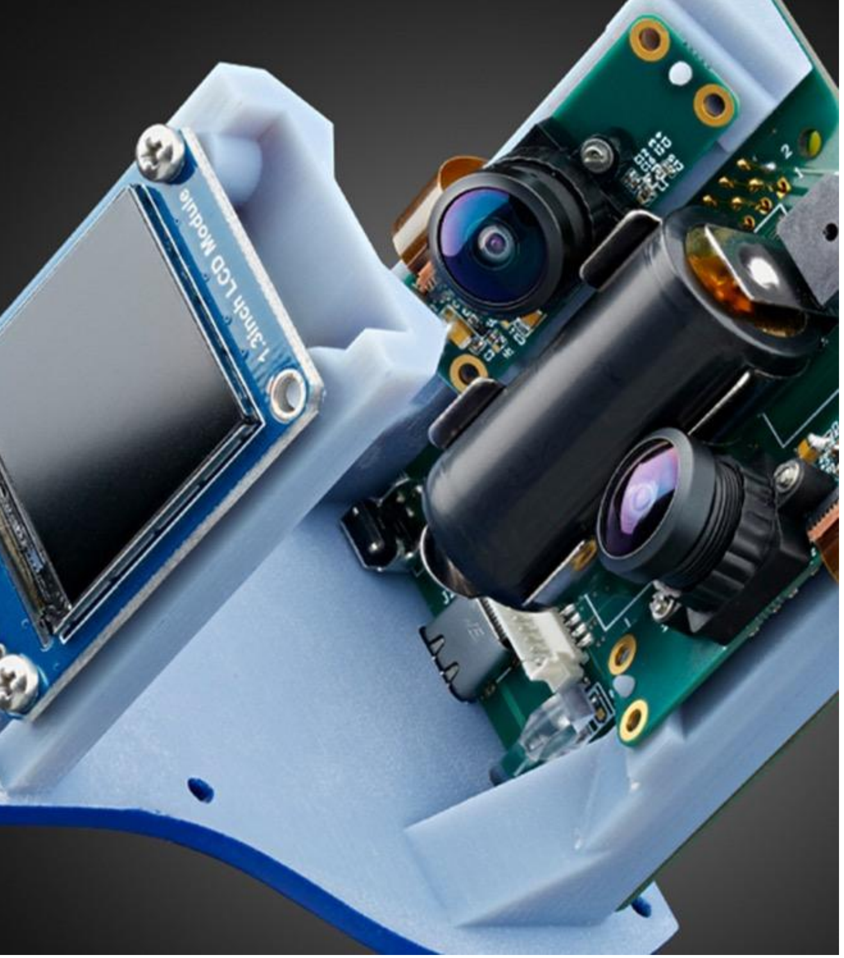

Laurie-Lou Senaud, Lison Marthey

RESILEX webinar, Monday 20.01.2025

ECO-DESIGN PV MODULES: BIO-BASED MATERIALS INVESTIGATION

ReSilex

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40 YEARS OF INNOVATION

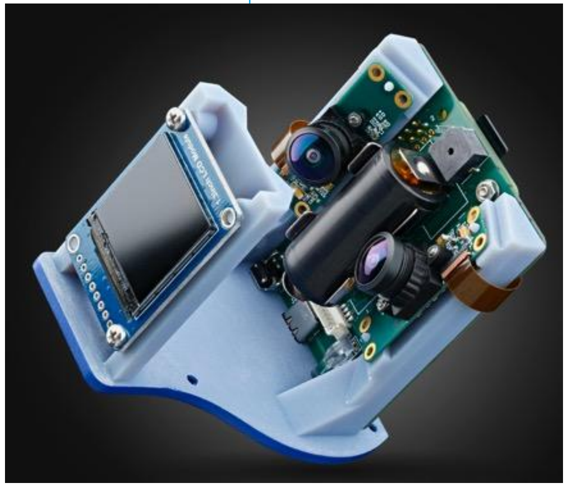
CSEM COMPANY OVERVIEW

We are a public-private,
non-profit, Swiss
technology innovation center.

We enable competitiveness
through innovation by
developing and transferring
world-class technologies to industry.

