PECDEMO

Photoelectrochemical Demonstrator Device for Solar Hydrogen Generation

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Brussels, 21-22 November

PROJECT OVERVIEW

Project Information	
Call topic	Validation of photoelectrochemical hydrogen production processes
Grant agreement number	621252
Application area (FP7) or Pillar (Horizon 2020)	FP7 Hydrogen production and distribution
Start date	01/04/2014
End date	31/03/2017
Total budget (€)	3,337,682.79
FCH JU contribution (€)	1,830,644.00
Other contribution (€, source)	-
Stage of implementation	86% project months elapsed vs total project duration, at date of November 1, 2016
Partners	HZB, EPFL, IIT, DLR, UPORTO, EVONIK INDUSTRIES AG, SOLARONIX SA

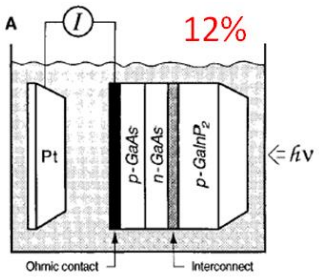
PROJECT SUMMARY

Overall objective (MAIP): Research and development on new, fully sustainable hydrogen production pathways

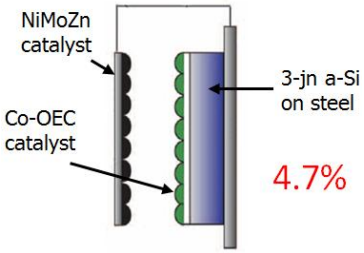
Expected Results PECDEMO:

- To demonstrate a stand-alone solar water splitting device with active area **≥50 cm²**, solar-to-H_2 efficiency of **8%**, stable for more than **1000h**
- To demonstrate scalability by combining multiple devices into a **larger water splitting module** and perform **field tests**
- To evaluate the potential for large-scale commercialization by extensive **techno-economic** and **life-cycle analyses**
- To **disseminate** PECDEMO's results in the scientific community and to **generate interest with industry**

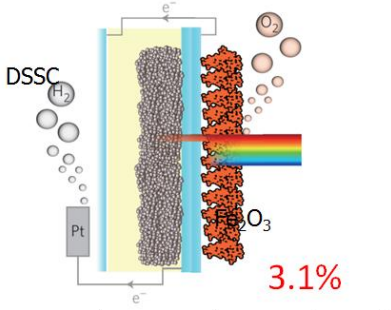
SoA: several small-scale (~1 cm²) water splitting devices:



