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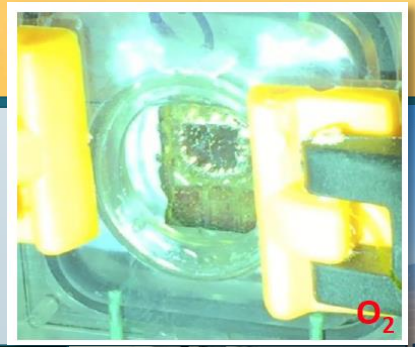
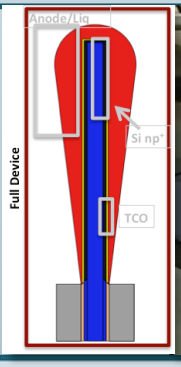
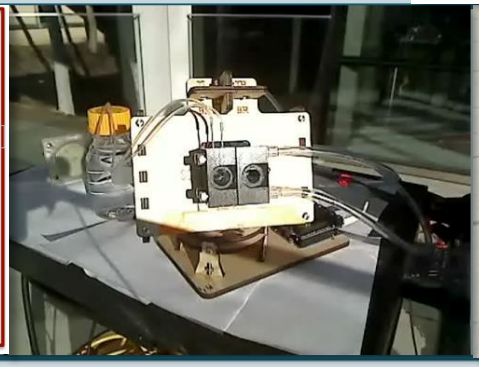
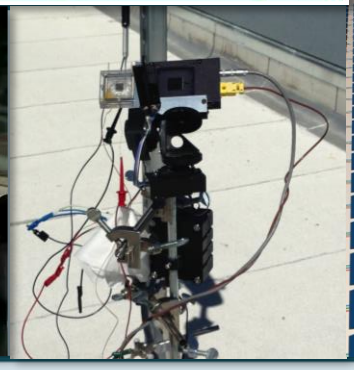
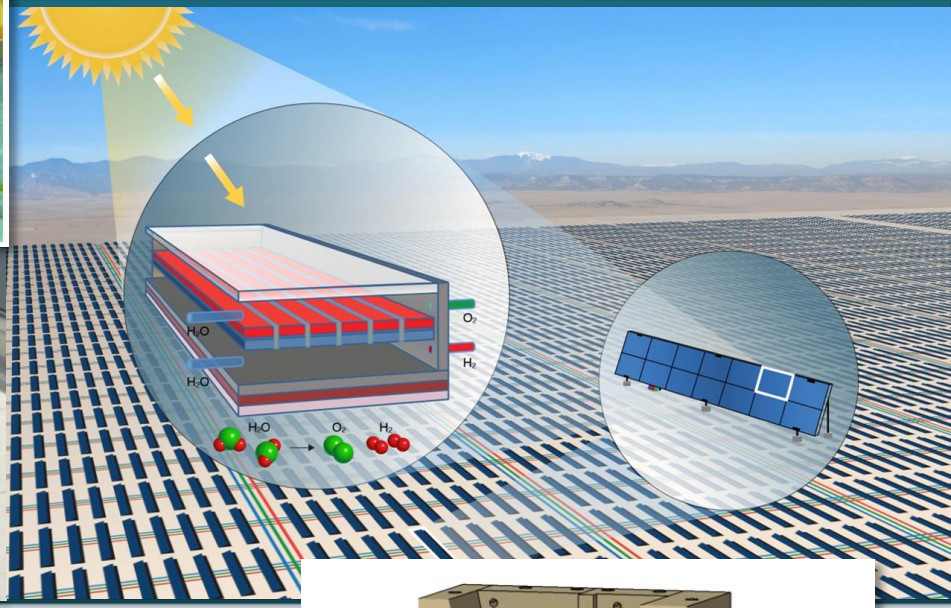
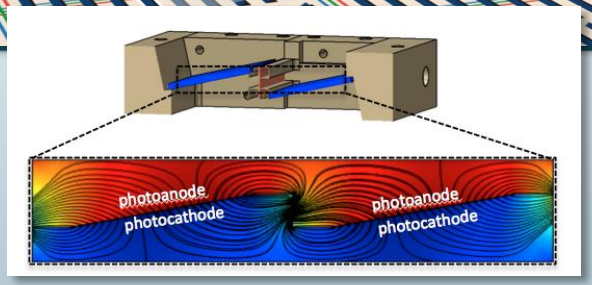