CSEM DNA COMES FROM WATCHMAKING ROOTS

Small & precise



Complex

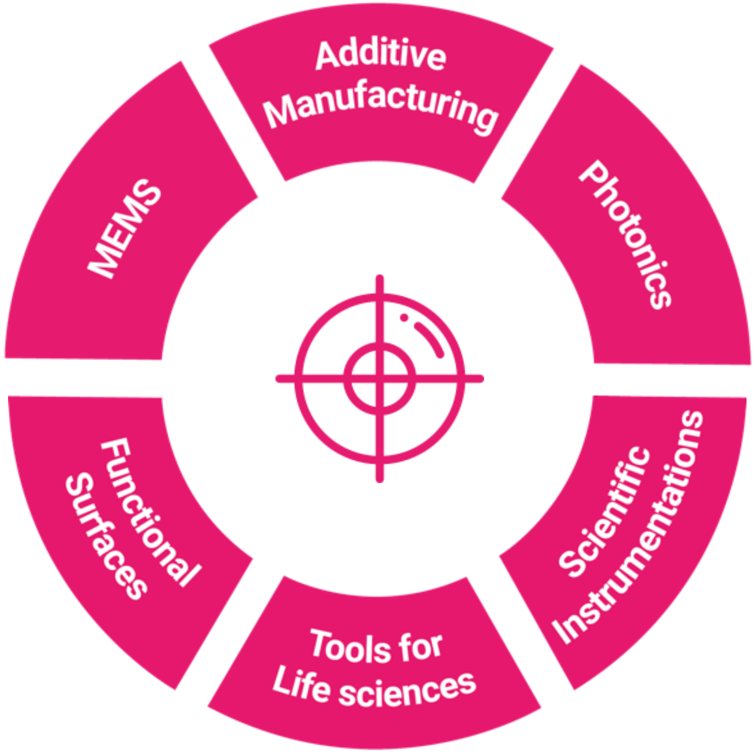
Ultra-low-power

Multidisciplinary

CSEM FOCUS ON THREE RESEARCH PRIORITIES

Digital Technologies

Precision Manufacturing



Sustainable Energy

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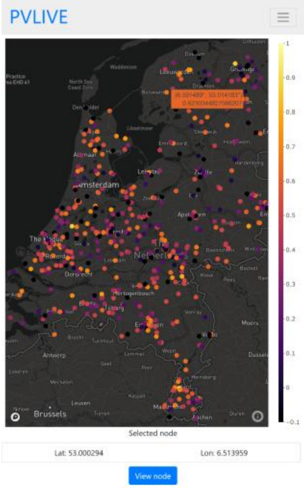
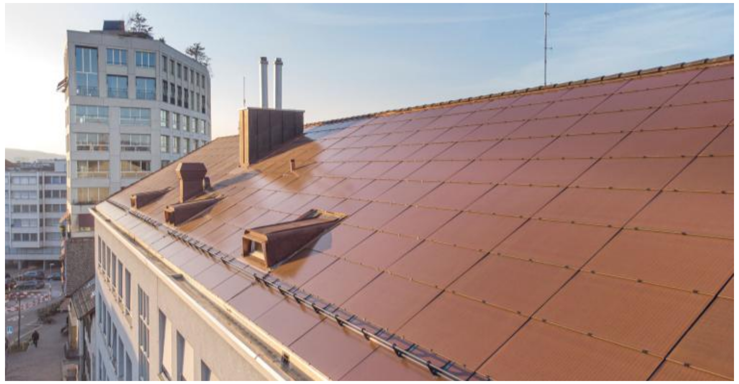
SUSTAINABLE ENERGY: RESEARCH ACTIVITIES





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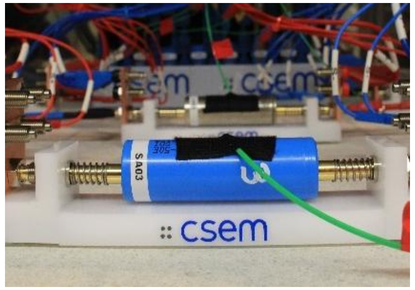
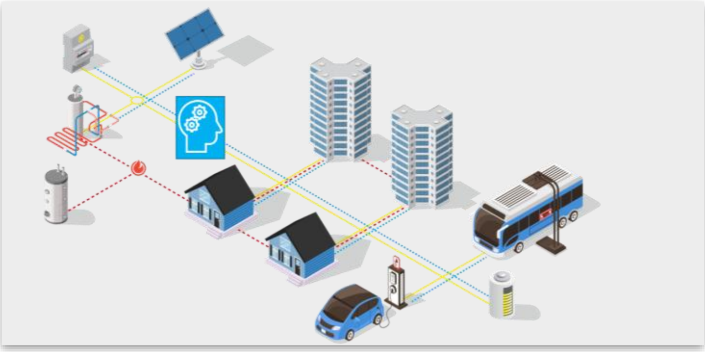
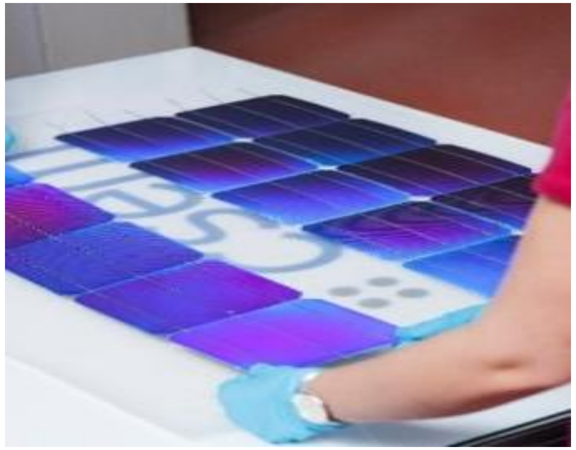






[**] in gCO_2eq/kWh
[1] IPCC 2014 - Climate Change 2014: Mitigation of Climate Change

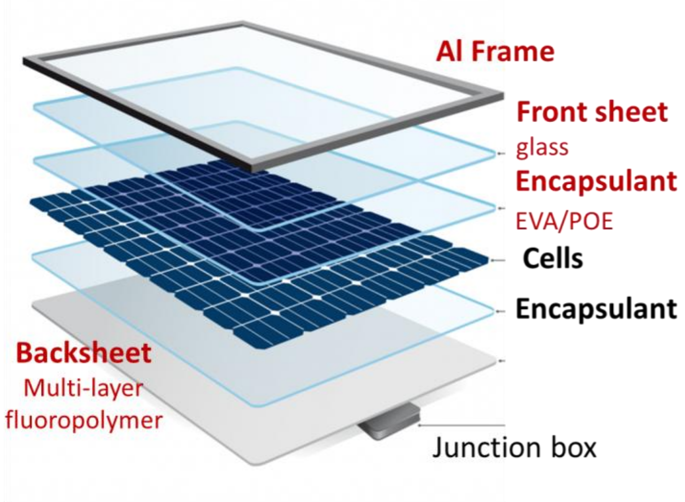
RESILEX PROJECT: PV MODULES

- PV provide electricity with less than 5% of the GHG emission[**] of coal power[1] but ways for improvement at manufacturing and end of life level

Photovoltaics (PV) is key for transition to lower environmental impact energy sources

PV modules on roof

Individual PV module



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RESILEX PROJECT: PV MODULES

- PV provide electricity with less than 5% of the GHG emission[**] of coal power[1] but ways for improvement at manufacturing and end of life level

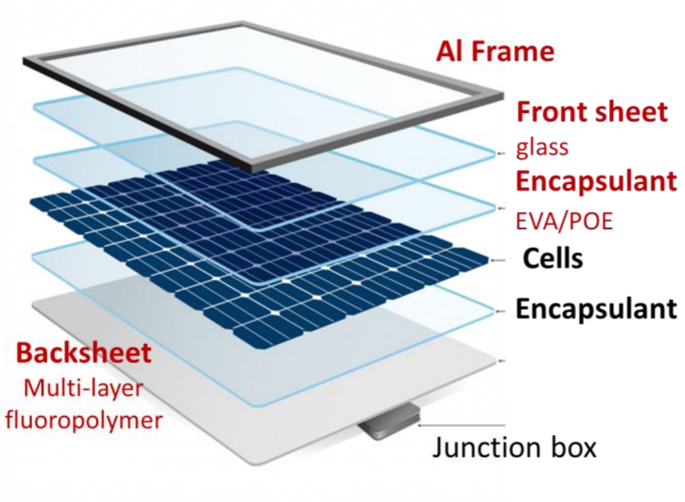
Demonstrate sustainable, eco-designed PV cells & modules

