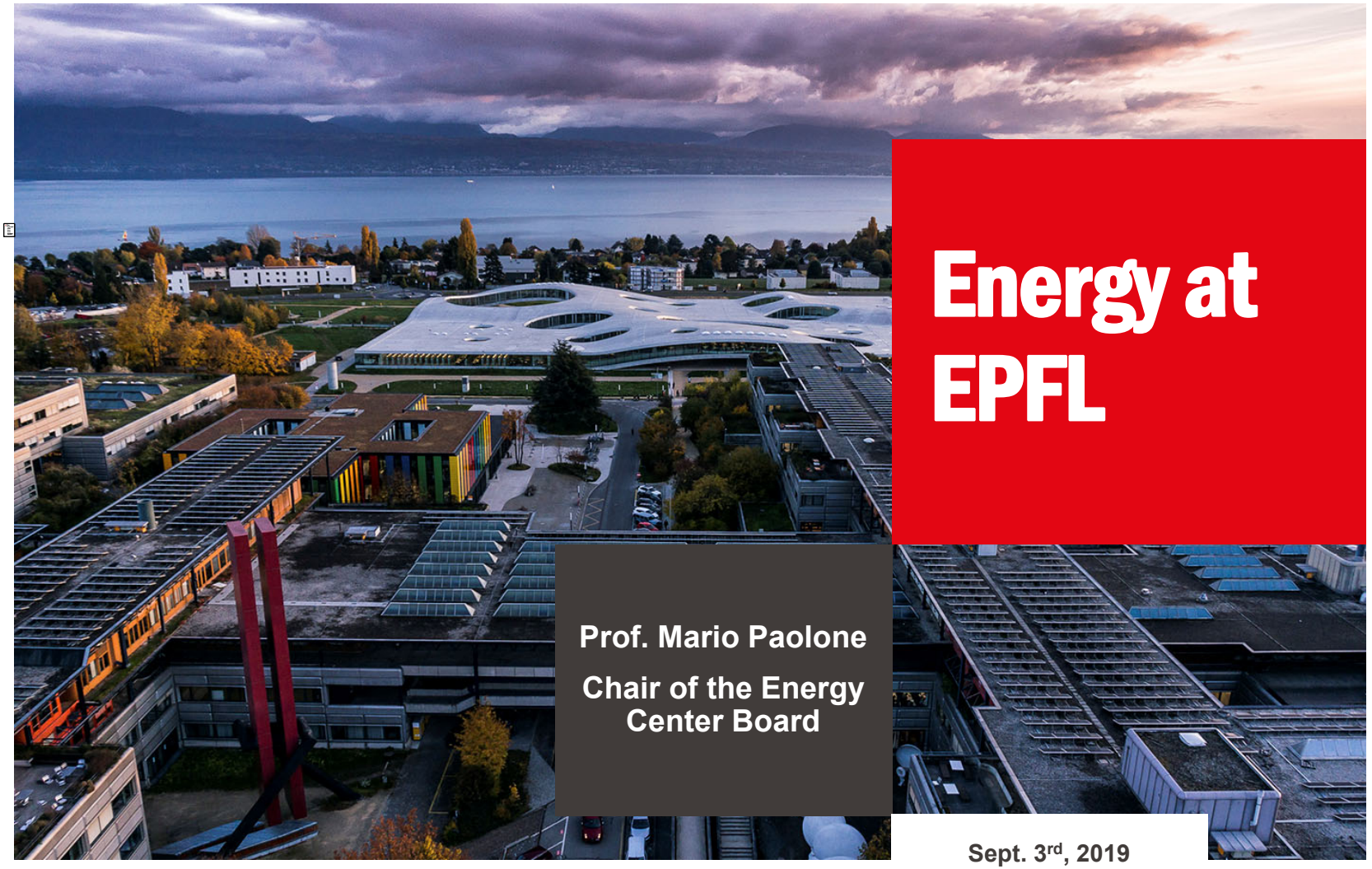
EPFL



# Energy at EPFL

**Prof. Mario Paolone**

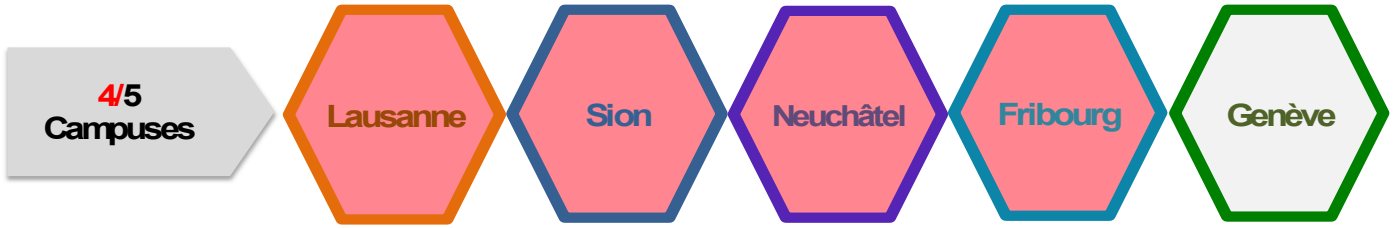
**Chair of the Energy Center Board**

**Sept. 3rd, 2019**

Energy Center (CEN)

