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PECSYS Virtual Workshop
5th November 2020

WP 1 PECSYS Project Overview

S. Calnan (Helmholtz Zentrum Berlin, DE)
With contributions from all Consortium partners

Disclaimer

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sonya.calnan@helmholtz-berlin.de

Outline

1. Project fact sheet
2. Specific objectives and expected impacts
3. PECSYS concept
4. PECSYS approach
5. Project implementation
6. Overview of technical work packages to be presented today

sonya.calnan@helmholtz-berlin.de

Factsheet PECSYS

www.pecsys-horizon2020.eu
Jan 1, 2017 to Dec 31, 2020

Demonstrate a system for solar driven H_2 production on an area exceeding 10 m^2

Performance measure	Target	Relevance
Hydrogen production rate	≥ 16 g/hr	Yield at maximum irradiance
Solar to hydrogen (STH) efficiency	> 6%	Efficiency
Device stability, ΔSTH	< 10% after ½ year	Service life, reliability
Cost target, LCOH	< € 5/kg*	Economic feasibility

*LCHP: levelised cost of hydrogen production, EU Fuel Cells and Hydrogen Joint Undertaking Initiative target for 2015

Coordinator

Until Oct 2019

sonya.calnan@helmholtz-berlin.de

Specific objectives and expected impacts

Specific Objectives

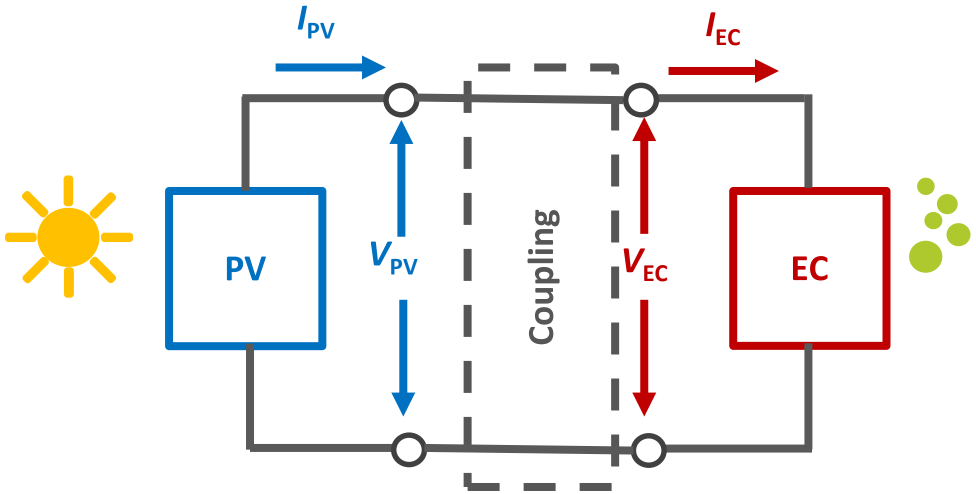
- New record PV-EC devices for thin film silicon, crystalline-Si and CIGS based approaches
- Electrolysis cells adapted for low and intermittent current densities
- Sealing concepts beyond state-of-the-art
- Demonstration of 10 m^2 solar to hydrogen system with long lifetime

Expected Impacts

- A better understanding of the effect of variable solar irradiation and thermal management of systems for direct hydrogen production from sunlight
- Scale-up and proof of technical feasibility through in-field testing
- Cost analysis and quantification of environmental impact