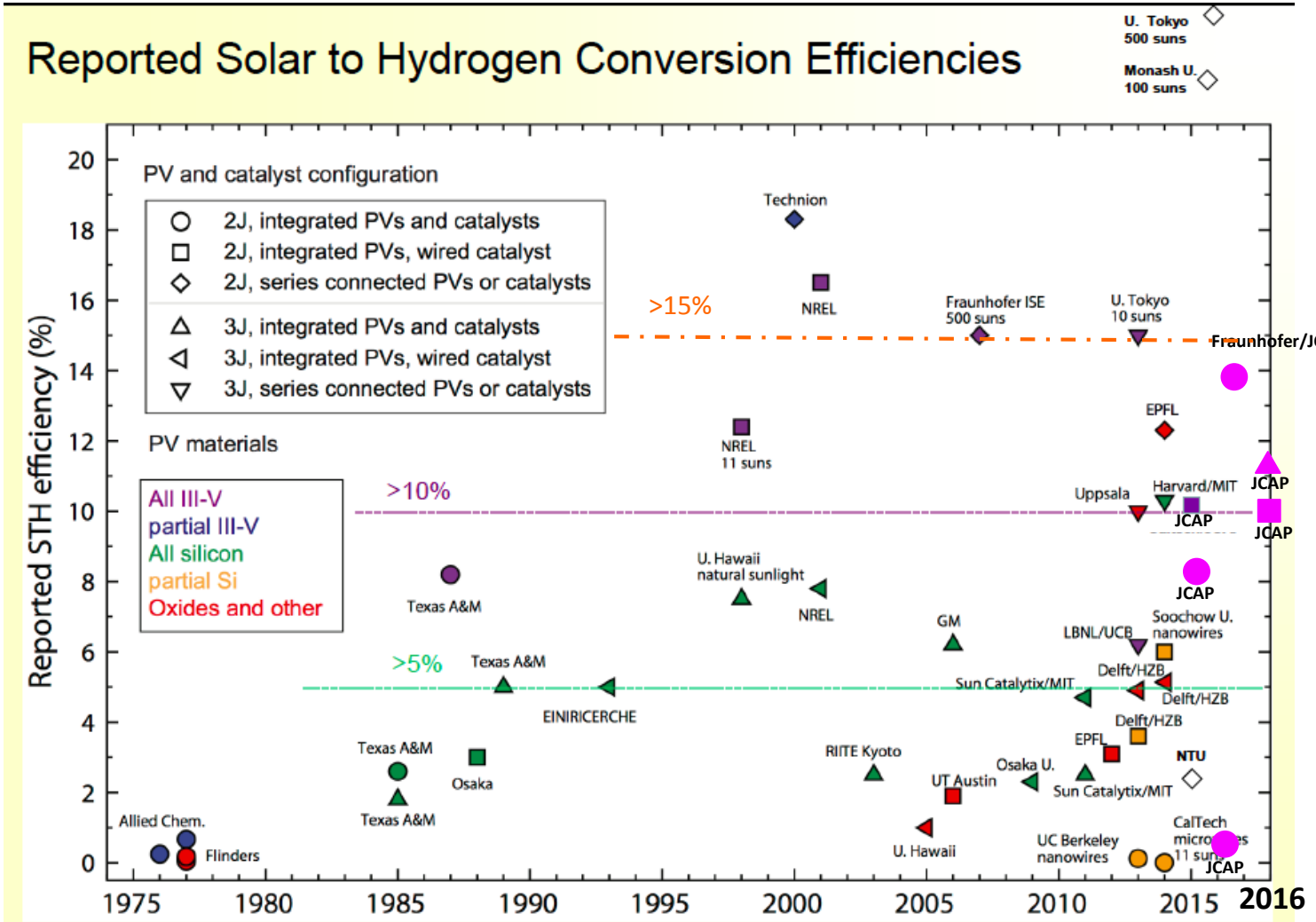
SOLAR PEC H_2 DEVICES

FRANCES HOULE
JOINT CENTER FOR ARTIFICIAL PHOTOSYNTHESIS
LAWRENCE BERKELEY NATIONAL LABORATORY

AWSM workshop
April 14-15, 2016

THE STATE OF THE ART

Updated with 2015-16 demonstrations



Ager, Shaner, Walczak, Sharp, Ardo, *Energy and Environmental Science*, DOI:10.1039/C5EE00457H

Ager, JCAP T3, 10/7/15 - 2

