

## UNIQUE

### Carbon Based Perovskite Solar Cells with UNI-Directional Electron Bulk Transport: in the QUES of a Short Time to Market

*Project duration: from 09.2019 to 02.2023*

*Report submitted: 03.2023*

#### **Publishable Summary**

Photovoltaic research and commercial products that focus on sustainability and foster the future of local PV production in Europe are currently an imperative commitment. A profound, true, and fruitful collaboration among the main European centres developing carbon-based perovskite solar cells (C-PSC) is paramount for the achievement of such a vision. UNIQUE embraces this commitment with the industrial partners (SOLARONIX and DYENAMO) paving the way to the wider industrial scenery and offers the chance to develop a European, efficient and sustainable PV technology which can be produced locally. UNIQUE aims to bring back the EU strategic PV manufacturing know-how and value chain to Europe.

Unique European know-how and industrial involvement is combined in this project to realize high-efficient large area perovskite devices with long lifetimes for a truly commercially viable perovskite PV technology. Sustainable, industrial-relevant processes and low-cost materials are implemented to aim at a competitive new-generation of PV. Short energy- and CO<sub>2</sub>-payback times and a low CO<sub>2</sub> emission are key factors accounted for in this project.

UNIQUE combines the effort of partners from TRL 3 - EPFL (deposition of highest efficient perovskites) and UAM (functionalization of carbon electrodes), to TRL 4 - CEA (development of novel gas barriers), LEPMI (lifetime extrapolations) and ISE (development of standardized uni-directional devices) and to TRL 5 - UNITOV (high precision laser patterned interconnected cells), SWANSEA (outdoor testing and adjustment to industrial processing), DYENAMO (batch synthesis of materials) and SOLARONIX (prototyping of C-PSC modules and printable uni-directional materials).

To reach highest stability and efficiency of the developed perovskite PV devices, printable solution-processed inorganic porous metal oxides with carbon counter electrode, functionalized interfacial passivating layers and high-quality perovskite crystals compose the enhanced cell architecture to achieve a uni-directional charge transport. With this approach, carbon electrode-based perovskite solar cells have been fabricated, reaching a record power conversion efficiency (PCE) of 18.5%, which is one of the highest for metal electrode free devices. Furthermore, in the course of the project, process steps and equipment for the fabrication of submodules have been built up, resulting in carbon-based perovskite PV modules with size 20x25 cm<sup>2</sup>. All developed process steps are scalable and allow for subsequent increase of the module area. Fabricated modules could be encapsulated and monitored outdoors under operating conditions, thus providing a detailed insight into their stability in the current development stage, demonstrating the market exploitability by the fabrication of an outdoor installed C-PSC demonstrator.

Based on the project outcomes, industrial partners Dyenamo and Solaronix continue their activities with respect to material development for Perovskite PV and perovskite module fabrication, respectively. Furthermore, a number of partners both from the academic and industrial sector continue their successful collaboration in the framework of an ongoing Horizon Europe project (DIAMOND, <https://diamond-horizon.eu>), coordinated by Fraunhofer.

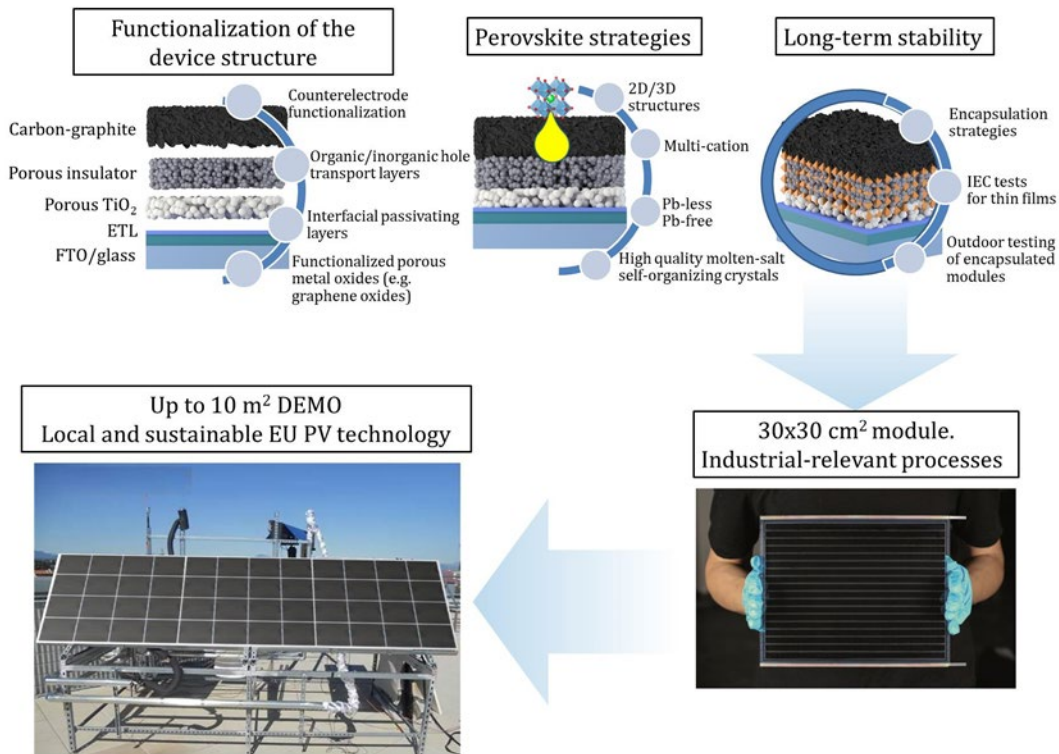


Figure 1: Technical approach within project UNIQUE, addressing key challenges for optimized performance, stability and scalability of the perovskite module technology

## Project consortium

Coordinator and all contact details:

Full name of organisation	Fraunhofer Institute for Solar Energy Systems ISE
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Participating countries and financing:

Country	Number of organisations involved	Project costs in EUR	Public funding in EUR
Germany	1	478 332	478 332
France	2	593 874	327 788
Switzerland	2	-	-
Italy	1	169 583	84 792
United Kingdom	1	-	-
Spain	1	228 000	148 000
Sweden	1	260 399	181 648
<b>Total</b>	<b>9</b>	<b>1 730 189</b>	<b>1 220 560</b>

### Funding agencies involved and contracts

Funding Agency	Contract N° and Title
PTJ	03EE1034, Verbundvorhaben: Unique - Kohlenstoffbasierte Perowskit-Solarzellen mit UNI-direktionalem Elektronentransport: mit dem Ziel einer schnellen Markteinführung; Teilvorhaben: Zellentwicklung und Koordination
ANR	PROJET N° ANR-19-SOL2-0004-03 & -04 Convention Attributive D'aide Valant Conditions Particulieres
MUR	Project UNIQUE (SOLARERA18-00011). Funding decree n. 569 of 6/05/2020
MINECO-AEI	PCI2019-111889-2 Celulas Solares De Perovskita Con Electrodo De Carbono Y Un Transporte Unidireccional De Las Cargas: En La Busqueda De Una Comercializacion Rapida
SWEA	Project number 48383-1 Carbon Based Perovskite Solar Cells with Uni-Directional Electron Bulk Transport: in the Quest of a Short Time to Market (Kolbaserade perovskitsolceller för lokal europeisk produktion)