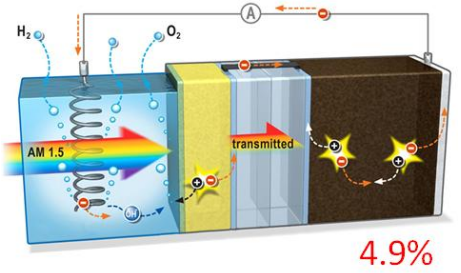
Turner, *Science (1998)*



Nocera, *Science (2011)*



Grätzel, *Nat. Photon. (2012)*



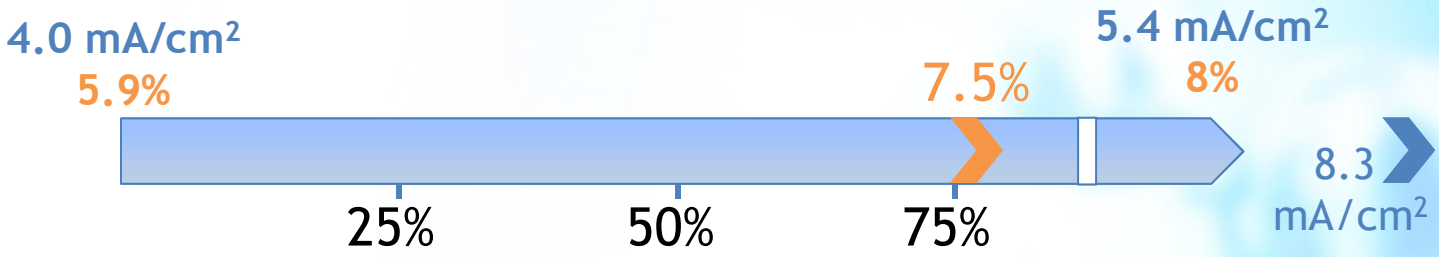
Van de Krol, *Nat. Comm. (2013)*

Project Progress / Actions - Efficiency

PEC DEMO

Achievement to-date

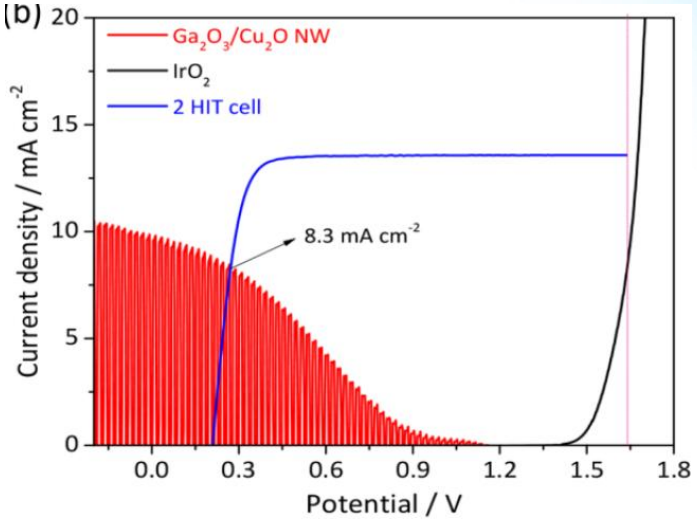
% stage of implement.



Aspect addressed	Parameter (KPI)	Unit	SoA 2016	FCH JU Targets		
				Call topic	2016	2020
Efficiency	Photoelectr. current	mA/cm^2	8.3	-	-	-
	Solar-to-H_2	%	7.5	8-10%	>5%	-

Future steps:

- Combine best Cu_2O electrodes and catalysts into device → should give 12.3% STH efficiency
- Decrease bandgap of $BiVO_4$ by N-doping and tune band positions with dipole molecules
- Improve photon management with distributed Bragg reflectors (DBR)