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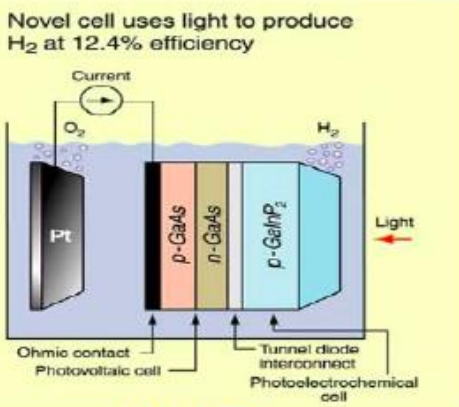
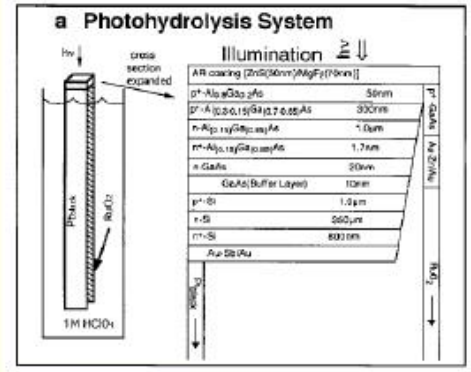
DEVICE TYPES FOR DEMONSTRATIONS

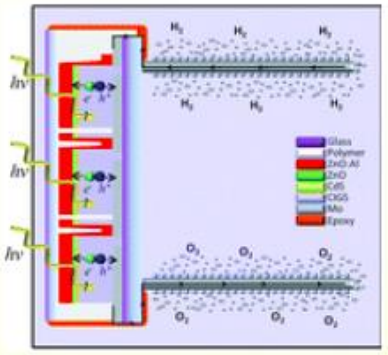
Selected laboratory scale solar to H_2 demonstrations



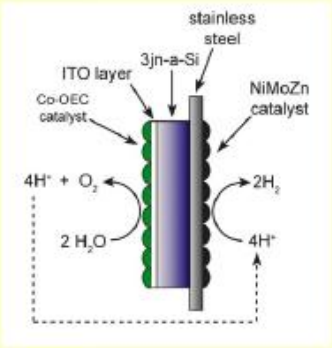
12% STH
Turner *et al*. (1998)
Pt/pn-GaAs//p-GaInP/Pt



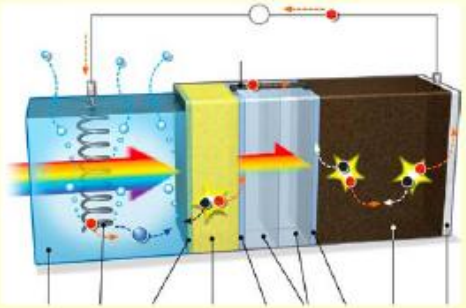
18% STH
Licht *et al*. (2000)
RuO_2/pn-AlGaAs//pn-Si/Pt black



