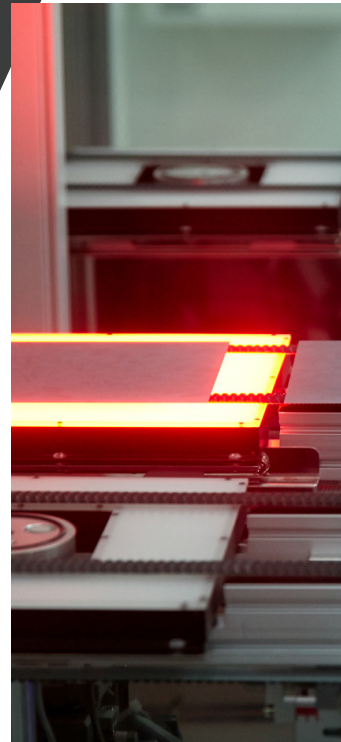
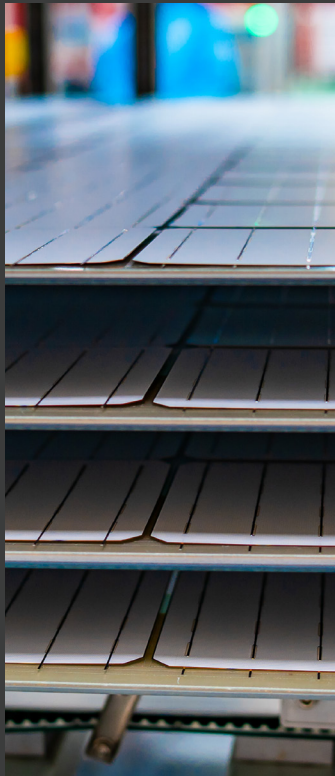


Shaping the future of solar energy with tandem technology



pepperoni-project.eu



Newsletter #4

Welcome to the fourth issue of the newsletter of the PEPPERONI project!

Approaching the project completion in October 2026, PEPPERONI now has entered its final phase in achieving our objectives of advancing perovskite/silicon photovoltaic (PV) technology towards mass-manufacturing of tandem PVs. Over the last months, partners have increasingly focused on advancing materials and processes towards improved reliability and integration strategies essential for pilot-scale manufacturing requirements. This progress was confirmed during the review meeting held in February 2026 at Qcells' premises in Germany.

Commenting on this transition, Fabian Fertig, PEPPERONI Technology Development Coordinator at Qcells, states:

“PEPPERONI is moving from individual performance milestones towards integrated, industrially feasible solutions. The conducted work showcases impressively that tandem technology has what it takes to meet the demanding requirements for manufacturing and reliability.

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Developments

how is the PV landscape evolving?

The global PV manufacturing landscape is continuing on a strong growth track, with significant implications for the equipment value chain.

According to a recent [VDMA study](#), global spending on PV manufacturing equipment is expected to grow from \$16.6 billion in 2025 to \$43.8 billion by 2035, representing a 2.6-fold increase. The manufacturing landscape is undergoing structural transformation. While large-scale module production remains highly concentrated in Asia, the expansion of PV manufacturing capacity worldwide is creating significant demand for advanced production equipment, including cell and module manufacturing, such as thin-film deposition, interconnection and encapsulation technologies. In this context, European companies maintain strong technological capabilities. This creates clear opportunities for suppliers to contribute to the industrialisation of emerging technologies such as perovskite/silicon tandem PV.

what does it mean for PEPPERONI?

As the industry moves towards higher-efficiency architectures and more complex device integration, the demand for flexible, high-throughput and cost-efficient manufacturing solutions will continue to rise. This creates a clear window of opportunity for European technology providers.

For PEPPERONI, this trend is directly relevant. Project partners including [Mondragon Assembly](#) (MASS), [Teknisolar](#), [VON ARDENNE](#) and [FOM Technologies](#) (FOM) are active in key equipment segments required for scaling tandem technologies.

