



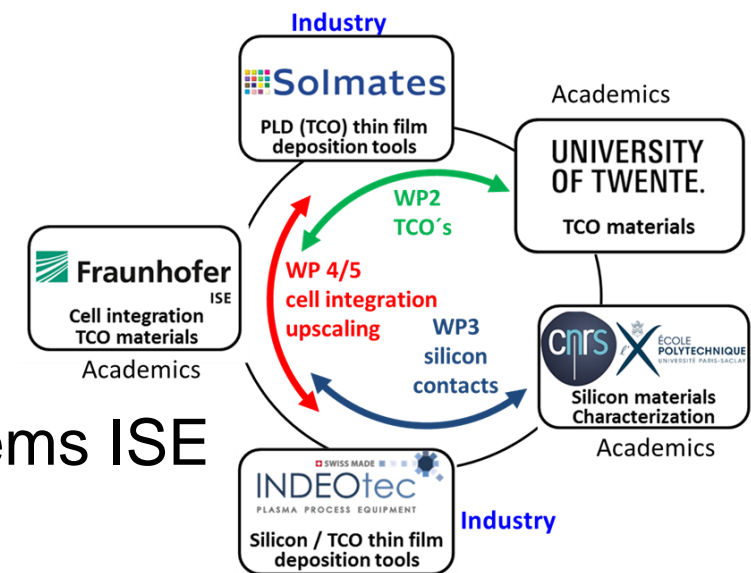
## Cost efficient, upscalable and stable transparent conductive oxides for silicon solar cells based on passivated contacts.

### “CUSTCO”

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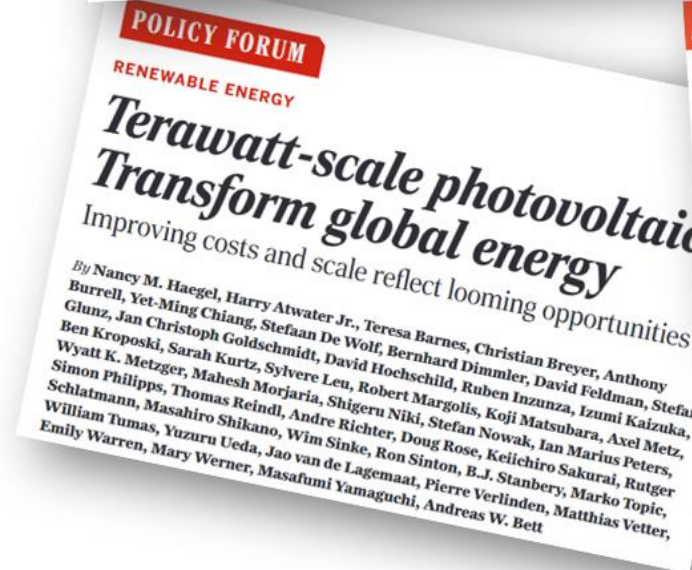
- **Scientific, technical, commercial challenge(s) addressed**
- **Key outcomes, results and benefits**
- Experiences gained in transnational set-up
- Critical factors and lessons learned for future successful transnational R&I projects

## TeraWatt Era: Innovation of PV Landscape to Enable Massive Grows

### Technological Innovation for Sustainable Production of Solar Cells

#### Key factors (amongst others) are


- High conversion efficiency
- Efficient and sustainable use of materials
  - Metals for conductors / electrodes