- Investigation of various components & materials at cell and module levels to reduce the environmental impact of PV modules

Photovoltaics (PV) is key for transition to lower environmental impact energy sources

PV modules on roof

Individual PV module



Investigation of eco-design/bio-based materials for PV module components

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[1] Müller et al., Solar Energy Materials and Solar Cells, 230, 9 2021
[2] Heath et al., Journal of the Air & Waste Management Association, 72(6):478–539, 6 2022

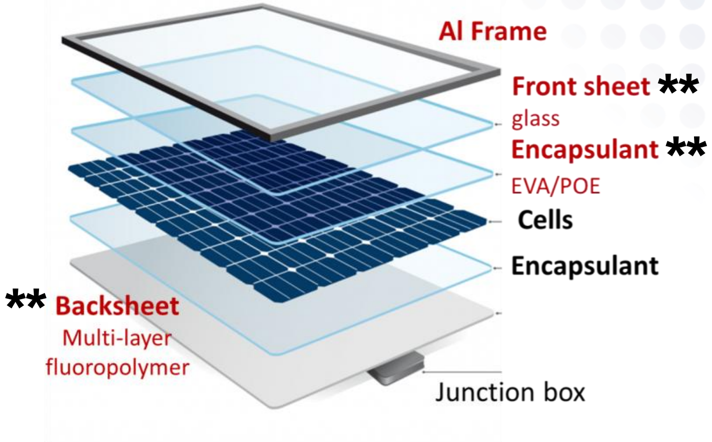
ECO-DESIGN PV MODULES

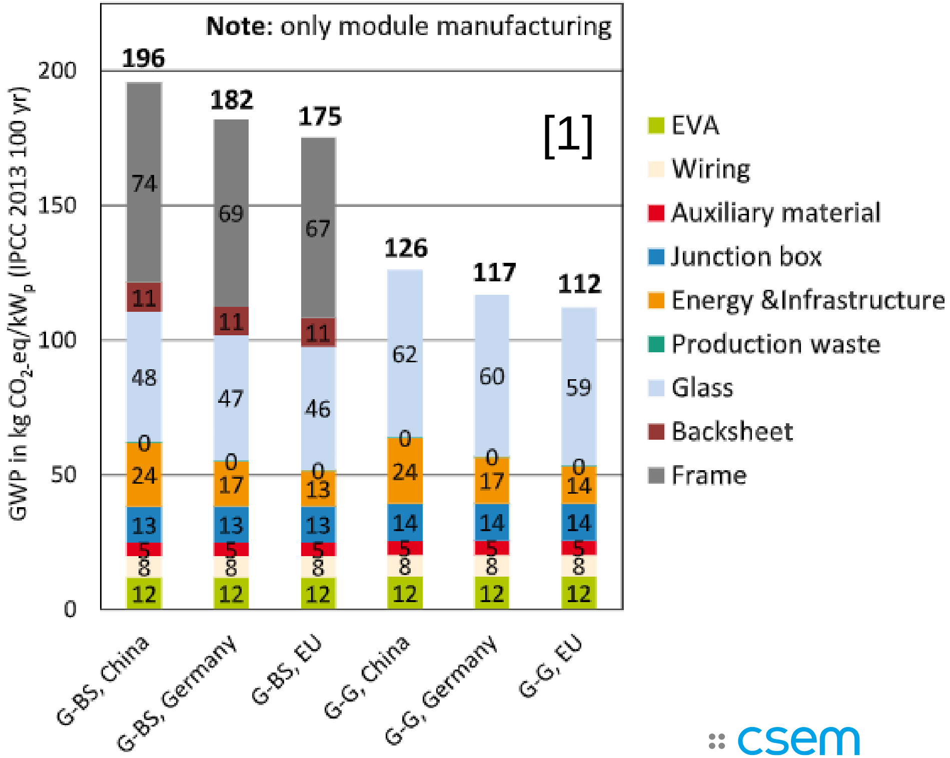
Conventional module BOM:

- Components with impacts on environment[1]: aluminium frame > glass > oil-based and/or fluorinated polymers**

Eco-design BoM investigation:

- Reduce environmental impact: circular economy precepts[2]
- While keeping high reliability (kWh) and efficiency (KWp & KWh)





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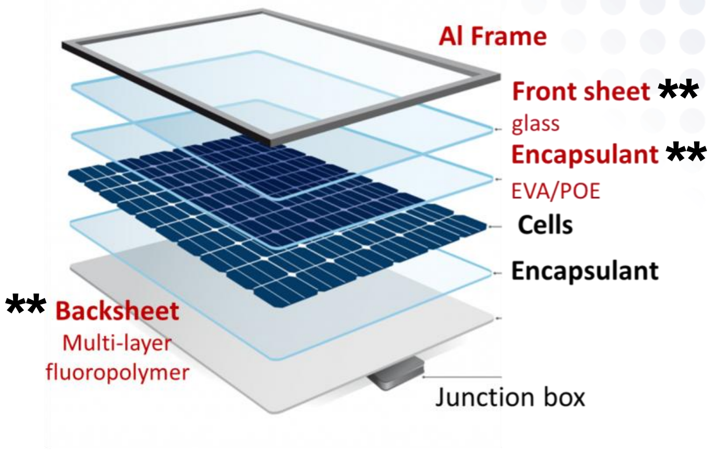
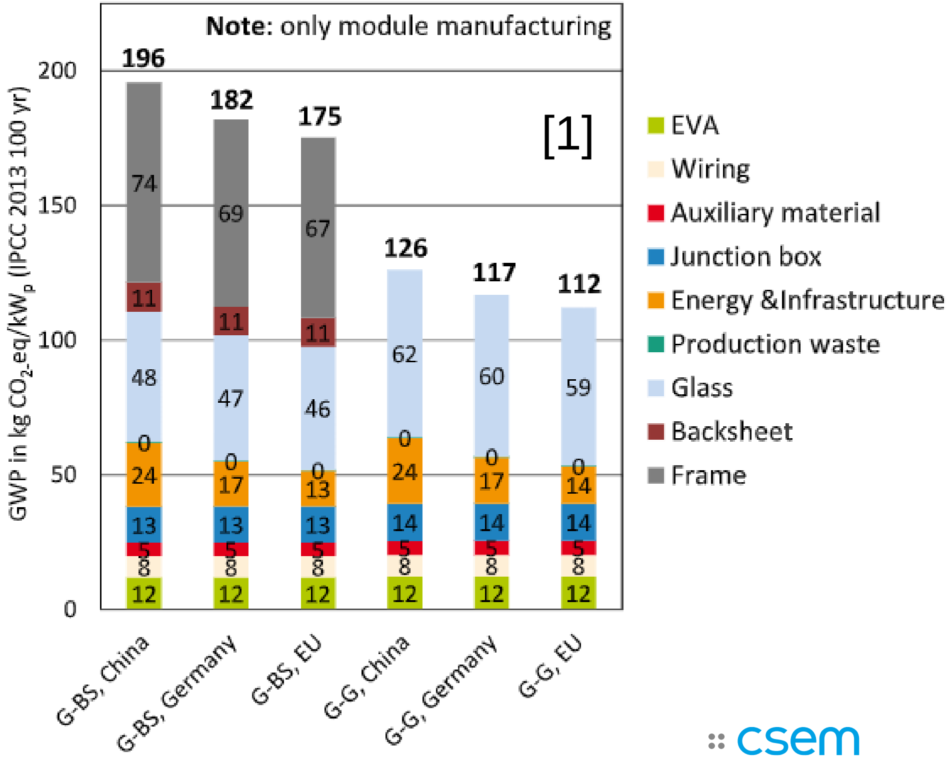
Biobased materials:

