



## D3.4 – Flexible in-line pre-lamination machine compatible with flexible tabber-stringer

T3.6 Flexible in-line prelamination machine integrable in a flexible industrial tabber-stringer



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## Document control sheet

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## SEAMLESS-PV PROJECT

### A novel manufacturing process for integrated photovoltaics

Integrated photovoltaics (IPVs) have demonstrated their success and impact in their use as building-integrated photovoltaics. They are also considered promising in several other sectors. Their adaptation to other industries or devices could offer surprising benefits. Unfortunately, the very need for adaptable IPV solutions hinders their expansion as their current manufacturing processes cannot create IPV solutions customised to each sector. The EU-funded SEAMLESS-PV project aims to tackle this by developing revolutionary tools for photovoltaic manufacturing as well as new IPV products that offer improved efficiency, adaptability and integrability while at the same time showcasing their cost-effectiveness in comparison to competitors.

The title of SEAMLESS-PV project is *“Development of advanced manufacturing equipment and processes aimed at the seamless integration of multifunctional PV solutions, enabling the deployment of IPV sectors”*. SEAMLESS-PV is a Horizon Europe Innovation Action started in January 2023 that will continue through December 2026.

More information can be found at:

<https://www.seamlesspv.eu/>

<https://cordis.europa.eu/project/id/101096126>

## EXECUTIVE SUMMARY

This report shows the unique prelamination tool developed in the SEAMLESS-PV project to allow the study of efficient prelamination to explore increased flexibility in PV manufacturing. It is reviewed in a concise way the definition, design and assembly of the tool. Initial prelaminates are shown after delivery of the tool in R&D lab and early process development.

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## Disclaimer

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## Project partners

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# 1 INTRODUCTION

## 1.1 Description of the deliverable content and purpose

This report discloses the following demonstrator from the project: prelamination tool developed for flexible production of integrated PV components. This demonstrator allows the manufacturing of pre-encapsulated strings as a first operation in a two-step process for PV module fabrication. A second step is then needed to finalise integrated products, on a wide panel of substrate and shapes.

The goal is to present a prototype of an integrated equipment dedicated to the fabrication of PV prelaminates or pre-encapsulated PV cells string, with ECA-stringing and prelamination steps. These intermediate components are suitable for further integration for BIPV or VIPV applications. This demonstration is supported by specific Tasks T3.6.

## 1.2 Reference material

Not Applicable

## 1.3 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 SEAMLESS 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 3.1         | Fine tuning of specifications and design of the flexible equipment |

## 1.4 List of abbreviations

Table 1.2 List of abbreviations

| Acronyms | Meaning                 |
|----------|-------------------------|
| HMI      | Human Machine Interface |
| IPV      | Integrated PhotoVoltaic |

## 2 Preparation of the tool in MASS workshop

### 2.1 Introduction: principle and tool design

To our knowledge, this tool was a first-of-a-kind in the domain of PV manufacturing. Roll-to-roll tools, already used in some area of PV market as organic PV for example, inspired our design. Roll-to-roll is a usual technique in polymer industry to process foils and sheets.

Several innovative concepts were brought to increase the amount of heating energy, as we wished to process materials with more mass than thin organic layers. Various heating sources were implemented to heat material sheets and stacks. Three different heat sources, either radiative or conductive, are set-up with independent control through dedicated HMI commands.

The tool laminates crystalline silicon solar cells with various encapsulant sheets. The solar cells are electrically connected in a first process. The prelaminator operates on individual strings of solar cells. To keep a stable stack during the process, the tool implements a moving roll while the stack remains still during the process. The length of the strings depends on the final design of the integrated PV module. The tool can process strings longer than 1 m.

The actual tool is still in a prototype phase and loading and unloading operations are manual. The design and the HMI software is compatible with a tabber-stringer (from MASS). Additional automatic handling tools have been designed but not implemented at this point. The automation of the process itself provides a better control. This is more important at this point than raising the productivity.

### 2.2 Assembly of the tool

The different parts of the tool were specified and ordered, from either MASS workshop or external supplier. The mechanical frame is made of rails and the various active parts were installed and connected to air or electrical supplies. All electrical supplies are gathered in secured cabinets at the bottom of the machine.