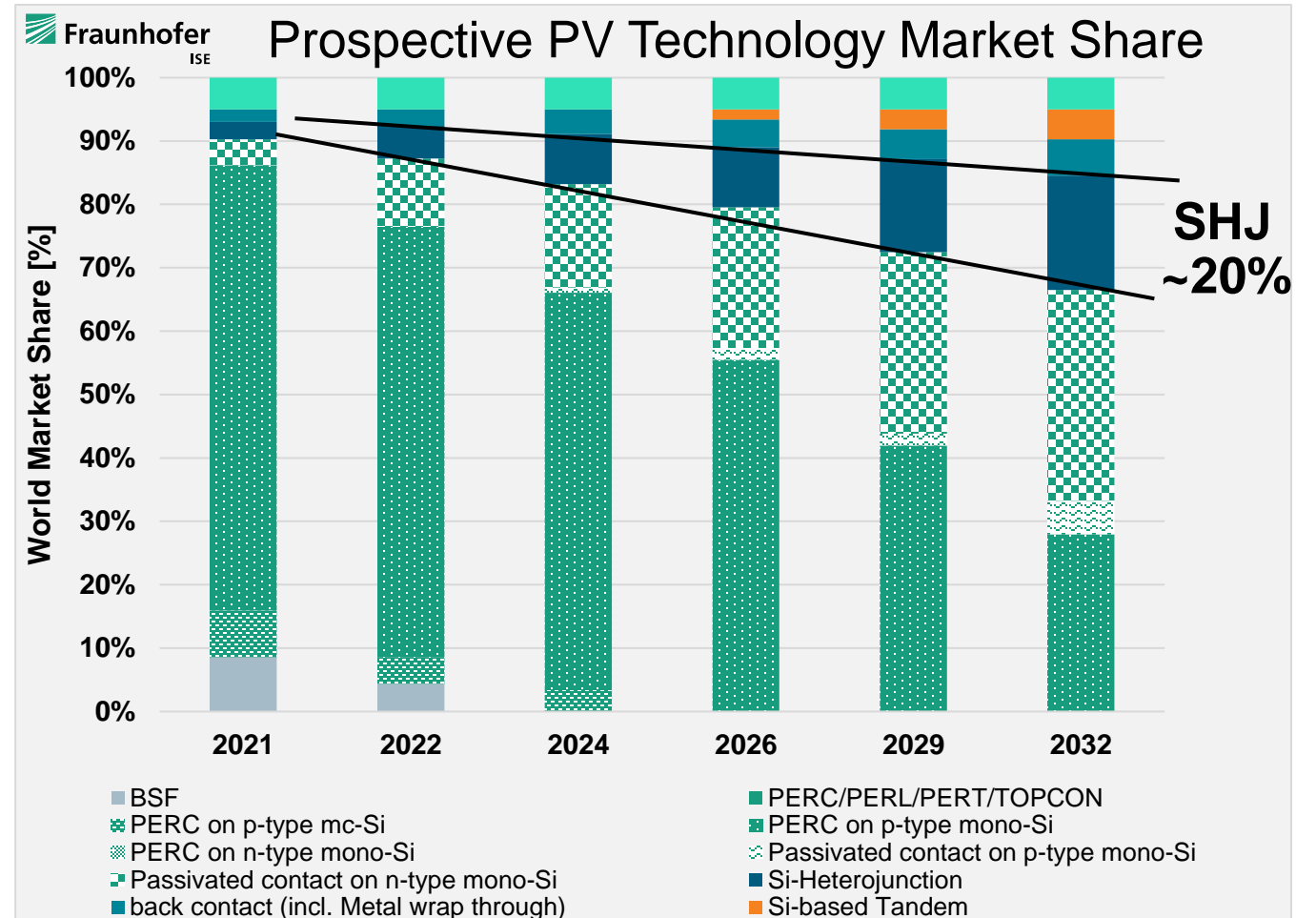


## Silicon Heterojunction Technology (SHJ)

### Innovations Needed for the Electrodes to Become a Mainstream Technology

#### Key factors (amongst others) are



- High conversion efficiency  
→ **Silicon heterojunction cells** 
- Efficient and sustainable use of materials
  - Metals for conductors / electrodes<sup>1-3</sup>