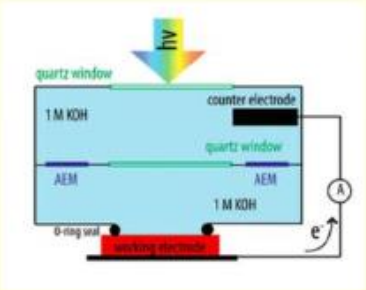
10% STH
Jacobsson *et al*. (2013)
3xCIGS tandem + Pt



~3% STH
Nocera *et al*. (2011)
Co-Pi/3J-a-Si/NiMoZn



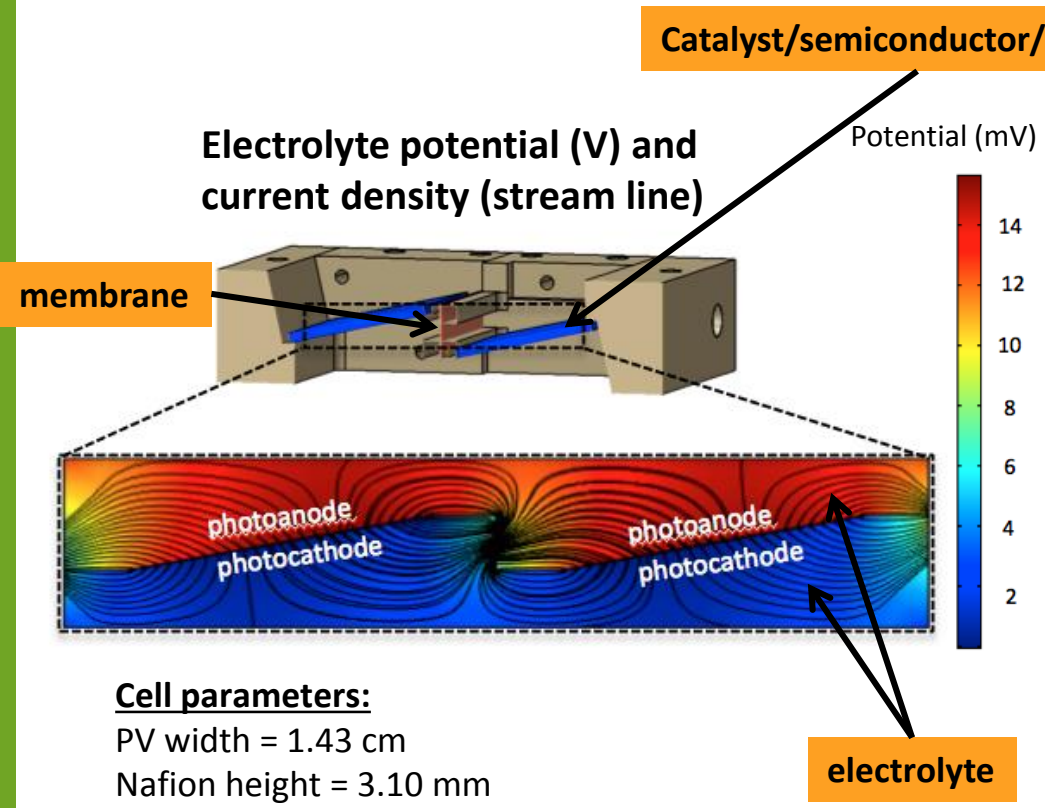
~5% STH
van de Krol *et al*. (2013)
Co-Pi/$BiVO_4$//2J-a-Si/Pt wire