Security is one of the most important aspects of the tool's operation, since this is a manual tool. Several functions have been added to the specification to guaranty a safe operation. The prelaminator remains a prototype, but it can be used by skilled personnel without specific expertise. In this sense, the tool complies with a CE marking requirements, under self-assessment established in Spain by MASS authorized person<sup>1</sup>.

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<sup>1</sup> The CE marking, known as the European Conformity marking, is a declaration by manufacturers, importers or distributors that the product complies with the technical and legal requirements set out in European directives. Products considered as industrial machinery are regulated by the CE marking directive 2006/42/EC, which ensures an adequate level of health and safety for consumers and workers. The essential requirements cover physical safety, the health effects of the product, the design of safety principles taking into account the intended use and possible misuse, and information for end-users, including markings, warnings, operating and maintenance instructions.



**Figure 1: Assembly of the tool in MASS workshop.**

The HMI runs on an internal PC and the functions of the tool are activated through a unique touch-screen. Several modes are available, and recipes can be created to allow the automatic move of the roll and control the various heating systems. The operator can modify the speed and the pressure of the roller by changing the settings of the recipes.

### **3 Installation of the tool in CEA lab**

#### **3.1 Tool delivery in R&D lab**

CEA and MASS carried on tests at MASS's workshop to assess conformity of the tool against the specification established together. Preliminary trials show that we have enough energy and control to manufacture initial prelaminates. We discussed some late improvements for a better security and ease of use that have been implemented on the finalised version of the prelaminator. After finalisation, packaging and shipping of the machine were organised, from Spain to France.

During the tool assembly in MASS, CEA prepared all need facilities for the operations: electrical supply and centralised compressed air. In case of an excess of heat coming from the tool, a connection to a specific air exhaust is possible.

After reception and check, the tool was moved to its position in CEA's laboratory platform. The tool was connected to the needed facilities to be able to start processing in CEA.



Figure 2: Final verification after the installation in CEA.

### 3.2 Tool operations for process development

After teaching the personnel about the machine operation, CEA researchers were able to build some design of experiments to start definition and optimisation of the prelamination process. Initial tests help to define the process window for the three heating sources. The sensitivity of the results versus various temperature set points were evaluated. The Initial criterium was basically the visual aspect of the produced samples, that were manufactured using single PV cells or couple of half-cells. CEA and MASS are regularly talking about performances and possible enhancement of the tool.