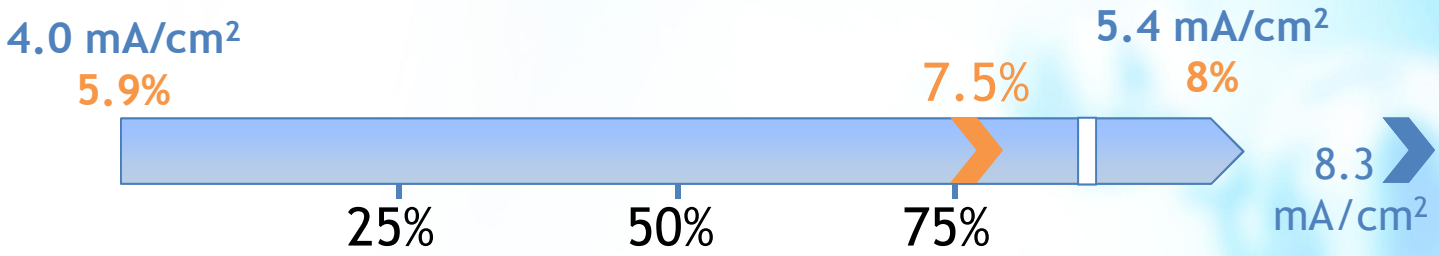


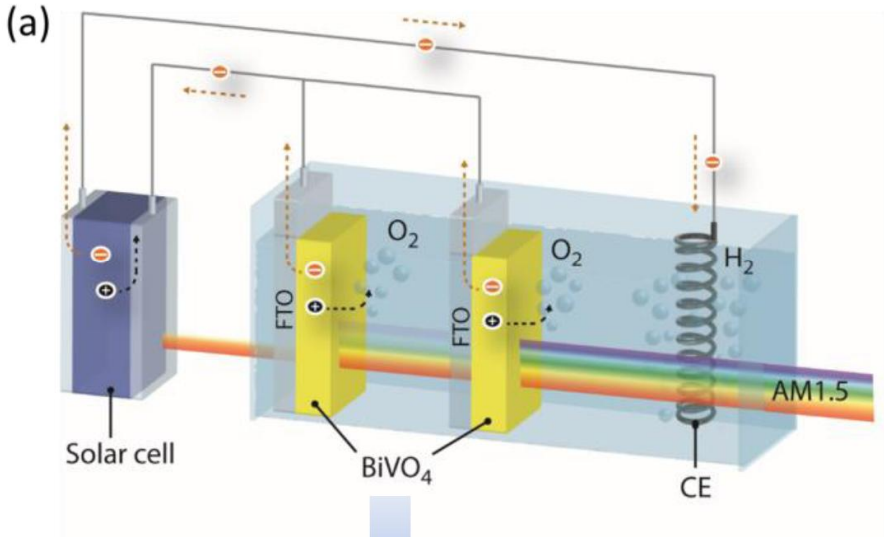
Project Progress / Actions - Efficiency

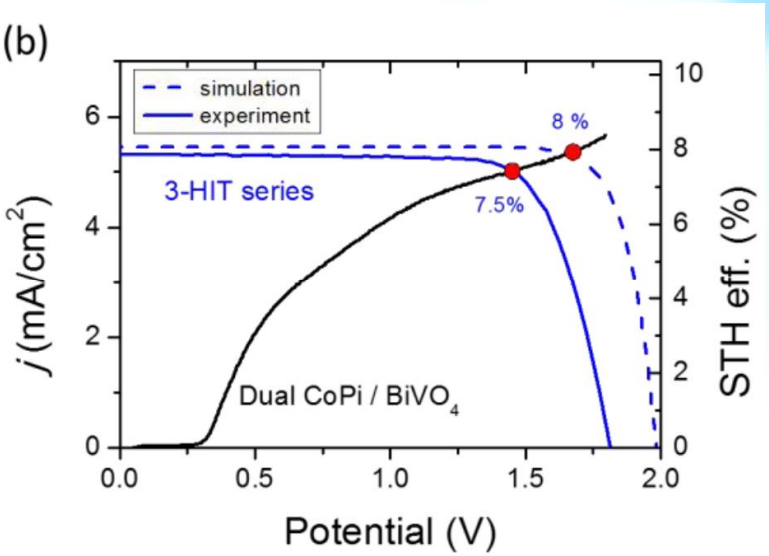
PEC DEMO

Achievement to-date

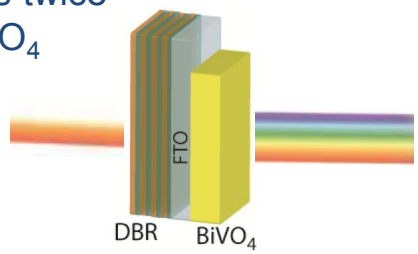
% stage of implement.