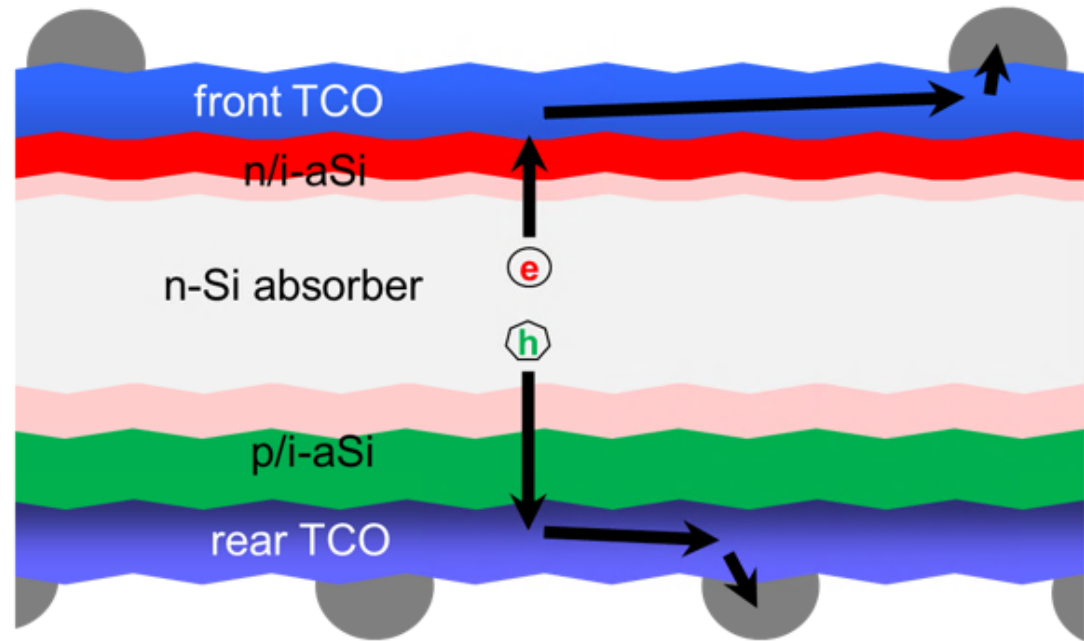


## Silicon Heterojunction Technology (SHJ)

### Innovations Needed for the Electrodes to Become a Mainstream Technology

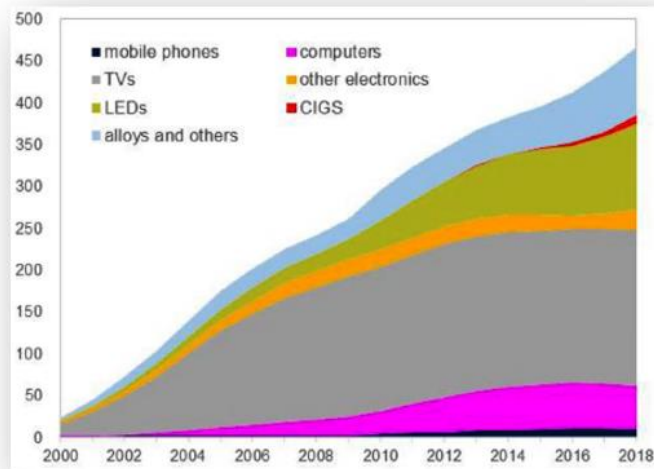
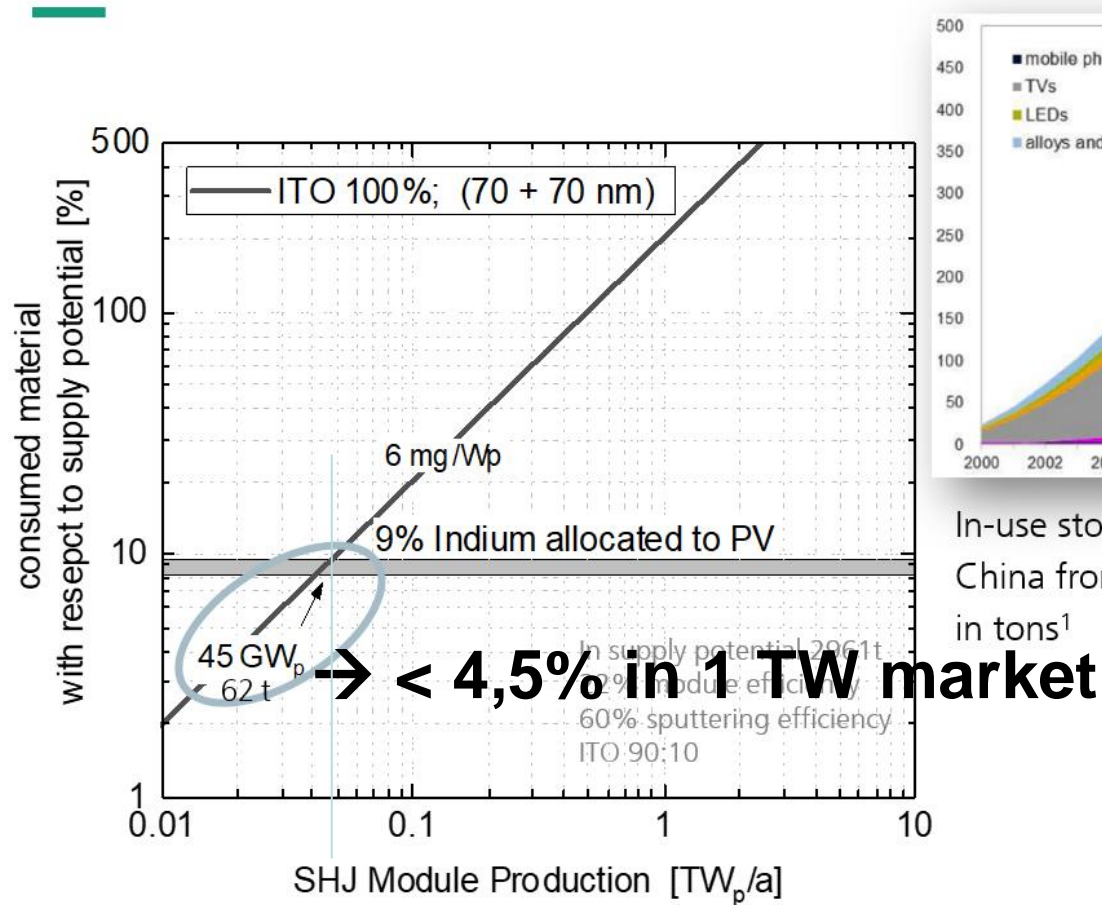
#### Key factors (amongst others) are

- High conversion efficiency  
→ **Silicon heterojunction cells** 
- Efficient and sustainable use of materials
  - Metals for conductors / electrodes<sup>1-3</sup>
- Ag grid electrodes
- **Indium based TCOs**
- Sometimes Bi for interconnection 

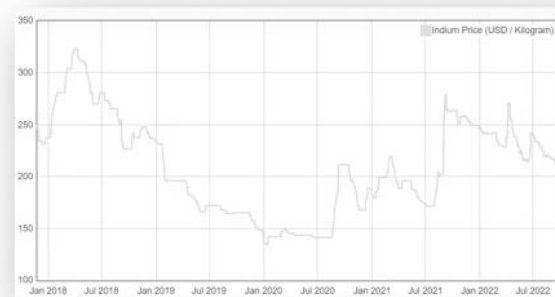


## Indium - Current SHJ Techn. would only be a Niche Product in TeraWatt-PV

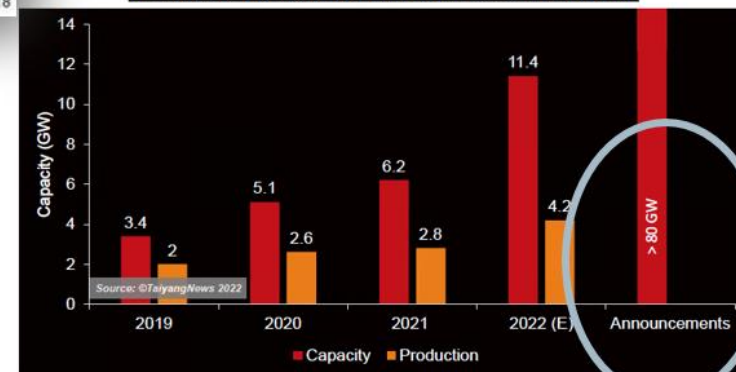
Indium Supply, Competition with other Markets / Devices, Price, End-of-Life Recycling, ...