10% STH with separation
Lewis *et al*. (2015)
Ni/pn-GaAs//p-GaInP/NiMo

Planar Device: the Louvered Design with full product separation

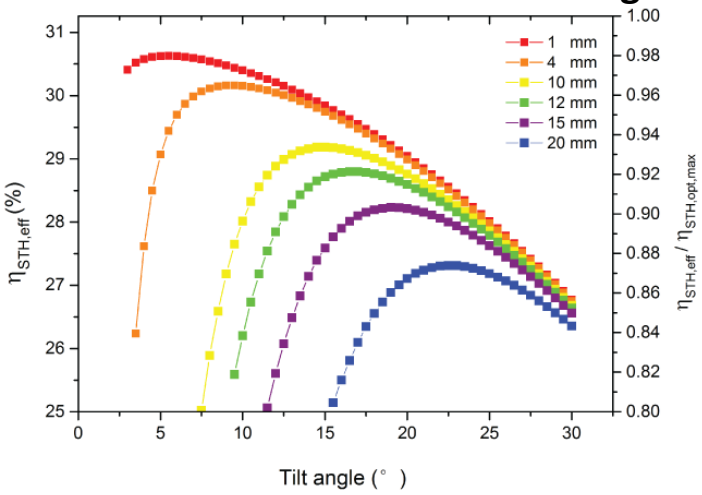
Geometry optimized by multiphysics modeling



Cell parameters:

PV width = 1.43 cm
Nafion height = 3.10 mm
Channel height = 3.25 mm
Catalysts: IrO_2 and Pt
Solution: 1 M H_2SO_4
Nafion conductivity: 10 S m^{-1}
TCO conductivity: 10^5 S m^{-1}

Solar to H_2 conversion efficiency as a function of the electrode tilt angle



Membrane height can not exceed 15 mm to achieve 90% of the ideal conversion efficiency.

Walczak, et.al., ChemSusChem, 2015, DOI: 10.1002/cssc.201402896

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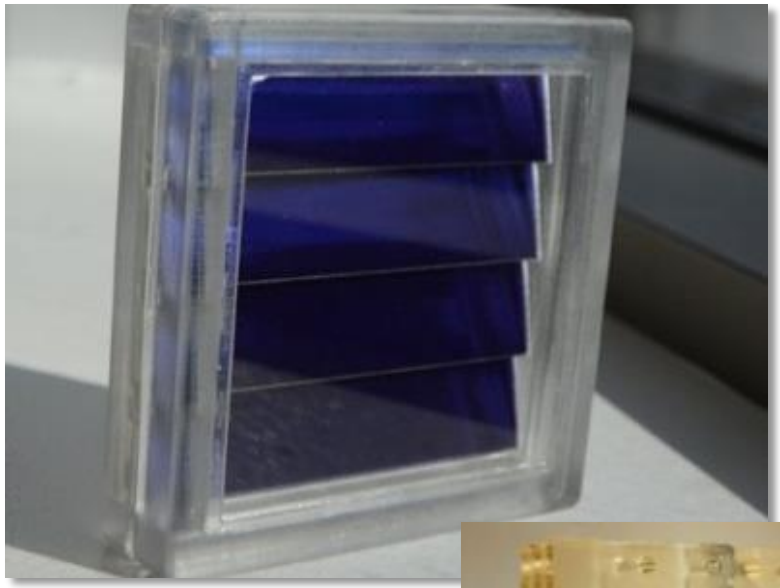
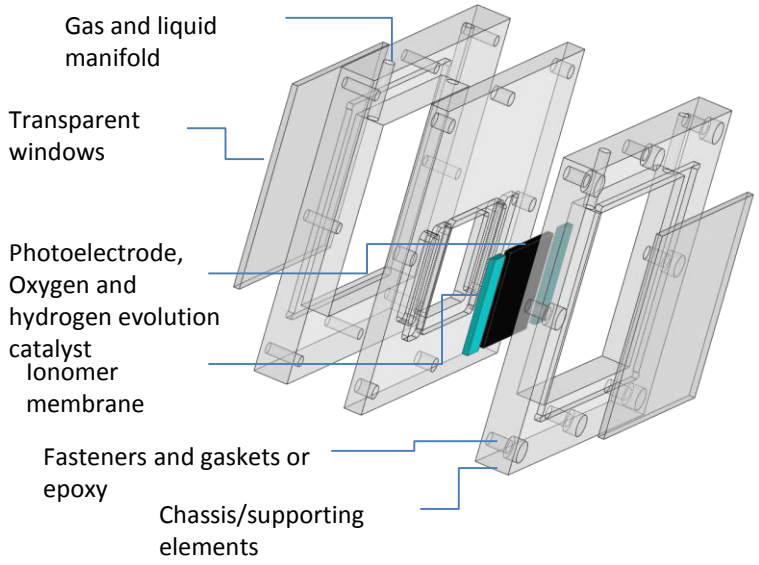
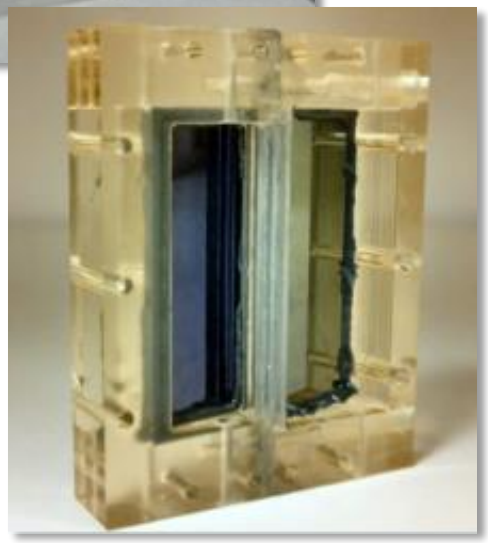
LOUVERED DEVICE VARIATIONS



