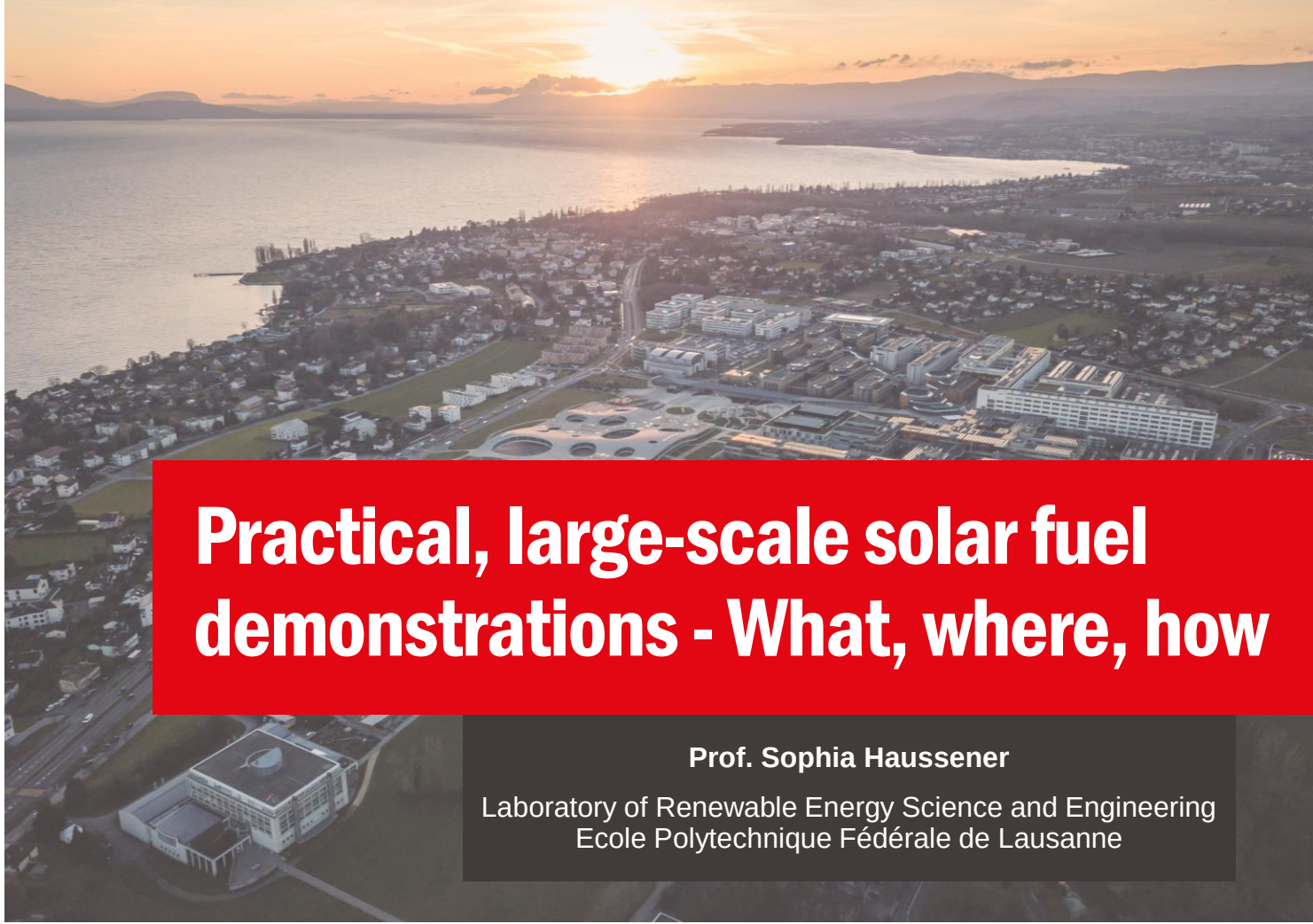


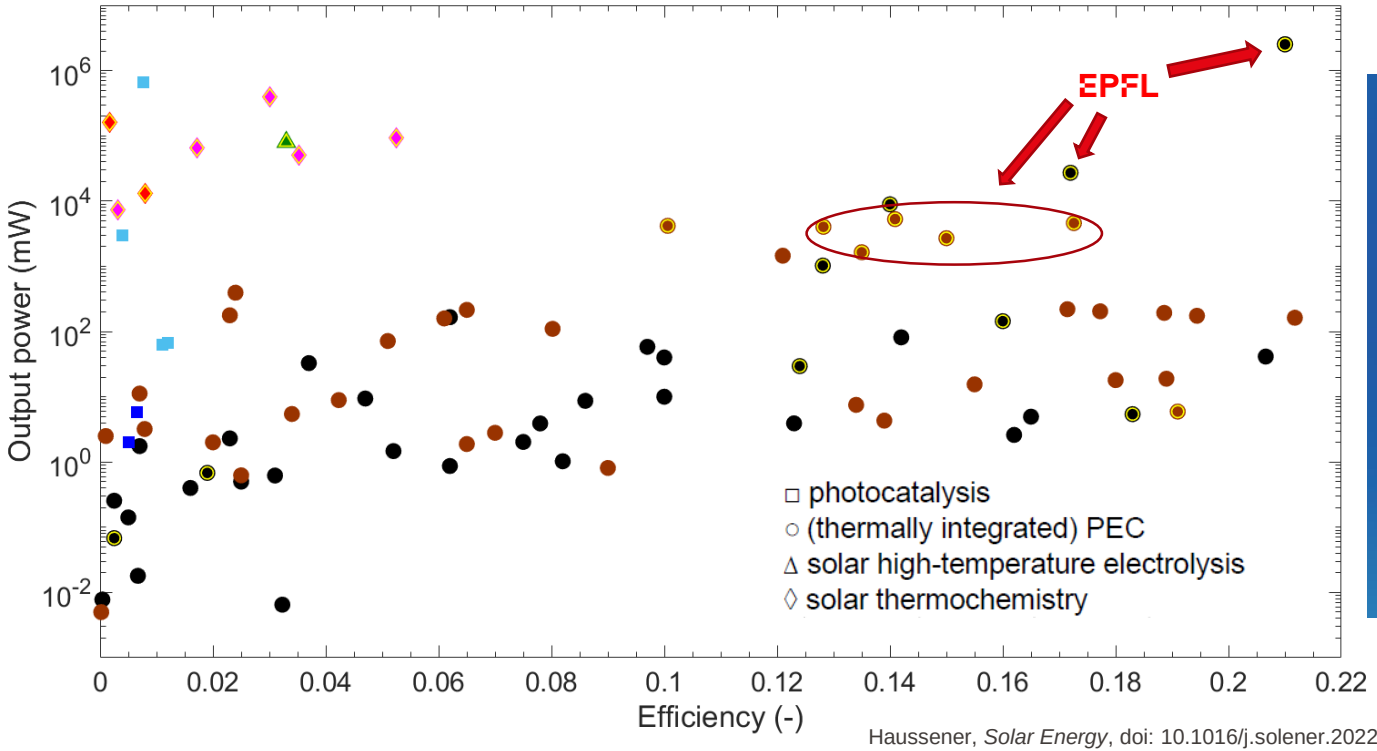
Practical, large-scale solar fuel demonstrations - What, where, how