In-use stock of indium in China from 2000 to 2018 in tons<sup>1</sup>

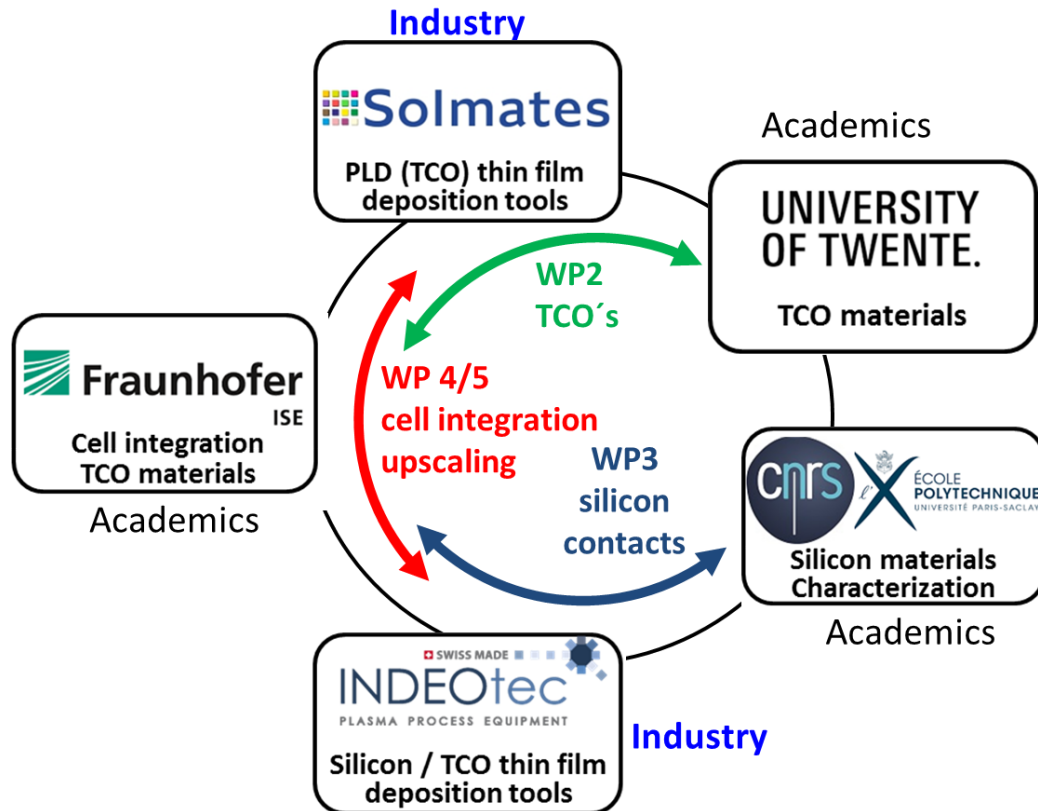


Production, Capacities & Announcements for HJT



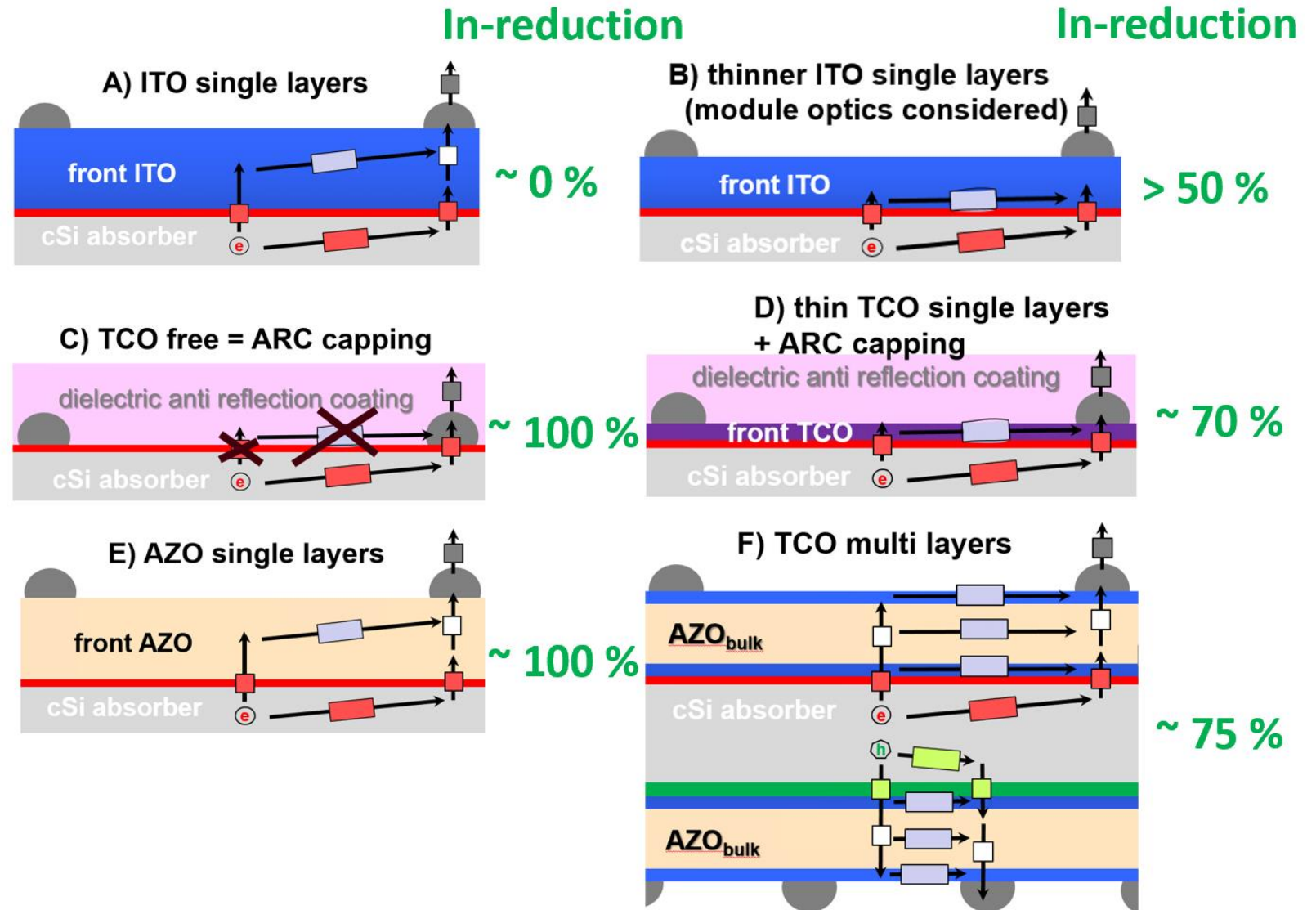
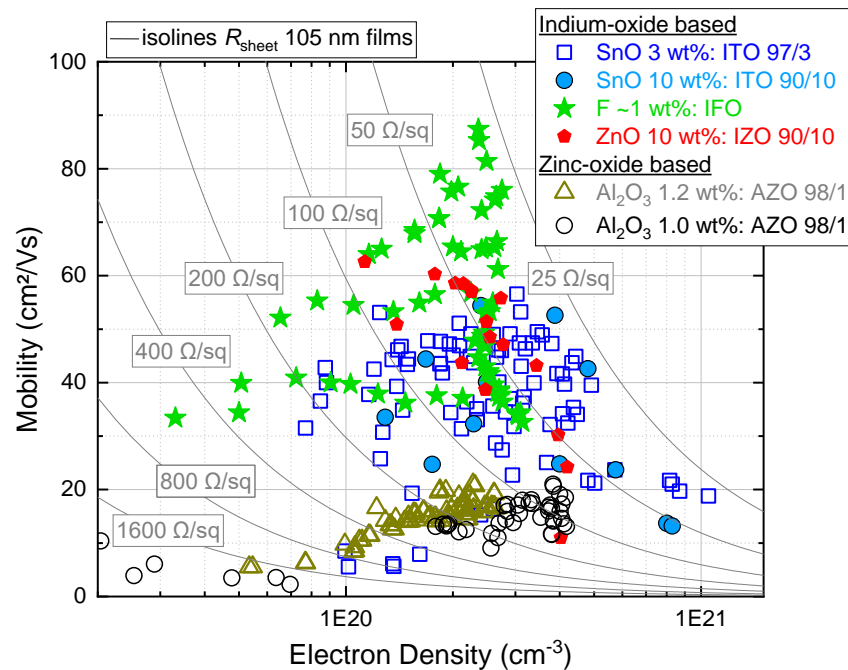
High interest: HJT has attracted a lot of traction, especially when it comes to expression of interest. While the announcements exceeded 80 GW end of 2021, the actual installed capacity was merely at about 6 GW.

## Indium-lean and Indium-free SHJ cells



WP	Lead	Title
<b>1</b>	<b>ISE</b>	<b>Administration</b>
		1,1 Coordination
		1,2 Reporting
<b>2</b>	<b>UT</b>	<b>TCOs</b>
		2,1 Indium-free/high mobility TCOs screening
		2,2 Compatibility with mass production
		2,3 Optimization indium-free/indium TCOs
<b>3</b>	<b>CNRS</b>	<b>Silicon thin films</b>
		3,1 Adaption to optimum TCO process conditions/temperature stability
		3,2 Low Si-TCO contact resistance
<b>4</b>	<b>ISE</b>	<b>Device integration</b>
		4,1 Implementation/optimization of promising materials in device structure
		4,2 Annealing/hydrogenation of TCOs
		4,3 Thermal/long-term stability of TCO bulk and interface properties
<b>5</b>	<b>ISE</b>	<b>Solar cell and module processing</b>
		5,1 Small-volume processing and mini-module integration
		5,2 Module stability
<b>6</b>	<b>CNRS</b>	<b>Simulation and Characterization</b>
		6,1 Evaluation of optical/electrical TCO losses and limitations
		6,2 Advanced material and interface analysis
		6,3 Loss analysis of solar cells and modules
<b>7</b>	<b>ISE</b>	<b>Economical evaluation</b>
		7,1 Evaluation of preselected promising cell designs