- Completely or partially derived from biomass (wood, bio-based polymers or bio-based composites)
- Can decrease dependance on fossil resources and mitigate associated environmental consequences

Are bio-based material suitable for PV? Is it environmentally relevant?





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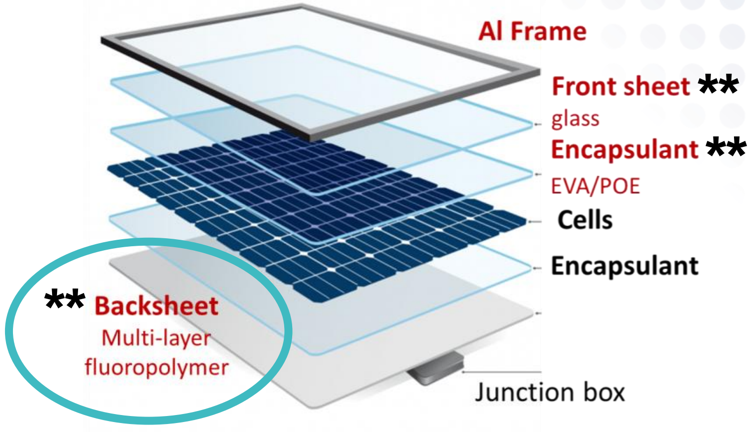
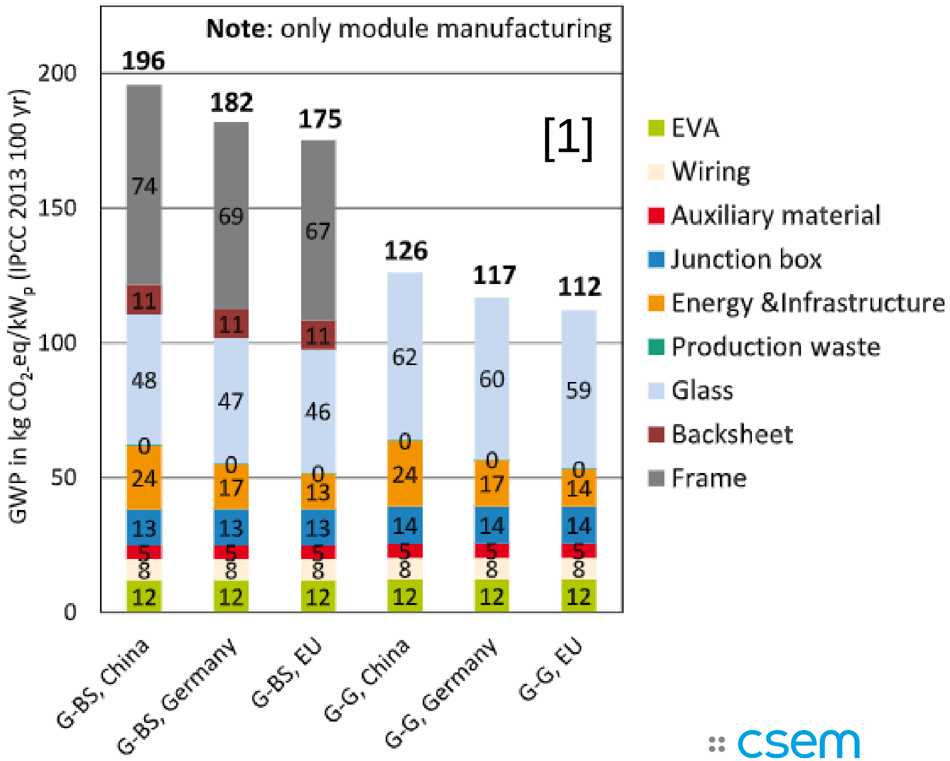
ECO-DESIGN BACKSHEET

- Front glass presents high impact ➔ could be replaced by polymer frontsheet using rigid backsheet for mechanical stability
- Conventional backsheet low environmental/CO_2 impact but:
    - Non-rigid material
    - Multiliayer polymers PET/fluorinated ➔ oil-based and fluor is costly to treat and manage during end-of-life due to fluorinated emissions and wastes[2]