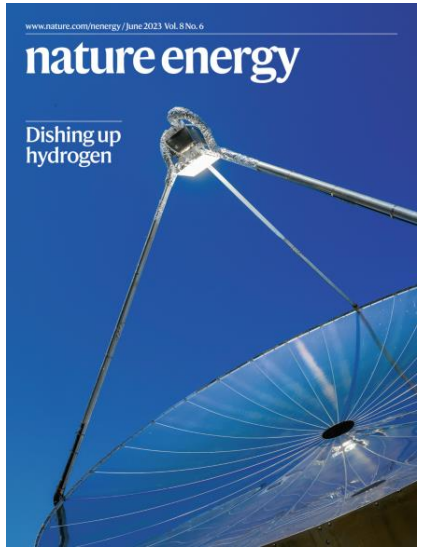
Prof. Sophia Haussener

Laboratory of Renewable Energy Science and Engineering
Ecole Polytechnique Fédérale de Lausanne

HydroGEN Workshop 2022

SolarFuelsDB





Haussener, *Solar Energy*, doi: 10.1016/j.solener.2022.09.019, 2022

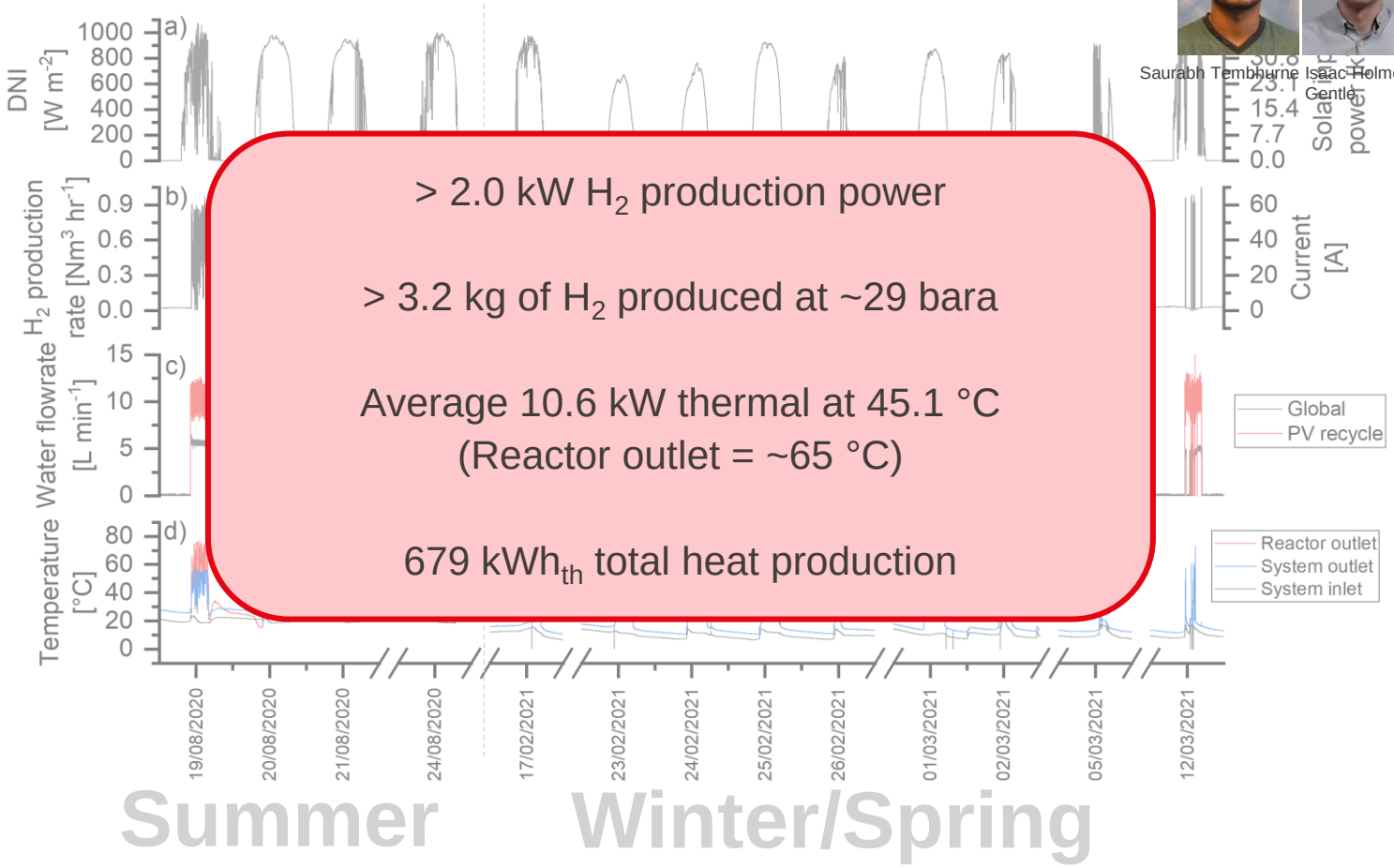
Holmes-Gentle, Tembhurne, Suter, Haussener, *Nature Energy*, doi: 10.1038/s41560-023-01247-2, 2023