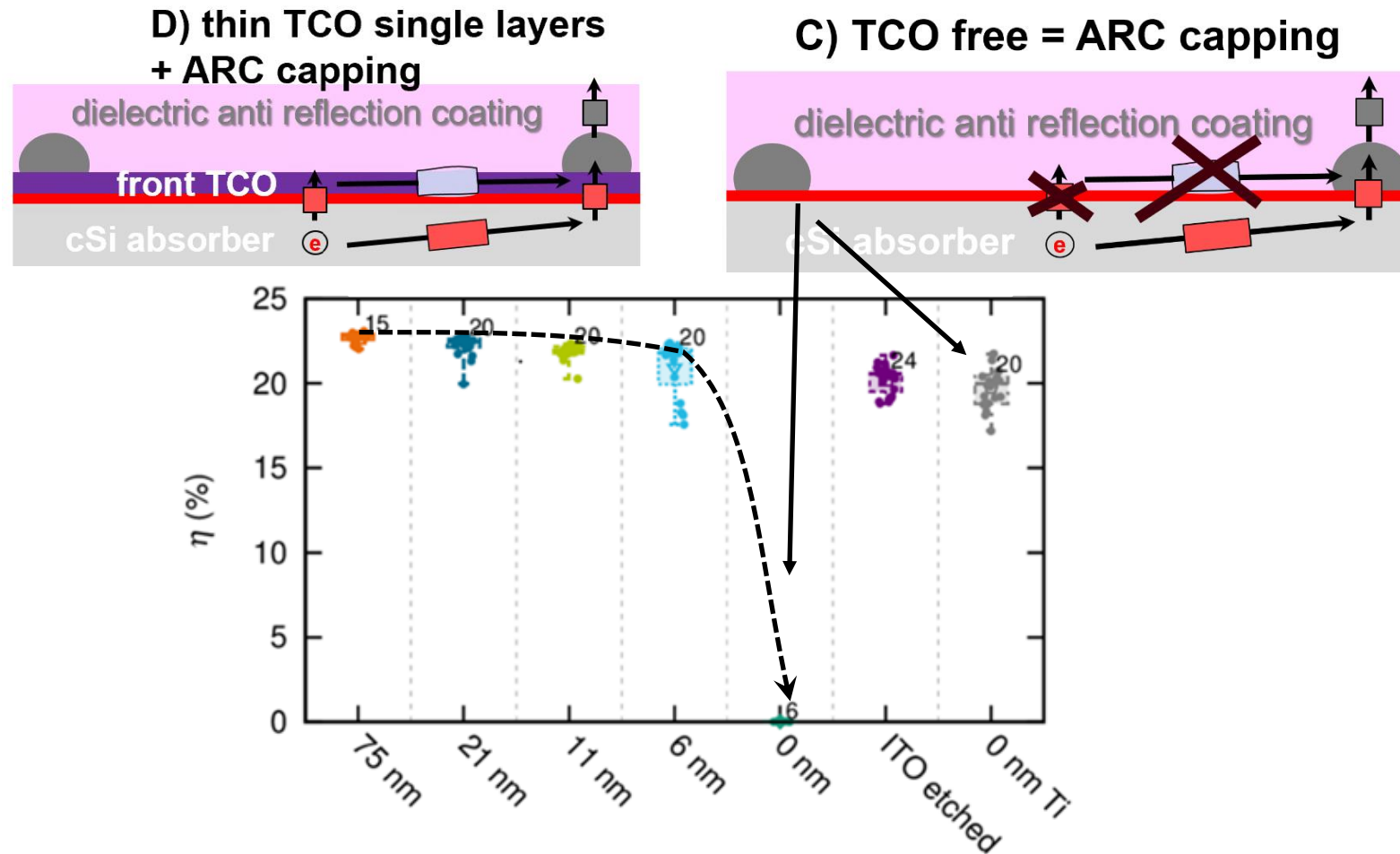
## Indium-lean and Indium-free SHJ cells