10 cm x 10 cm



Unfolded – PEC with membrane side panels



5 cm x 5 cm

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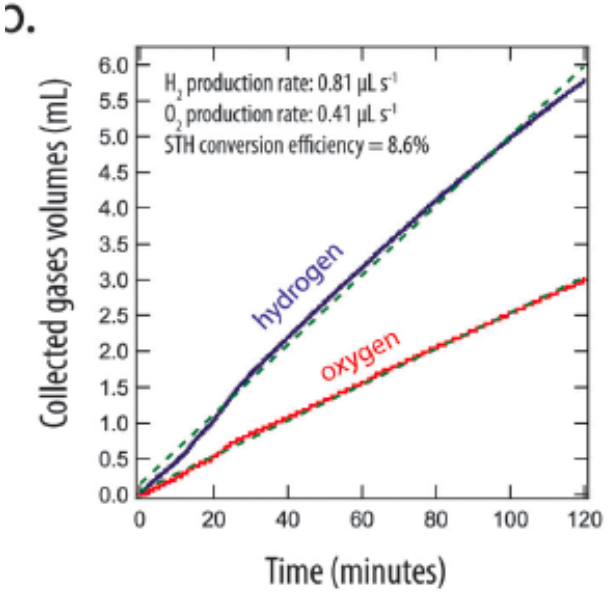
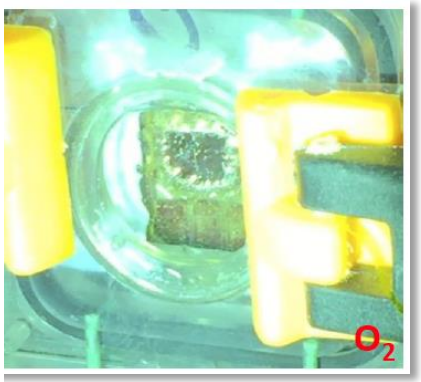
HIGH EFFICIENCY WATER OXIDATION SYSTEMS – UNFOLDED LOUVERED

