

Alternative equipment and processes for Si PV manufacturing: An opportunity to bring PV production back to Europe

Junjie Zhu, Helge Malmbekk
Institute for Energy Technology

Junjie.zhu@ife.no

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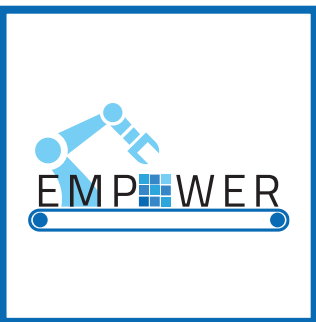
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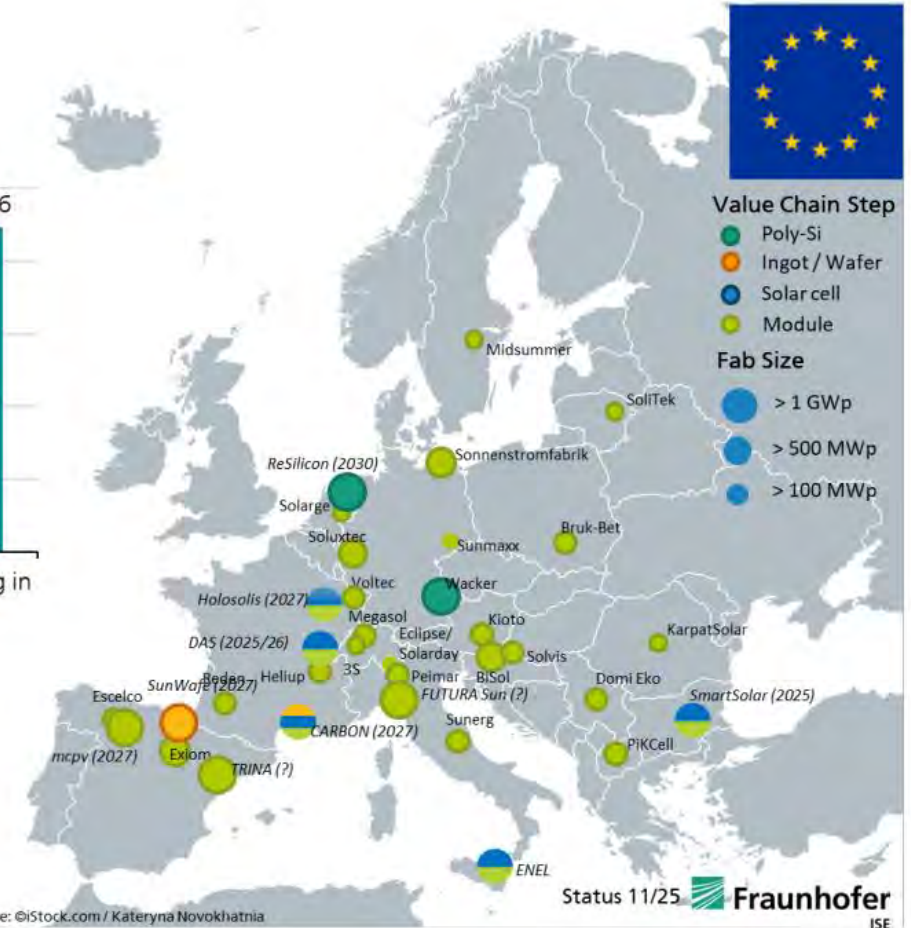
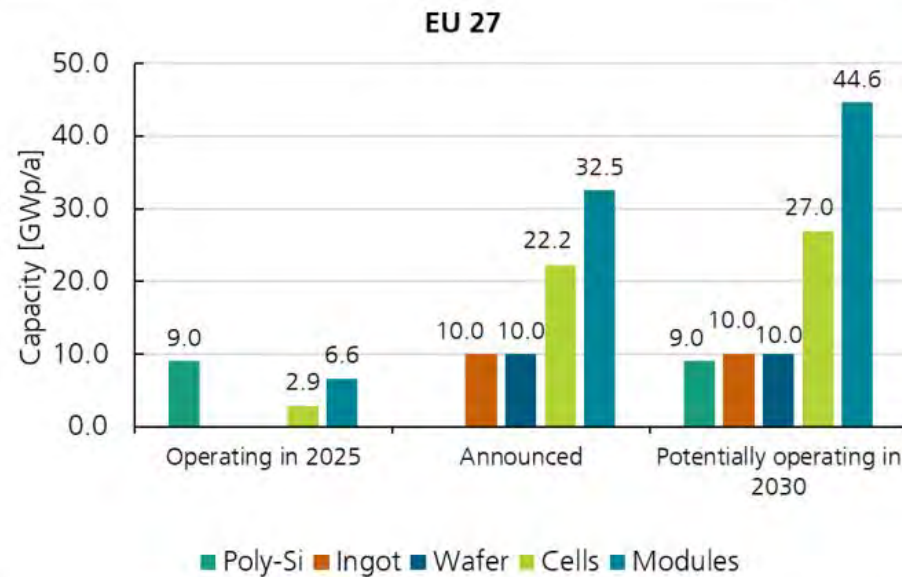
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PV manufacturing in Europe



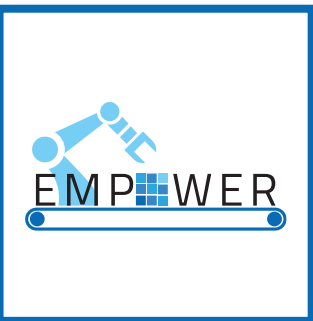
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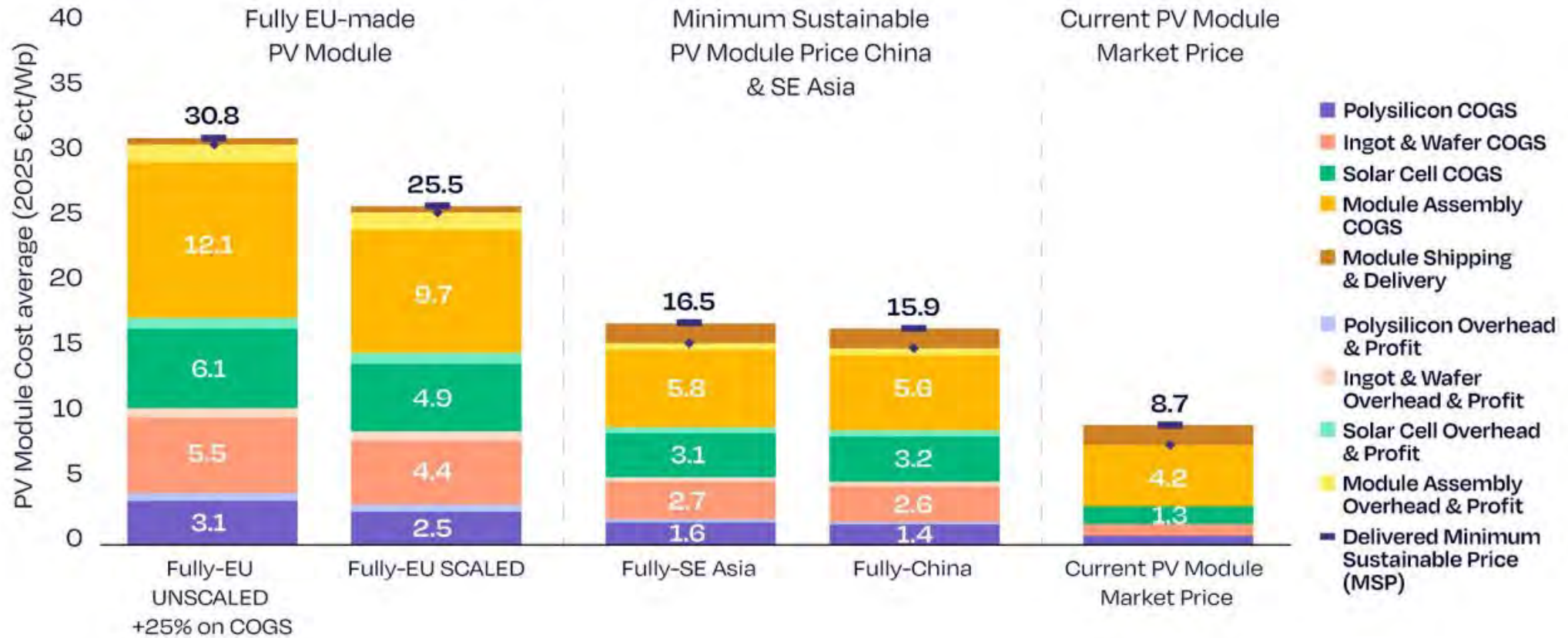
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PV module production cost