Holmes-Gentle, Tembhurne, Suter, Haussener, *Nature Energy*, doi: 10.1038/s41560-023-01247-2, 2023

13-day Experimental Campaign

Saurabh Tembhurne Isaac Holmes-Gentle Clemens Suter

Haussener, LRESE



> 2.0 kW H_2 production power

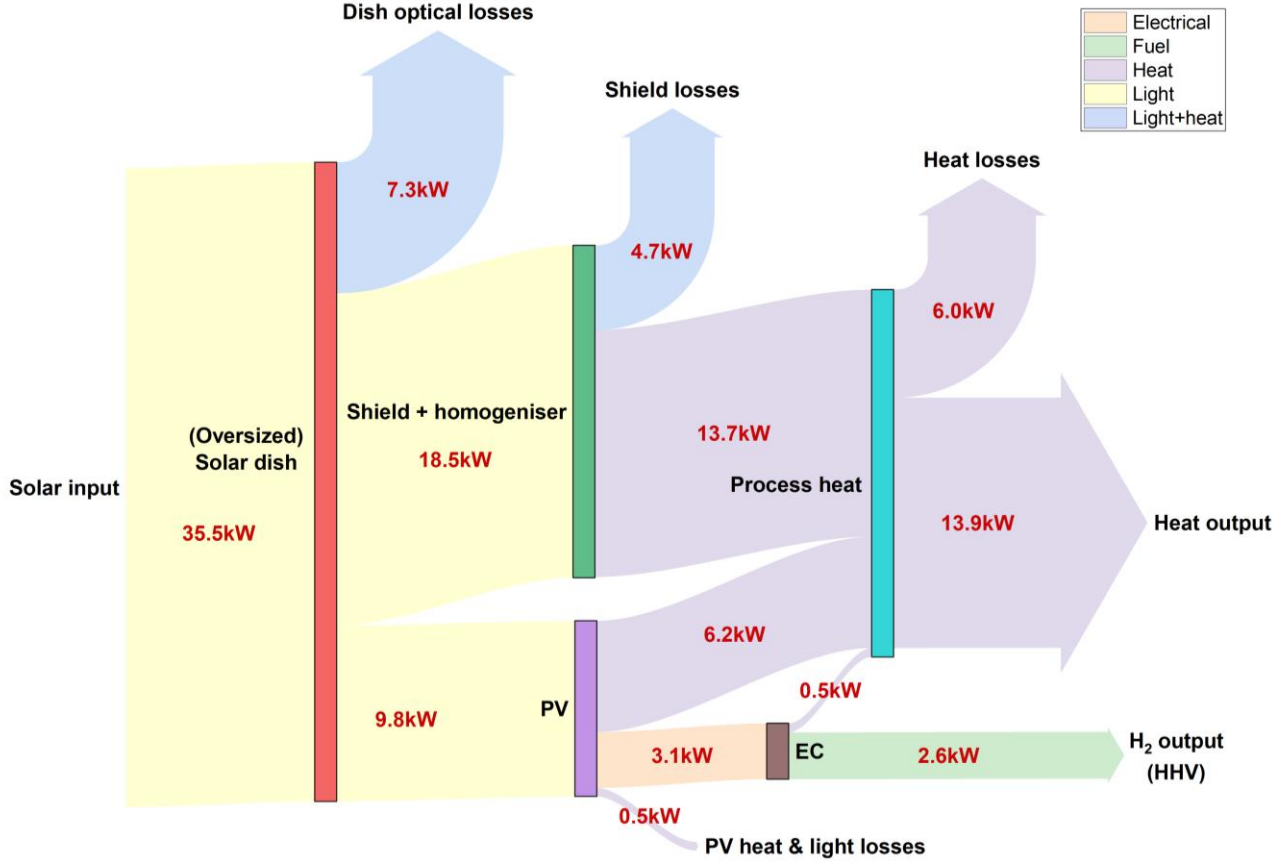
> 3.2 kg of H_2 produced at ~29 bara

Average 10.6 kW thermal at 45.1 °C
(Reactor outlet = ~65 °C)

679 kWh_{th} total heat production

Holmes-Gentle etal., *Nature Energy*, doi: 10.1038/s41560-023-01247-2, 2023

Performance Metrics



- Average system efficiency (taking into account ~0.6 kW external power):

$\eta_{system,H_2} = 6.6\ \% \pm 0.6\ \%$ (HHV)

$\eta_{system,H_2} = 5.5\ \% \pm 0.5\ \%$ (Gibbs)

$\eta_{system,thermal} = 35.3\ \%$

- To compare with literature - define a Solar-To-Hydrogen "device-level efficiency":

$\eta_{STH} = 20.3\ \% \pm 2.3\ \%$ (Gibbs energy)

