# Photovoltaic Driven Water Electrolysis Technologies for Green Solar Hydrogen Generation Developed within the PECSYS Project

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# 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

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JÜLICH Forschungszentrum

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enel Green Power

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Until Oct 2019


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# Motivation and Approach

## Motivation

- To scale-up and prove the technical feasibility of directly coupled PV-electrolysis through in-field testing
- To understand, better, the effect of variable solar irradiation and thermal management of systems for direct hydrogen production from sunlight.

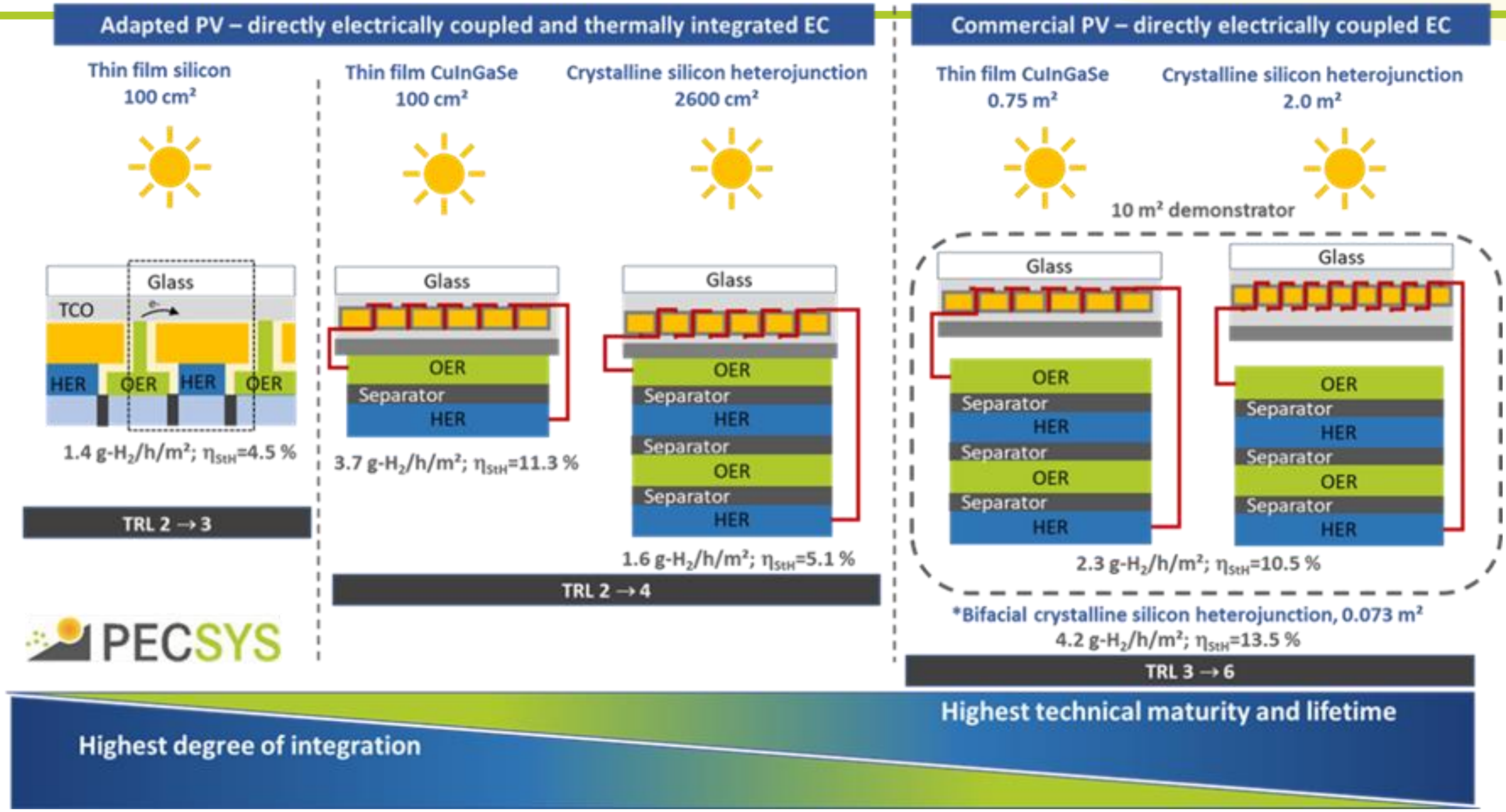
## Approach

- Reducing and/or simplifying the balance of (electrolyser) plant to permit modularity and reduce costs
- Eliminating power regulating electronics in directly coupled systems by careful matching of the voltage of the PV and electrolyser to enhance solar to hydrogen (StH) conversion efficiencies
- Thermal integration of both sub components to benefit from the opposing temperature response

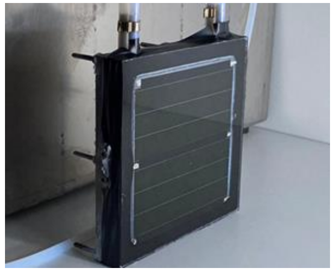