Delivered Minimum Sustainable Price (MSP) for solar PV Module



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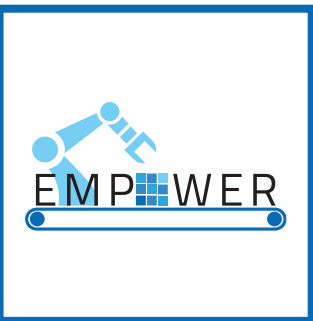


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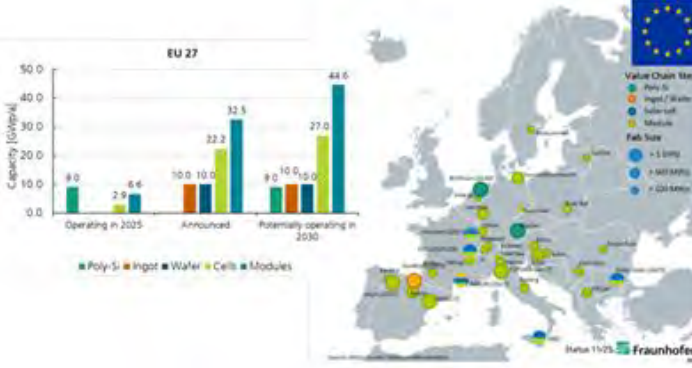
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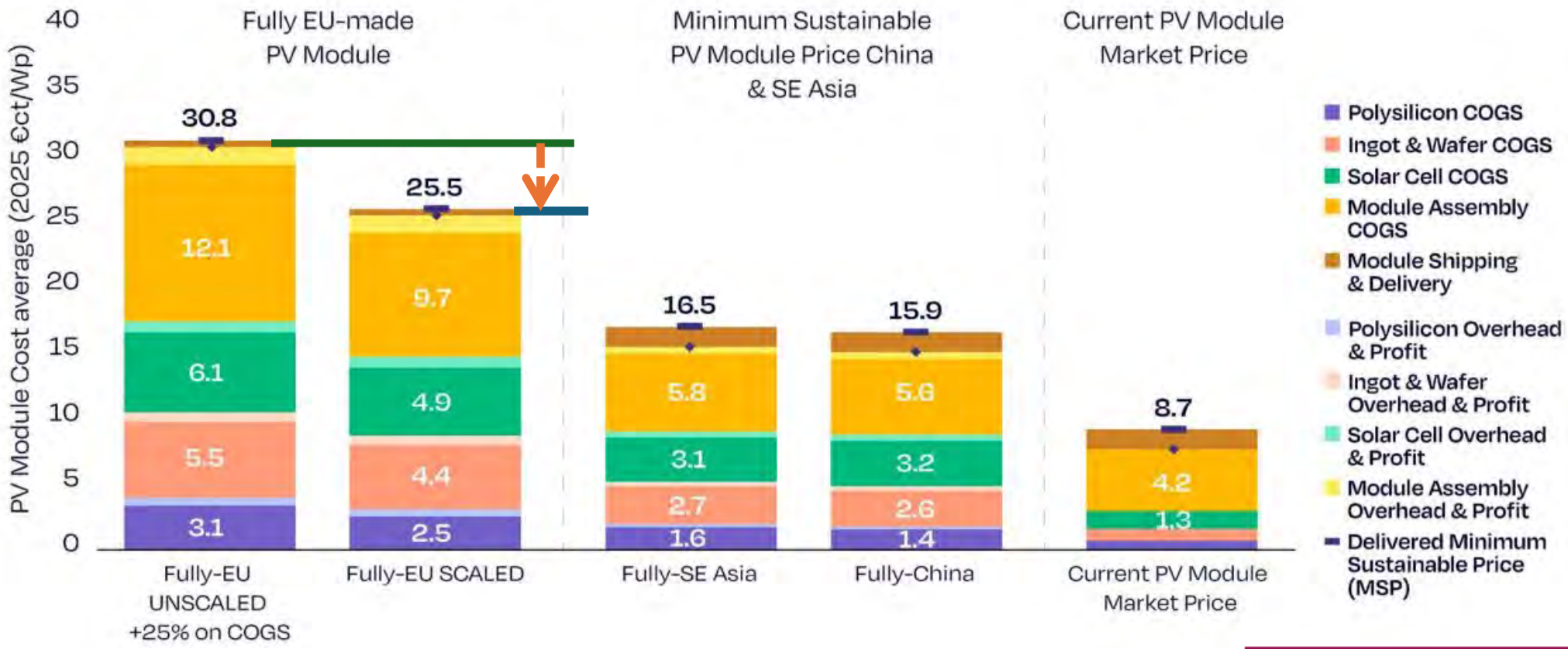
Source: Fraunhofer ISE



PV module production cost



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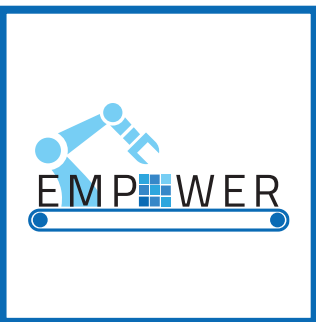


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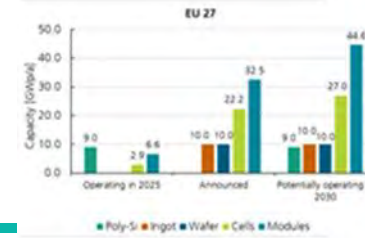
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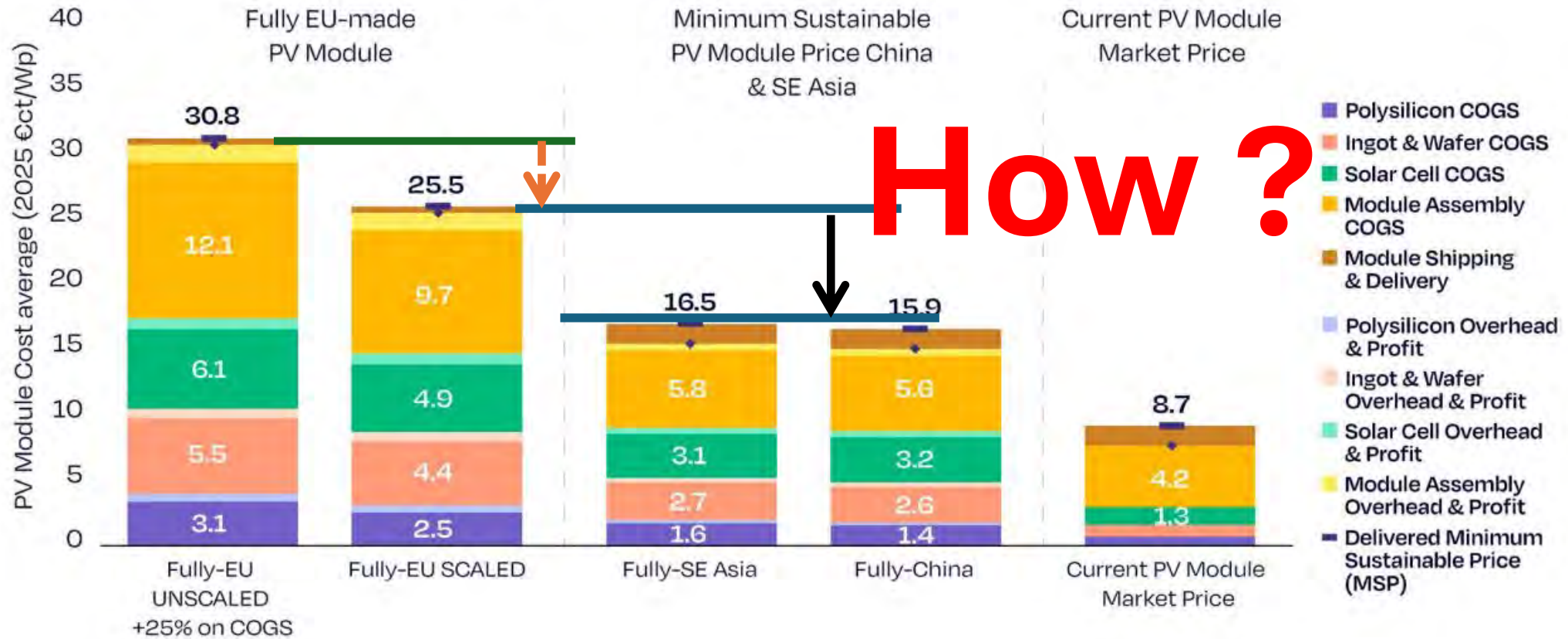
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PV module production cost



