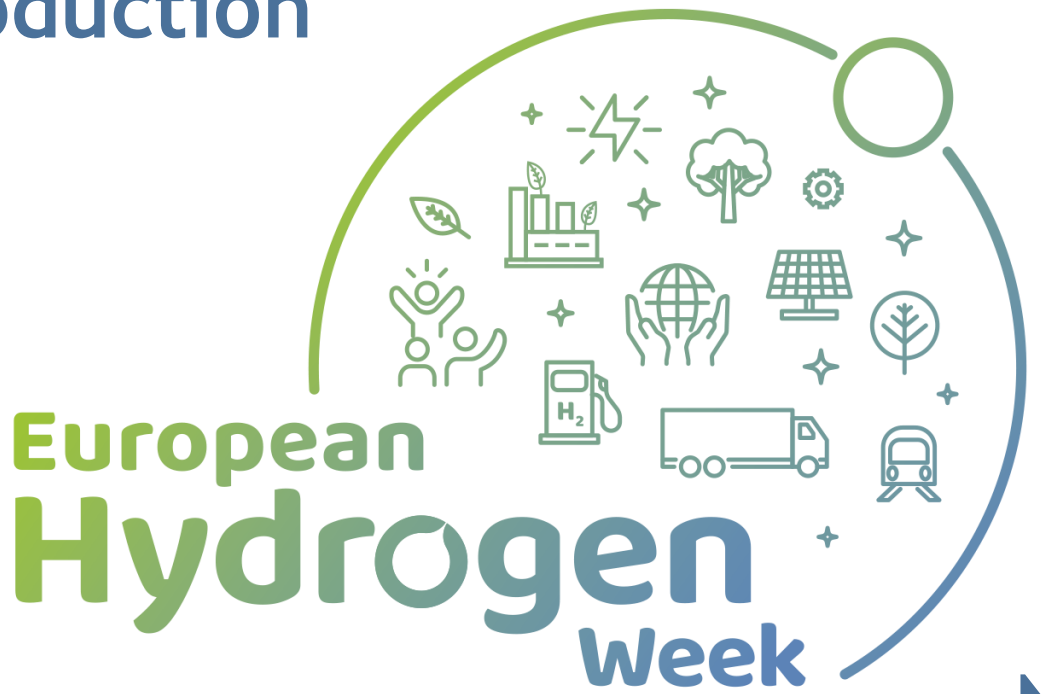
Hydrogen Production



N. Lymperopoulos
D. Tsimis
C. Pavel

Project Officers

European Hydrogen Week

PRD parallel sessions on H_2 Production

2nd Dec. 11:00 - 12:20

Electrolysers for Industrial Applications - 1

2nd Dec. 13:00 - 14:20

Electrolysers for Industrial Applications - 2

2nd Dec. 14:30 - 15:50