## Proof-of-principle TCO / Indium-free SHJ cells<sup>1</sup>

- Current industrial metallization scheme identified as one limitation



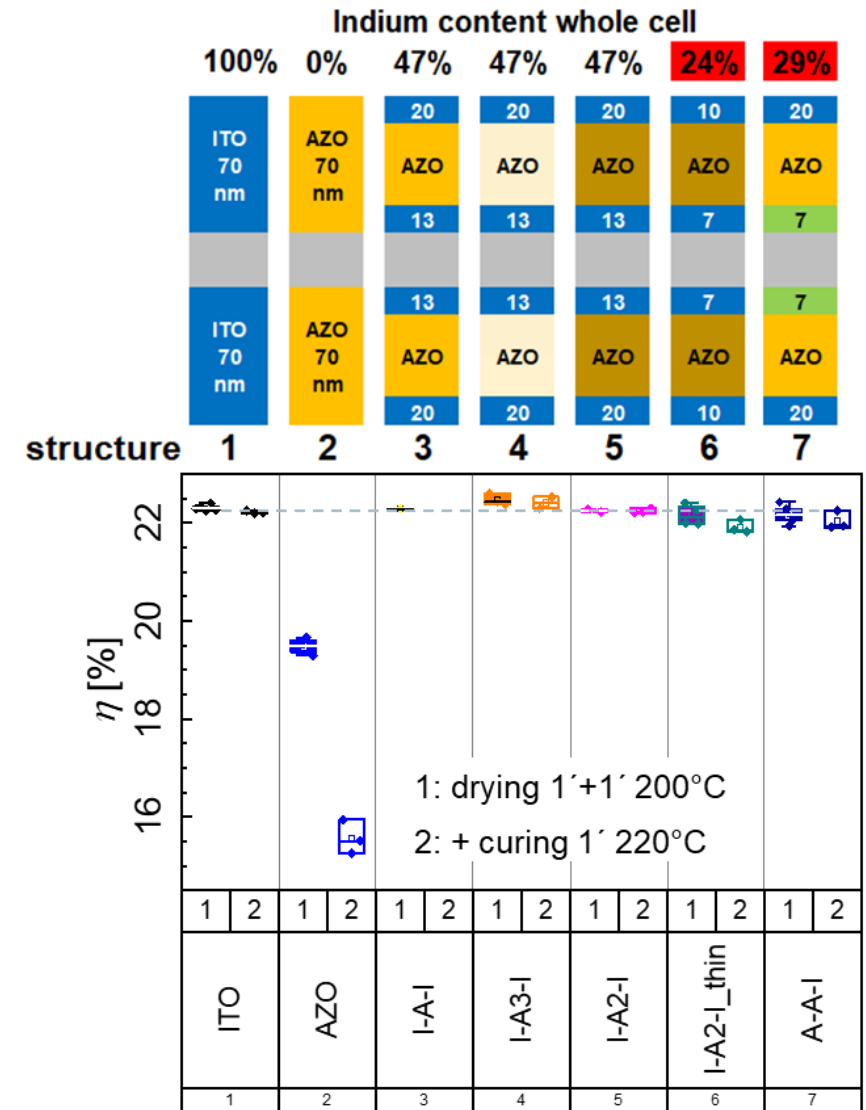
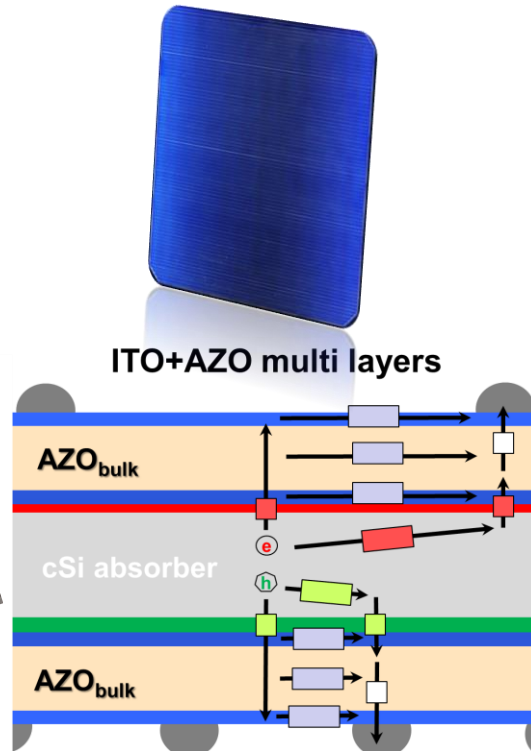
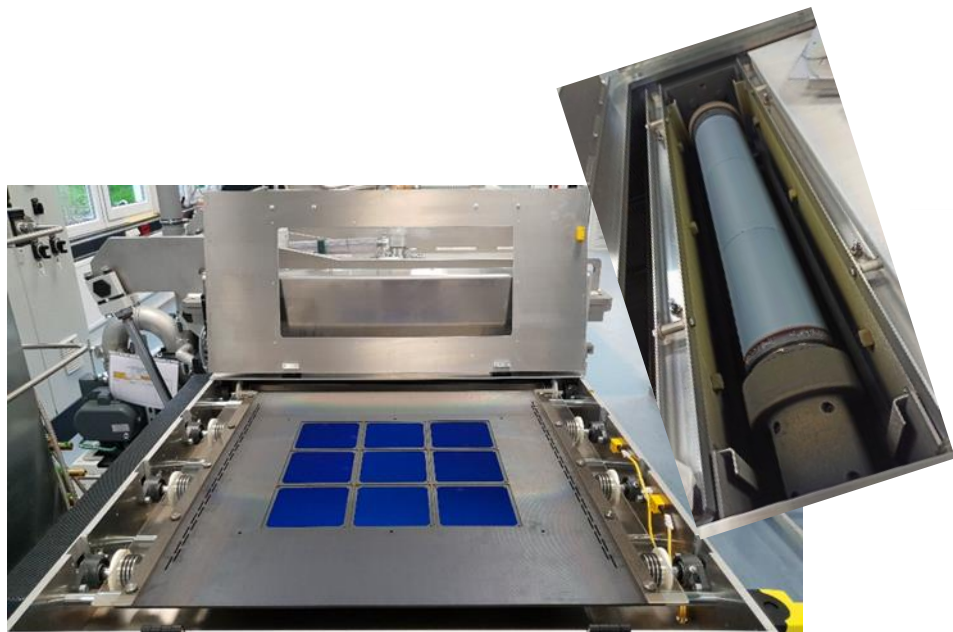
# « Exchange of Experiences » - Webinar

