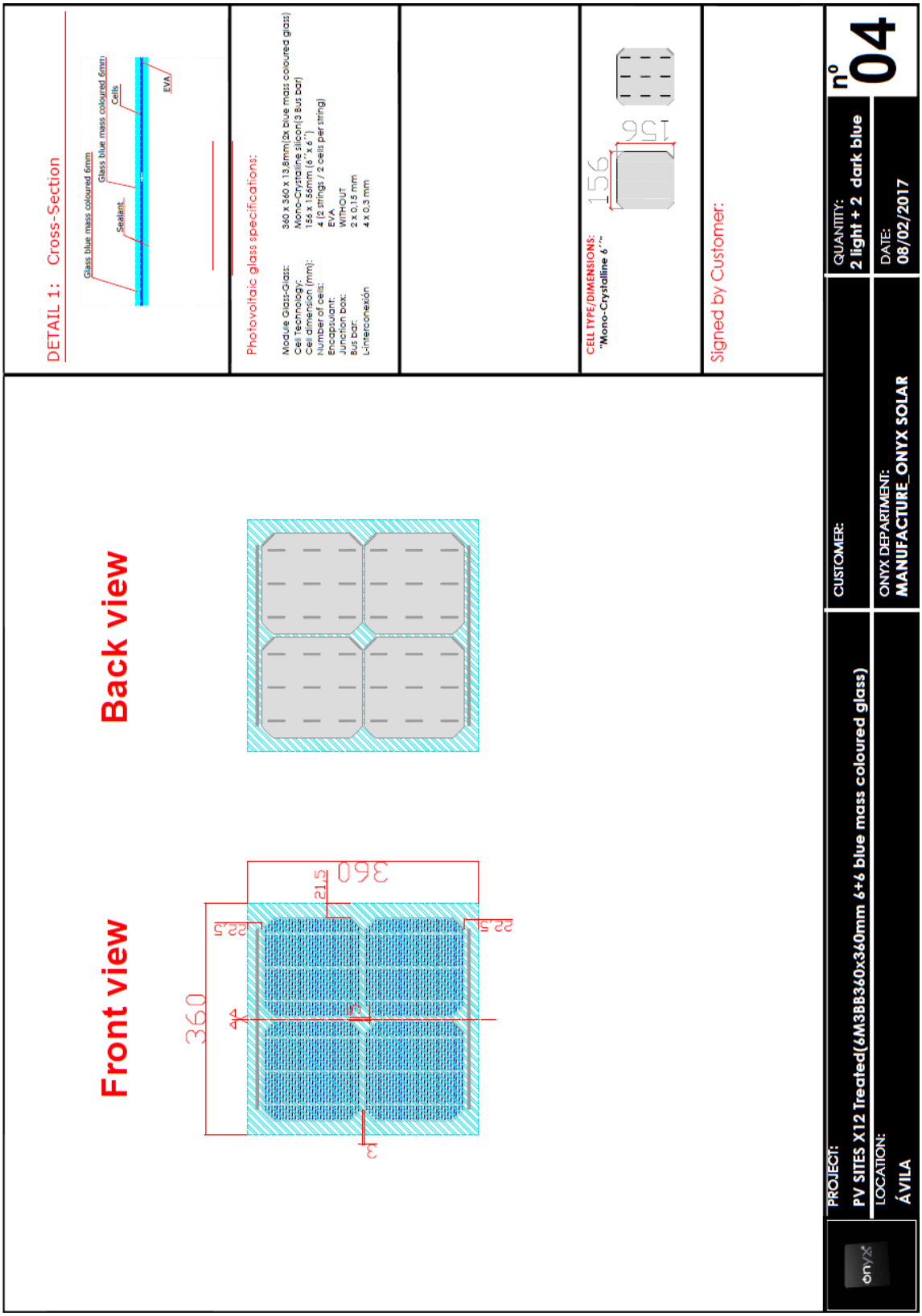

Figure 2.40 Manufacturing drawing of samples X12-8 and X12-9

3 CONCLUSIONS

This deliverable shows the final results of the samples developed for Indoor Validation Testing. It represents the final step regarding the development of operational prototypes designed to comply with applicable standards that will be tested within Task 3.7. In this sense, the results showed in this document are preceded by the work carried out within WP1, WP2 and the first deliverables of WP3.

Therefore, thanks to the work carried out in WP3 and previous WPs the overall objective of this deliverable has been consequently achieved and a multiple answer to the market needs defined in T1.1 has been provided by successfully developing a set of c-Si technology-based products specially designed to cope with these needs which have been deeply studied and analyzed within Tasks from T3.1 to T3.5. Most adequate tests sequences of these products have been defined by the involved partners to comply with applicable standards. Previous analyses carried out in D1.3 have been considered as a basis to define the final sequences. Final results of the indoor testing of these prototypes will be shown in D3.9 and will serve as basis for future outdoor testing and demonstrative buildings using these technologies.

The manufactured samples of the low concentration system (under the responsibility of Tecnalia) are delayed due to the fact that the design phase has been longer than expected. A larger set of configurations than initially expected have been explored in order to optimize the system performance. Therefore, the manufacturing of the Fresnel lenses has been launched in M15. A 3 month delay is expected for the physical samples to be manufactured. Overall in the project, this delay can be recovered, as the laboratory testing task will be active until M24, which gives 6 months for the testing of the product. Regarding the outdoor exposure, samples are foreseen for M21 and therefore no delays are expected. These products do not form part of demonstration activities in real buildings.

4 REFERENCES

As this document is the result of the work undertaken in previous deliverables of WP3, especially D3.1 to D3.6, the references can be considered the same as those used in the mentioned deliverables.