Holmes-Gentle etal., *Nature Energy*, doi: 10.1038/s41560-023-01247-2, 2023

Comparison with published literature

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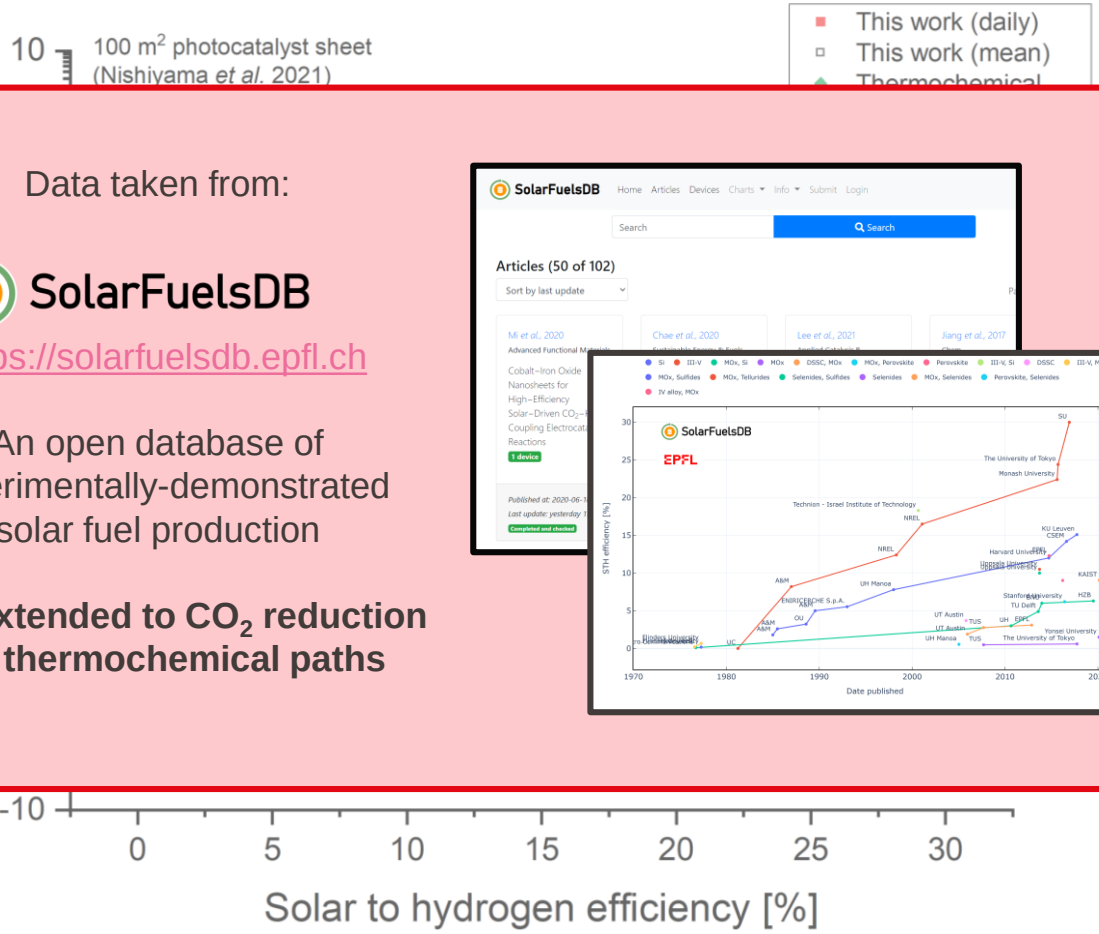


Data taken from:

SolarFuelsDB

https://solarfuelsdb.epfl.ch

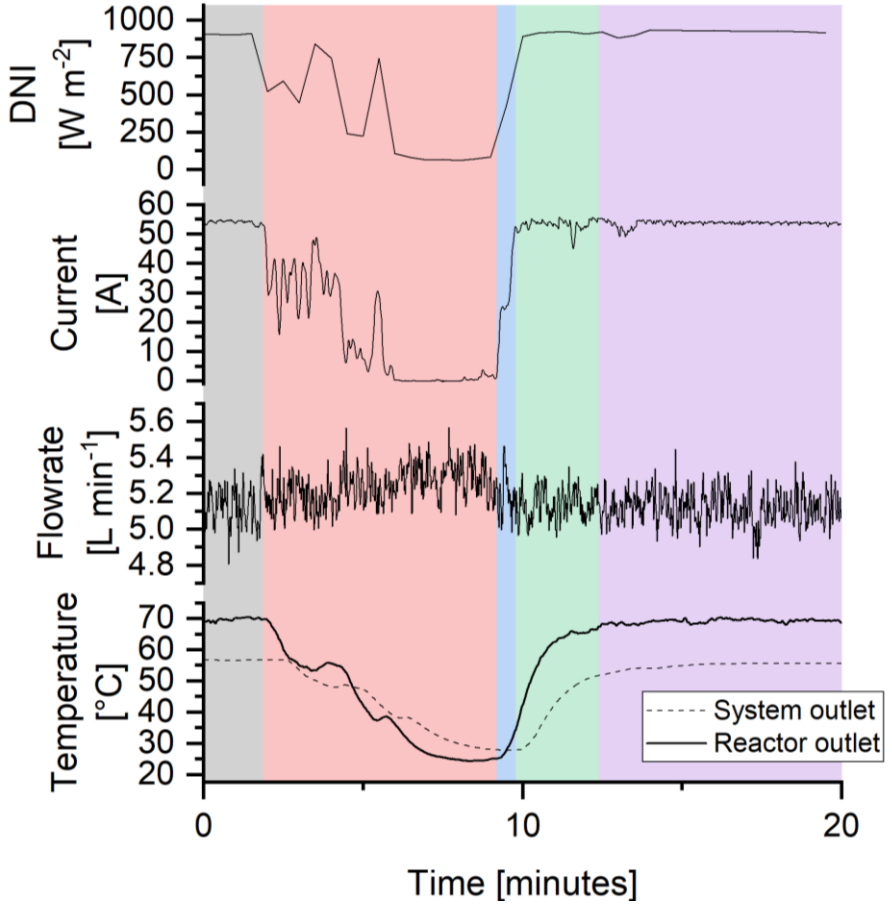
An open database of experimentally-demonstrated solar fuel production