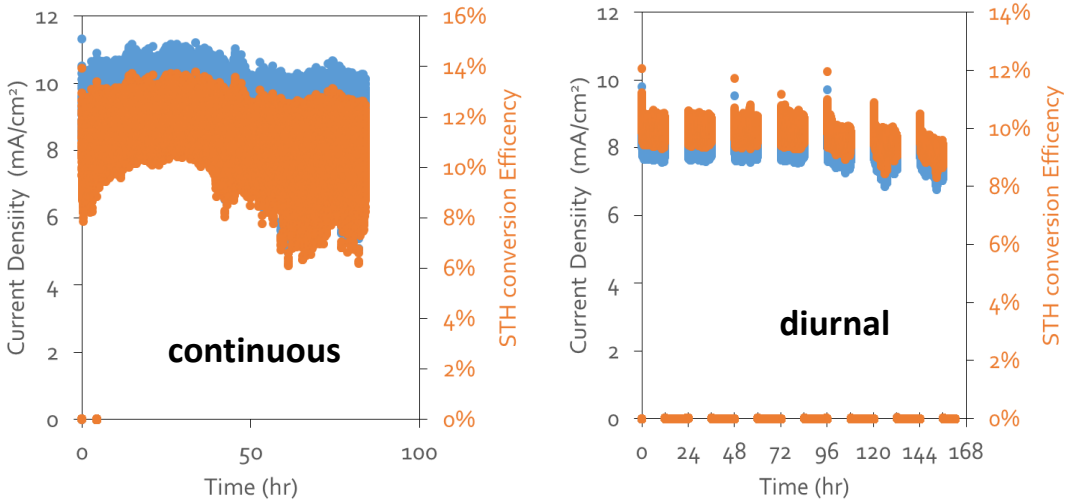




photoanode

III-V semiconductor stack

8.6% STH efficiency in 1M KOH, 1 cm^2



photocathode

III-V semiconductor stack

10-12% STH efficiency in 1M H_2SO_4, 1 cm^2

Karl Walczak, Jeff Beeman, David Larson, Rui Liu, CX Xiang, Frances Houle, Ian Sharp, in preparation 2016

Verlage, E. et al. Energy & Environmental Science, 8 (2015) 3166

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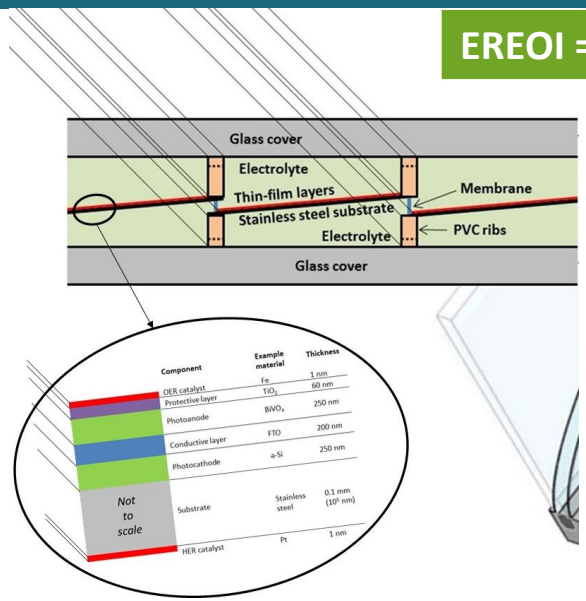
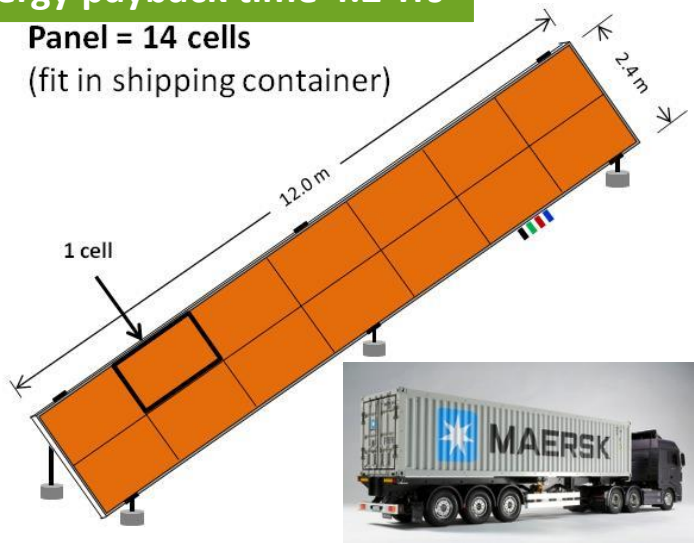
1 GW Scale Solar Hydrogen Plant Model: 10% STH, 10 year lifetime