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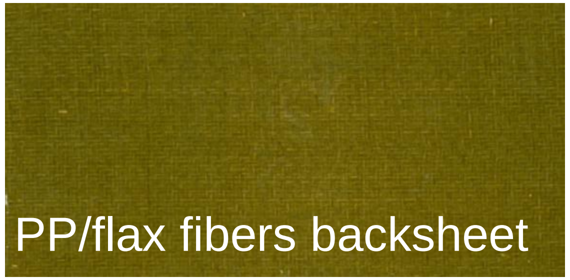
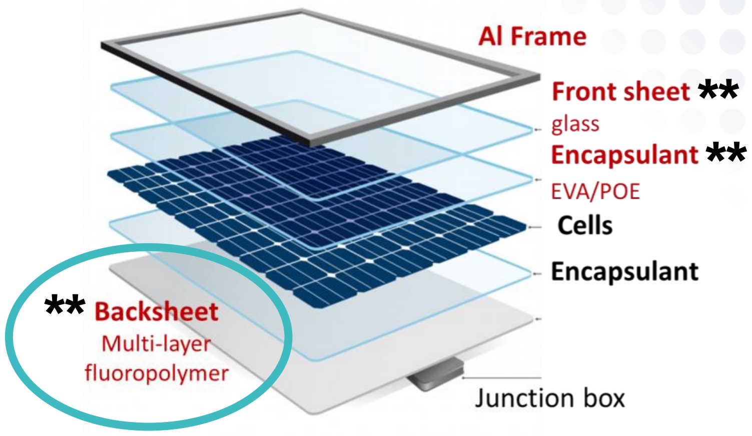
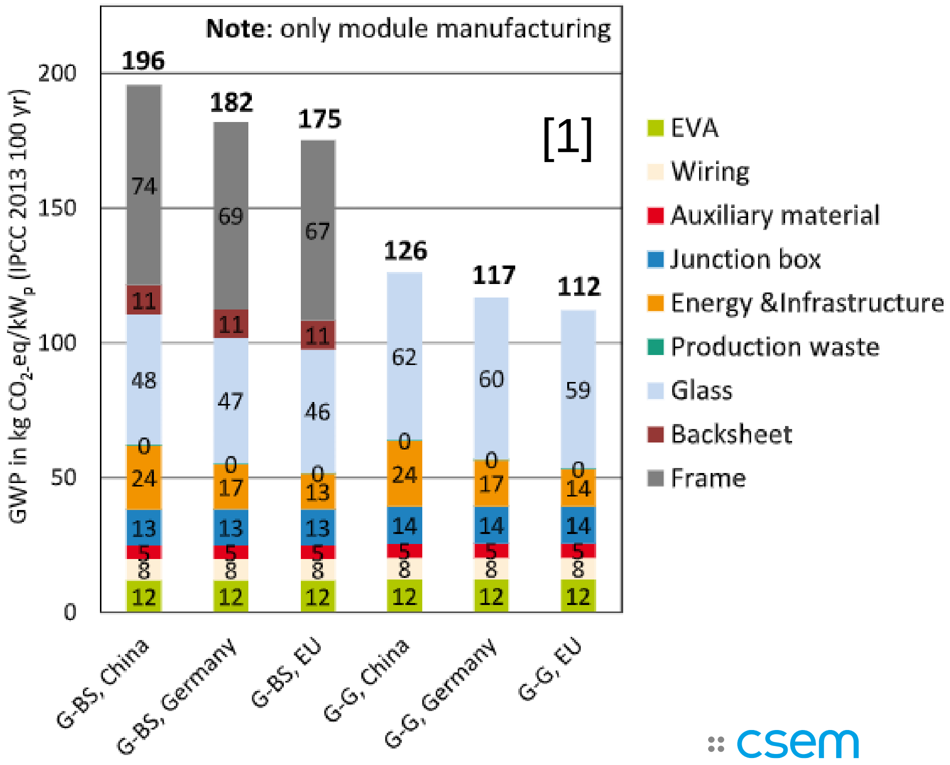
  - Multiliayer polymers PET/fluorinated ➔ oil-based and fluor is costly to treat and manage during end-of-life due to fluorinated emissions and wastes[2]
- **Objective:** developments of eco-design rigid composite backsheet to replace conventional one

➔ Investigation of biobased backsheet made of flax fibers composite and polypropylene (PP)



- Flax = bio-based material
- PP could be bio-sourced





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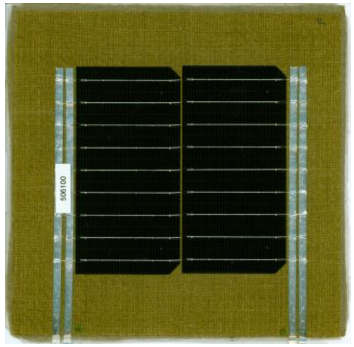
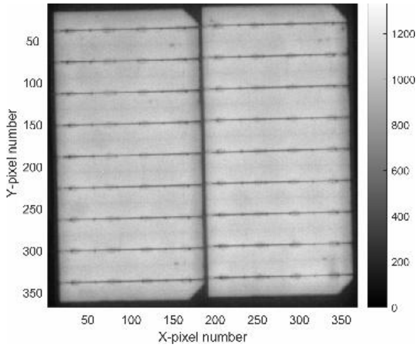
IMPLEMENTATION OF FLAX BACKSHEET

Conventional structure: glass/backsheet
- Majority of PV modules

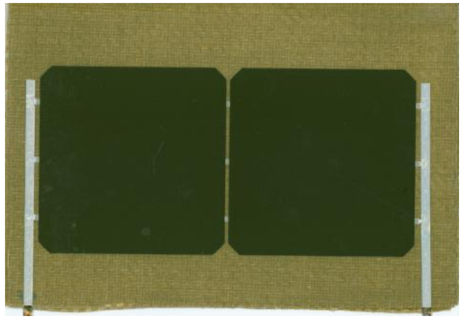
EL images



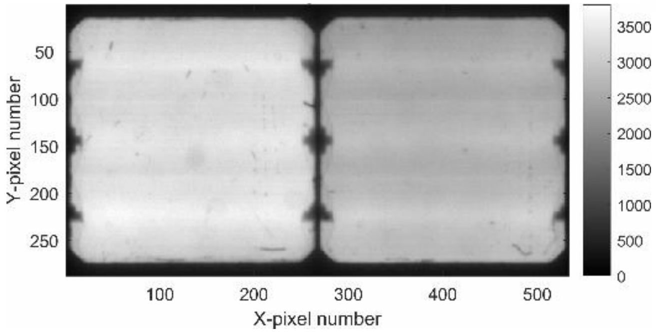
Bifacial PERC solar cell



Lightweight structure: polymer frontsheet/rigid backsheet
- For specific application or weight limited roofs



Back contacted (IBC) solar cell



➔ Successful lamination process: compatibility with other materials, no bubbles, no cell breaking

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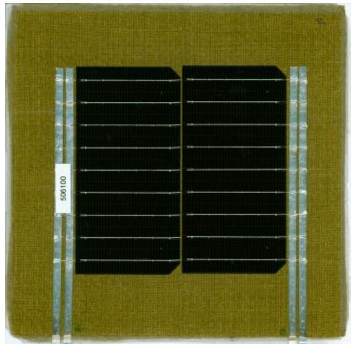