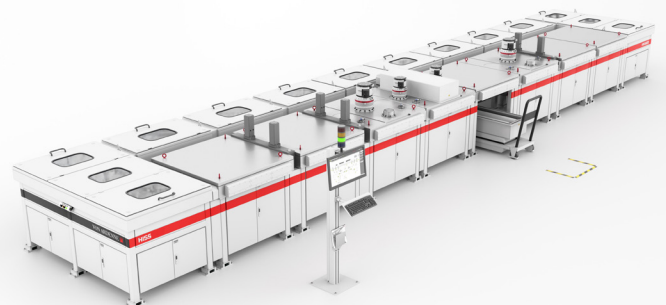
Read more in the "[Partner spotlight](#)" section.



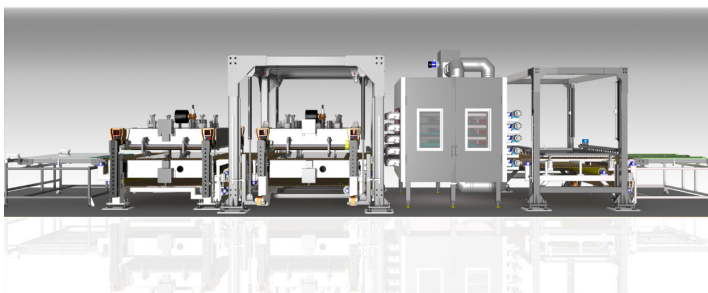
Example of slot-die coating equipment from FOM



Example of Tabber & Stringer (MTS-3000) from Mondragon Assembly



Example of modular coating systems from VON ARDENNE



Example of membrane-less laminator from Teknisolar

how close is industrial deployment?

Recent developments confirm that perovskite/silicon tandem photovoltaics are rapidly moving beyond laboratory research towards **industrial pilot-scale implementation**. The focus across the sector is shifting from record lab efficiencies to large-area devices, module integration and manufacturing readiness.

Leading PV players continue to push performance boundaries. LONGi has reported a certified **tandem cell efficiency of 35% on 1 cm² lab scale**, while Trina Solar has demonstrated a **3.1-m² large 841 W tandem module prototype**, highlighting the progress achieved at module level. These milestones show that the technology is not only advancing in the lab but also being translated into formats relevant for commercial deployment. At the same time, the industry is making clear steps towards scaling production. Tongwei has commissioned a **fully automated tandem pilot line**, while equipment providers such as Maxwell are developing **turnkey manufacturing solutions for tandem technologies**. These developments underline the growing importance of industrial process integration and high-throughput production.

Commercial and field validation activities are also accelerating. Oxford PV has initiated market introduction of tandem modules produced in Europe, while companies such as Swift Solar (US), which recently acquired silicon-heterojunction production assets and IP from former PV company Meyer Burger, and Microquanta are advancing pilot deployments and application-specific solutions, including building-integrated PV.

Taken together, these achievements indicate that **tandem PV is entering a decisive phase**: The key challenge is no longer limited to achieving high efficiencies and large area, but the focus shifted to **ensuring long-term reliability and cost-effective mass-manufacturing**, central points to PEPPERONI's objectives.



[Read more](#)

- Tongwei tandem pilot line: <https://www.perovskite-info.com/tongwei-commissions-fully-automated-perovskite-silicon-tandem-cell-pilot-line>
- Trina Solar tandem module prototype: <https://www.pv-magazine.com/2025/06/18/trina-solar-announces-841-w-perovskite-silicon-tandem-solar-module-prototype/>
- Trina Solar tandem milestones: <https://www.pv-magazine.com/2025/12/24/trina-solar-posts-milestones-for-tandem-efficiency-module-power/>
- Oxford PV updates: <https://www.oxfordpv.com>

how is the project progressing?

Following the successful completion of its second reporting period, the PEPPERONI project reached an important milestone with **its review meeting held in February 2026**. The meeting took place at Qcells' premises in Thalheim, Germany, bringing together project partners and the Project Officer for an in-depth assessment of progress.