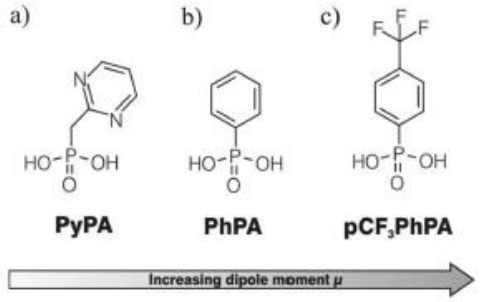






Light passes twice through $BiVO_4$ with DBR



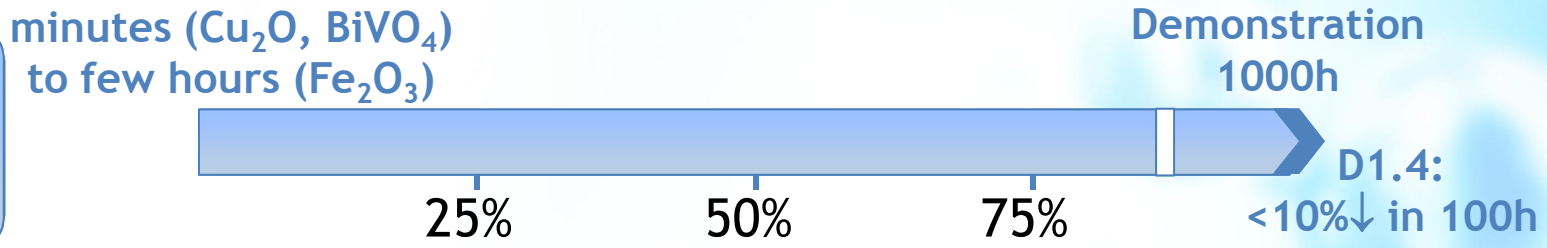


Functionalization of $BiVO_4$ with dipolar molecules to shift band edges

Project Progress / Actions - Stability

Achievement to-date

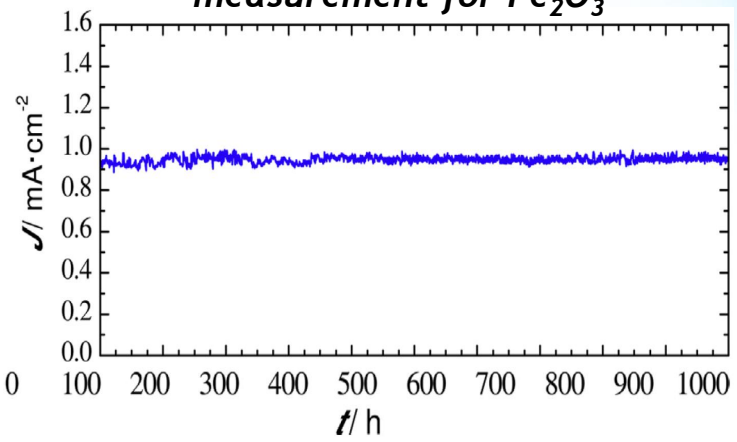
% stage of implement.



Aspect addressed	Parameter (KPI)	Unit	SoA 2016	FCH JU Targets		
				Call topic	2016	2020
Stability	Demonstrated lifetime	hours	1000	1000	-	-

- Stability of Cu_2O was <5 min. at project start, currently <10% performance decrease in 55h
- $BiVO_4$: <10% decrease in 100h at pH 8.6 (D1.4)
  50% decrease in 65h at pH 13

First ever 1000h stability measurement for Fe_2O_3



Future steps:

- Improve stability of Cu_2O and $BiVO_4$ by optimization of protection layers

Project Progress / Actions - Stability

Achievement to-date

% stage of implement.

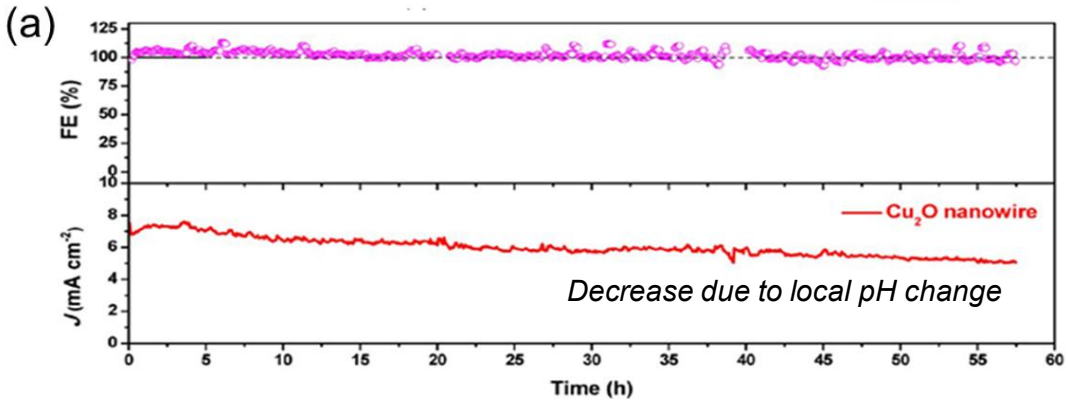
minutes (Cu_2O, $BiVO_4$) to few hours (Fe_2O_3)