Now extended to CO_2 reduction and thermochemical paths

Holmes-Gentle etal., *Nature Energy*, doi: 10.1038/s41560-023-01247-2, 2023

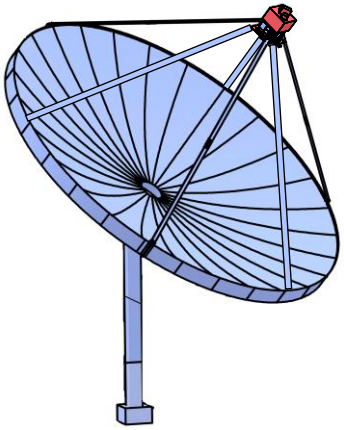
Control and System Dynamics

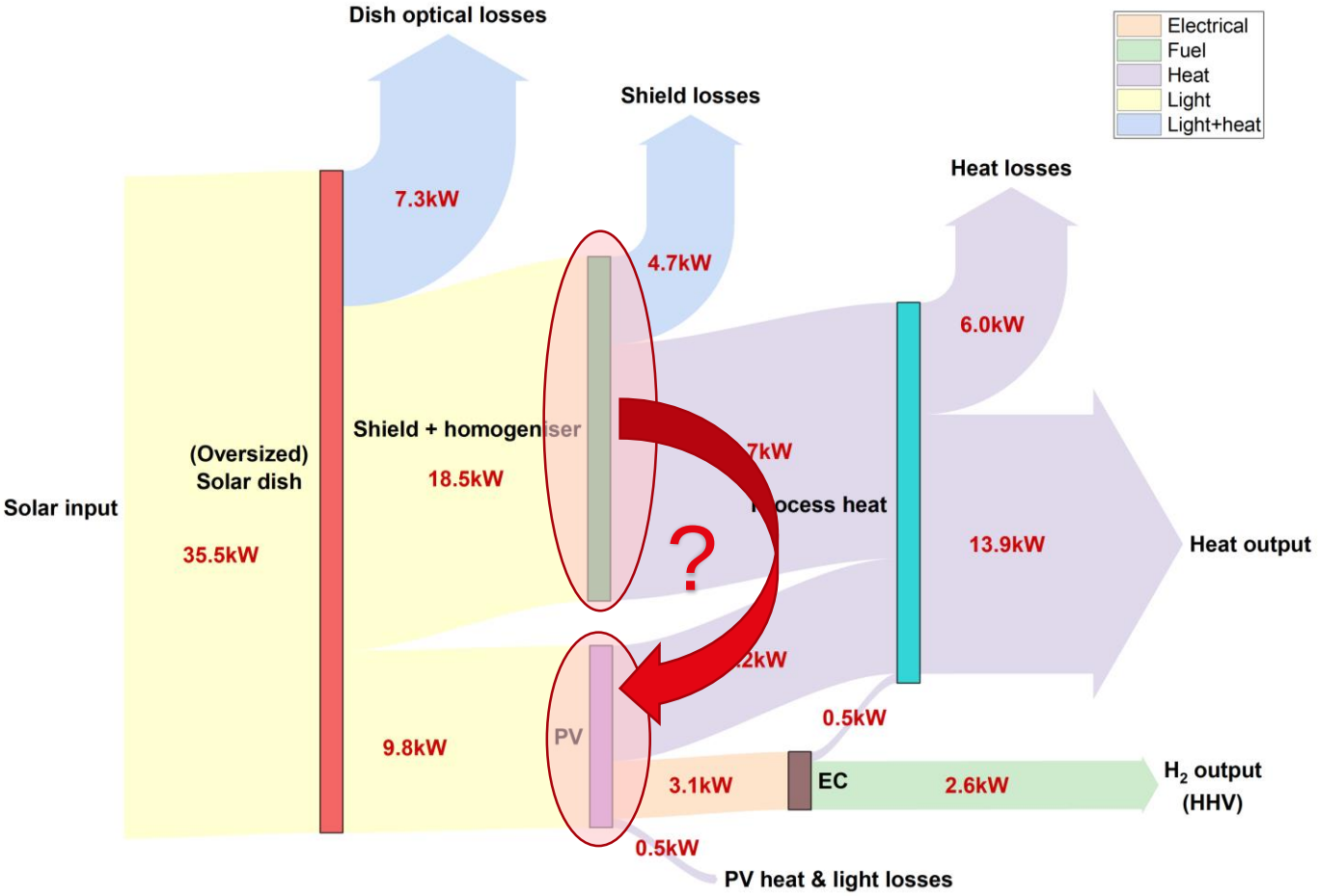
- Responsive dynamics to DNI fluctuations, water flowrate setpoint changes etc.
- Fast start-up/shutdown (~5 minutes each)
- Predicted dynamic operational characteristics experimentally confirmed
- Demonstrated operability of system under variety of conditions



Holmes-Gentle etal., *Int. J. Hydrogen Energy*, 46, 10666–10681, 2021
Holmes-Gentle etal., *Nature Energy*, doi: 10.1038/s41560-023-01247-2, 2023

System Optimisation *via* Detailed Process Simulation





Holmes-Gentle etal., *Nature Energy*, doi: 10.1038/s41560-023-01247-2, 2023

Simulation Results and Optimisation

Parameter	Experimental results	Optimised system (Simulation)
η_{system,H_2} (Gibbs) / (Enthalpy)	5.5 % / 6.6 %	**16.2 % / 19.5 %**
$\eta_{system,thermal}$	35.3 %	**37.2 %**
T_{out}	45 °C	**63 °C**
$\dot{m}_{global}$	4.9 L min^{-1}	**4.2 L min^{-1}**

Assuming reasonable and feasible improvements:

- PV area is scaled (to maintain constant average concentration), and all light shield light falls on the PV
- Light homogeneity on PV is 90% improved
- Pipe insulation was added (UA = ~70 W/K)

Holmes-Gentle etal., *Nature Energy*, doi: 10.1038/s41560-023-01247-2, 2023

More Scaling

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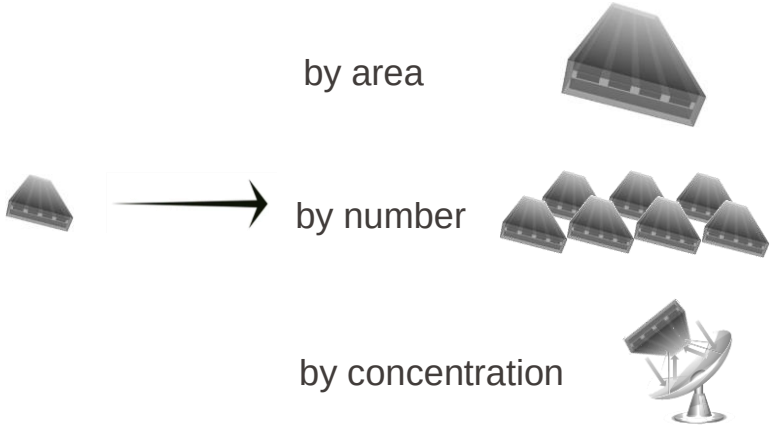
- Industrial demonstrator targeting the 100kW-scale