# 13 Study Programmes, 350 Research Labs

# 4 out of 5 EPFL Campuses
## active in energy research

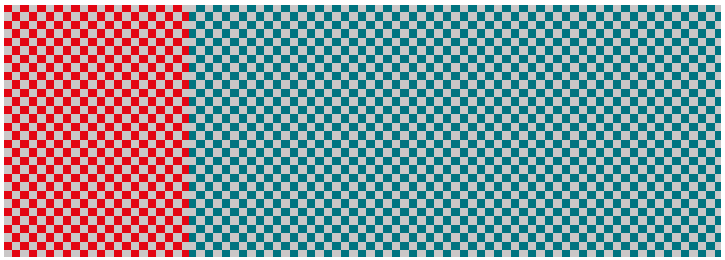


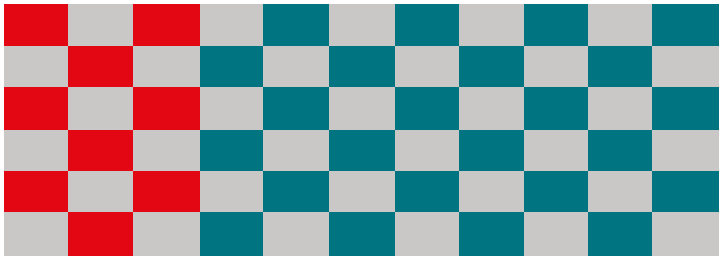

# Energy research across the EPFL

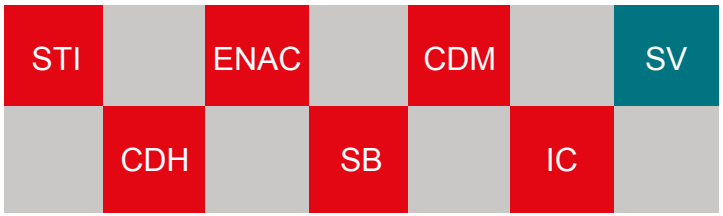
**90 / 350**
**Laboratories**

**9/33**
**Interdisciplinary Centers**

**6 / 7**
**Faculty / Colleges**







# Energy R&D @EPFL:
## a broadband endeavor

Energy Systems