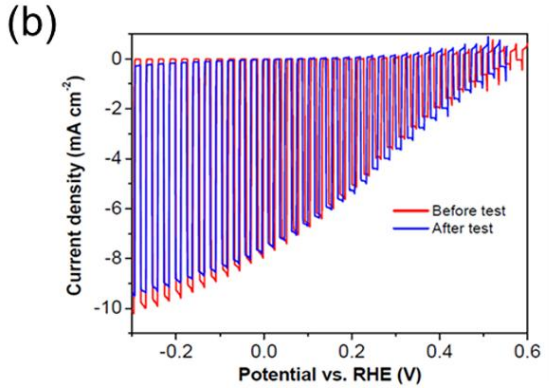
Demonstration 1000h

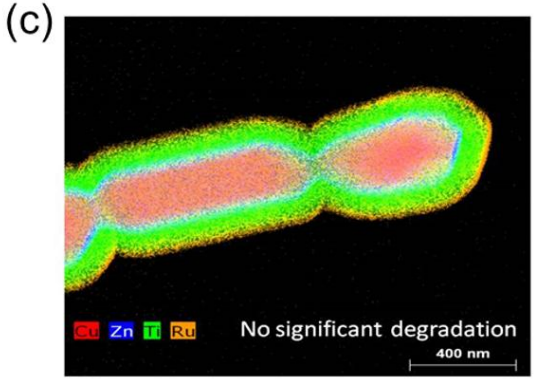
25% 50% 75%

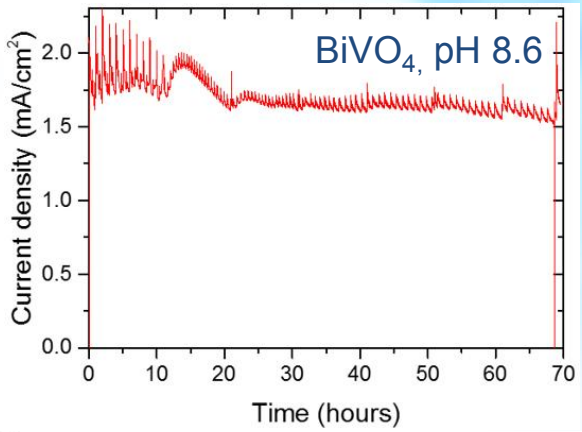
D1.4: <10%↓ in 100h

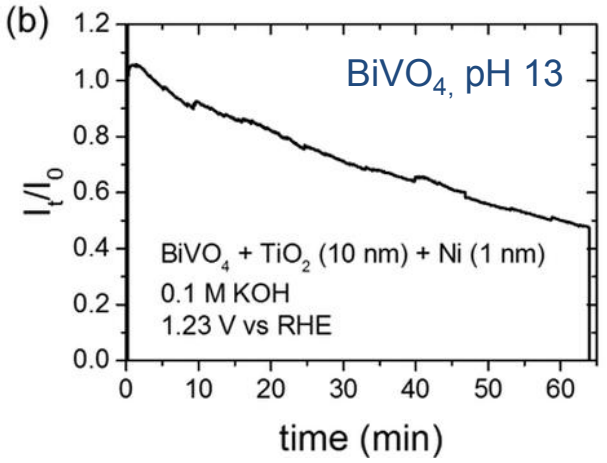
Stability of Cu_2O Nanowire Photoelectrodes