sonya.calnan@helmholtz-berlin.de

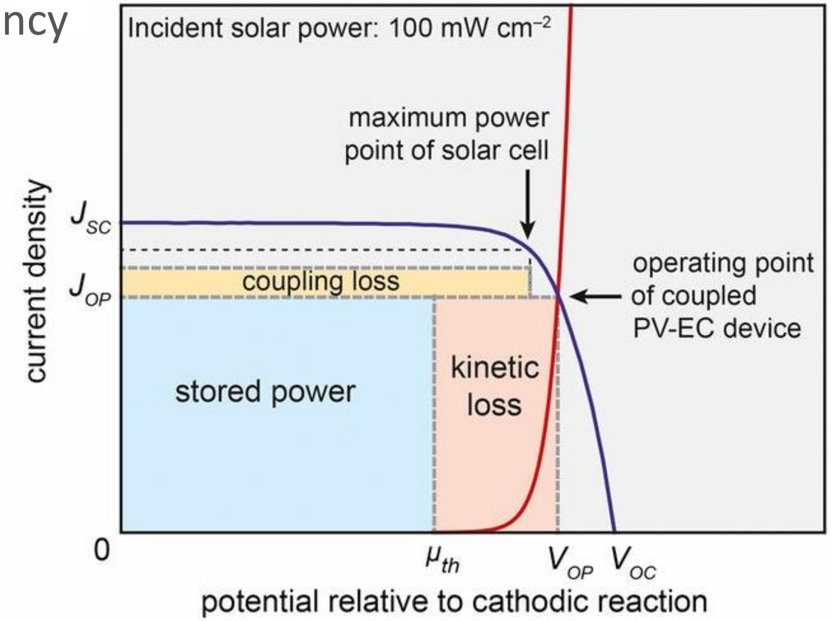
PECSYS Concept



Solar to hydrogen conversion efficiency

$$\eta_{STH} = \frac{j_{op} \times (1.23\ V) \times \eta_F}{P_{light}}$$

$$\eta_{STH} = \frac{\Phi_{H_2} \times \Delta G}{P_{light} \times S}$$



Winkler et al. PNAS 2013;110:E1076-E1082

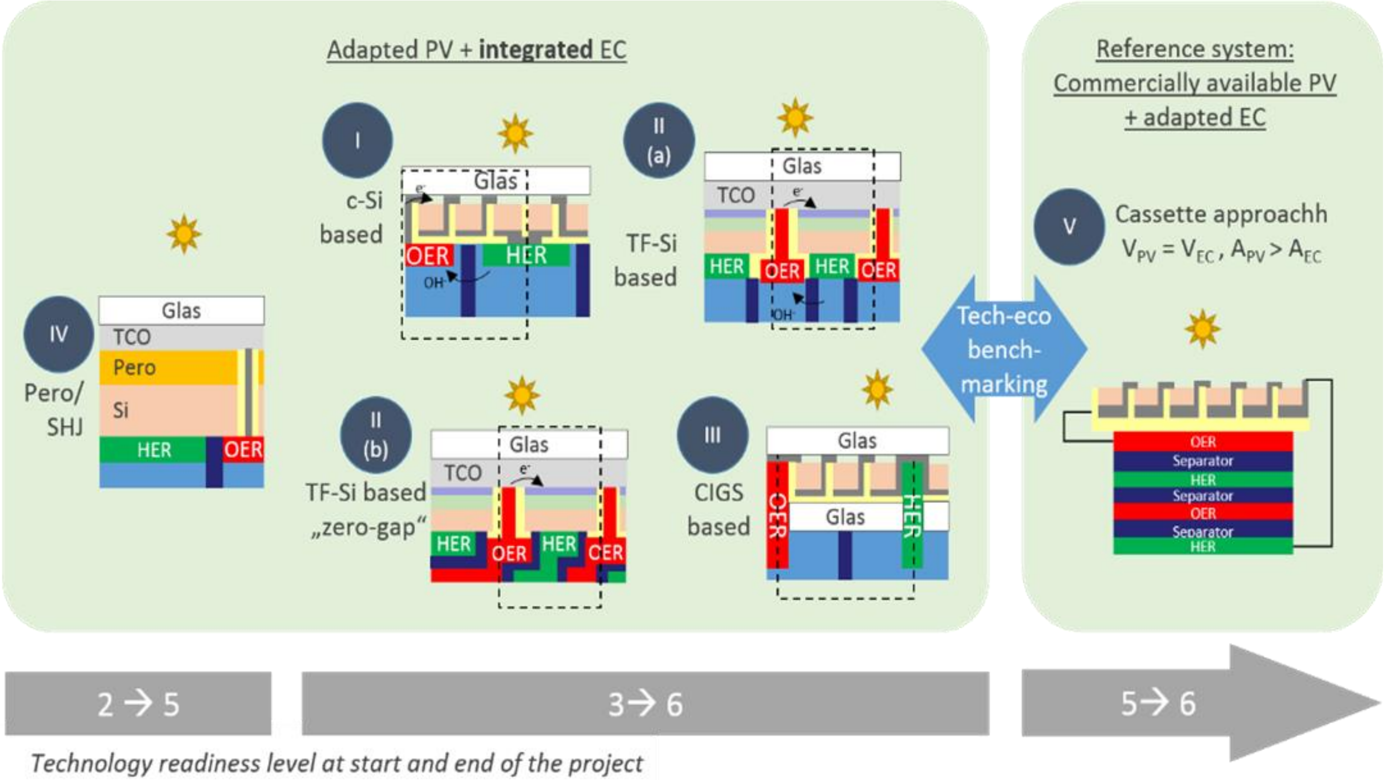
- Compared to decoupled systems:
    i. Reduced capital costs due to the absence of expensive parts (inverters, wires)
    ii. Improved performance at elevated temperatures (positive temperature coefficient)
    iii. Reduced ohmic transport losses due to small distances
- Efficiency advantage over photoelectrochemical water splitting [1].
- Cost advantage over solar thermal hydrogen production [2].
- Technically feasible in temperate climates unlike concentrated PV or solar thermal hydrogen production [2].