Exclusive use of incident solar energy to provide both heat and electricity to the electrolyser enhances StH efficiency while maintaining a near zero carbon footprint.

# Various Technologies and Materials investigated

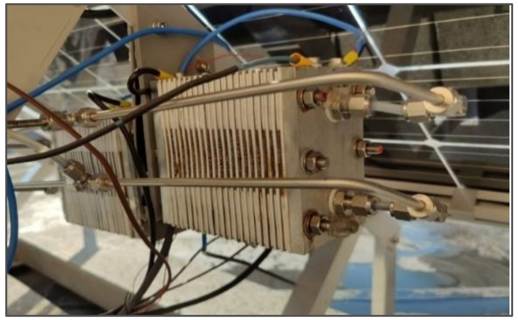
Adapted PV combined with liquid alkaline electrolysers using **Ni, Mo or Fe** based catalysts




Commercial PV combined with PEM electrolysers using **Pt and Ir** based catalysts


# Demonstrator for solar driven $H_2$ production on an area > 10 m²



(i) Simplified balance of plant for PEM electrolyser stack

- Water feed through only the cathode without pumps[1]
- No active heating or cooling of electrolyser
- No power conditioning electronics

(ii) **Better efficiency and longer operation** than other systems with PV directly coupled to PEM electrolysers

| Location | Year | Photovoltaic array | | | Time in operation (h) | Average StH eff. ($\%_{LHV}$) | $\dot{m}_{H2}$ (g/h-m²) |
|---|---|---|---|---|---|---|---|
| | | Type | Area (m²) | Power (kWel) | | | |
| Juelich, (DE), PECSYS | 2020 | Silicon HJT & CuInGaSe | 10.5 | 1.73 | >2680 | ~10 | 2.3 |
| Thuwal, (SA)[2] | 2020 | Polycrystalline silicon | 1.5 | 0.27 | ~10 | 9.4 | 1.2 |
| Tsukuba, (JP)[3] | 2013 | Polycrystalline silicon | 21.5 | 2.6 | ~20 | ~5 | -/- |