During the review, work package leaders presented key achievements, discussed open points and aligned on priorities for the final phase of the project. **The visit also included a tour of the tandem pilot line**, offering a concrete perspective on how project results are being translated into industrially relevant processes. These were further discussed at the recent General Assembly meeting, hosted by FOM Technology in Copenhagen, Denmark. You can find details in [our news section](#).

what do new publications reveal?

[*60 cm² perovskite-silicon tandem solar cells with an efficiency of 28.9% by homogeneous passivation*](#)

DOI: <https://doi.org/10.1038/s41467-025-63673-y>

A homogeneous passivation strategy for wide bandgap perovskite absorbers is introduced, reducing surface and interface recombination losses while improving device uniformity across larger areas.

Key outcome: The study demonstrates 28.9% efficiency on 60 cm² tandem solar cells, confirming that high-performance devices can be achieved beyond small laboratory-scale areas.

Why does it matter? It tackles a central scaling challenge: maintaining high efficiency at industrially relevant cell sizes, supporting the transition towards reproducible and scalable tandem technologies.

[*What Is a Polyolefin? A Critical Overview of Ethylene Copolymers Used as Solar Photovoltaic Module Encapsulants*](#)

DOI: <https://doi.org/10.1002/pip.70038>

This publication provides a review of polyolefin-based encapsulant materials, focusing on ethylene copolymers such as polyolefin elastomers (POE) and thermoplastic polyolefins (TPO). It clarifies terminology often used inconsistently in the PV sector and analyses the properties, processing and performance of these materials in PV modules.

Key outcome: It introduces a clear classification of encapsulant materials and highlights key properties such as low water uptake and reduced ion diffusion, alongside processing and reliability considerations.

Why does it matter? Encapsulation is essential for module durability and long-term performance, particularly for tandem PV. This work supports improved material selection and more reliable module design.

[*Sequentially Evaporated Wide Bandgap Perovskite Absorber for Large-area and Reproducible Fabrication of Solar Cells*](#)

DOI: <https://doi.org/10.1002/solr.202500412>

This publication explores a sequential evaporation process for wide bandgap perovskite absorbers, enabling uniform film formation over large areas. The study focuses on improving reproducibility and scalability of perovskite layers for tandem applications requiring consistent performance across industrial-size substrates.

Key outcome: The approach demonstrates homogeneous, high-quality perovskite films with improved reproducibility, supporting more stable device performance and compatibility with large-scale fabrication.

Why does it matter? It addresses a key bottleneck in tandem PV scale-up: transferring high-efficiency materials from lab-scale to industrial formats, supporting more reliable and manufacturable processes, without the use of (wet) solution-based processes.

[Read more](#)

where do we stand?

The latest technology advances in the PEPPERONI project are reflected in key deliverables, tangible outcomes and reports marking progress across research and development activities. Over the past months, partners have produced several deliverables covering tandem cell fabrication, cell and module loss mechanisms, CTM performance, operational stability, pilot line equipment, LCA and techno-economic analysis, encapsulant film development, perovskite precursor production, recycling and hazardousness assessment, and public acceptance of PV technologies. These results support the next steps towards scalable perovskite-silicon tandem module production.

Follow our progress on [the project website](#).

Mondragon Assembly (MASS) is a European leader in PV manufacturing equipment, specialising in automated turnkey production lines and high-precision machinery for solar module production. The company provides integrated solutions covering the full manufacturing chain, from cell interconnection to module assembly and supports customers with process design, optimisation and industrial scale-up. In PEPPERONI, MASS has developed and installed the upgrades at the cell interconnection equipment for the pilot line at Qcells.



Susana Soto
R&D Project Manager



Jean Philippe Aguerre
Head of R&D dept.



Gorka García
Engineering dept.



Iñaki Zabaleta
Electrical responsible of the project

what's new?

Within the PEPPERONI project, MASS is driving the transition from laboratory-scale tandem PV concepts to industrially viable manufacturing solutions, positioning itself as a key enabler of next-generation photovoltaic production in Europe. The company's contribution focuses on the development of advanced interconnection technologies, such as low-temperature interconnection tabber & stringer systems, specifically adapted to the constraints of perovskite/silicon tandem cells.