[1] Kim et al., (2019) Chem. Soc. Rev., 48:1908
[2] Grube et al. (2020) Sust. Energy Fuels, 4:5818

PECSYS Concept

- Combines the learning curve of PV modules with the advantages of integrated devices
- Reduced material costs
  i. PV earth abundant photoabsorber materials
  ii. Reduced noble metal loading for PEM
  iii. Complete avoidance of noble metals catalysts for alkaline electrolysis
- Scale-up from $10^0 \rightarrow 10^3 \rightarrow 10^4$ cm^2
- Modular systems:
  i. Both PV and electrolysis allow flexible installed capacity from kW (distributed, residential) to MW (centralised, utility)
  ii. Primary target is for decentralized energy systems in the kW-range

PECSYS Approach



External factors required adaptation of the approach

- No more thin film silicon production in Europe
- Insolvency of one industrial partner (Solibro Research AB)
- Work force gaps, Corona, etc

Initial approach

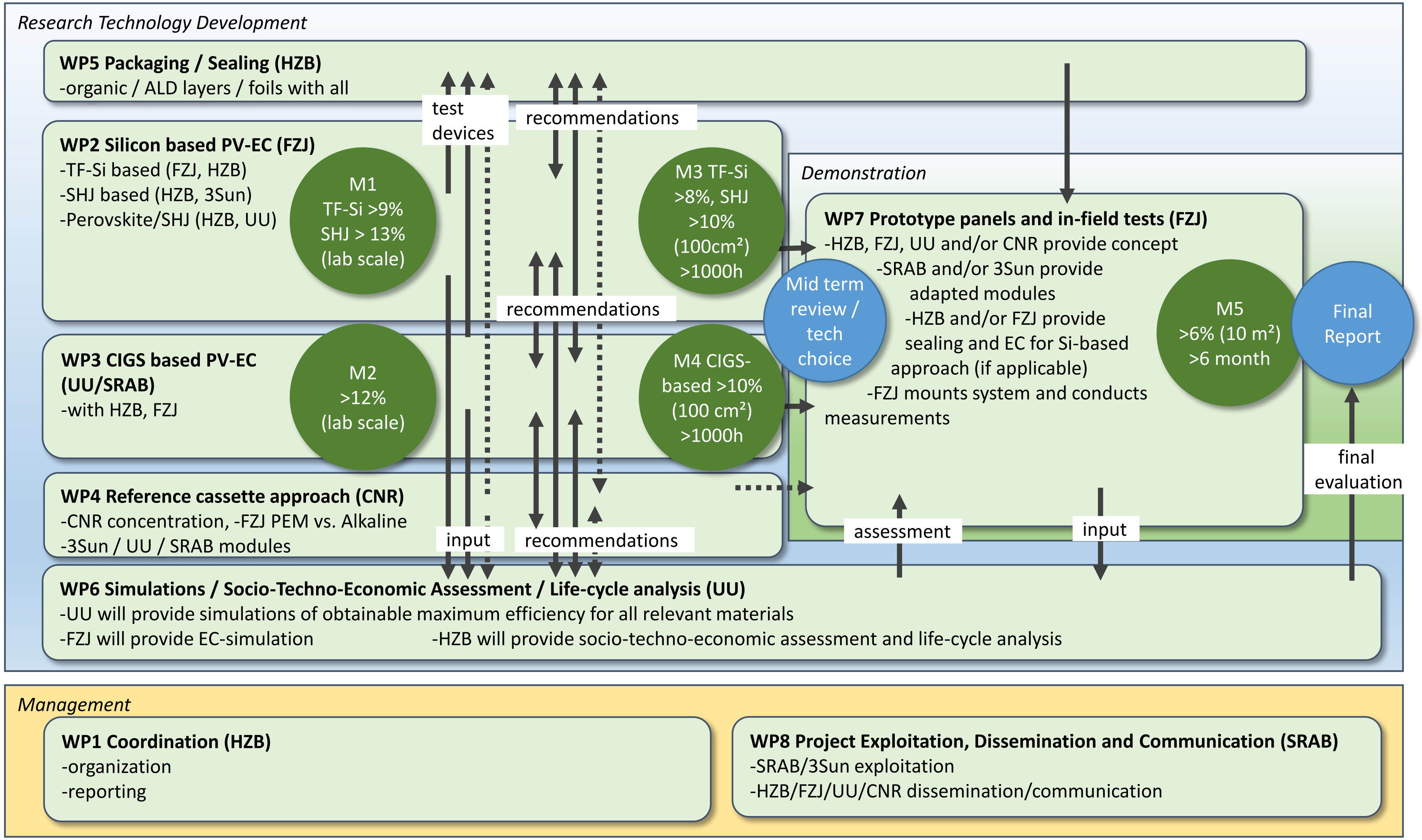
1. **Explore:** different PV-EC device technologies ~ cm²
2. **Select:** most efficient, reliable & economical options
3. **Implement:** scale to demonstration level > 10 m² systems

Revised approach

1. **Explore:** different PV-EC device technologies ~ cm²
2. **Scale up:** for all options as far as possible
3. **Implement:** Investigate outdoor behaviour regardless of scale

sonya.calnan@helmholtz-berlin.de

PECSYS Implementation



Details adapted to external changes

- No more thin film silicon production in Europe;
- Insolvency of one industrial partner (Solibro Research AB)
- Work force gaps, Corona, etc

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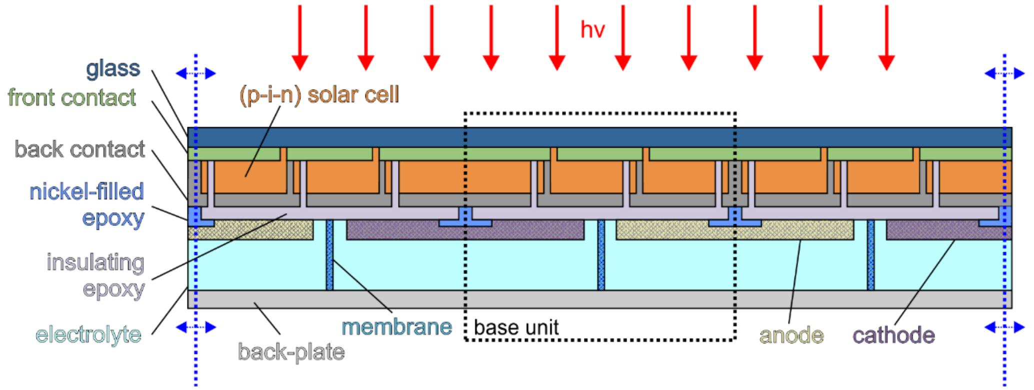
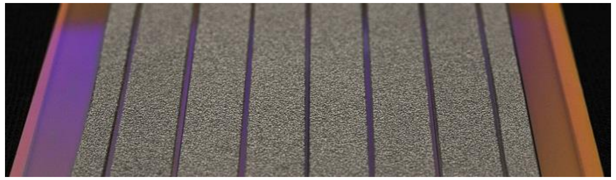
WP 2 Silicon based photovoltaic integrated alkaline water electrolysis