[1] Müller, et al., ***Energies***, 2019, 12(21): 4150.
[2] Muhammad-Bashir, ***Solar Energy***, 2020, 205:461.
[3] Maeda, et al. ***Journal of International Council on Electrical Engineering***, 2016, 6:1, 78-83.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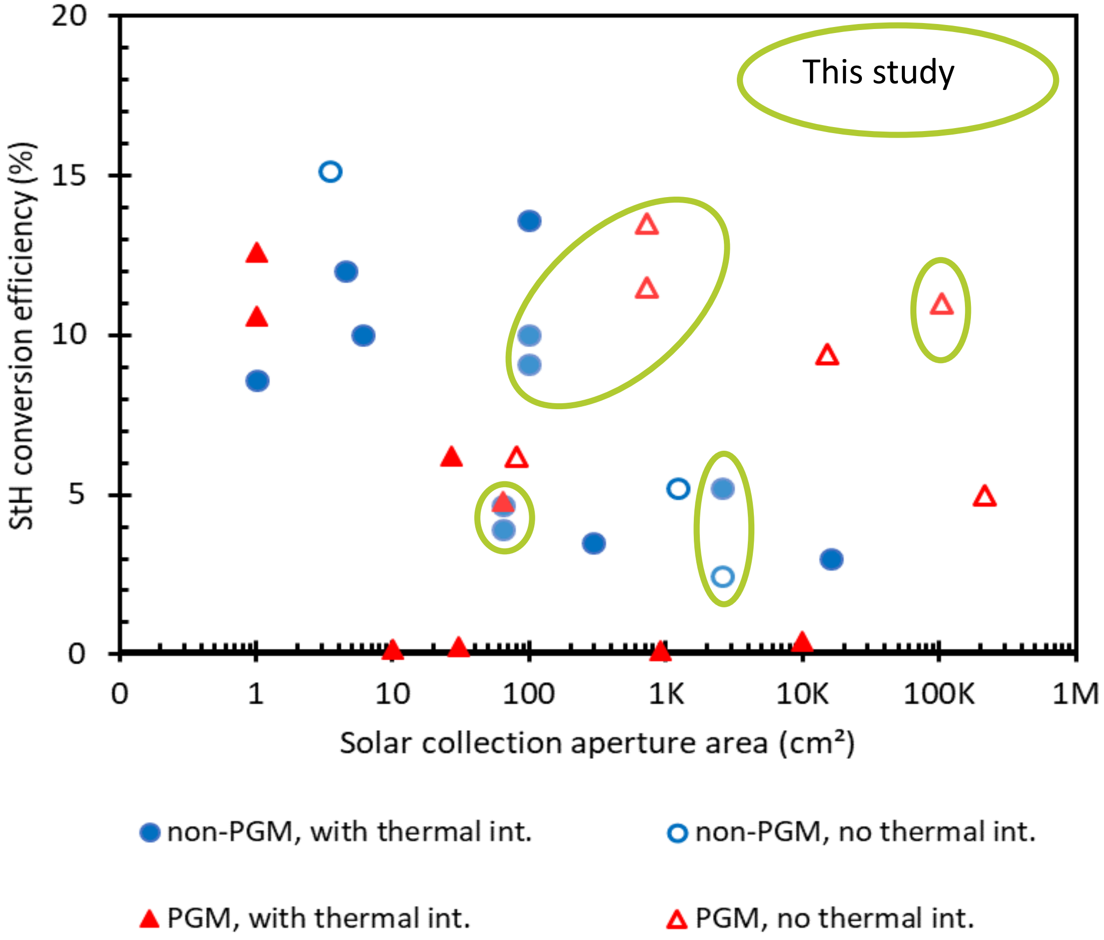
# Advanced Materials : Requirements and Challenges

## Comparison with reported systems*




*Calnan, *et al.*, ***Solar Rapid Research Letters, https://doi.org/10.1002/solr.202100479***

- Better performance using scarce platinum group metal PGM catalysts (Ir, Pt) for water splitting
- Higher efficiency photoabsorbers contain scarce materials like Ag, In, etc.
- Higher current densities need polymer electrolyte membranes
- Corrosion resistant materials needed for electrolyser components and for photoabsorbers in contact with electrolyte



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# Summary and Conclusions

- Several directly coupled PV + electrolysis approaches investigated spanning different levels of technical maturity and component integration

- Thermal integration significantly boosts efficiency and $H_2$ production

- Directly coupled PV electrolysis with among the best efficiency and capacity in class for each approach *