Project Progress / Actions - Scale-Up

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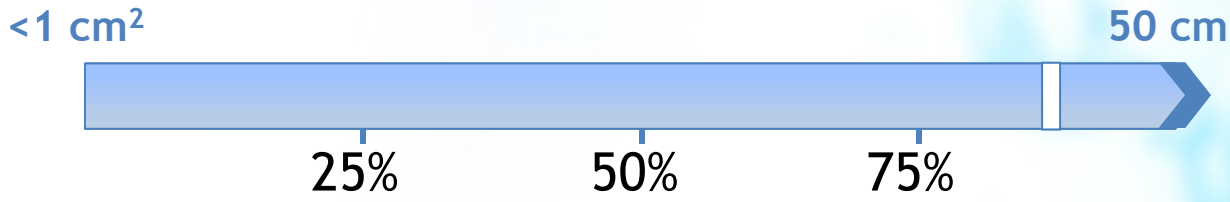
Achievement to-date

% stage of implement.

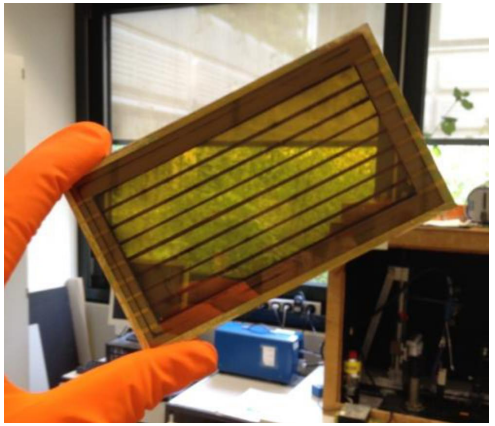


Aspect addressed	Parameter (KPI)	Unit	SoA 2016	FCH JU Targets		
				Call topic	2016	2020
Scale-Up	Electrode size	cm^2	50	50	-	-

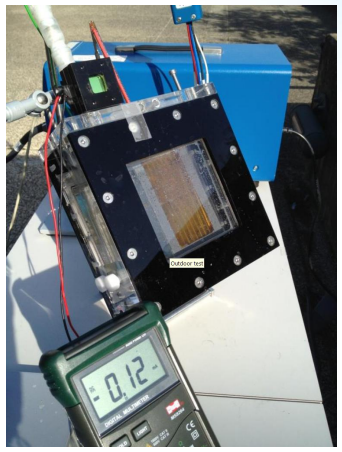
Future steps:

- Further reduce ohmic losses for large-area conducting substrates
- Improve homogeneity and quality of $BiVO_4$ and Cu_2O photoelectrodes
- Integrate photoelectrodes and photovoltaic bottom-absorbers in large-area device array (1x4)

50 cm² Cu_2O photocathode



Outdoor test

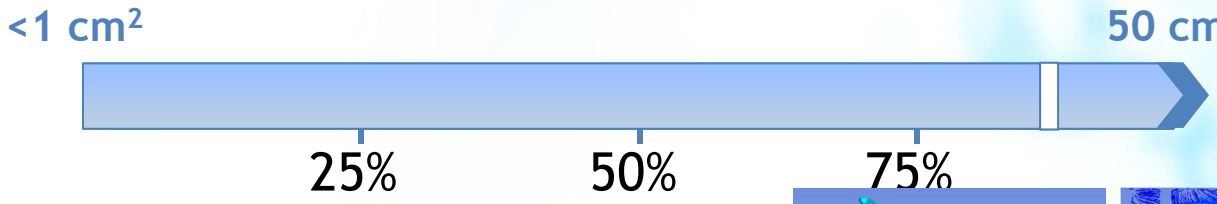


Project Progress / Actions - Scale-Up

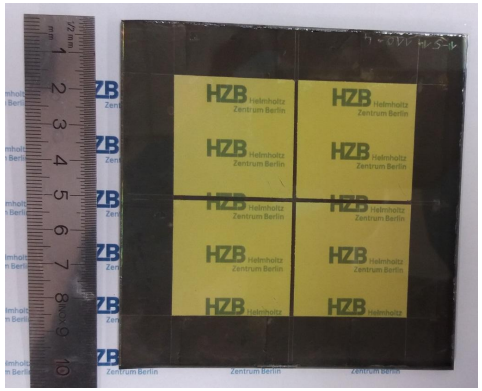
PEC DEMO

Achievement to-date

% stage of implement.