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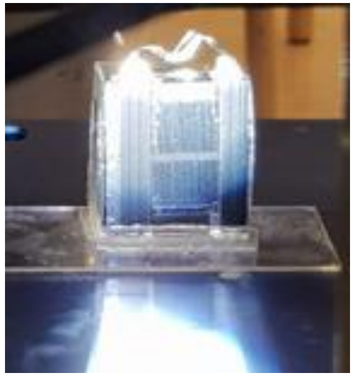
- Wireless monolithic design
- a-Si:H/µc-Si:H tandem PV cell
- Nickel foil electrodes glued to rear of PV part and exposed to 1.0 M KOH
- Scale-up from **1 cm² to 64 cm²** active device area

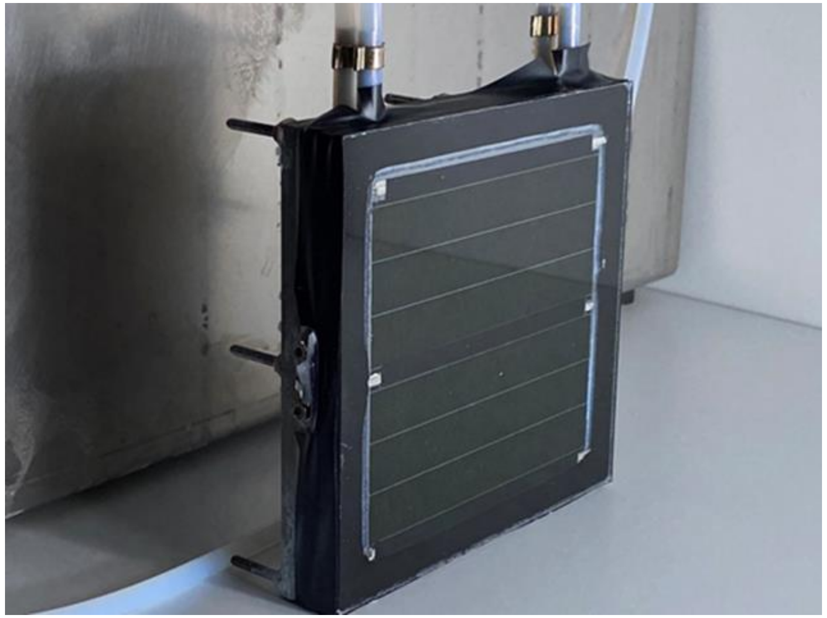
- PV module electrically and thermally coupled to alkaline electrolyser
- Silicon heterojunction photovoltaic module
- Electrolyser with nickel foam electrodes using 1.0 M KOH
- Scale-up from **294 cm² to 2500 cm²** photo collection area

09:50: Silicon based photovoltaic integrated alkaline water electrolysis by Dr Erno Kemppainen

WP 3 CuInGaSe based photovoltaic integrated alkaline water electrolysis

Development of higher voltage CIGS materials and of catalyst modules, and upscaling of the CIGS based approach with non-precious HER and OER catalysts.