Insights, outcomes and results – 28 September 2023



## TCO multi layers<sup>2</sup>

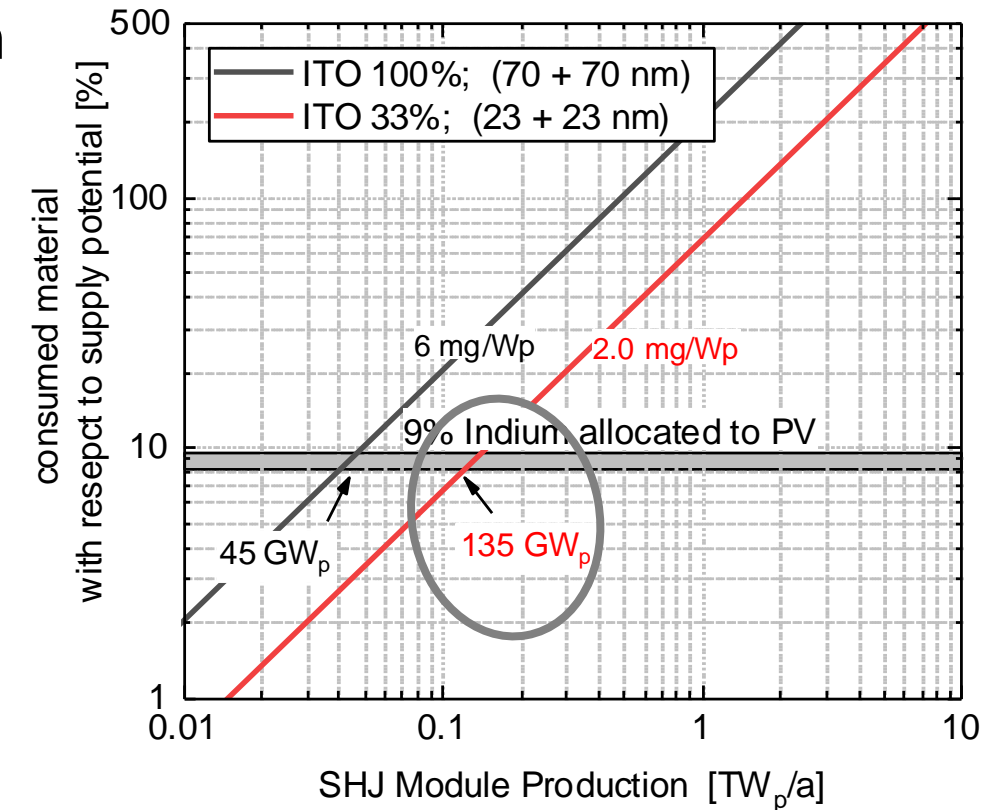
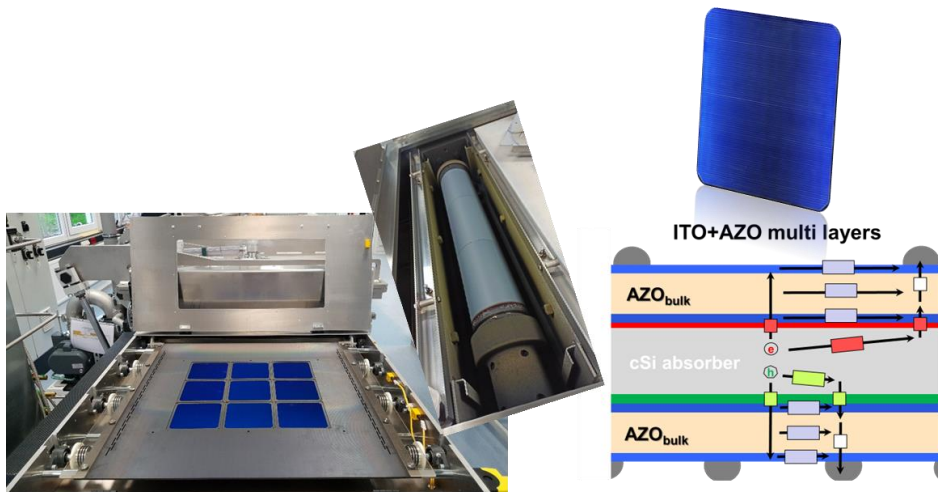
- Effective means for In-lean SHJ devices
- In-free bulk TCO layer sandwiched between thin In-based layers



## Indium will become a challenge for SHJ technology once it approaches mainstream

- In-lean SHJ devices a viable short-term solution
- More disruptive innovation needed for significant sustainable production volumes

Low TRL material science = high TRL upscaling  
→ In-free TCO's for large scale PV deployment



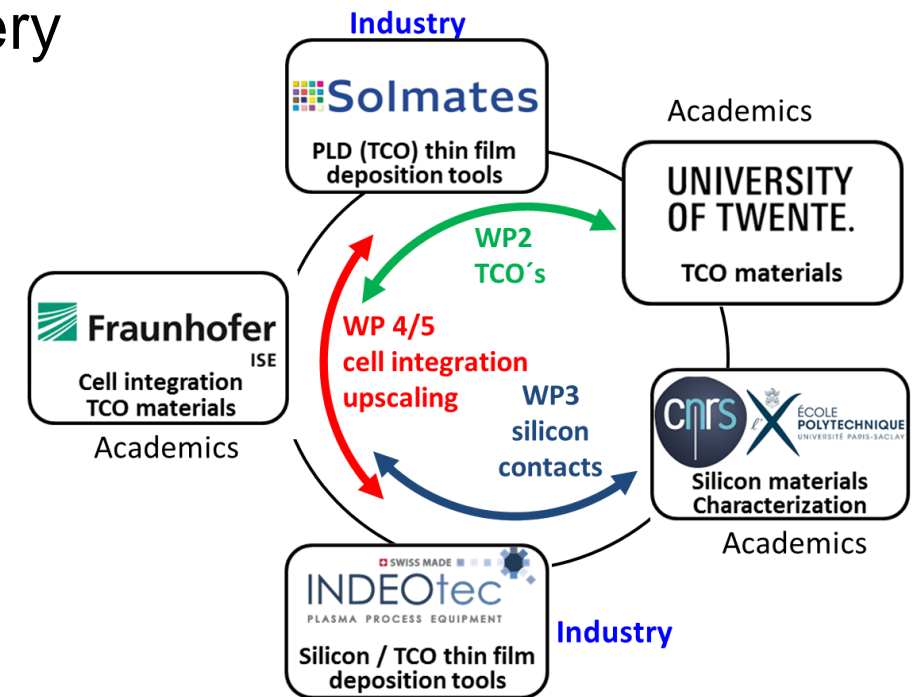
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Covid brought along some real challenges for the consortium

- National and trans-national agencies have been very supportive

## SOLAR-ERA.NET / CTEP

- Unique platform to foster EU-wide (+partners) collaboration and research
- Absolutely vital / efficient means to accelerate the energy transition in EU+
- Practical benefits over “classical” EU calls (HORIZON, ....)





# Thank you for your attention!

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## Contact

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