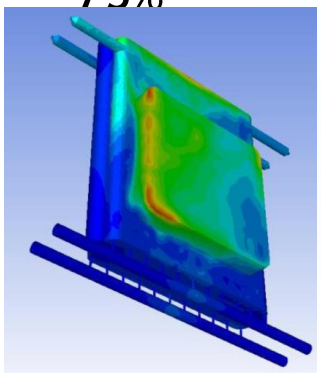


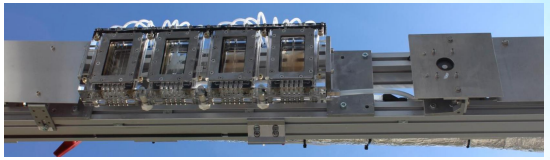
50 cm² $BiVO_4$ photoanode



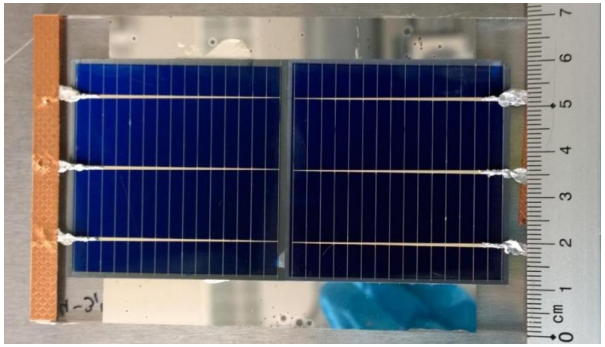
Perovskite solar cell with 47.6 cm² active area

CFD calculations on temperature distribution and electrolyte flow

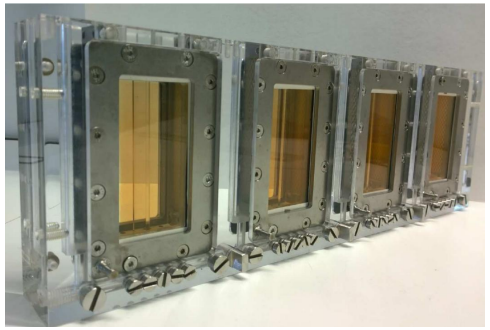




50 cm² silicon HIT cell



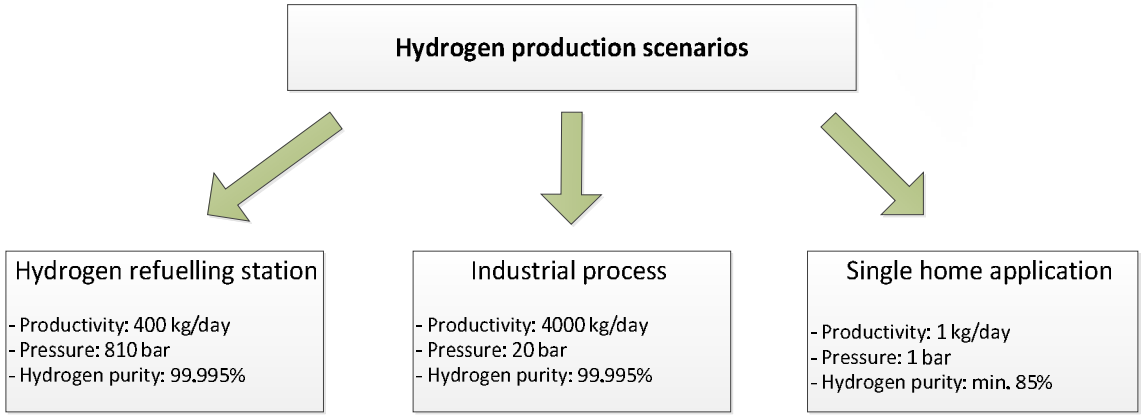
1st field test of 1x4 array starts on 28 Nov. 2016