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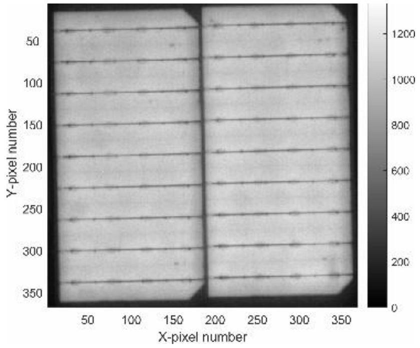

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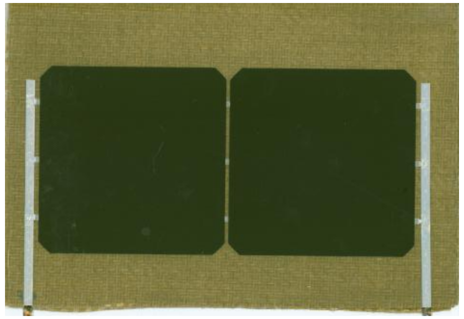

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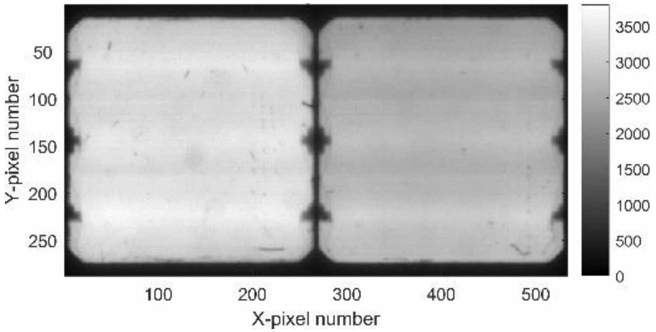
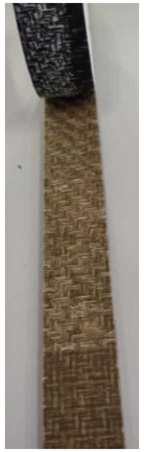


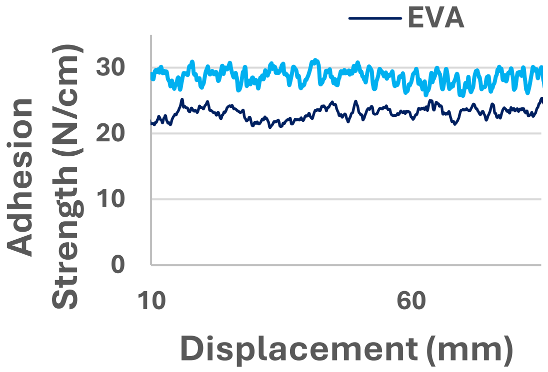
➔ Successful lamination process: compatibility with other materials, no bubbles, no cell breaking

Challenges:

- Low adhesion between encapsulant and backsheet: **key for reliability**
- Delamination interface: inside the composite itself, at the PP resin/flax fibers interface

➔ Further investigations to improve the composite adhesion required





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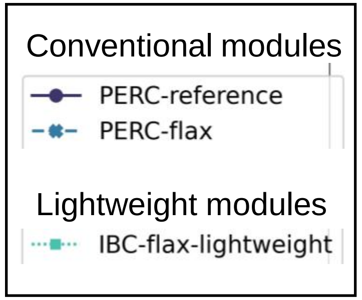
FLAX BACKSHEET MODULES RELIABILITY

Reliability testing:

- Damp Heat (DH): 85°C, 85%RH
  - Critical for humidity sensitive cell technologies
  - IEC norm: power loss <5% after 1000 hours
- Thermal Cycling (TC) -40°C → +85°C (at MPP for ramp up)
  - Critical for potential mismatch between thermal expansion coefficients of the different PV components
  - IEC norm: power loss <5% after 200 cycles



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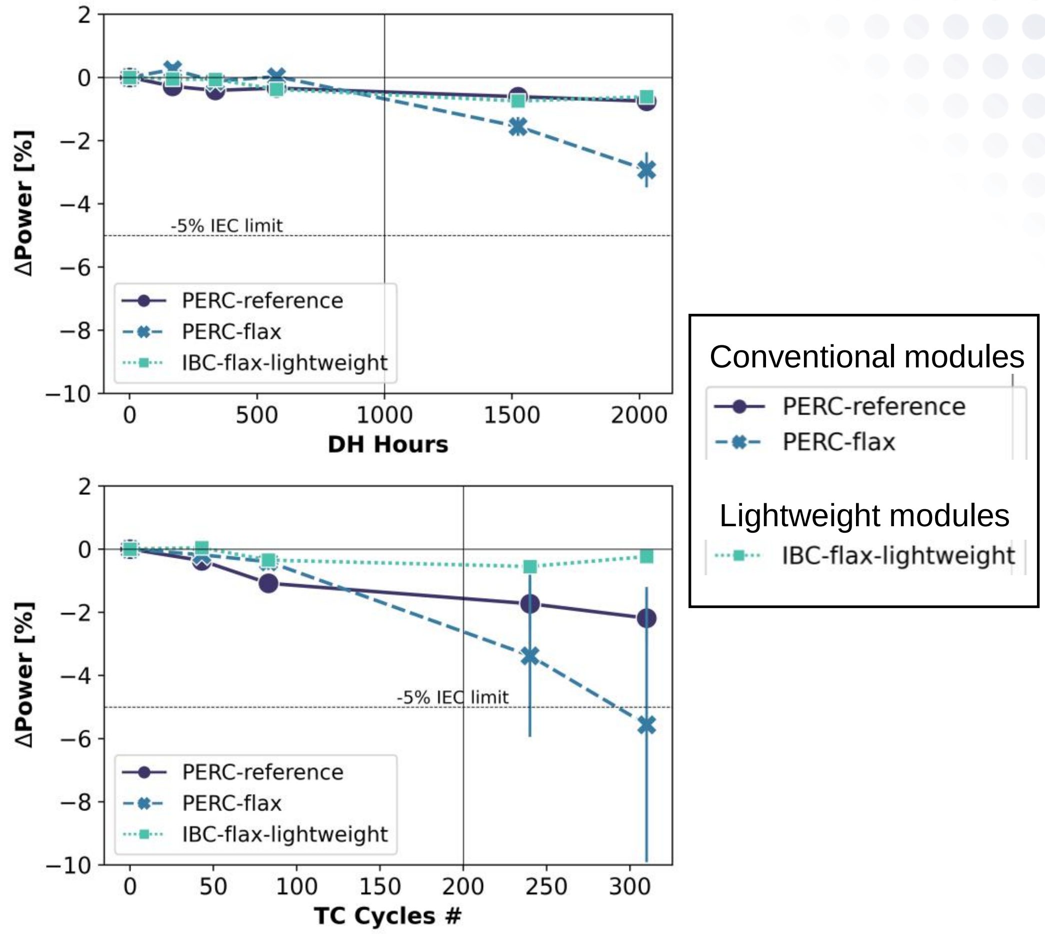
  - Critical for potential mismatch between thermal expansion coefficients of the different PV components
  - IEC norm: power loss <5% after 200 cycles
- Lightweight PV modules integrating flax backsheet presents high reliability, similar to the conventional structure
  - <u>DH:</u> all PV modules pass 2x IEC norm
  - <u>TC:</u> all PV modules pass 1x IEC, conventional structure with flax backsheet fall below -5% after ~270 hours