SoHHytec
SOLAR FUEL, THE SMARTER WAY



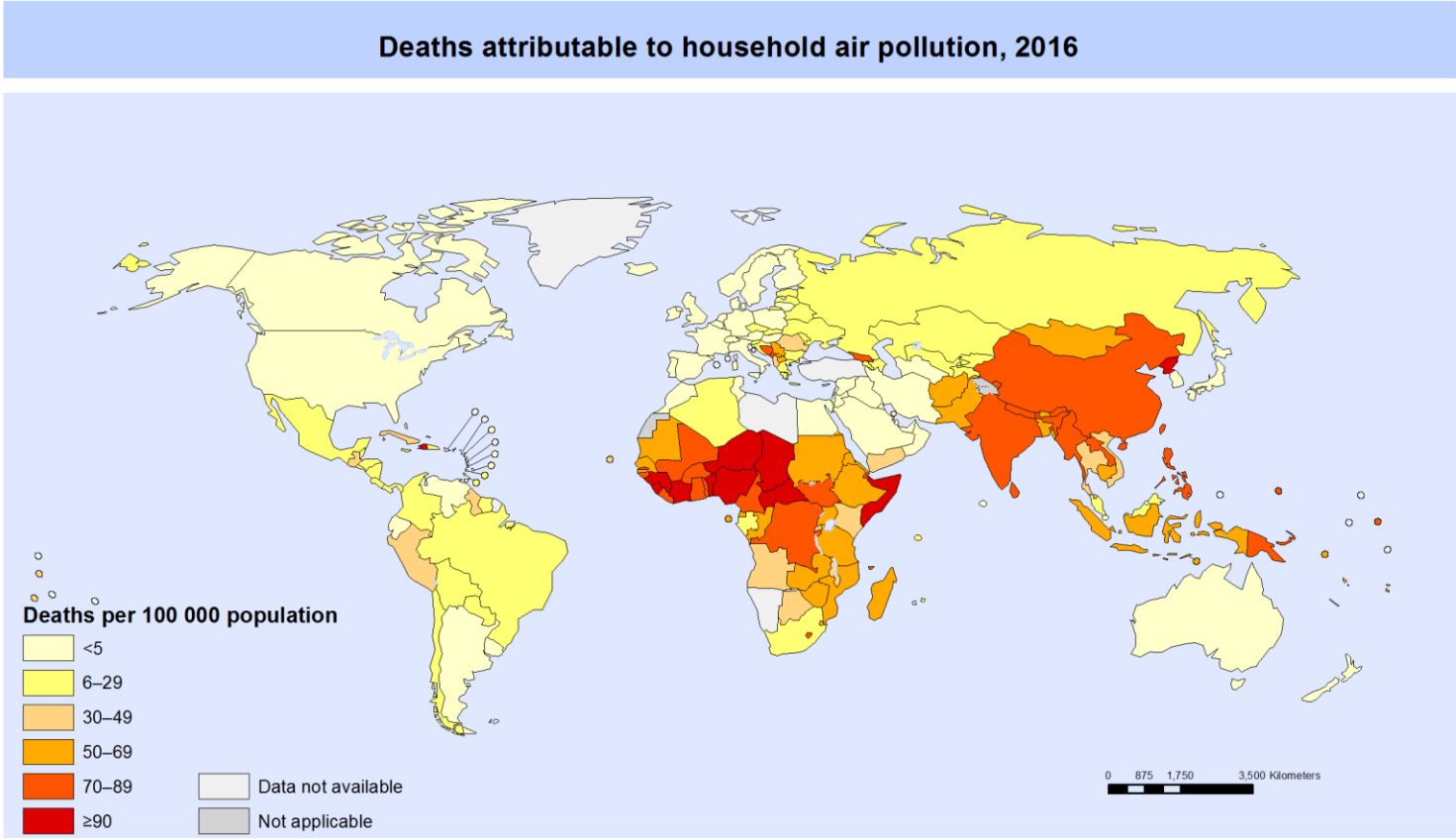
Solar Fuels in Context of Global South

- Can any of our solitions be relevant for non-industriallized countries?
- Case study:

Solar hydrogen based cooking in Cameroon to reduce indoor air polution

Photo: visited mother and child near Douala, Cameroon, starting meal preparation, 2022

Need for fuel for clean, safe, modern cooking



The boundaries and names shown and the designations used on this map do not imply the expression of any opinion whatsoever on the part of the World Health Organization concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. Dotted and dashed lines on maps represent approximate border lines for which there may not yet be full agreement.

Data Source: World Health Organization
Map Production: Information Evidence and Research (IER)
World Health Organization

World Health Organization

Opportunities in clean, safe, modern cooking

- Strategies to reduce health and environment impacts (from World Health Organization):
  - Shifting from solid fuels to cleaner energy technologies – for instance, liquid petroleum gas, biogas or solar power generation – can potentially yield the largest reduction in indoor air pollution levels while minimizing environmental impacts of energy production and consumption in general
  - Improved design of stoves and ventilation systems
  - Public awareness of the health risks of indoor air pollution