Grid

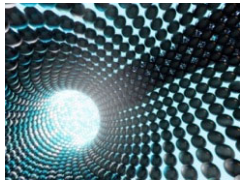
Renewable

Energy and digitalisation

Mobility and transport

Energy & environment

Materials for energy

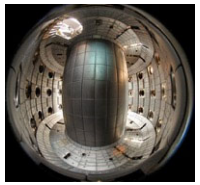


Energy efficiency

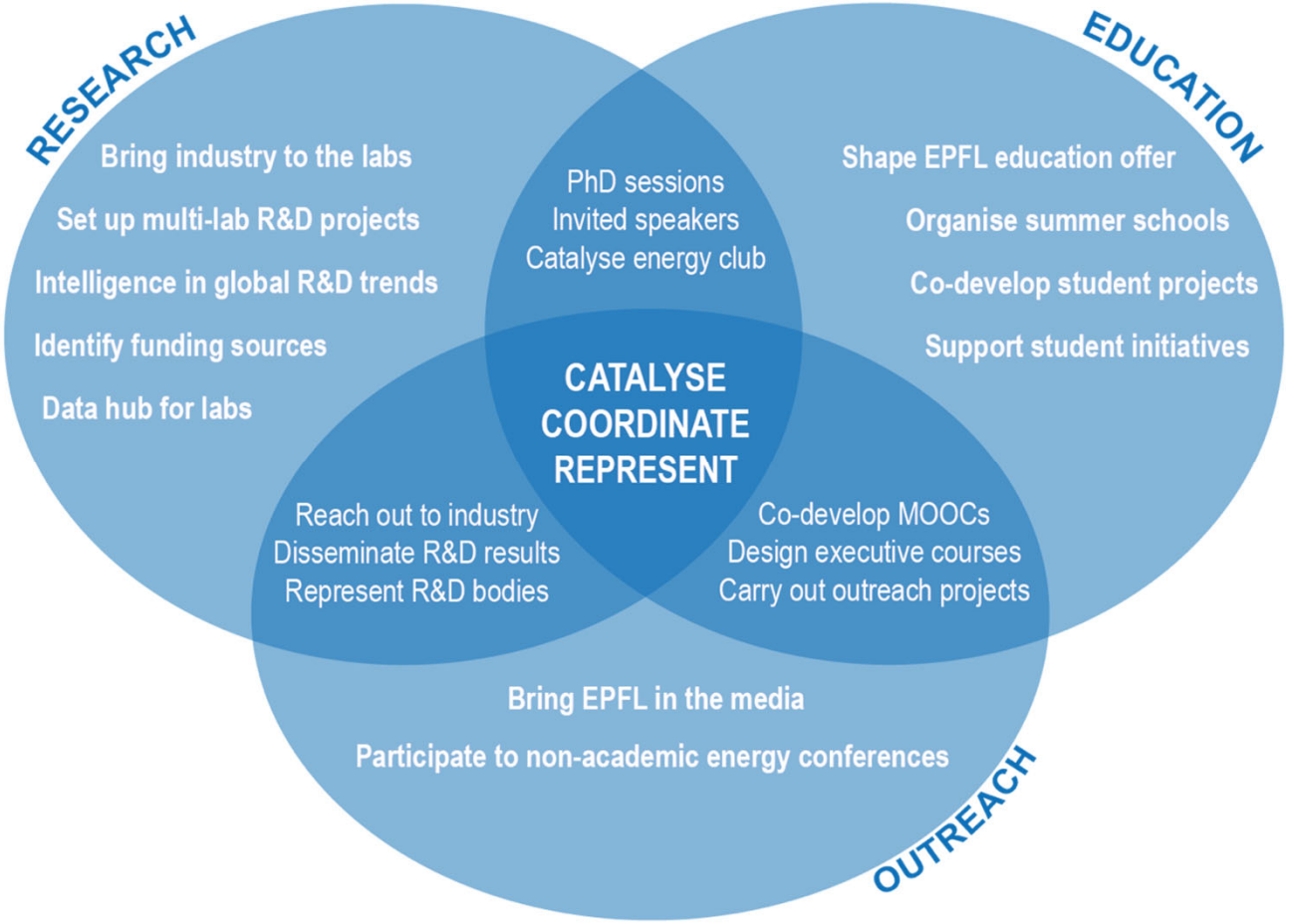

Energy storage

Socio-economics

Nuclear

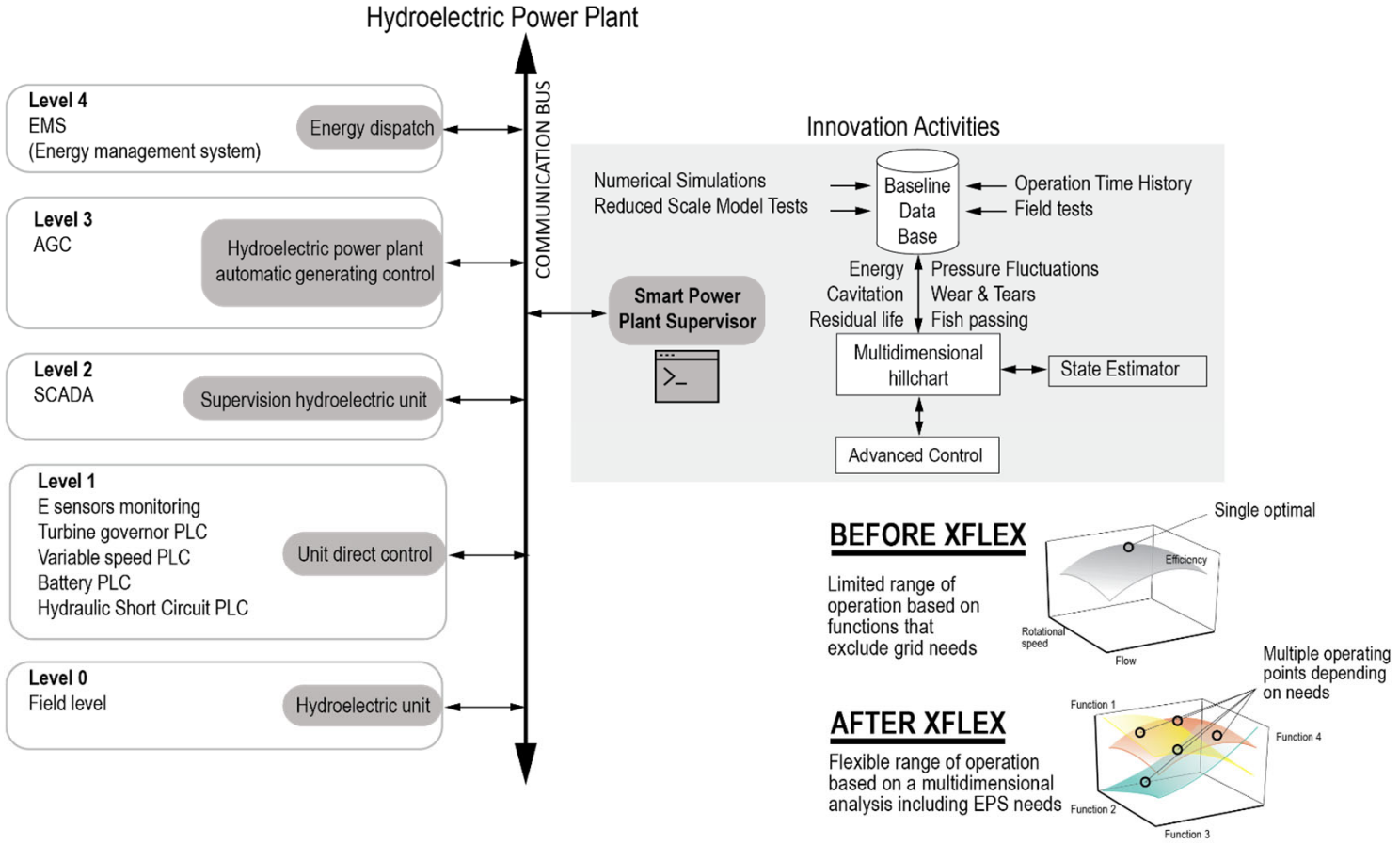


# CEN activities



# Energy showcase:

## EU-H2020 Hydropower Extending Power System Flexibility - XFLEX



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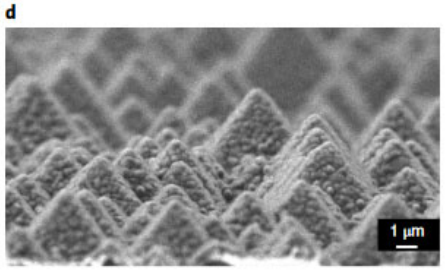
# Energy Showcase:
## Photovoltaics




**d**,**e**. Secondary electron SEM image of the perovskite layer (**d**) and a cross-section of the full perovskite top cell deposited on the SHJ bottom cell (**e**),