→ Promising results: Flax backsheets pass 1x the IEC norm in DH and TC for both conventional and lightweight structure

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[2] Heath et al., Journal of the Air & Waste Management Association, 72(6):478–539, 6 2022

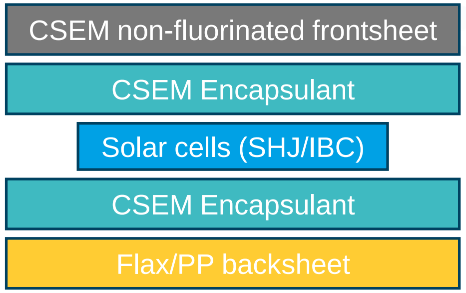
FLAX BACKSHEET MODULES IMPROVEMENTS

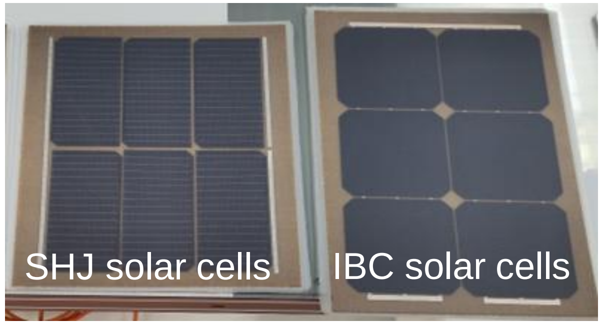
Further eco-design BoM improvement:

- Reduce environmental impact
- Improve reliability

Lightweight PV modules:

- Polymer frontsheets exist but many are fluorinated[2] ➔ CSEM developed its own non-fluorinated frontsheet
- Backsheet flax/PP
- CSEM formulation for encapsulant can be bio-sourced





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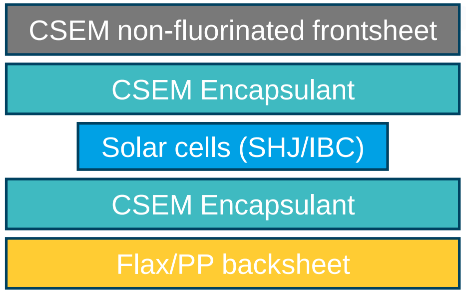
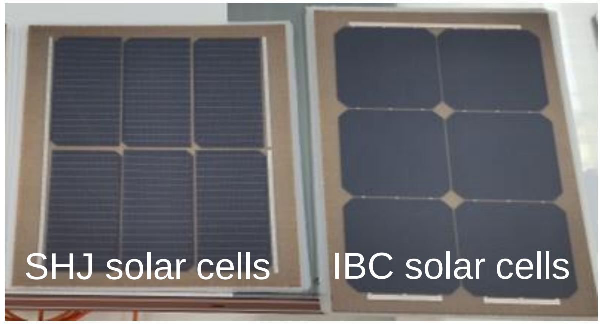
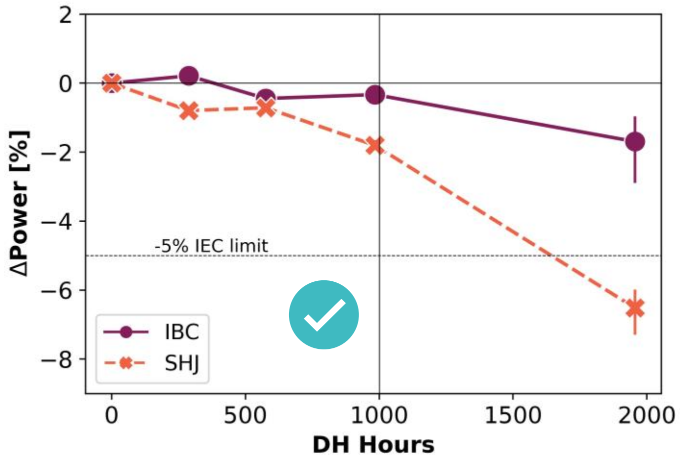
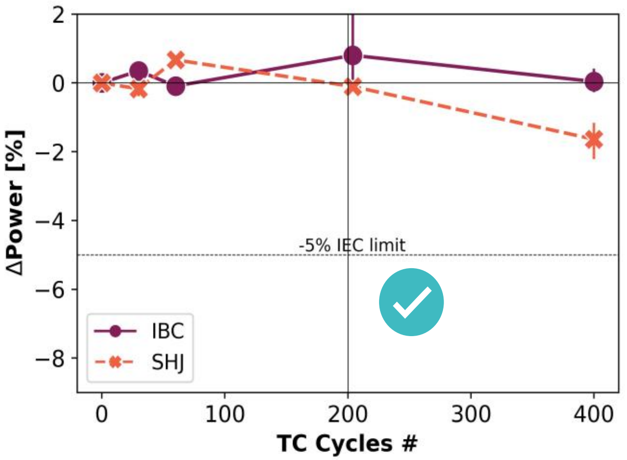




DH: IBC still stable after 2xIEC & SHJ passed below IEC norm after 1500 hours ➔ SHJ solar cell technologies are more sensitive to humidity