Next Generation Electrolysers

3rd Dec. 14:00 - 15:20

Early Research on alternative routes for Hydrogen production

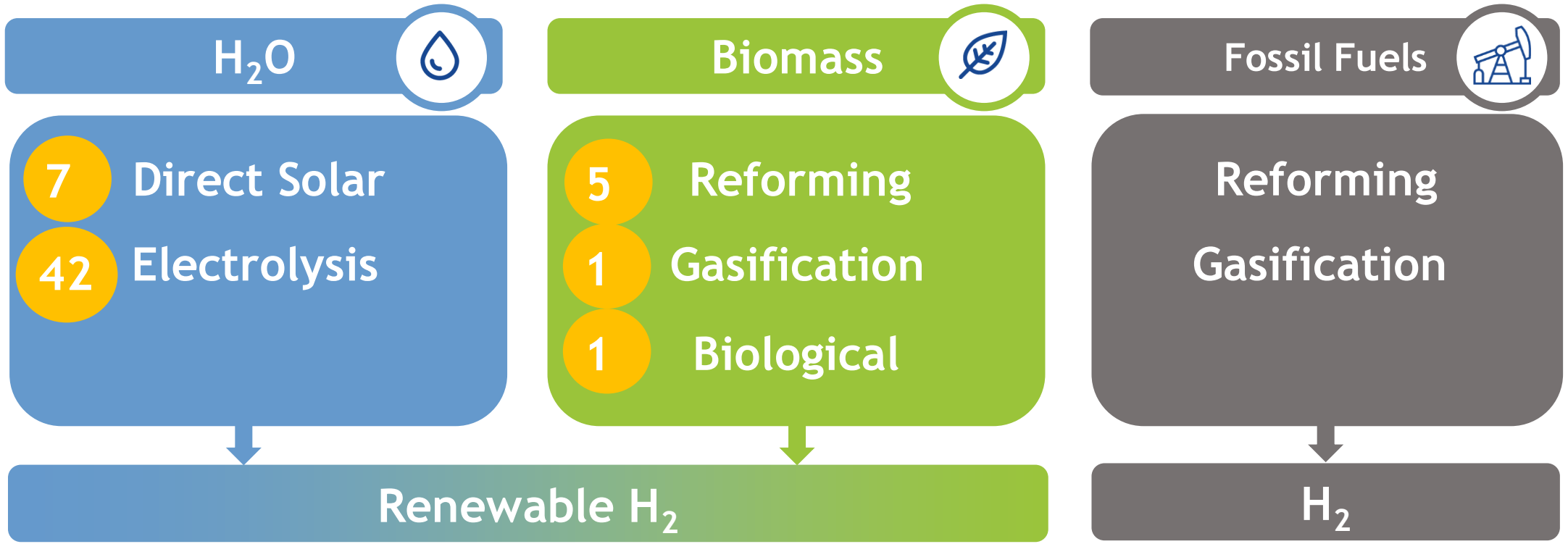
#PRD2021
#CleanHydrogen

FCH

European Commission

Hydrogen Production Technical Coverage

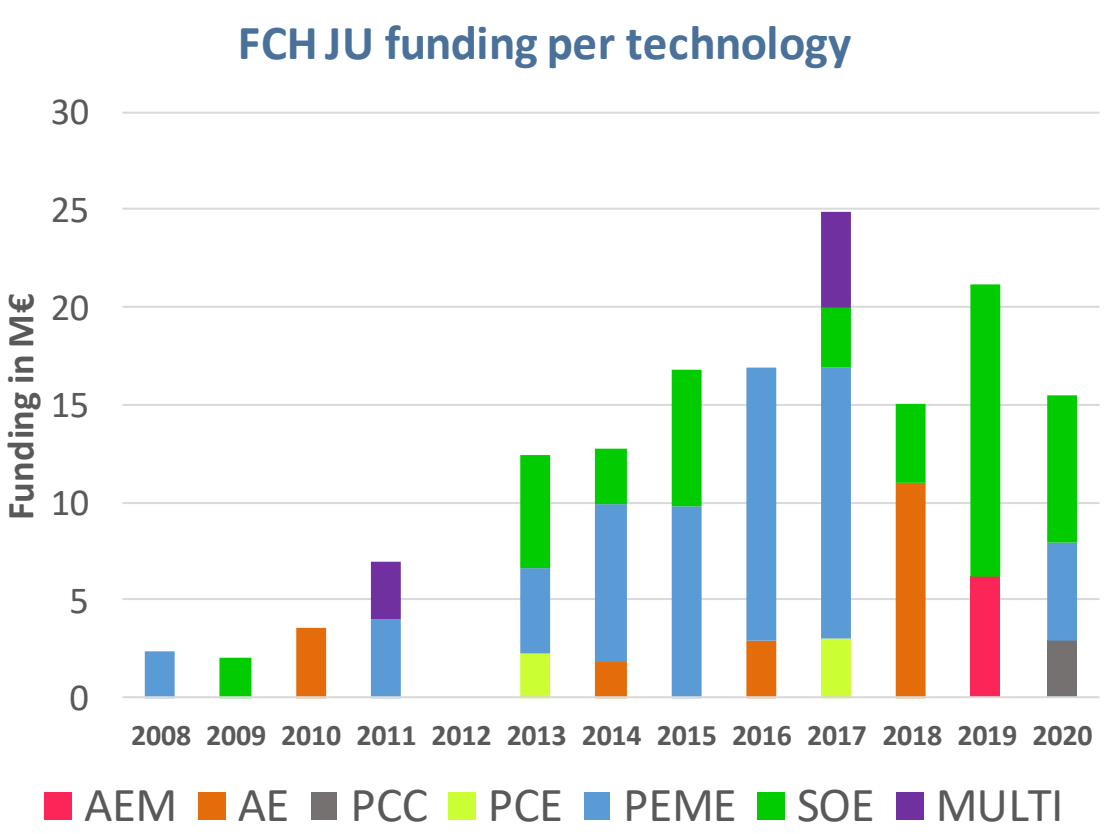
56 projects, 177.4 MEuro, 16.5% of FCH JU support. Only renewable H_2