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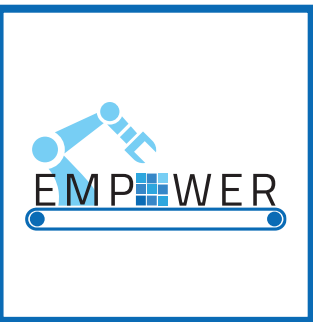


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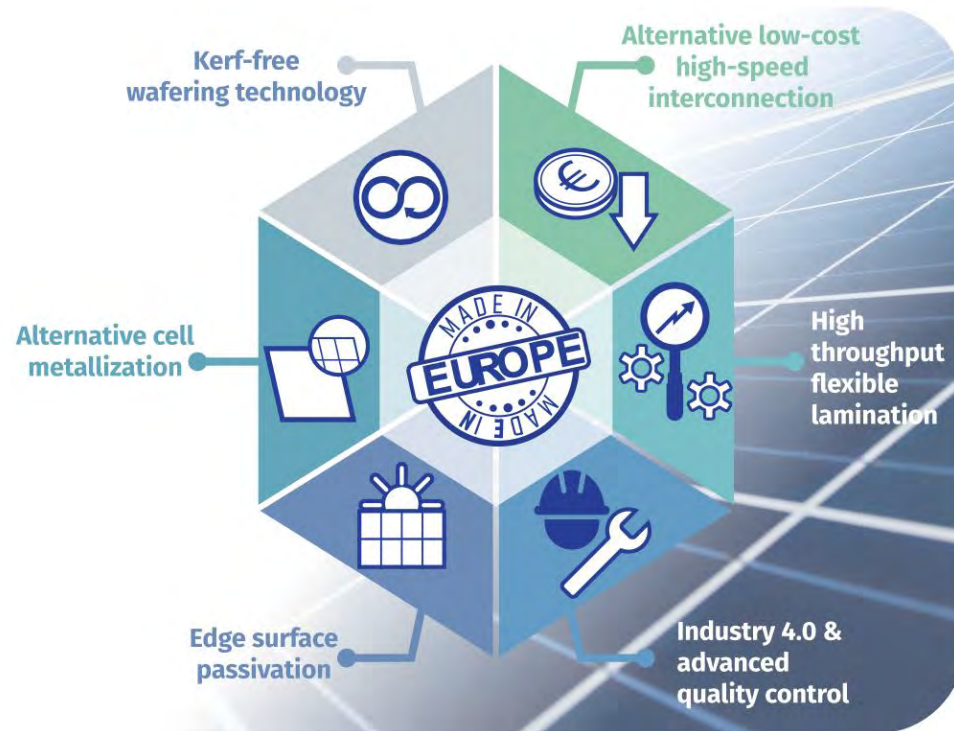
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EMPOWER unlocks next-generation PV manufacturing in Europe by:

- Reducing production costs (CapEx & OpEx) across the value chain
- Enhancing sustainability through material and energy savings
- Increasing yield, quality and production efficiency
- Demonstrating scalable solutions for reindustrialising PV production in Europe



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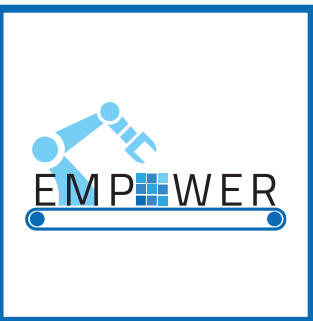
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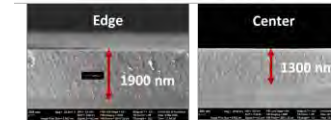
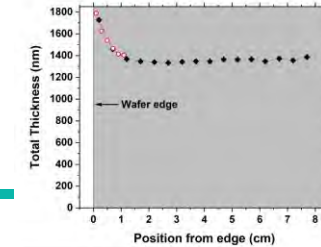
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EpiNex Wafers



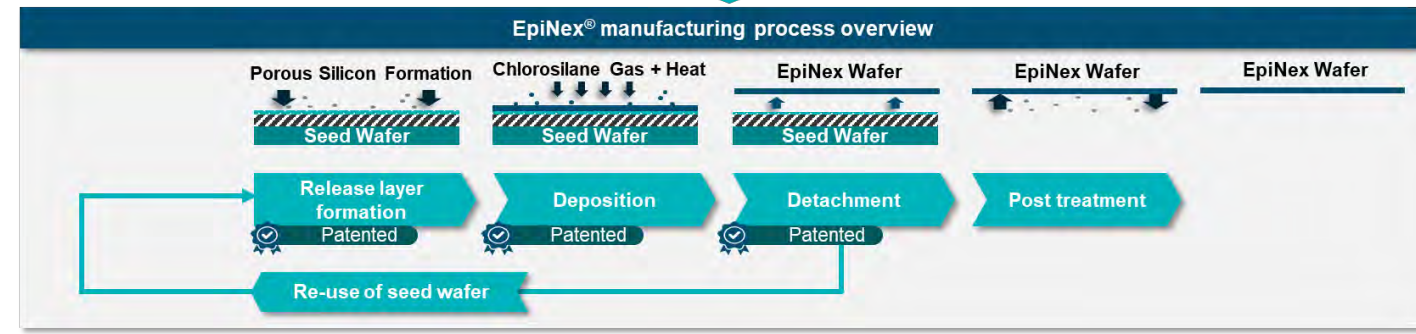
- Alternative to Cz-growth
 - CVD growth
 - 60% Energy reduction
 - >90% Silicon utilization
 - Low CO₂ footprint
- Increasing throughput
 - First commercial factory in Germany under construction
- Quality testing
 - Process optimization
 - Wafer analysis
 - Integration of Ind4.0
- Tailor product to cells
 - Doping, Oxygen content



Current traditional/mainstream manufacturing process (Cz¹)



NexWafe EpiNex® Process



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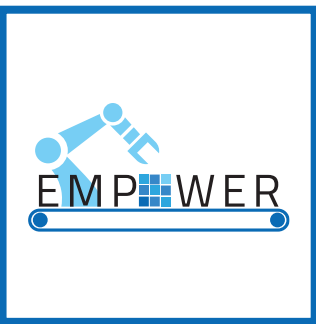
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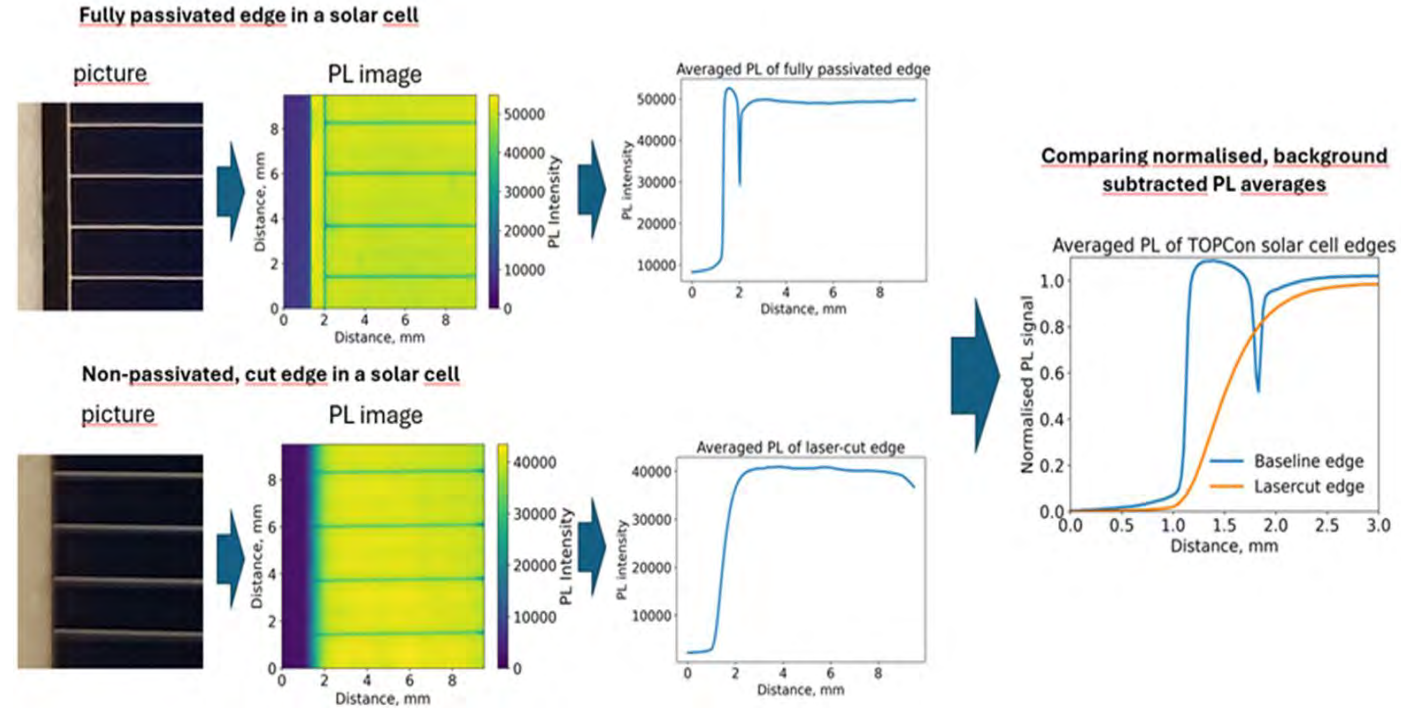