➔ Lightweight PV modules integrating **non-fluorinated frontsheet**, **CSEM encapsulant** and **flax backsheet** pass the IEC norm in TC and DH





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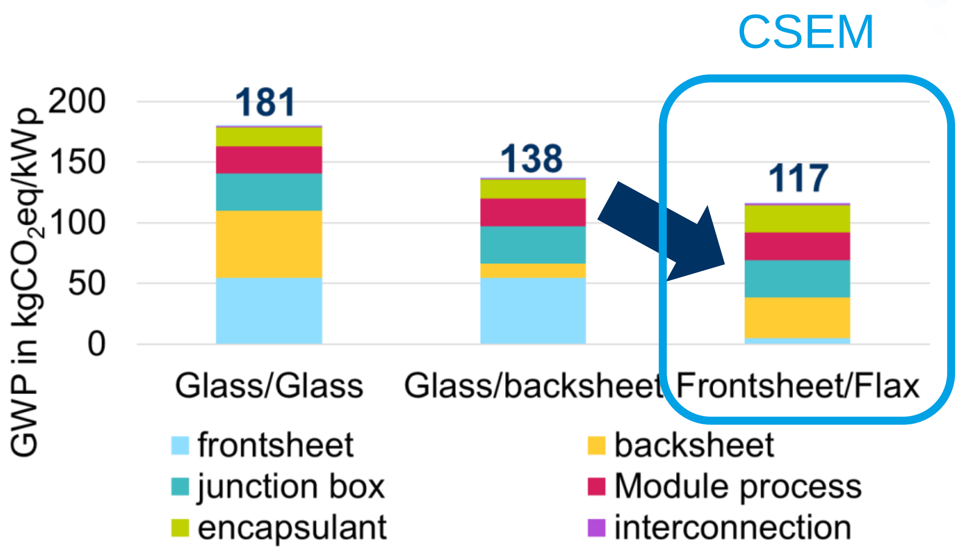
FLAX BACKSHEET MODULES RELIABILITY

Environmental impact of the modules production:

- Glass-glass modules ➔ highest global warming potential due to the glass contribution
- CSEM non-fluorinated polymer frontsheet and flax backsheet ➔ lowest environmental impact

Global warming potential (GWP) in kCO$_2$eq/kWp of the modules production



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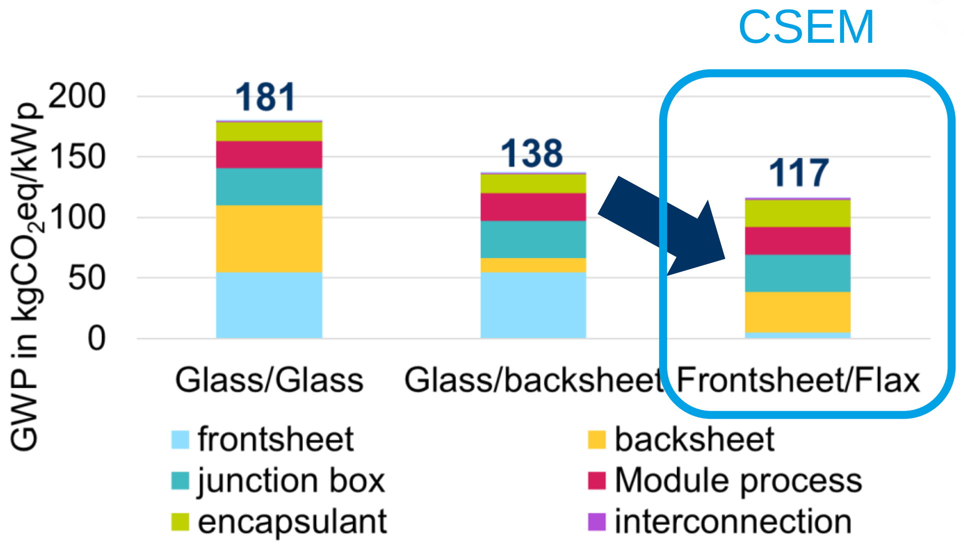
Flax backsheet:

- Higher environmental impact than conventional backsheet
- But provides the mechanical stability allowing to remove the glass ➔ reduce the total PV module GWP

➔ In-depth investigation of the different LCA impact categories to compare flax and conventional backsheet env. impacts

➔ Results are for module manufacturing (CO_2eq./kWp): important to investigate the module lifetime and end of life(CO_2/kWh)

Global warming potential (GWP) in kCO_2eq/kWp of the modules production



➔ PV module reliability impact: find the best trade-off between long lifetime and eco-design PV module BOM

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CONCLUSION AND NEXT STEPS

- Environmental benefits of PV modules with biobased materials are not always guaranteed and require validation
  ➔ Require holistic approach considering module performance, module lifetime, module production and end-of life
- Removing front glass of PV modules is significant to reduce its environmental impact
  ➔ Need of a rigid composite backsheet to bring mechanical stability
- Flax backsheets demonstrated promising results:
  - Successful lamination process compatible with others PV module components
  - Passed the IEC norm in DH and TC for both conventional and lightweight structures
  - Non-fluorinated composite & the PP can be bio-sourced

➔ The environmental impact of flax backsheet will be investigated in more details, especially by comparing the different impact categories, to investigate their contributions in the total CO_2eq emission

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THANK YOU FOR YOUR ATTENTION

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Senior R&D engineer

Crystalline Silicon Solar Cells

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REFERENCES

- [IPCC 2014 - Climate Change 2014: Mitigation of Climate Change] Bruckner T., I.A. Bashmakov, Y. Mulugetta, H. Chum, A. de la Vega Navarro, J. Edmonds, A. Faaij, B. Fungtammasan, A. Garg, E. Hertwich, D. Honnery, D. Infield, M. Kainuma, S. Khennas, S. Kim, H.B. Nimir, K. Riahi, N. Strachan, R. Wiser, and X. Zhang, 2014: Energy Systems. In: Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Edenhofer, O., R. Pichs-Madruga, Y. Sokona, E. Farahani, S. Kadner, K. Seyboth, A. Adler, I. Baum, S. Brunner, P. Eickemeier, B. Kriemann, J. Savolainen, S. Schlömer, C. von Stechow, T. Zwickel and J.C. Minx (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA?

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FACING THE CHALLENGES OF OUR TIME