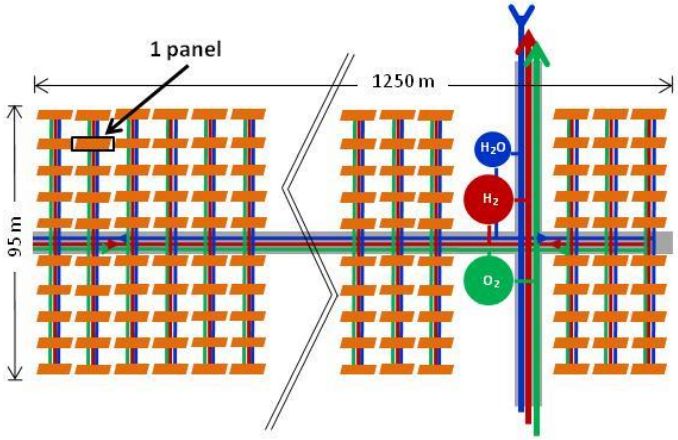
EREOI = 2.3, energy payback time 4.2 Yrs



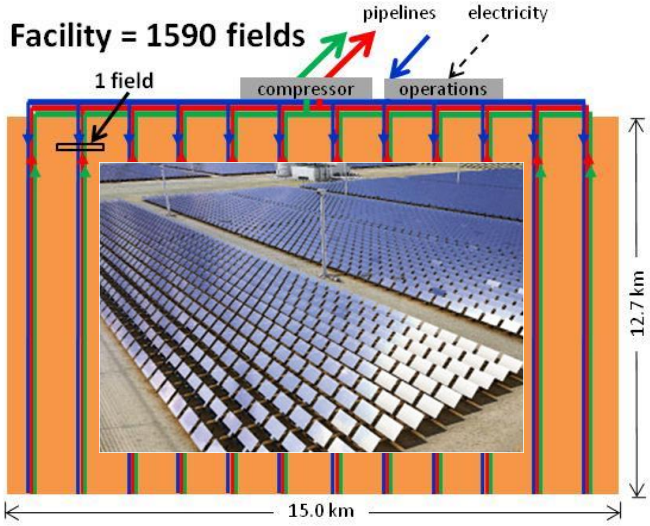
Panel = 14 cells
(fit in shipping container)



Field = 1000 panels



Facility = 1590 fields



Roger Sathre et al, Energy Environ. Sci. 7, 3264-3278 (2014) ; Energy Environ. Sci. 2016

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Thanks to the JCAP team and DOE Basic Energy Sciences!

The Joint Center for Artificial Photosynthesis (JCAP) is the nation's largest research program dedicated to the development of an artificial solar-fuel generation technology. Established in 2010 as a U.S. Department of Energy (DOE) Energy Innovation Hub, JCAP aims to find a cost-effective method to produce fuels using only sunlight, water, and carbon-dioxide as inputs. JCAP is led by a team from the California Institute of Technology (Caltech) and brings together more than 140 world-class scientists and engineers from Caltech and its lead partner, Lawrence Berkeley National Laboratory. JCAP also draws on the expertise and capabilities of key partners from the University of California campuses at Irvine (UCI) and San Diego (UCSD), and the Stanford Linear Accelerator (SLAC). In addition, JCAP serves as a central hub for other solar fuels research teams across the United States, including 20 DOE Energy Frontier Research Center.

For more information, visit http://www.solarfuelshub.org.