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Laser cutting and Edge passivation

- Optimized laser cuts
- Selective plasma assisted deposition on edges
- Batch process – Carrier optimization
- Reached 67,500 cuts/h
 - Up to 80% recovery



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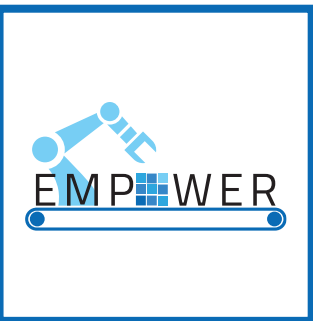
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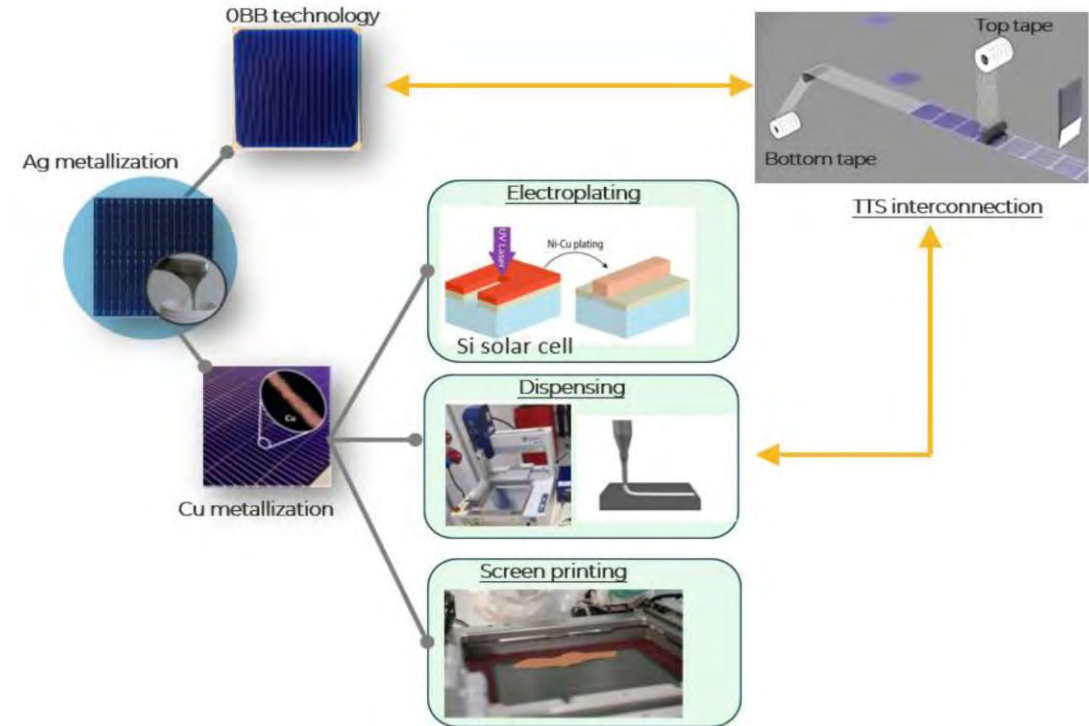
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Cu metallization

- Ag → Cu
- OBB technology
- Electroplating
- Screen printing Ag-coated Cu
- Screen printing Cu
- Integrate with stringing (low temp)



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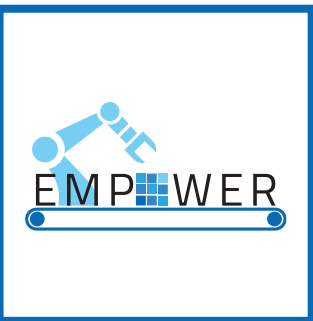
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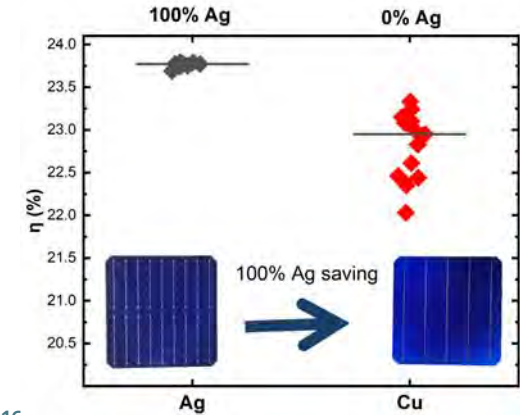
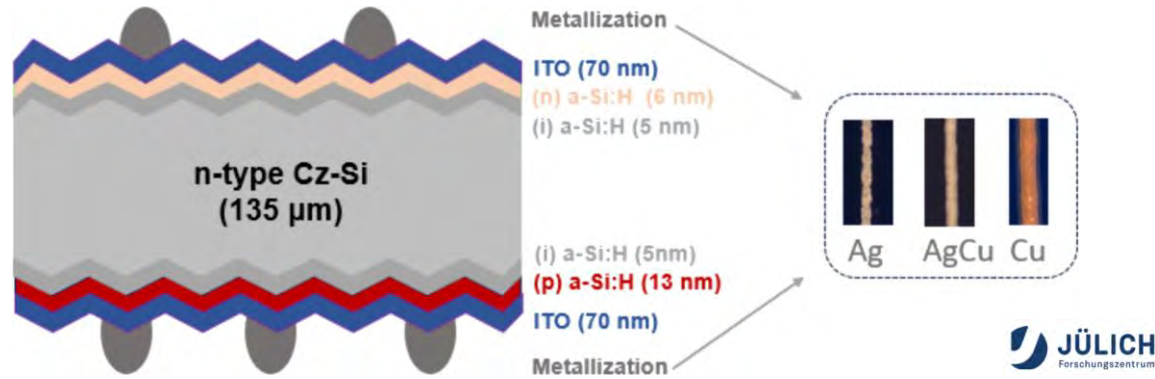
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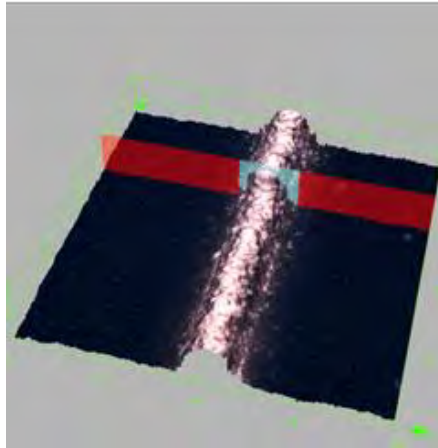
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Cu metallization