ARTICLES
https://doi.org/10.1038/s41563-018-0115-4
nature materials

## Fully textured monolithic perovskite/silicon tandem solar cells with 25.2% power conversion efficiency

Florent Sahli[1,3]*, Jérémie Werner[1,3], Brett A. Kamino[2], Matthias Bräuninger[1], Raphaël Monnard[1], Bertrand Paviet-Salomon[2], Loris Barraud[2], Laura Ding[2], Juan J. Diaz Leon[2], Davide Sacchetto[2], Gianluca Cattaneo[2], Matthieu Despeisse[2], Mathieu Boccard[1], Sylvain Nicolay[2], Quentin Jeangros[1]*, Bjoern Niesen[2] and Christophe Ballif[1,2]

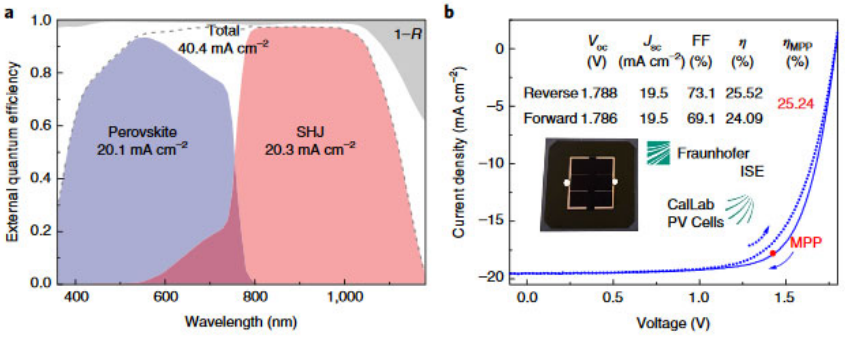
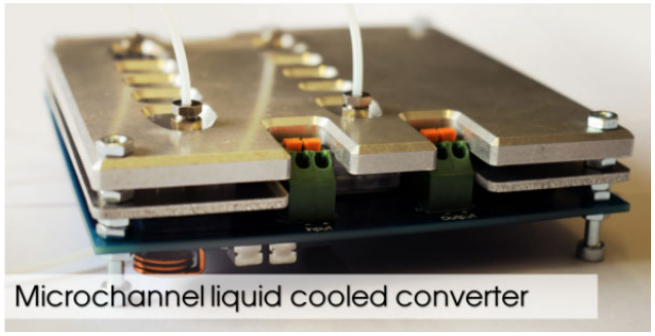
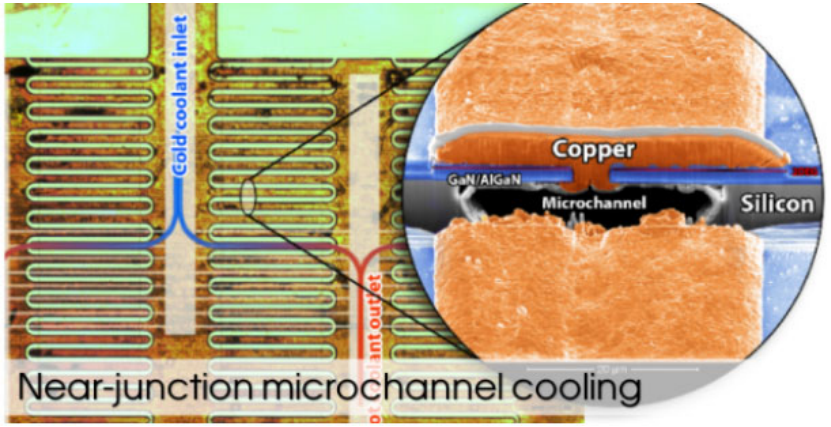