Non renewable, expensive

Requires: long cooking time, sun availability when cooking, planning ahead

GoSun

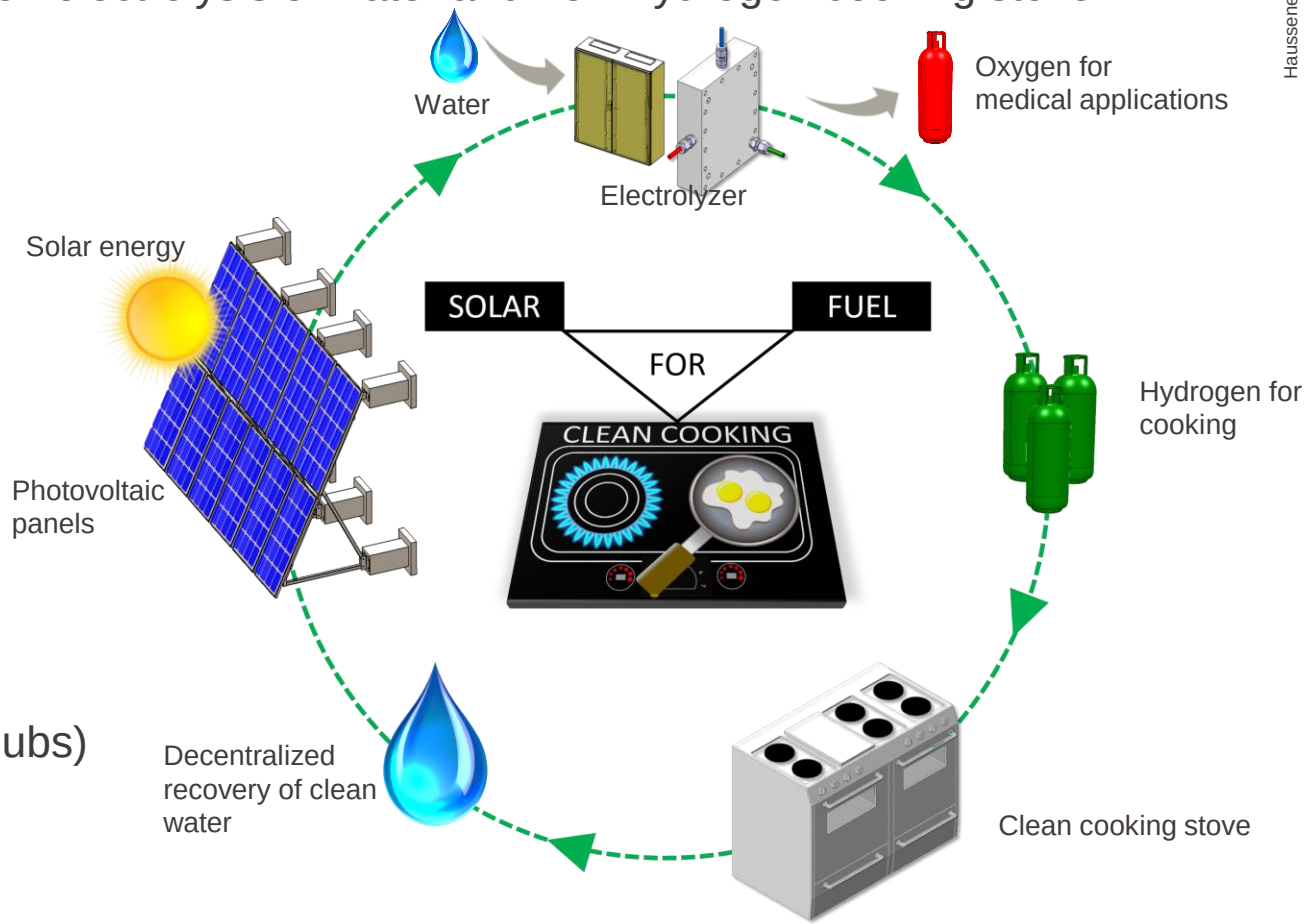
Haussener, LRESE

Opportunities in clean, safe, modern cooking

- Our approach: Solar-driven electrolysis of water and new hydrogen cooking stove

Some advantages:

- Clean-burning fuel
- Renewable fuel
- Can be used on-demand
- Positive "side effects":
  - clean water
  - oxygen for medical use
  - useful beyond cooking
- Community driven (local hubs)



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Solar Fuels in Context of Global South

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Fredy Nandjou

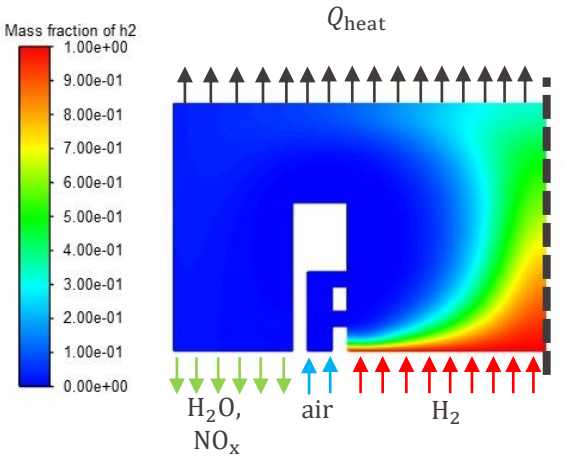
Fridolin Tchouante


Matthieu Jonin


Stefan Troendle

Catalytic Hydrogen Cooking Stove

- Design of an efficient, low-emission stove, allowing for condensation of exhaust



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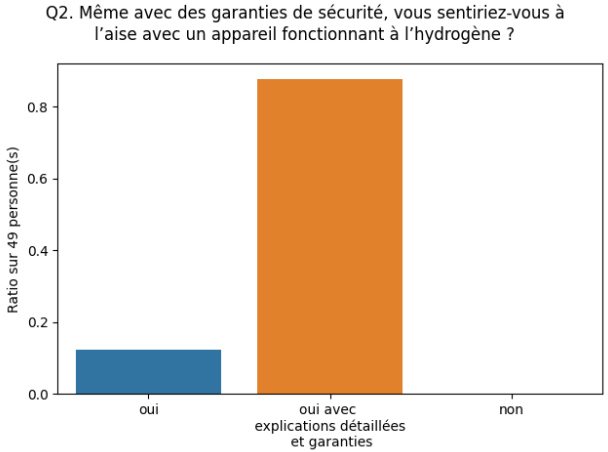
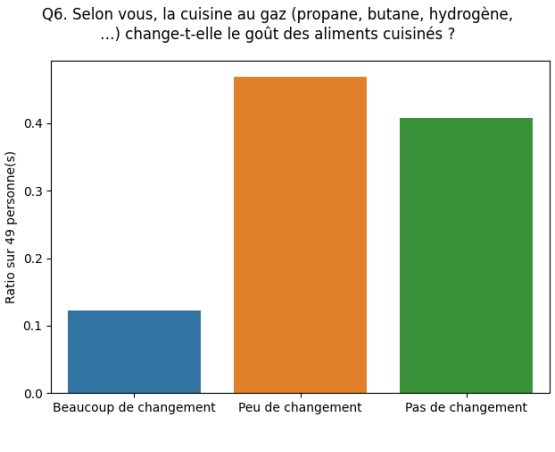
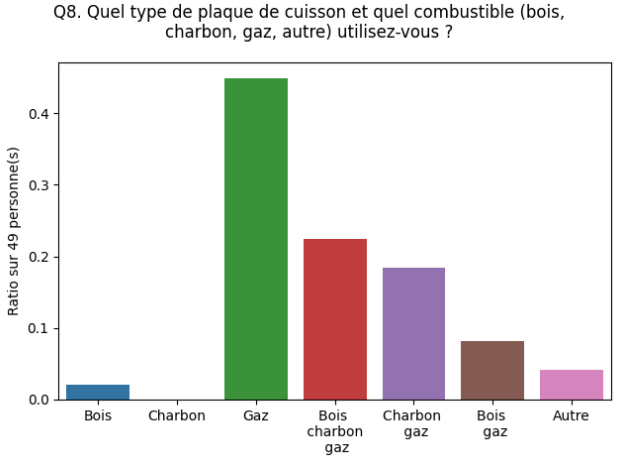
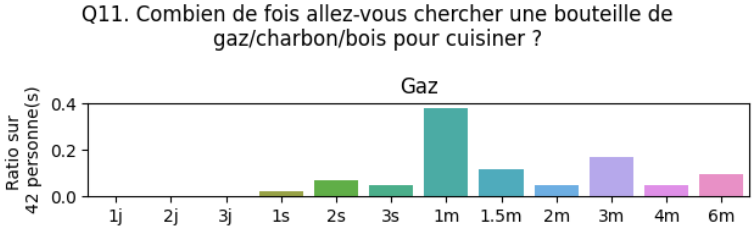
Cooking with Hydrogen