- Durability of electrolysers requires more research

- Further scale up of all concepts, considering materials used, required for higher technical maturity

*Calnan, *et al*., ***Solar Rapid Research Letters, https://doi.org/10.1002/solr.202100479***


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# Thank you for your attention

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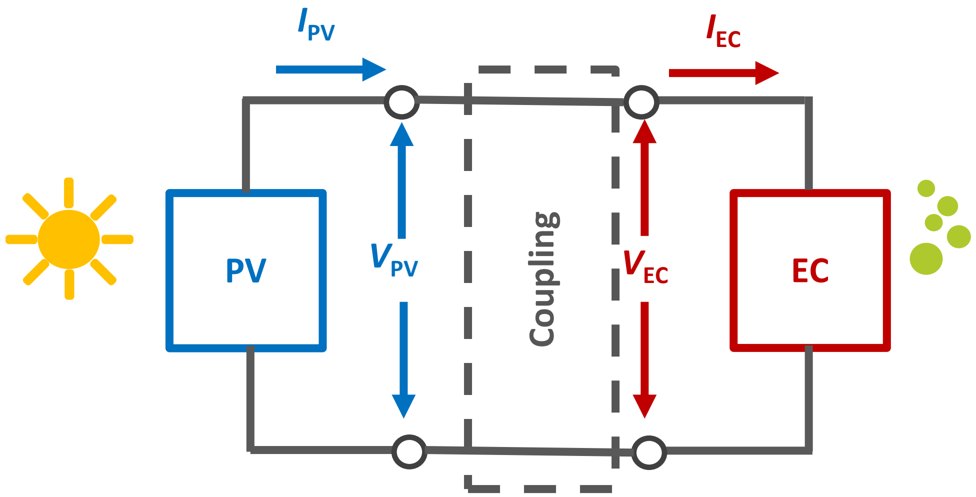
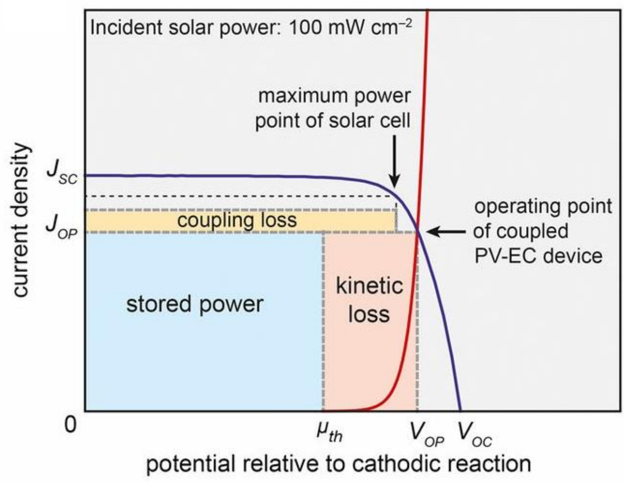
# PECSYS Concept: Directly coupled photovoltaic electrolysis




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

Solar to hydrogen conversion efficiency

$$\eta_{StH} = \frac{j_{op} \times (1.23\ V) \times \eta_F}{P_{light_{in}}}$$

$$\eta_{StH} = \frac{\Phi_{H_2} \times \Delta G}{P_{light_{in}} \times Area_{PV}}$$

Under standard conditions (1 atm. and 25 ° C), a minimum voltage, $E^0$ (reversible voltage) and corresponding to 1.23 V vs. (RHE = 0 V), is required for overall reaction.

$$2H_2O \rightarrow 2H_2\ (g) + O_2\ (g)$$

- Practical electrolysis requires a voltage higher than $E^0$ to drive the full electrochemical cell and to overcome parasitic loads.
- PV modules must be sized to ensure that the photovoltage over a wide range of operating conditions is sufficient for unassisted overall water splitting in the connected electrolyser



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