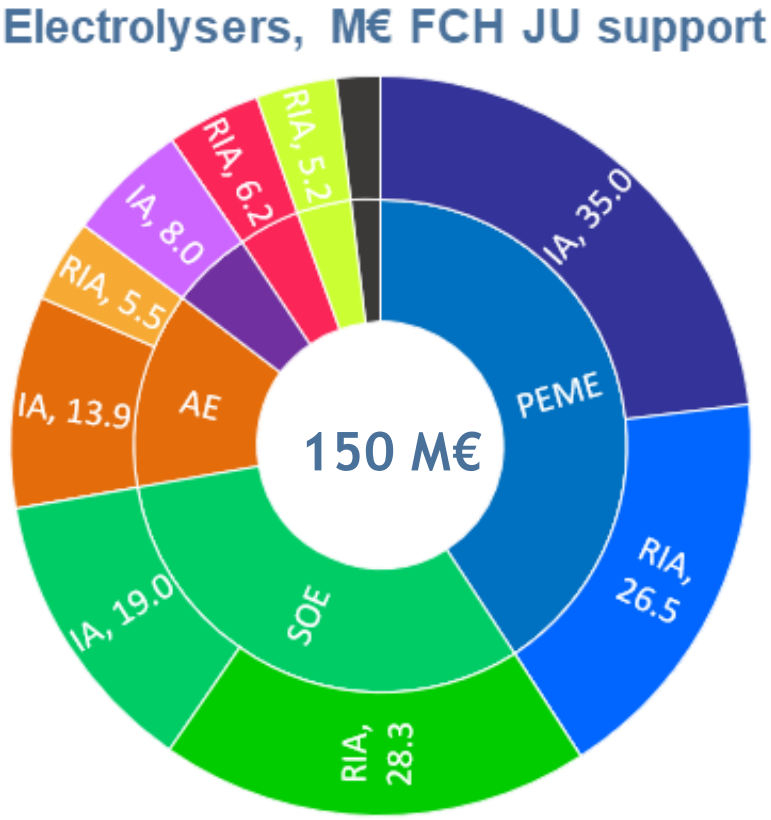


#PRD2021
#CleanHydrogen

Electrolysis Research and Demonstration

Support increasing annually, covering different types of electrolysers