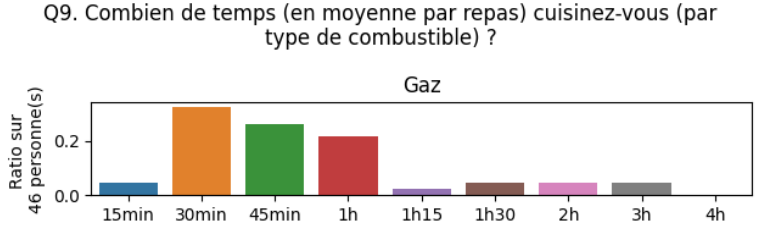
- Public perception and acceptance (surveys and interviews in Cameroon)





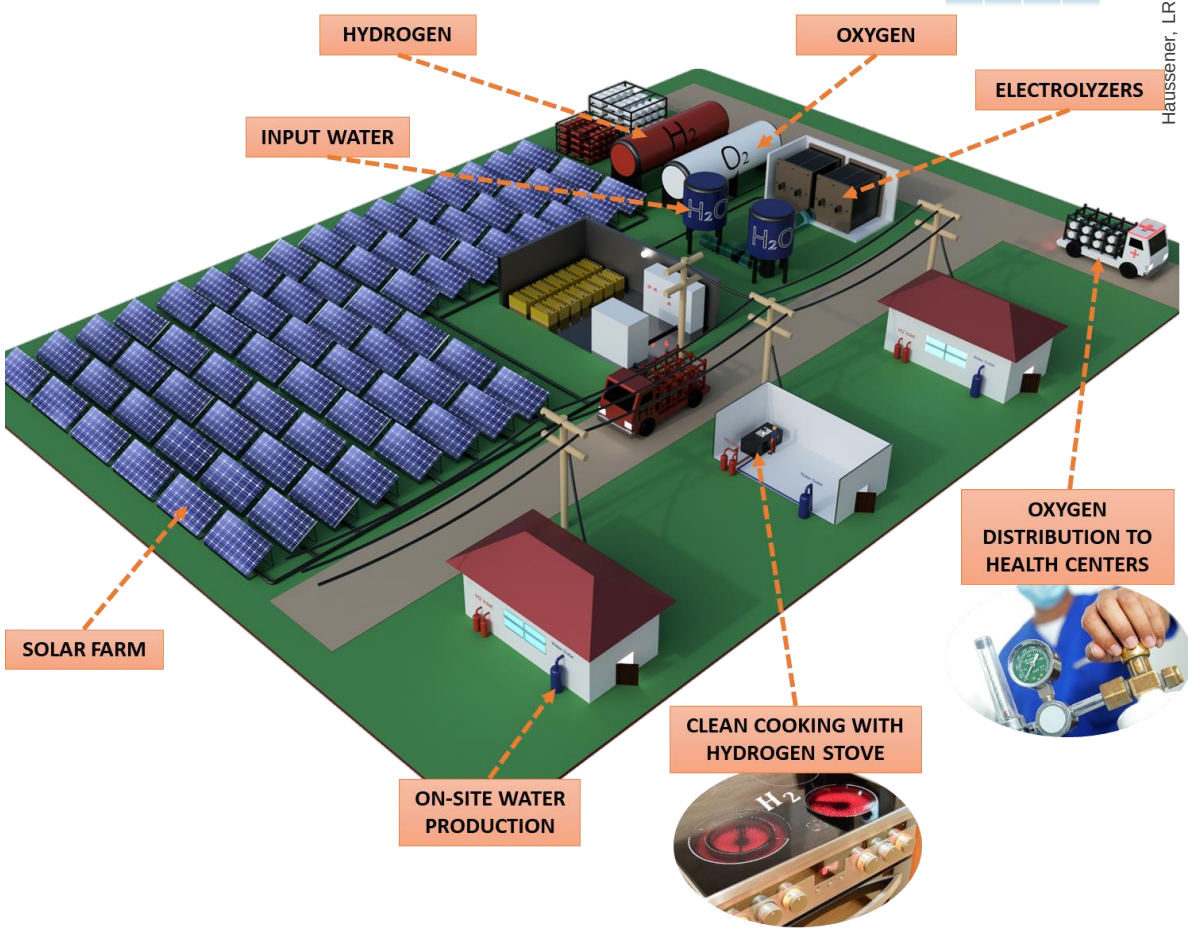






Part of a Bigger Sustainable Energy Transition

- Design and installation of solar hydrogen processing plants
- Distribution of hydrogen to households
- Co-production and distribution of green oxygen to health centers
- Development of a local hydrogen economy with local neighborhood hubs



Summary

- **Scaled system demonstrated** under real world conditions and for multiple months of operation

- Solar hydrogen is also interesting for “unusual” applications that are however of bog relevance in the **Global South** – specifically as cooking fuel

- **New ideas** are still needed for scientific curiosity and to make the solar fuels-case even better

Acknowledgements

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