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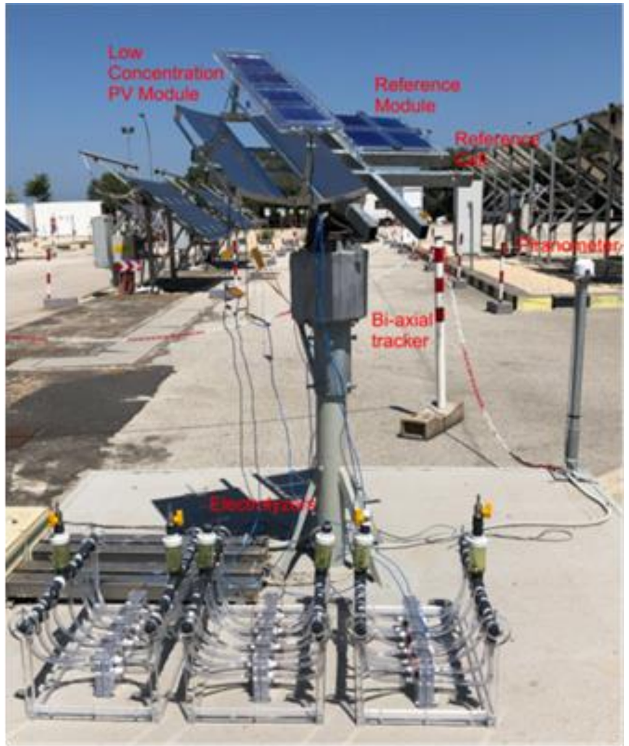
SOLIBRO
A Hanergy Company

- PV module electrically and thermally coupled to alkaline electrolyser
- CuInGaSe photovoltaic module + electrolyser with nickel foam electrodes using 1.0 M KOH
- Scale-up from ~**1 cm² to 80 cm²** photo collection area
- CuInGaSe bandgap adjusted ensuring η_{STH} over 10% for all sizes

10:20: CIGS based integrated PV-EC device approach, Prof. Tomas Edvinsson (Uppsala Universitet)

WP 4 Reference cassette (discrete PV + electrolyser) approach

Improvements in „conventional“ PV directly coupled to PEM or alkaline electrolysers



Consiglio Nazionale delle Ricerche

enel Green Power

Bifacial PV with low solar concentration

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Bifacial PV with albedo effects

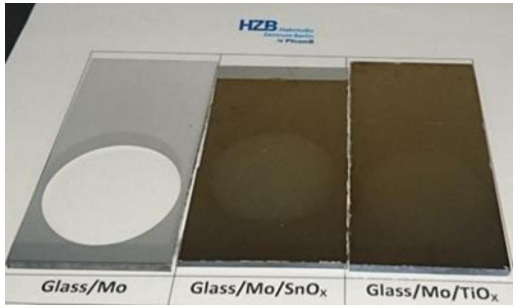
- Direct electrical coupling
- Bifacial SHJ PV + low concentration to alkaline electrolyser
- Bifacial SHJ PV + PEN electrolyser

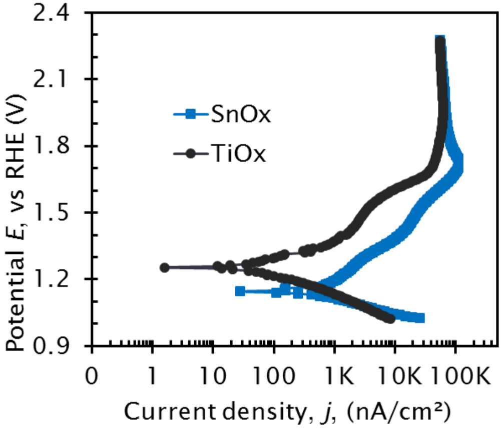
10:50: PV-EC systems based on low concentration and bifacial photovoltaics

By Dr Stefania Privitera (CNR)