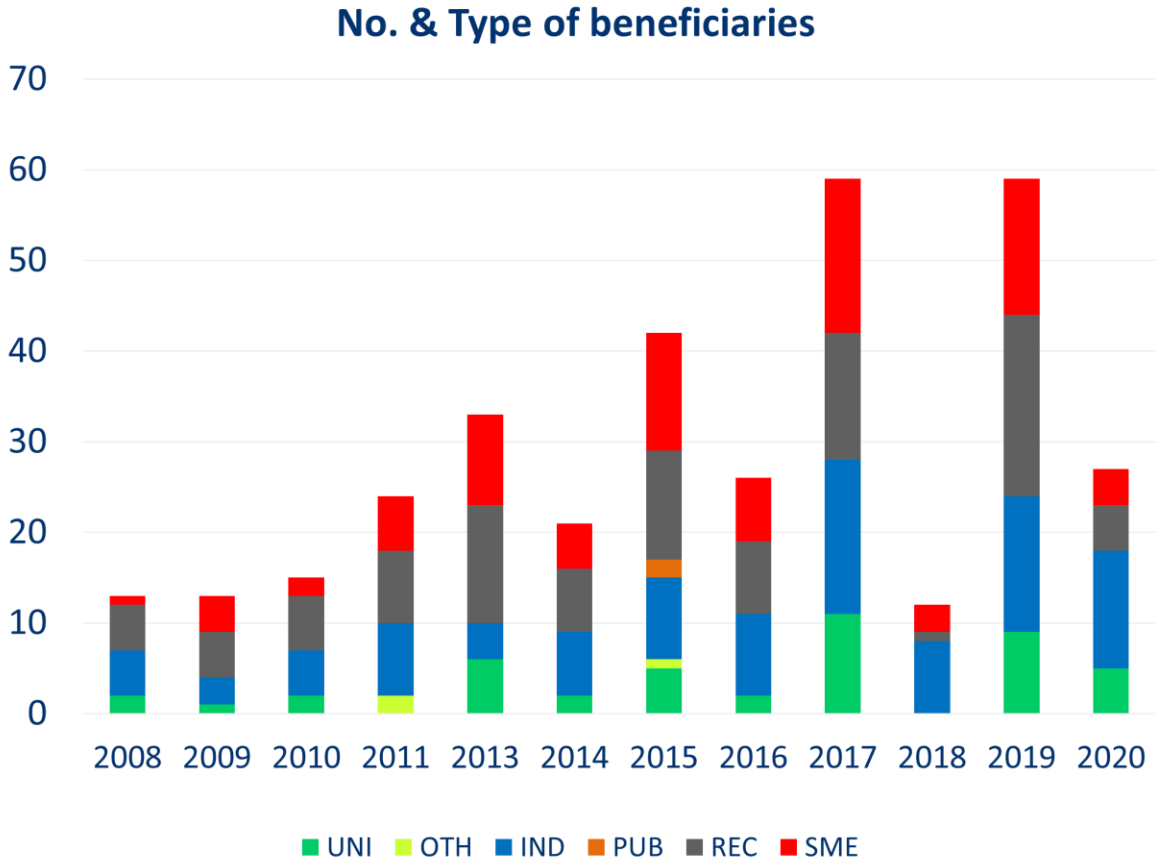


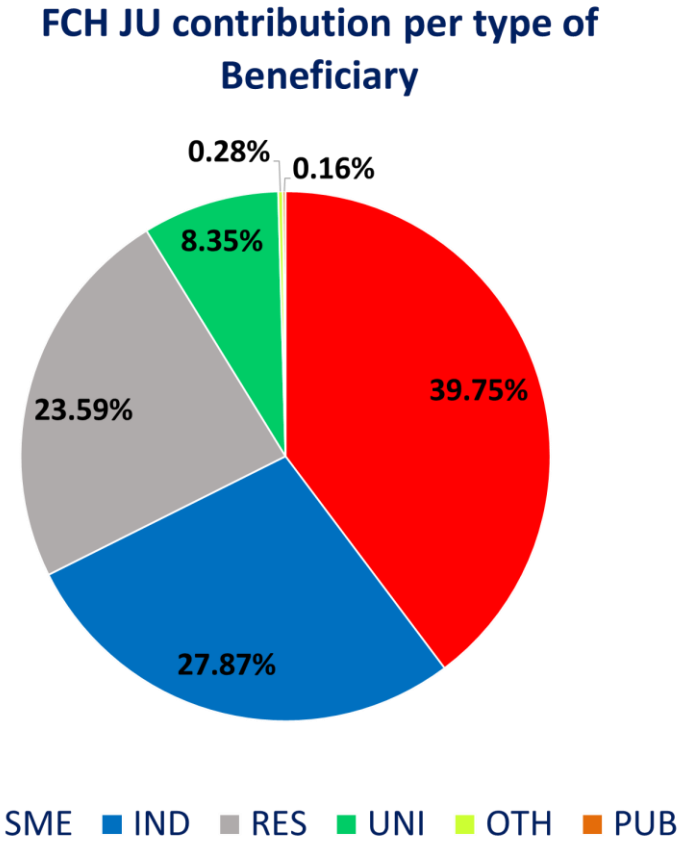
RIA: Research & Innovations Actions (RTD)
IA: Innovation Actions (Demo)