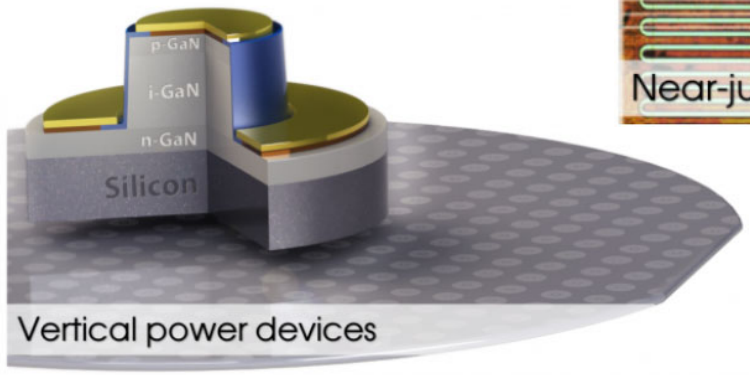

**Fig. 4 | Certified performance of the fully textured perovskite/silicon tandem cell. a**, EQE spectra of a current-matched fully textured monolithic perovskite/SHJ tandem cell featuring a 1.6 eV perovskite absorber with a thickness of 440 nm alongside the 1–*R* curve, both excluding losses due to the front side metal grid. **b**, Corresponding certified *J*–*V* data (1.42-cm² aperture area, device shown in the inset), which was measured with a scan rate of 100 mV s⁻¹.

# More showcases:
## Power- and wide-bandgap electronics


Microchannel liquid cooled converter



Near-junction microchannel cooling



Vertical power devices

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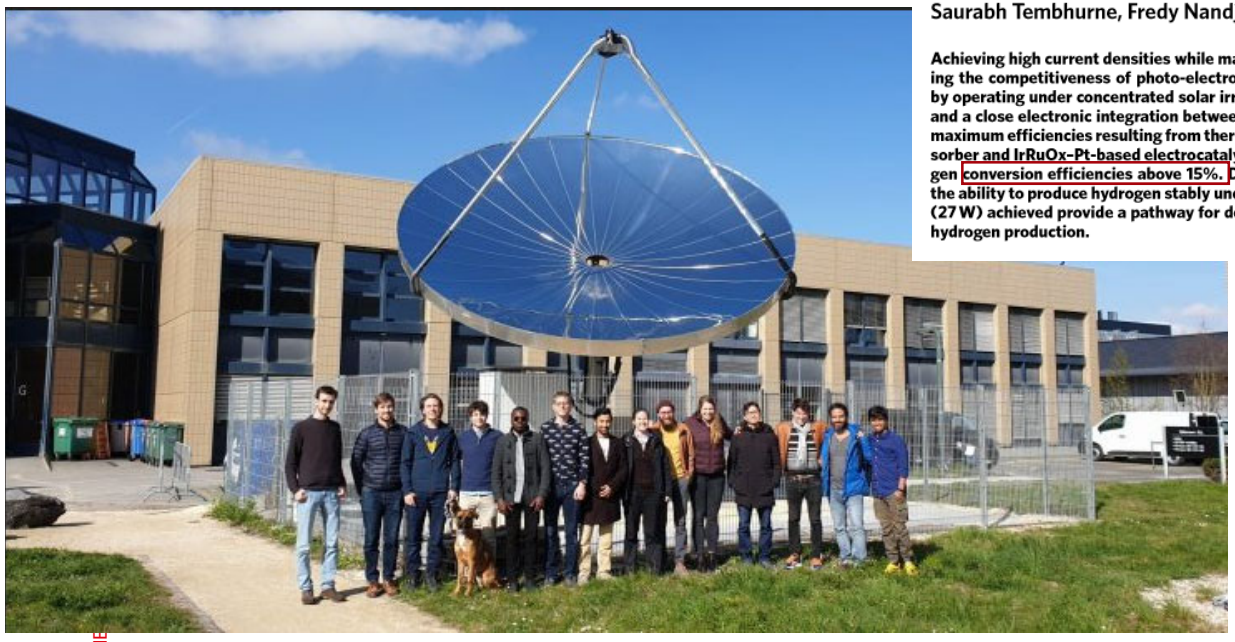
# Energy Showcase:
## Photo-electrochemical $H_2$ generator



nature energy

ARTICLES

https://doi.org/10.1038/s41560-019-0373-7

## A thermally synergistic photo-electrochemical hydrogen generator operating under concentrated solar irradiation

Saurabh Tembhurne, Fredy Nandjou and Sophia Haussener *

**Achieving high current densities while maintaining high energy conversion efficiency is one of the main challenges for enhancing the competitiveness of photo-electrochemical devices. We describe a concept that allows this challenge to be overcome by operating under concentrated solar irradiation (up to 474 kW $m^{-2}$), using thermal integration, mass transport optimization and a close electronic integration between the photoabsorber and electrocatalyst. We quantify the increase in the theoretical maximum efficiencies resulting from thermal integration, and experimentally validate the concept using a III–V-based photoabsorber and IrRuOx–Pt-based electrocatalysts. We reach current densities higher than 0.88 A $cm^{-2}$ at calculated solar-to-hydrogen conversion efficiencies above 15%. Device performance, dynamic response and stability are investigated, demonstrating the ability to produce hydrogen stably under varying conditions for more than two hours. The current density and output power (27 W) achieved provide a pathway for device scalability aimed towards the large-scale deployment of photo-electrochemical hydrogen production.**