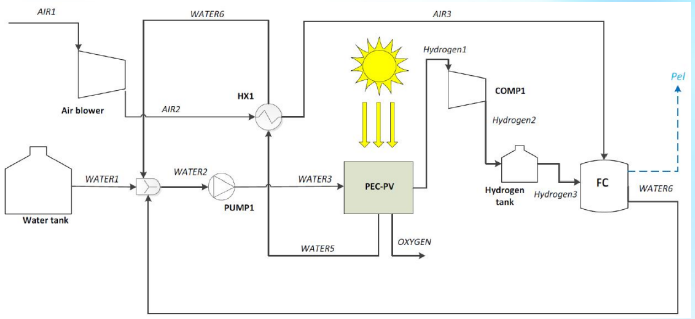


Project Progress - Miscellaneous

Work package on Techno-Economic and Life Cycle Analyses

- Three concepts developed for H_2 production scenarios in different locations
- Component sizing and flow sheeting completed
- Global warming potential was calculated for various scenarios





Status Deliverables and Milestones

- Deliverable 1.2 not entirely met: device efficiency of 7.5% instead of 8%
- All other deliverables and milestones have been successfully completed

SYNERGIES WITH OTHER PROJECTS AN PROGRAMMES

Interactions with projects funded under EU programmes	
NanoPEC *(2009-2011)*	The three best-performing materials from the NanoPEC project were selected for the optimization, device design, and scale-up efforts in PECDEMO. Several partners were/are in both projects.
BI-DSC	Experience from BI-DSC activities helped to achieve a demonstration of 1000h stability for Fe_2O_3 photoanodes.
Interactions with national and international-level projects and initiatives	
MeOx-4-H2	Fundamental studies on W-doped $BiVO_4$ in MeOx-4-H2 revealed charge trapping mechanism that inspired a new doping strategy for PECDEMO's $BiVO_4$ photoanodes.
HNSEI	Fundamental efforts on semiconductor/catalyst interactions in HNSEI revealed why CoPi is such a great catalyst for $BiVO_4$; this avoided wasted efforts on noble metal catalysts in PECDEMO.
PECHouse	Close collaboration between PECHouse and PECDEMO researchers have resulted in record efficiencies for Cu_2O photocathodes.

DISSEMINATION ACTIVITIES

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Public deliverables

- D1.4 Stable device with <10% performance decrease after 100 h operation
- D3.3 Public report on large-area PEC/PV components
- D4.3 Public report on device design
- D7.1 Mid-term assessment report
- D8.1 Basic framework of website database is online and operational

Conferences/Workshops

- 2 organised by the project: IPS-20 Intl. Conf. (2014) & MRS Symposium (2016)
- 34 in which the project has participated (but not organised)

Social media

Patents: 0

Publications: 19

- J. Luo, J-H. Im, M.T. Mayer, M. Schreier, M.K. Nazeeruddin, N-G. Park, S.D. Tilley, H.J. Fan, M. Grätzel, "Water photolysis at 12.3% efficiency via perovskite photovoltaics and Earth-abundant catalysts", Science, 345 (6204), 1593 (2014)
- S. Kirner, P. Bogdanoff, B. Stannowski, R. van de Krol, B. Rech, R. Schlatmann, "Architectures for Scalable Integrated Photo Driven Catalytic Devices - A Concept Study", Int. J. Hydrogen Energy 41, 20823 (2016)

Thank You!

- Coordinator: roel.vandekrol@helmholtz-berlin.de