#PRD2021
#CleanHydrogen

Electrolysis Research and Demonstration

Support mostly to SMEs and Research Institutions





RIA: Research & Innovations Actions (RTD)
IA: Innovation Actions (Demo)

#PRD2021
#CleanHydrogen

LT Electrolysis Demonstration projects

In 11 years electrolyser capacity increased 500× and funding per MW installed reduced 100×

Project: **Don Quichote**
Place: Belgium
Date: **2011**
Electrolyser: Hydrogenics
Funding: 5.0 m€

0.15 MW

Project: **Haeolus**
Place: Norway
Date: **2017**
Electrolyser: Hydrogenics
Funding: 5.0 m€

2.5 MW

Project: **H2future**
Place: Austria
Date: **2016**
Electrolyser: Siemens
Funding: 12 m€

6.0 MW

Project: **Djewels**
Place: The Netherlands
Date: **2018**
Electrolyser: McPhy
Funding: 11 m€

Djewels → Scale-up → HEAVENN

20 MW → 60MW

3x100 MW

1.2 MW

Project: **Hybalance**
Place: Denmark
Date: 2014
Electrolyser: Hydrogenics
Funding: 8.0 m€

3.2 MW

Project: **Demo4grid**
Place: Austria
Date: **2016**
Electrolyser: IHT
Funding: 2.9 m€

10 MW

Project: **Refhyne**
Place: Germany
Date: **2017**
Electrolyser: ITM
Funding: 10 m€