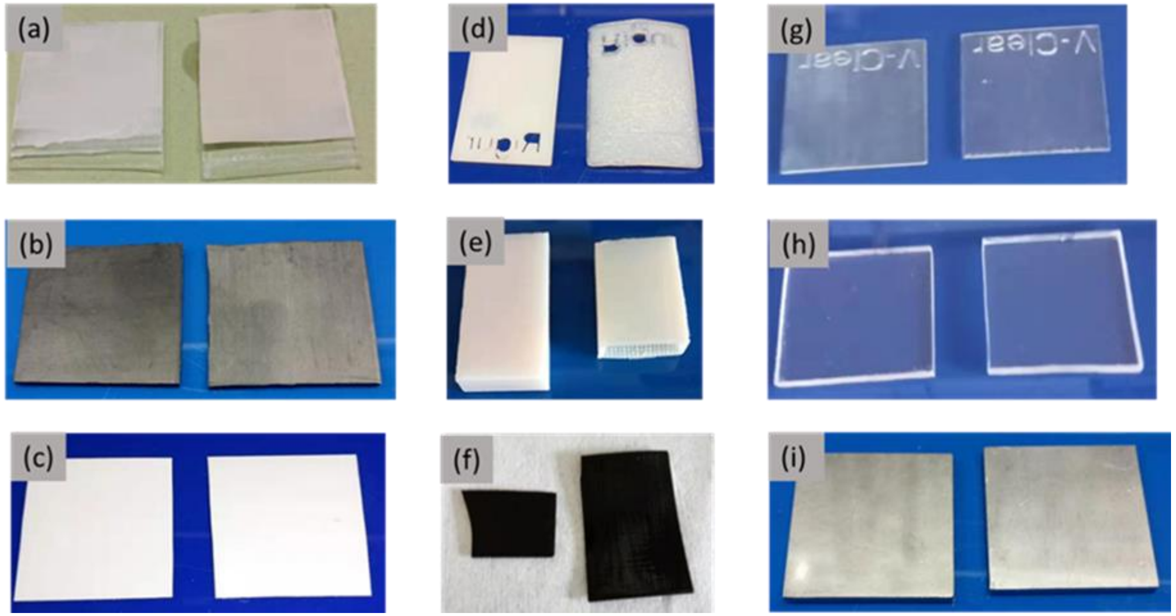
WP 5 Packaging and sealing

Aimed at increasing the lifetime of integrated PV-EC devices to ensure the project's overall objective of more than six months operation with less than 10% degradation





Electrochemical corrosion tests



Material surveys followed by corrosion tests to select packaging and sealing materials

- Corrosion protection tests for monolithic thin layer
- Corrosion and heat stability tests for non-monolithic packaging and sealing materials

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11:35: Containment and sealing approaches for photovoltaic integrated water electrolysis by Dr S. Calnan (HZB)

WP 6 Device simulation / Socio-techno-economic- & life-cycle-analysis

Understanding of the system in terms of technology development- and cost-potential

Simulation model for sizing area PV component in relation to electrolysis component for maximum yield depending on location e.g. Juelich, DE

HZB(PV)-UU(EC)	A_{EC} / A_{PV}	0.01	0.1	1
	E_{PV-EC} (kWh/m²)	27	79	116
	STH (%)	3	8	13
	ETH(%)	17	50	73
	Yearly H_2 (mg from 1 cm² catalyst)	82	241	352
	Yearly H_2 (kg for 10 m² PV)	8	24	35
SRAB(PV)-UU(EC)	A_{EC} / A_{PV}	0.01	0.1	1
	E_{PV-EC} (kWh/m²)	30	87.	110
	STH (%)	3	9	11
	ETH(%)	19	56	71
	Yearly H_2 (mg from 1 cm² catalyst)	92	267	336
	Yearly H_2 (kg for 10 m² PV)	9	27	34