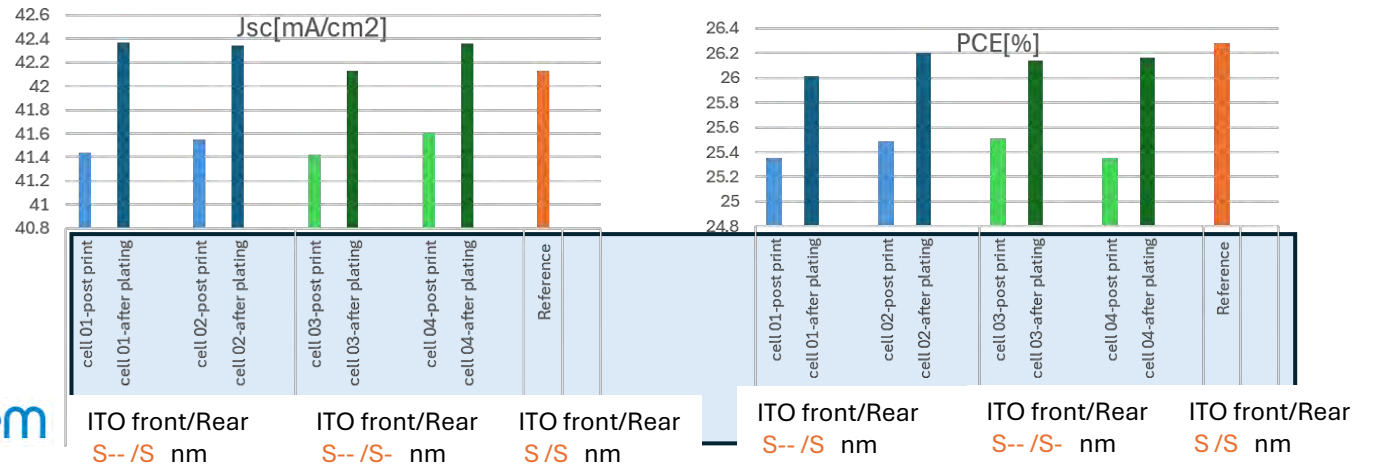


Screen Printing on SHJ



<https://doi.org/10.1002/pip.70016>

Cu electroplating on SHJ



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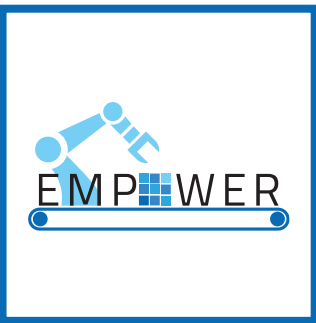


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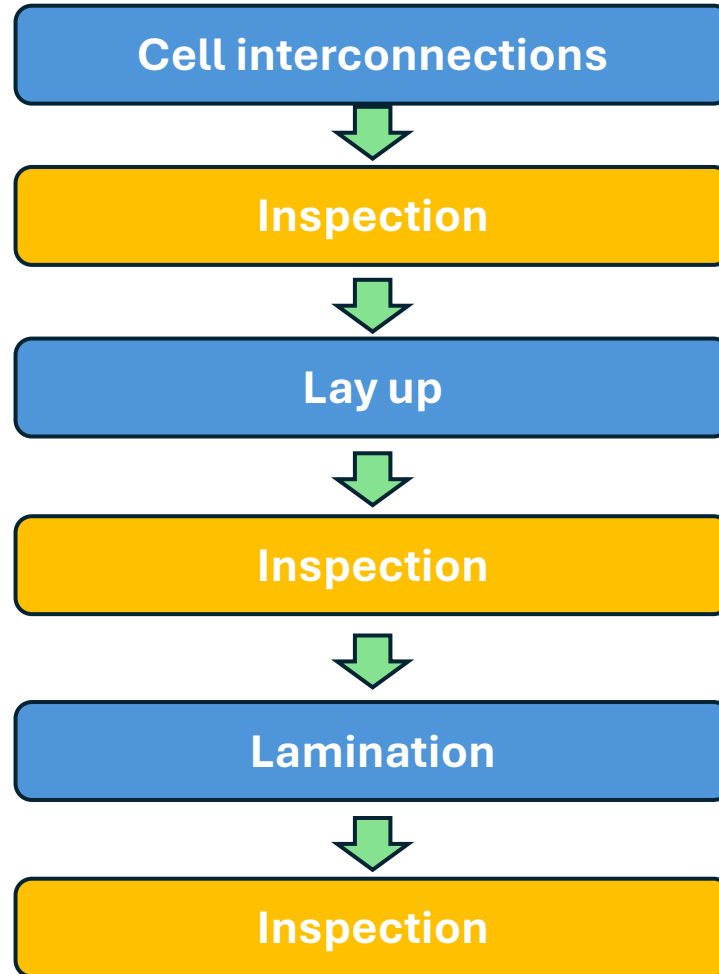
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Ag consumption decreased from 5 mg/W to 1.5 mg/W, In consumption was reduced from 4.7 mg/W to 2.8 mg/W for a similar level of cell efficiency.



PV module fabrication



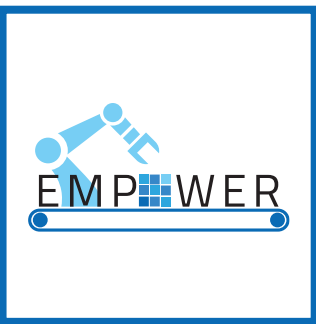
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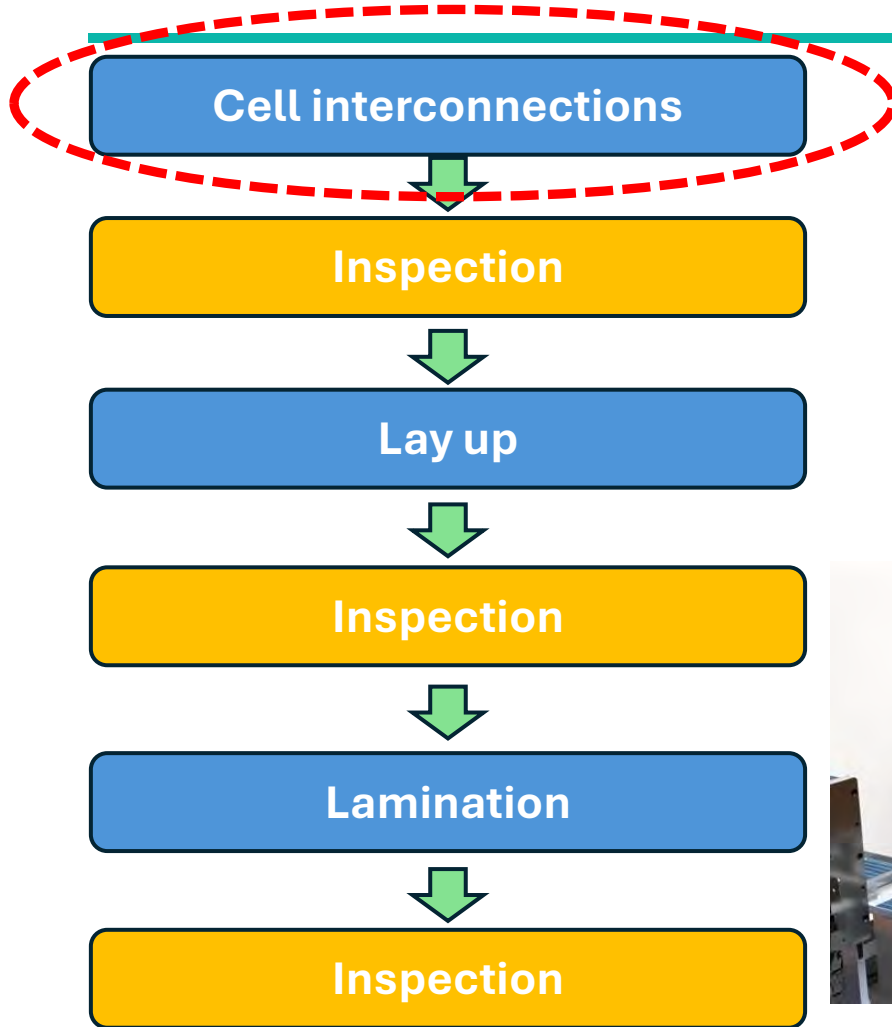
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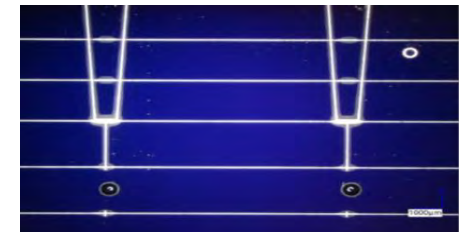


PV module fabrication

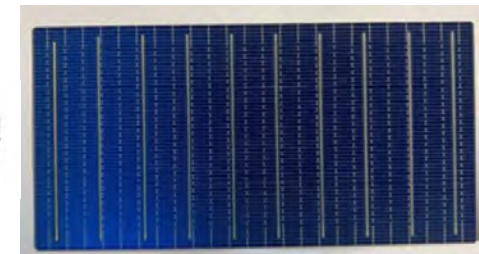


Stringer

- i. **Machine 1, Scale-up (Mondragon)**
 - ❖ Scale up to 7000 cells/h
 - ❖ Full scale production of TopCon and SHJ strings