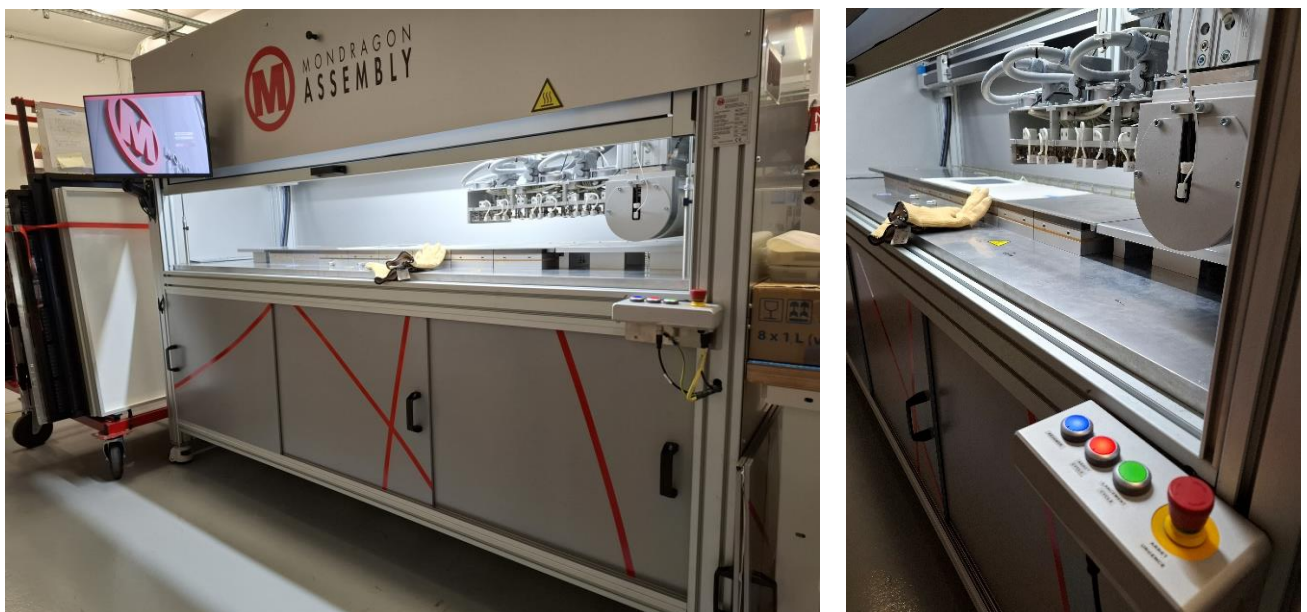


Figure 3: Tool operation and prelamination process development.

Actually, four researchers regularly operate the tool without major issues. Three of them acquired enough knowledge to prevent failures and optimise automatic recipes.

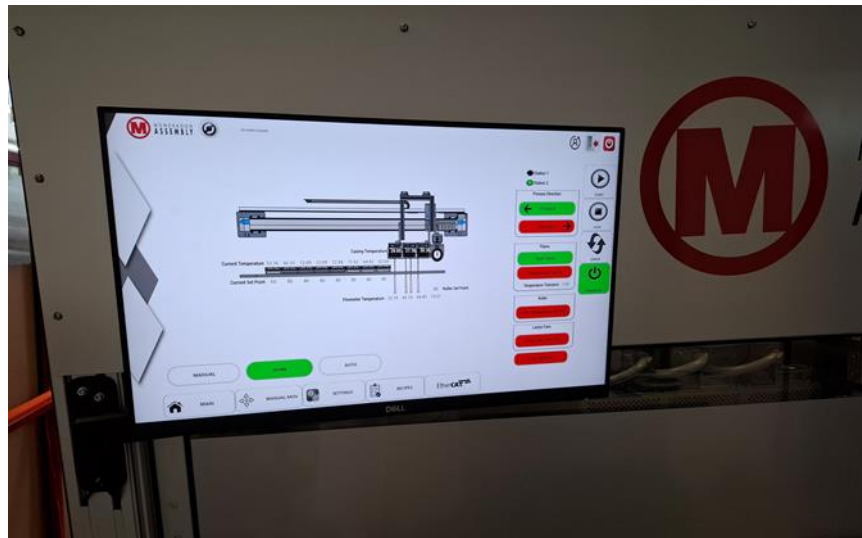


Figure 4: The graphical interface.

### 3.3 Outlook

CEA has now the capability to operate prelamination tests on a fully dedicated tool, first-of-a-kind in the area of PV flexible manufacturing. Several tens of samples have been produced. The process of record has been defined for the first materials. Other materials are now under investigation, some failure modes have been identified and a full characterisation protocol is now in use to get a better assessment of prelaminates and the ability to move to the next step of final lamination or moulding into a finalised IPV product.

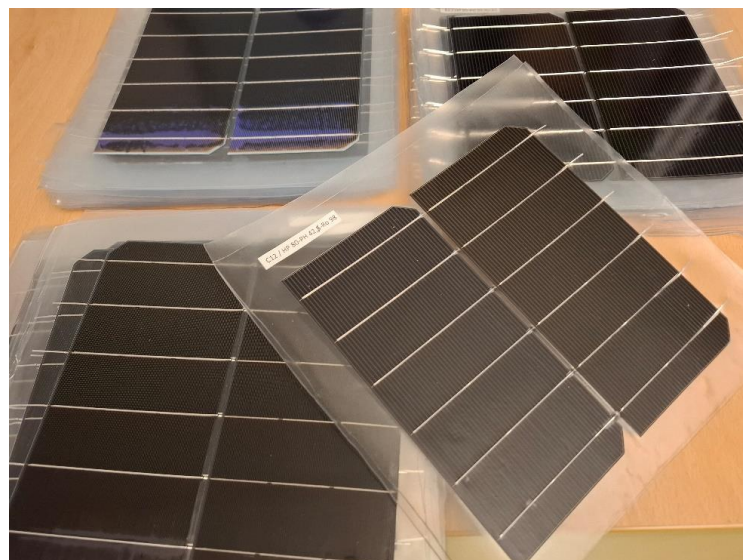


Figure 5: Examples of prelaminates showing the efficiency of actual prelamination process.



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