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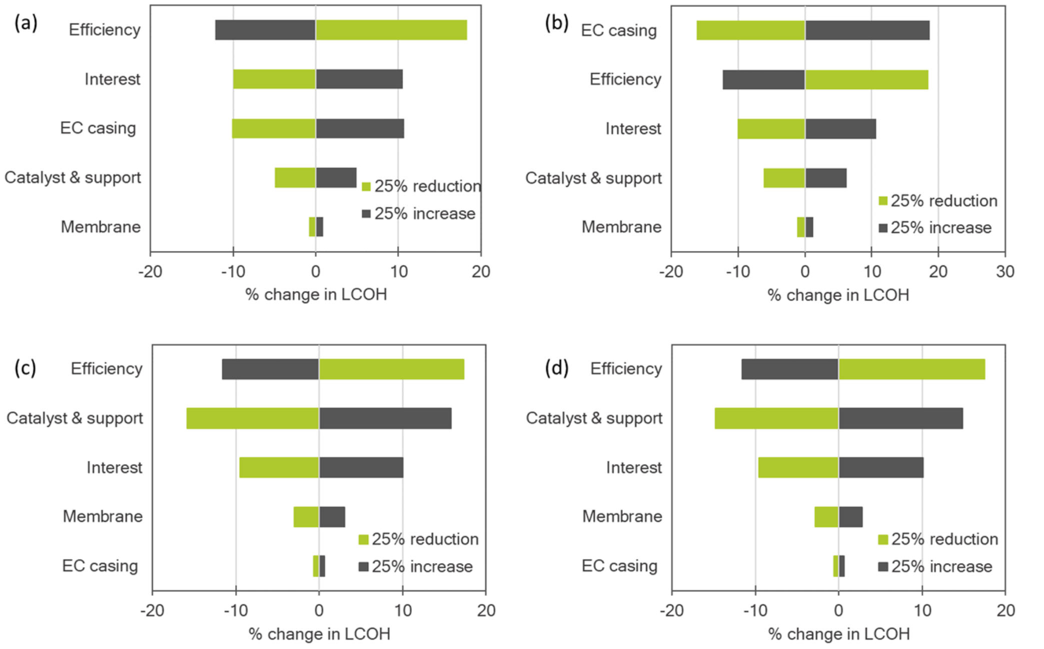
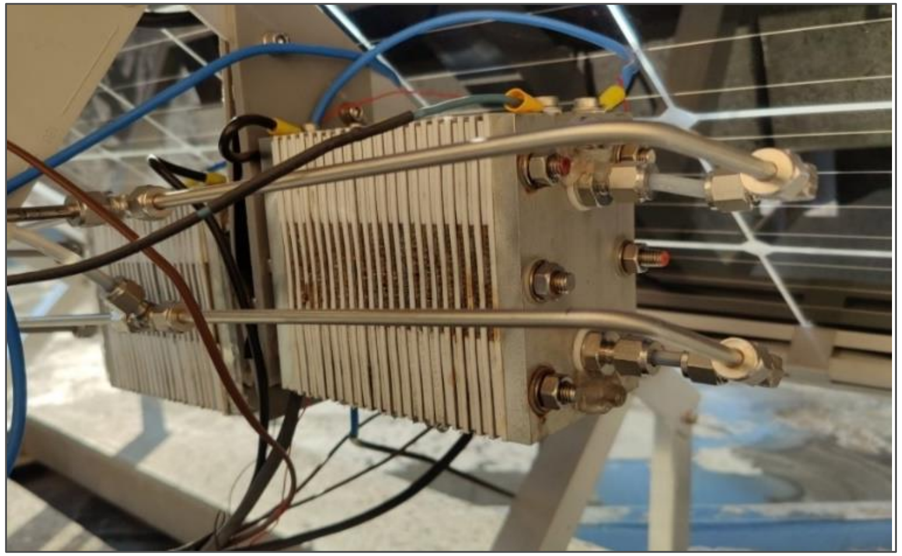
Simulation model extended to include more flexibility and for input into technoeconomic and lifecycle analysis



12.05: Simulation of hydrogen production based on weather data by Prof Marika Edoff (Uppsala Universitet)

Prototype panel and field tests

Realisation of 10 m^2 system and testing



- Improvements in „conventional“ PV directly coupled to PEM e.g. water feed through only the anode
- Online performance monitoring for outdoor conditions
- Studies on diurnal cycling effects on performance

12:35: 10 m^2 outdoor test field by Dr Martin Müller (FZJ)

Contact Information

Scientific Coordinator

Dr. Sonya Calnan
Tel: +49-30-8062-15675
sonya.calnan@helmholtz-berlin.de

Administrative Coordinator

Dr. Daniela Kaden
Tel: +49-30-8062-15679
daniela.kaden@helmholtz-berlin.de

PVcomB
Helmholtz-Zentrum Berlin für Materialien und Energie GmBH
Schwarzschildstrasse 3
D-12489 Berlin, Germany

www.helmholtz-berlin.de
www.pecsys-horizon2020.eu

Welcome
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Thank you for your attention

sonya.calnan@helmholtz-berlin.de

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