NCA



ECA



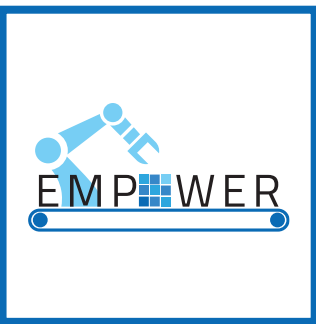
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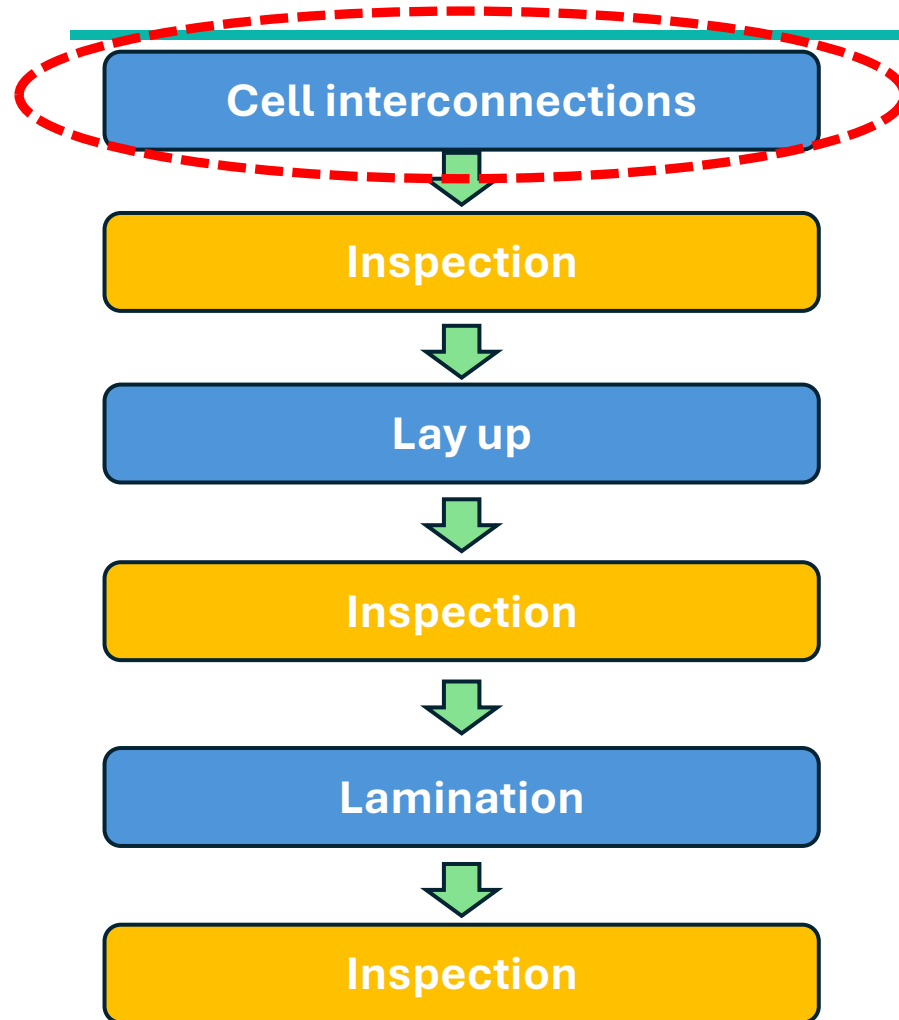
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PV module fabrication



Stringer

- i. **Machine 1, Scale-up (Mondragon)**
 - ❖ Scale up to 7000 cells/h
 - ❖ Full scale production of TopCon and SHJ strings

- ii. **Machine 2, Tape based interconnection at room temperature, TTS™ (STICKY)**
 - ❖ No Pb, No ECA
 - ❖ 2500 cells/h



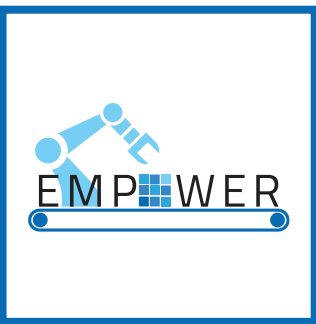
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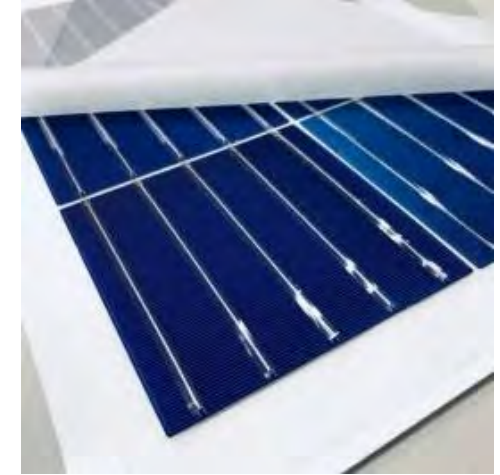
Interconnection based on TTS (Sticky)

TS 5000
from Sticky Solar Machinery



50 % less energy usage
– best in class.

STICKY
SOLAR
POWER



<https://www.stickysolarpower.com/the-tape-solution/>



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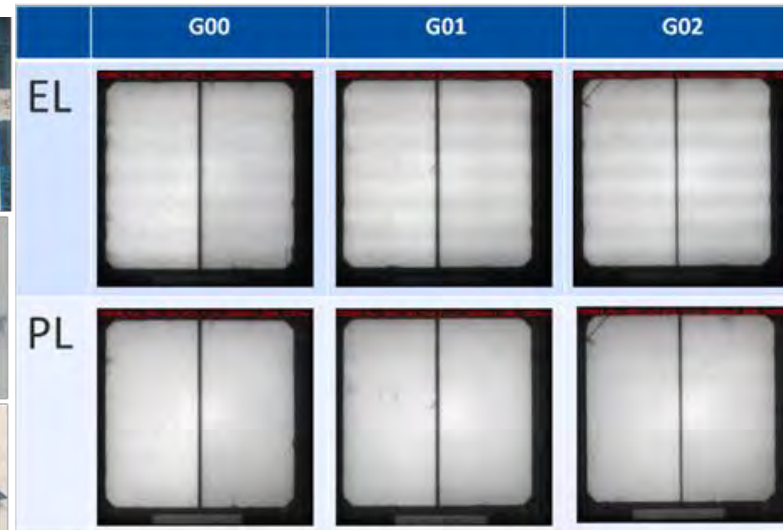
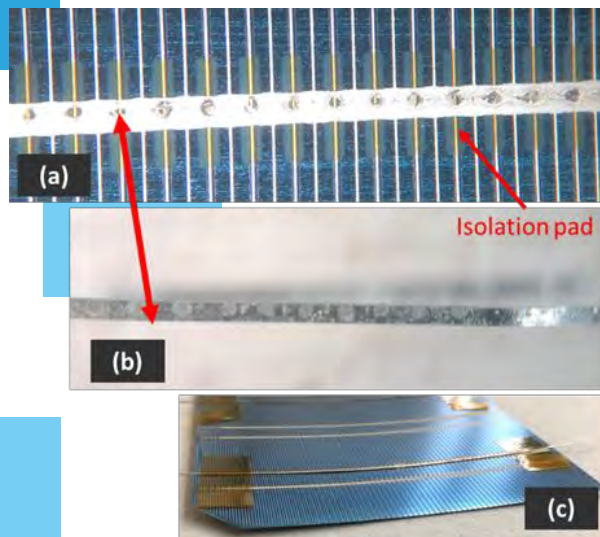


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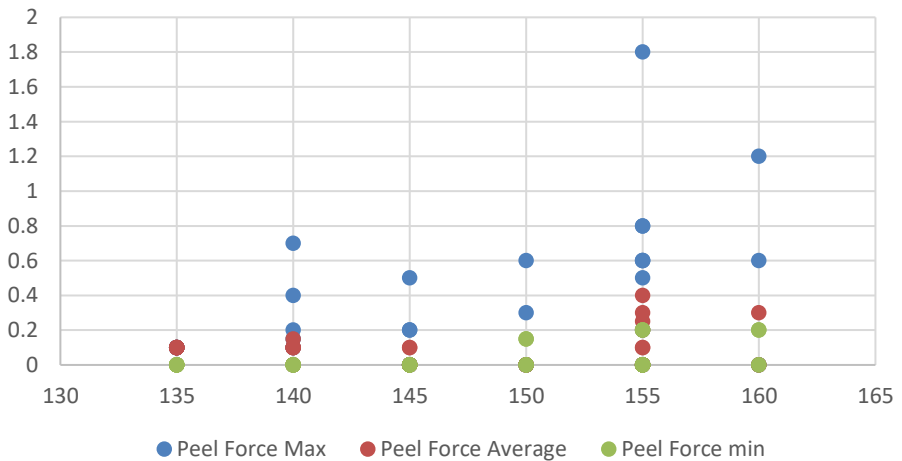