Green Deal Projects:
- **Refhyne II**
- **GreenHyScale**
- **GreenH2Atlantic**

Date: **2021**
Funding: ≈30 m€

European Commission

PEMEL

AEL

PRD 2021

#PRD2021
#CleanHydrogen

FCH

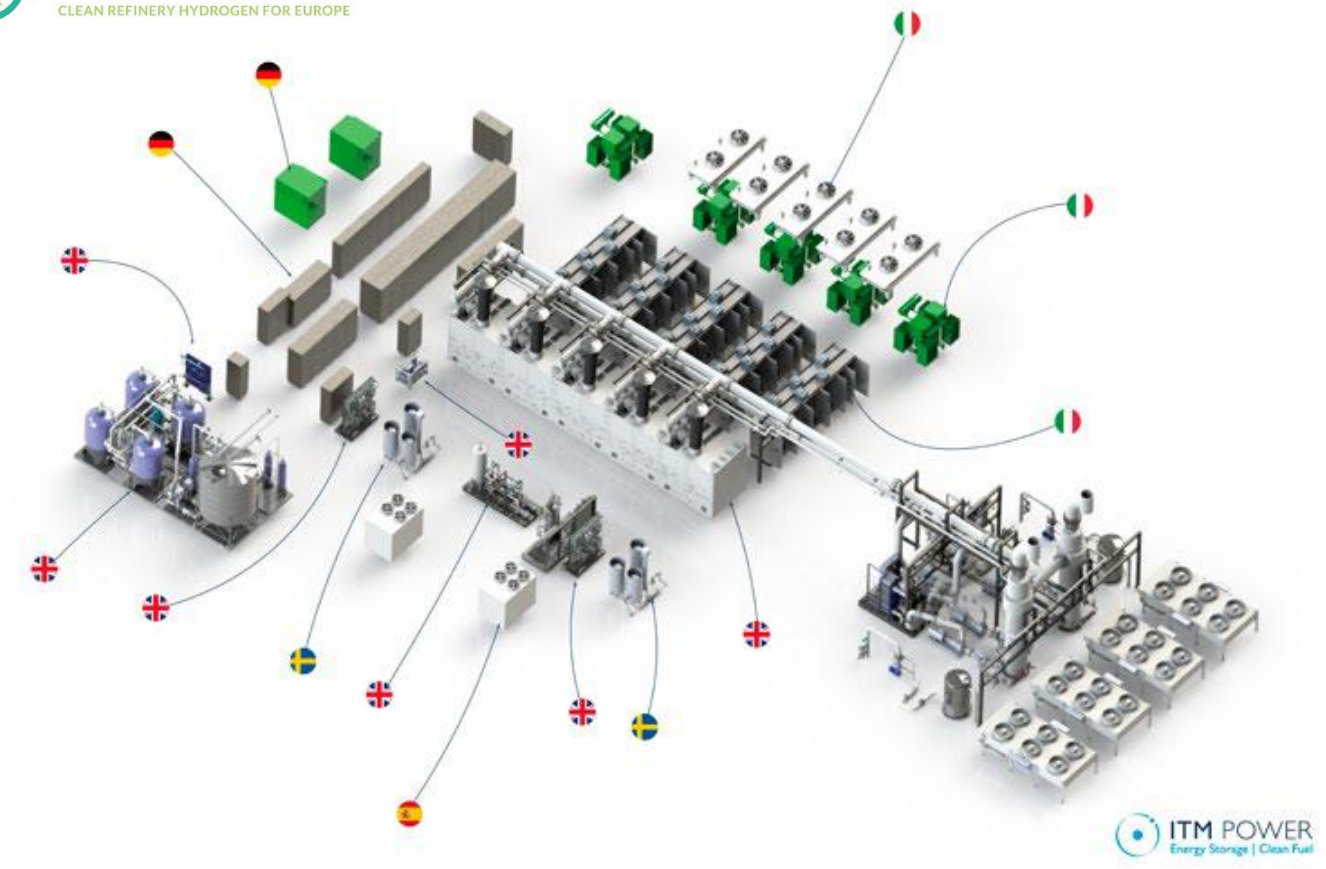
European Commission

LT Electrolysis Demonstration projects

EU Electrolyser industry ready to support EU H_2 policies

- Electrolyser OEMs addressing new tecno-economic challenges when operating electrolysers in industrial courtyards
- Industry familiarising with novel electrolysis, updating risk analysis
- Established a solid basis on which the EU H2 strategy was built
- Supporting the European value chain