Q: How is your equipment being adapted within PEPPERONI to meet the requirements of tandem PV?

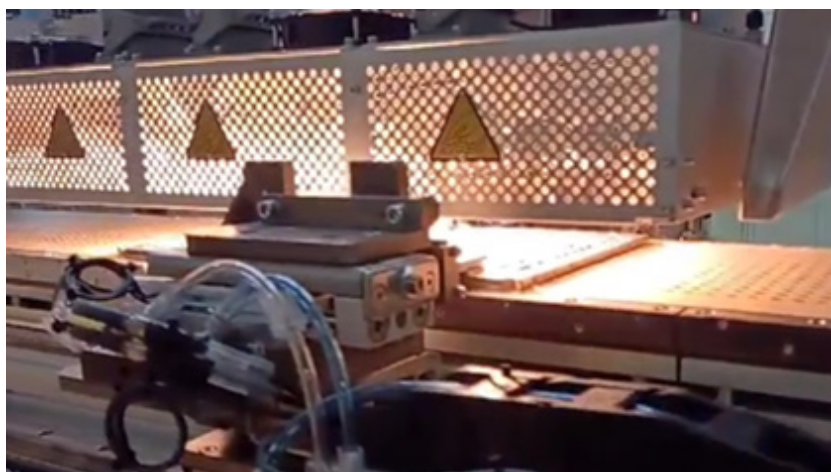
We are actively adapting our equipment portfolio to meet the unique constraints of perovskite/silicon tandem technologies, particularly focusing on low-temperature and gentle handling processes.

A key development is the evolution of tabber and stringer systems using reliable low-temperature interconnection. This approach ensures compatibility with perovskite layers while maintaining industrial throughput expectations.

Q: How is MASS adapting its turnkey manufacturing solutions?

We are leveraging our expertise in turnkey solutions to enable a seamless transition from conventional silicon lines to tandem-capable production. The strategy focuses on modular upgrades, allowing existing lines to incorporate new process steps such as low-temperature interconnection without complete redesign.

Beyond equipment development, MASS is actively working on the integration of these innovations into scalable, pilot-line environments, ensuring compatibility with industrial throughput, yield, and reliability requirements. What truly stands out from the project is the validation of these technologies in a real manufacturing context, demonstrating a clear and credible pathway toward the industrialization of tandem PV and reinforcing Europe's technological autonomy in high-efficiency solar manufacturing.



Tandem cell interconnection equipment

This minimises CAPEX for manufacturers while ensuring compatibility with next-generation cell architectures.

Through PEPPERONI, we are validating these concepts at pilot scale, supporting a realistic pathway toward industrial deployment in Europe.

FOM Technologies (FOM) is an equipment manufacturer specialising in slot-die coating and advanced thin-film deposition technologies. The company develops scalable coating solutions used in research and industrial environments, particularly for applications requiring high material precision and uniform thin-film layers, such as perovskite solar cells. Within PEPPERONI, FOM contributes its expertise in solution-based coating processes, supporting the development of scalable fabrication routes for perovskite layers.



Vladimir Popok
Director Science & Learning



Grzegorz Potoczny
Chief Technology Officer



Kamran Ahmed
Custom Projects

what's new?

Within the PEPPERONI project, a pilot-scale wafer roll-to-plate (R2P) slot-die coating machine was engineered and built to deposit solution-processed thin films, most notably perovskite precursor layers, onto individual silicon wafers at industrial throughput while preserving laboratory-grade film quality. The design addresses the central bottleneck in scaling perovskite-on-silicon tandem manufacturing: how to combine continuous, pre-metered slot-die coating with the handling precision required for single wafers of heterogeneous size, thickness and edge geometry.

Q: From your perspective, what are the main challenges when scaling tandem PV technologies to industrial production?