TTS application on BC solar cells

Group	G00		G01		G02	
Type of sample	String	Minimodule	String	Minimodule	String	Minimodule
Numer of samples	2	4	2	4	2	4
Type of cell	M6 9BB		M6 9BB		M6 9BB	
w/o flux	With flux		without flux		With flux	
Interconnection	Std soldering		Sticky tape		Sticky tape	



Peel Force vs. Lamination Temperature



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TTS application on BC solar cells-TC tests



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TTS application on BC solar cells-TC and DH tests

Group	G00	G01	G02
Initial			
After TC600			

	Initial	DH 500	DH 1000	DH 2000
G00				
G01				
G02				



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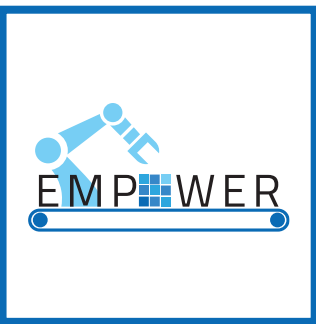


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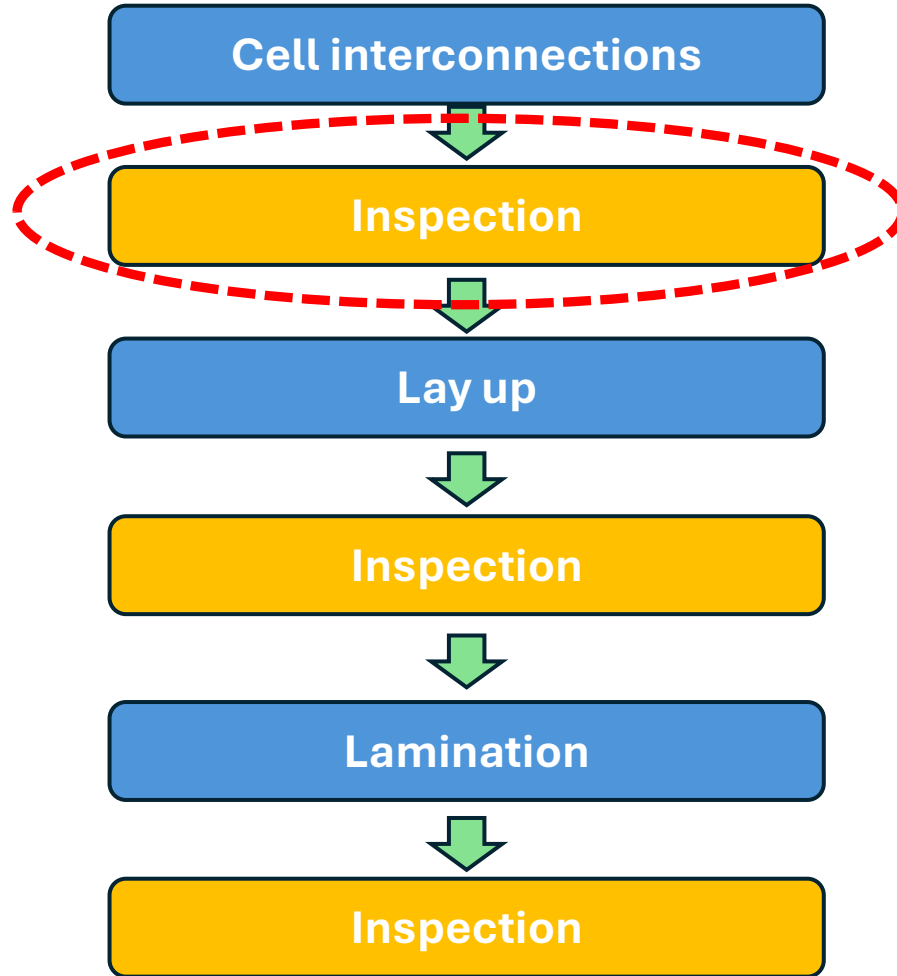
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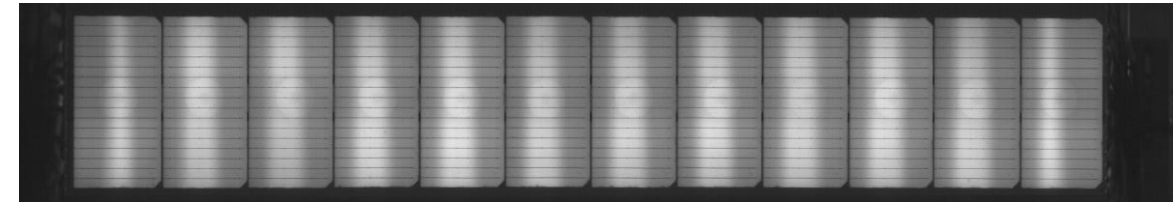




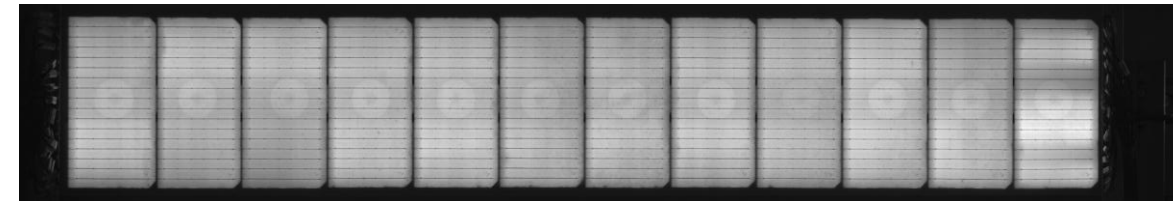
PV module fabrication



- EL and PL images for each string
- PL light and EL pins to inject current
- No slowdown in the stringing process



Images acquired by the newly installed PL



Images acquired by the newly installed EL



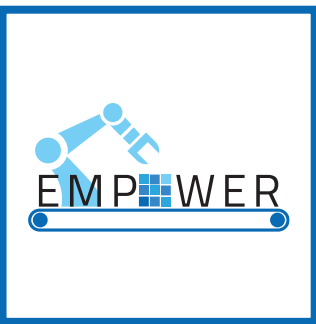
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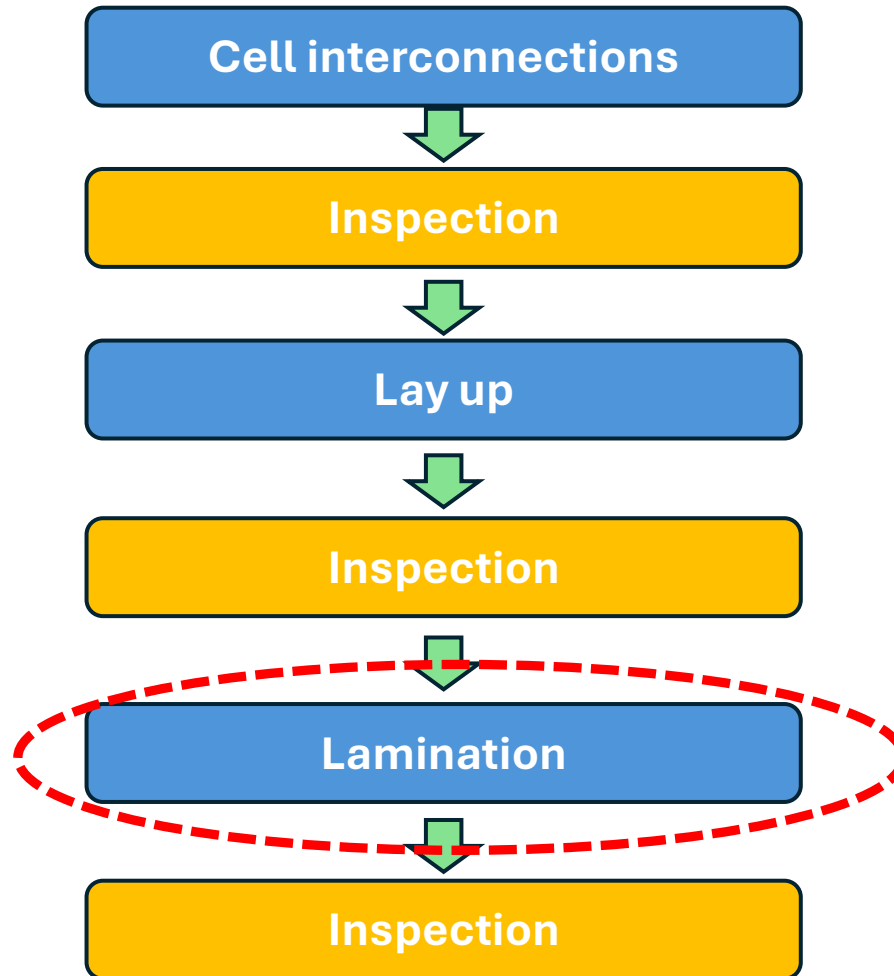
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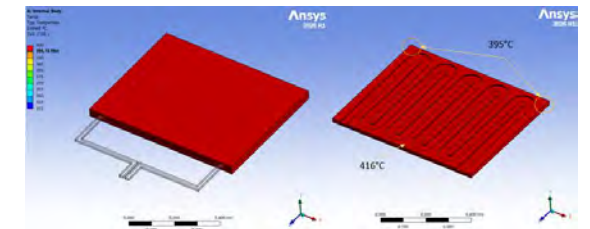