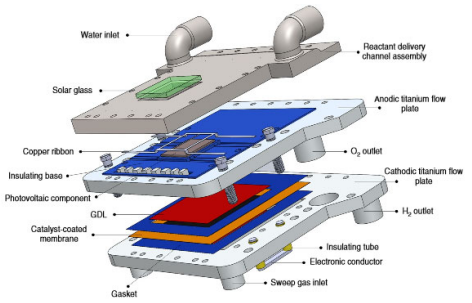



**Fig. 2 | Illustration of the integrated PEC device.** This device includes a reactant delivery channel assembly containing a solar glass window, beneath which lies the photoactive component. The photoactive component is in direct contact with the anodic titanium flow/collector plate. The anodic and cathodic titanium plates sandwich the catalyst-coated membrane, GDLs and gaskets, forming the electrochemical component where water splitting takes place. The coolant/reactant enters the delivery channel assembly and flows directly over the photoactive component, removing excess heat and transferring it to the catalytic sites.

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# Energy Showcase:
## Distributed electrical systems

IEEE TRANSACTIONS ON SMART GRID, VOL. 10, NO. 3, MAY 2019

## Control of Battery Storage Systems for the Simultaneous Provision of Multiple Services

Emil Namor, *Student Member, IEEE*, Fabrizio Sossan, *Member, IEEE*,
Rachid Cherkaoui, *Senior Member, IEEE*, and Mario Paolone, *Senior Member, IEEE*

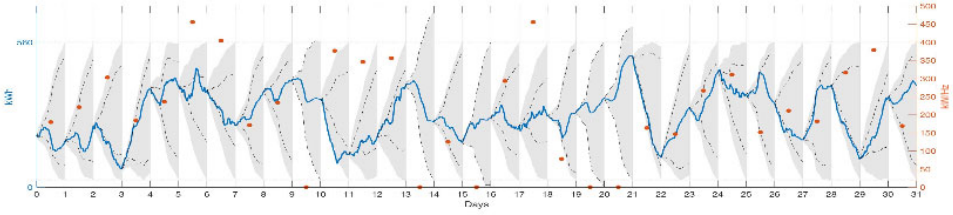


Fig. 4. Simulation results of 31 consecutive days of operation. Blue line: BESS stored energy; Grey area: total daily energy budget $\mathcal{E}_D + \mathcal{E}_{FR}$; Black dashed lines: bounds of the daily energy budget reserved to the dispatching service $\mathcal{E}_D$; red dots: daily values of $\alpha^o$ (referred to the right-hand y-axis).

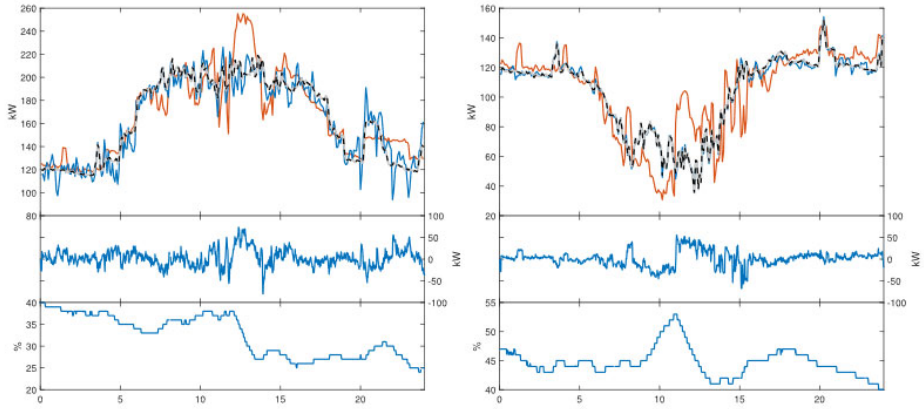


Fig. 5. Experimental results, left: day 1, right: day 2. Upper plots - feeder power profiles. Thick grey line: dispatch plan, red line: feeder prosumption, dashed black line: feeder real power (excluded the PFR power injection), blue line: feeder real power (with the PFR). Middle plots - BESS power injection. Lower plots - BESS SOE evolution.

