FACTSHEET #6

The objective of RESiLEX is to improve the resilience and sustainability of the entire Silicon value chain and reduce EU dependence on critical raw materials for solar panel and battery production. Silicon is considered a critical raw material for the EU due to its high supply risk and economic importance, mainly because of heavy reliance on imports

Driving down costs: eco-design innovations in silicon PV Cells for European Resilience



This document summarizes a more extensive analysis carried out by CEA-INES Solar on the economic evaluation and market potential of certain photovoltaic technologies deemed “sustainable”. Specifically, due to data availability, the document focuses on eco-design innovations at the cell and module level developed in Resilex. Here, we thus show the results of a Cost of Ownership (CoO) analysis for eco-designed cells integrated into a photovoltaic module.

The Silicon Photovoltaic Module Value Chain

It is worth recalling some important aspects for the various level of the PV valuechain, as well as peculiar features of the technology developed in Resilex.

- **Polysilicon**: Purified silicon is primarily produced in China (92% of the global share in 2023). The price of polysilicon significantly decreased in 2023 but remains higher outside of China.
- **Ingots and Wafers**: Monocrystalline ingots are produced using the Czochralski method and then cut into wafers. China also dominates production capacity here (98%). There is a trend towards larger and thinner wafers, reducing polysilicon consumption.
- **Solar Cells**: Cell technologies are evolving rapidly. PERC (Passivated Emitter and Rear Contact) technology is being replaced by next-generation technologies like TOPCon (Tunnel Oxide Passivated Contact) and HJT (Heterojunction).

- **HJT in RESiLEX**: the project focuses on heterojunction (HJT) cell technology. HJT cells are produced at low temperatures, and their process includes steps like chemical cleaning (Wet), deposition via PECVD (Plasma-Enhanced Chemical Vapor Deposition) and PVD ITO (Physical Vapor Deposition for Indium Tin Oxide), metallization, and curing.
- **HJT Cell Costs**: The cost of HJT cells produced in Europe (6.5-8.5 USD cent/Wp) is higher than that of TOPCon cells, mainly due to the more complex production process and the use of critical and expensive materials like silver and ITO. One of Resilex's goals is precisely to reduce silver and ITO consumption.
- **Module Assembly**: Photovoltaic modules protect cells and interconnect them. Module efficiency has increased significantly (from 16% in 2014 to 24% in 2023). HJT modules are among the most efficient. Photovoltaic module production costs in Europe are higher than in China (11-11.4 USD cent/W versus 7 USD cent/W), mainly due to labor costs. Most of the cost is attributed to processing and manufacturing operations (over 50%).



Innovation driven by Resilex

- **Cell-level innovations** done by the project focusses on reducing or replacing critical materials like silver (in metallization) and indium (in ITO) in HJT solar cells. Four innovation scenarios have been defined, and the first one, (Scenario 1) is presented here.
- **Scenario 1 (S1)**: this scenario involves reducing the thickness of the ITO layer and decreasing silver consumption by introducing copper for metallization. It requires adding a PECVD SiNx (silicon nitride) layer as an anti-reflective and protective layer.
- **Other scenarios (S2, S3, S4)** involve further ITO reductions (with potential replacement by AZO) and more complete silver replacement with copper, including through plating. These analysis will be available towards the end of the project’s lifespan.

Economic analysis

Methodology: the analysis is based on the Cost of Ownership (CoO), which includes material costs, capital expenditures (CAPEX), operational expenditures (OPEX), and labor costs. This report's analysis is a Life Cycle Cost (LCC) analysis that compares a standard HJT module with an alternative module (Module A1) incorporating the innovative cell from Scenario 1. Production is assumed to be in Europe (Polysilicon in Germany, Ingots/Wafers in Norway, Cells/Modules in France).

Results at the cell level:

- The reduction of ITO in Scenario 1 leads to a decrease in the PVD phase cost to 0.9 USD cent/W (compared to 1.167 USD cent/W for the reference).
- The reduction in silver use and its partial replacement with copper results in a 42% reduction in metallization cost, bringing it to 1.74 USD cent/W (compared to approximately 3 USD cent/W for the reference).
- Overall, the innovation in Scenario 1 leads to an estimated **10% reduction** in the HJT cell cost compared to a standard cell.

Results at the module level:

- Integrating the Scenario 1 cell into the overall module leads to a module cost **reduction of approximately 3%** compared to the reference module.

Conclusions and Future Perspectives

The analysis, summarized here, provides a preliminary overview of the innovations developed in Resilex, focusing on the eco-design of solar cells and the reduction of critical materials. The initial CoO analysis demonstrates the potential for **cost reduction offered by eco-design strategies, with a 10% decrease at the cell level and a 3% decrease at the module level for Scenario 1**.

The work highlights that the module assembly phase accounts for **61% of the total module cost**, indicating it is a significant lever for future cost optimization. Future evaluations will integrate additional data, including recycled silicon and eco-designed modules with alternative and more sustainable materials, to identify the most competitive and effective solutions

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