PV module fabrication



Laminator

- 1, Optimize the transport belt, saving ~40%
- 2, New kind of membrane fabric was installed, expected for ~70,000 cycles
- 3, Optimize chamber (Capability to operate, easy maintenance, etc.)
- 4, Optimize cooling station
- 5, Optimize heating table
- 6, Install Quality control box



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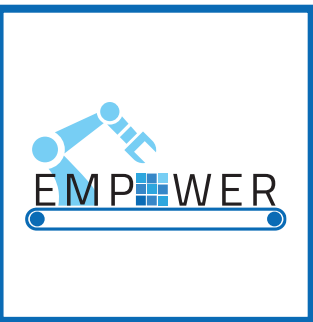


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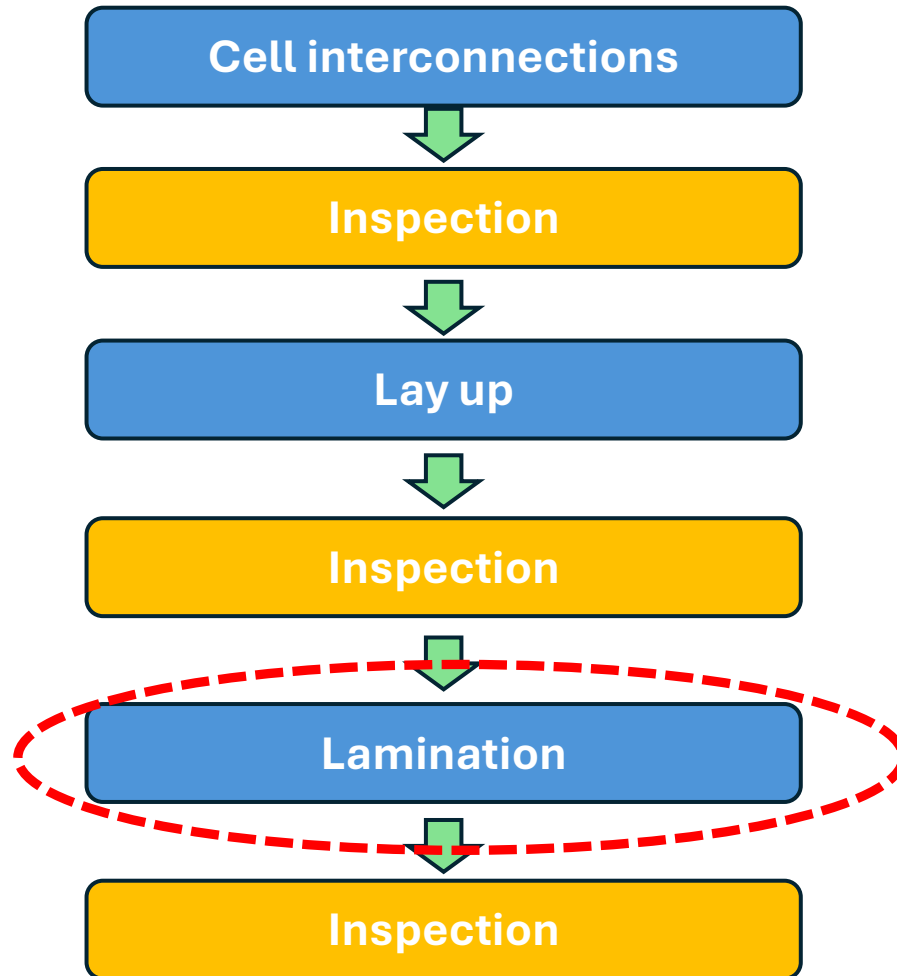
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BÜRKLE



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- 6, Install Quality control box

Opex-category	Potential
Energy Consumption Heating Unit	↓ medium
Energy Consumption alternative Heating System	↓ high
Maintenance Costs Membrane	↓ medium
Maintenance Costs Belts	↓ medium
Optimized effective press format	→ low



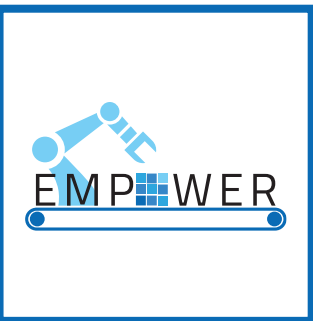
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PV module fabrication

Cell interconnections



Inspection



Lay up



Inspection



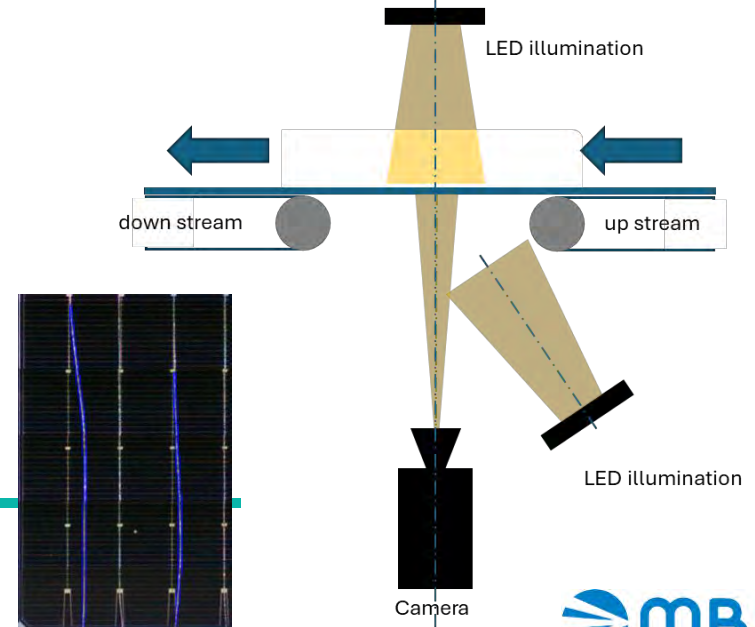
Lamination



Inspection



- MBJ Visual inspection after lamination
 - 1 m/s
 - 120 μm pixel resolution
 - Automatic cell and string gap measurement
 - Automatic visual inspection (bubbles in the laminate)
 - Deep learning for the visual inspection part
- Integration into the line
 - System is placed between two conveyers
 - Encoder for synchronization between camera and conveyors



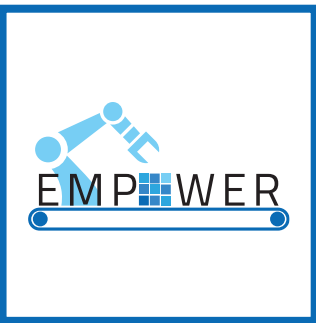
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Key Takeaways

- ❖ Alternative approaches can deliver significant cost reductions.
- ❖ Higher throughput, yield, and quality drive sustainable OpEx savings.
- ❖ Lower CapEx and OpEx are critical to restoring the competitiveness of EU PV manufacturing.
- ❖ Innovation in manufacturing is the key for bringing PV production back to Europe.



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