# More showcases:
## Grid2Mobility Demonstrator

### Service station project

**Electrical grid**

http://www.pgecurrents.com

AC

**Redox Flow Battery (RFB)**

This battery has a central role in this system, as it provides storage of cheap, surplus energy while supplying continuous power to the electrolysers and to the electric charging station. With a power of 200 kW and a capacity of 400 kWh, the battery buffers the consumption peaks associated with the vehicle charging and to continuously feed the electrolyser.


http://energy.gildemeister.com

DC

**Electrolysers**

An alkaline and a PEM electrolyser will be used in parallel. Both electrolysers will be compared in terms of their use flexibility. They are fed by a DC line from the RFB. With a power of 50 kW, the alkaline electrolyser will be run continuously at partial power, while the PEM electrolyser (30 kW) will primarily be started during periods of high hydrogen demand.

http://www.mcphy.com

https://www.youtube.com/watch?v=6gaaEQ0HnG0

$H_2$
10-40 bar

**Hydrogen storage**

Hydrogen will be stored on-site in 50 L bottles at 200 bar. The total hydrogen storage capacity is sufficient to recharge 10 cars. This hydrogen storage also provides an additional energy buffer for the site.

http://pureenergycentre.com/hydrogen-storage/

$H_2$
350 bar (fast)
or 700 bar (slow)

DC

**Electric cars charging station**

This charging station will be fed directly from the DC bus of the RFB. It will provide fast charging to the battery of the car (>50 kW) using the standard connections CHAdeMO and CCS.

http://www.plugincars.com

**Hydrogen refilling station**

In the first phase, this service station will supply hydrogen to two fuel cell cars. It will initially provide hydrogen at 350 bars or 700 bars with a recharge capacity of 4 cars per day.


https://en.wikipedia.org/wiki/Hydrogen_station

EPFL

# International Performance

## Shanghai's Global Ranking of Academic Subjects 2019 - Energy Science and Engineering

**ShanghaiRanking's Global Ranking of Academic Subjects 2019 - Energy Science & Engineering** 2019

Field : Engineering | Subject : Energy Science & Engineering | Methodology

| World Rank | Institution* | Country/Region | Total Score | Score on PUB |
|---|---|---|---|---|
| 1 | Nanyang Technological University | | 272.7 | 56.2 |
| 2 | Massachusetts Institute of Technology (MIT) | | 256.0 | 58.0 |
| 3 | Tsinghua University | | 253.5 | 100.0 |
| 4 | Stanford University | | 253.2 | 52.7 |
| 5 | Swiss Federal Institute of Technology Lausanne | | 251.8 | 47.2 |
| 6 | University of California, Berkeley | | 246.5 | 65.7 |
| 7 | University of Chicago | | 230.2 | 60.3 |
| 8 | Georgia Institute of Technology | | 228.9 | 51.3 |
| 9 | South China University of Technology | | 227.0 | 64.5 |
| 10 | Huazhong University of Science and Technology | | 226.9 | 70.6 |

ACADEMIC RANKING OF WORLD UNIVERSITIES SINCE 2003

*Source:* *www.shanghairanking.com*

**Rank 2nd in 2018**
**Rank 5th in 2017**

# H2020 on energy

- EPFL has 42 ongoing H2020 research projects on energy (signed contracts with PIs since 2014)
- for a total funding of 44.6 Meuro
- …not counting MSCA and ERC



# Sample of EPFL “Cleantech” start-ups

BlueWatt ENGINEERING

OsmoBlue ENERGY

Zaphiro Technologies

hydrique.

Iprova INVENT FIRST

Estia

Advanced MicroFluidics

AQUAVISION

greatcellsolar Global leaders in hi-tech solar

GridSteer


Merci
Mario
Paolone