One of the key challenges is maintaining the strict cleanliness and environmental conditions required for high-efficiency tandem devices while also ensuring a compact equipment footprint and sustainable operational costs. Cleanroom infrastructure, energy consumption and process stability all play an important role in achieving economically viable production. Another important aspect is adapting highly optimised laboratory processes to stable, repeatable and high-throughput industrial manufacturing conditions. This transition requires close collaboration between research partners, material developers and equipment manufacturers to optimise process parameters, material handling, and production strategies suitable for scale-up.

Q: How is your equipment being adapted within PEPPERONI?

We analysed the process flow and identified the critical parameters influencing coating quality, process repeatability and device performance.



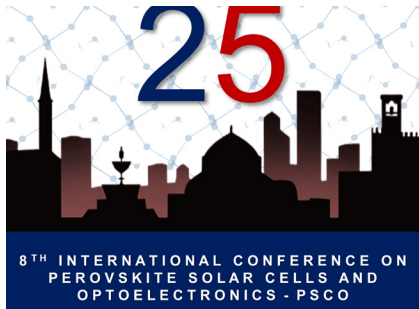
Slot-die coating machine

A key engineering challenge was preventing back-side contamination of silicon wafers during coating and transport, as even minor contamination can affect downstream processing and device quality. To address this, a dedicated wafer-handling and transport solution was developed to protect and seal wafer edges and backsides while ensuring stable positioning during coating. The machine platform, derived from advanced R2R slot-die coating technology and adapted for wafer-based tandem PV applications, combines scalable coating expertise with the precision needed for silicon wafers, supporting the transition towards industrial-scale tandem solar cell production.

PEPPERONI on the road

where did you see us so far?

From September until December 2025, PEPPERONI partners presented at many international conferences and events, including ...



15 September - PSCO
[Read more](#)



22 September - EU PVSEC
[Read more](#)



1 October - ISOS 16
[Read more](#)



20 October - MIW
[Read more](#)



28 October - ALD Day
[Read more](#)



2 December - BECOME PV
[Read more](#)

PEPPERONI partners are actively disseminating research results at conferences and events. Stay tuned to not miss out on the opportunities to gain insights into technology advancements, including encapsulation materials and strategies, tandem cells degradation processes and more.



what to expect?

International conferences and events

PEPPERONI partners will continue to share their research results at key events in 2026, including IEEE PVSC and TandemPV in June, the final webinar in October and many more in between!

TandemPV 2026

The sixth [tandemPV Workshop](#) will take place in Berlin, Germany, from 17 to 19 June 2026. It is a unique platform that brings together leading experts and researchers from the silicon and thin-film photovoltaic communities, fostering collaboration and innovation at the forefront of photovoltaic innovation.

EU PVSEC 2026

PEPPERONI partners will present results at [EU PVSEC 2026](#), taking place from 14 to 18 September 2026 in Rotterdam, the Netherlands. Through this PEPPERONI will contribute to scientific and industry discussions on next-generation PV. In addition, PEPPERONI will co-organise a joint **parallel event** with other EU-funded projects focused on perovskite technologies, under the theme: *Opportunities for Sustainable Perovskite PV Commercialisation*.

Final PEPPERONI event

PEPPERONI will hold its final event online in mid-October 2026, bringing together partners and stakeholders to present and reflect on the project's key results. The exact date and programme will be announced soon. Stay tuned!

Stay connected

what is in there for you?

Our newsletter not only brings you closer to PEPPERONI but also provides:

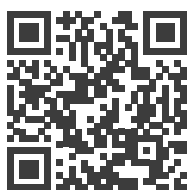
- Updates on the latest advancements and breakthroughs in perovskite/silicon tandem technology from PEPPERONI partners.
- Valuable insights, analysis, and expert opinions in PV value chain innovation.
- A community of like-minded individuals and experts, fostering collaboration and knowledge exchange.
- Potential opportunities for partnerships, investments, or career advancements in PV research/industry.

Subscribe today to embark on an exciting journey of research and innovation!



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acknowledgement



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