REFHYNE
CLEAN REFINERY HYDROGEN FOR EUROPE



#PRD2021
#CleanHydrogen

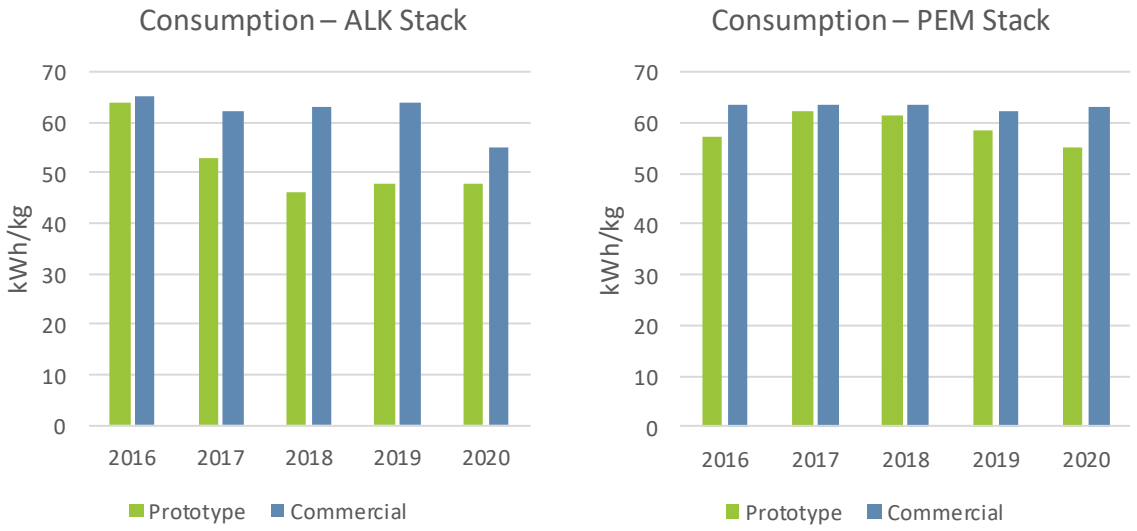
FCH

European Commission

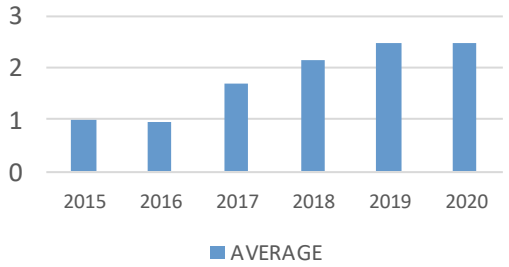
LT Electrolysis R&I projects

Achievement of MAWP targets safeguards Europe's leading position

Energy cons. @ system level <55 kWh/kg

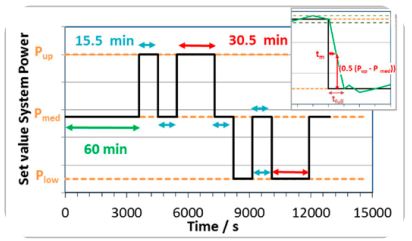


PEM Current density > 3 A/cm²



NEPTUNE

Standardised Testing Protocols



QualyGridS

#PRD2021
#CleanHydrogen

PRD 2021

LT Electrolysis R&I projects

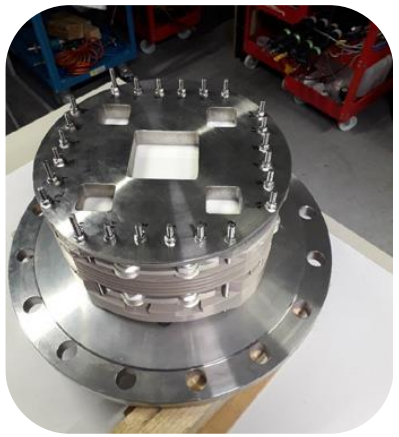
2018: 2 projects on game-changer low temp electrolysers

NEPTUNE

- 25kW, 100bar self-pressurising PEM electrolyser with simplified BoP
- MEA degradation rate @ 4 A/cm² & 80°C, 4.4 µV/h/cell > 2,000h
- endurance & dynamic testing

PRETZEL

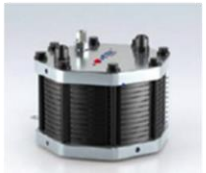
- 25 kW, 100bar PEM electrolyser system
- η=77%, Ti PTL 6 A·cm-2 @ 52C, non-precious metal coatings
- endurance testing

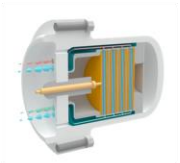


LT Electrolysis R&I projects

2020: 3x Anion Exchange Membrane electrolyser projects

ANIONE	CHANNEL	NEWELY Next Generation Water Electrolyser
2 kW AEM electrolyser	2 kW AEM electrolyser	2 kW AEM electrolyser, hydraulic compression
Reinforced AEMs, no CRM electrocatalysts	1 A/cm2; 0.1M KOH	Pure H_2O feed
Novel stack designs to reduce CAPEX	< 600Euro / kW CAPEX	40 bar; 45° C operation





- H_2 evol catalyst @ 0.1 M KOH
- O_2 evol catalyst @ 0.1 M KOH
- AEMEL Testing protocols
- AEMEL hub

PRD 2021

#PRD2021
#CleanHydrogen

FCH

European Commission

HT Electrolysis Demonstration projects

HTEs finding their place in the industrial courtyard, facilitating strategic partnerships

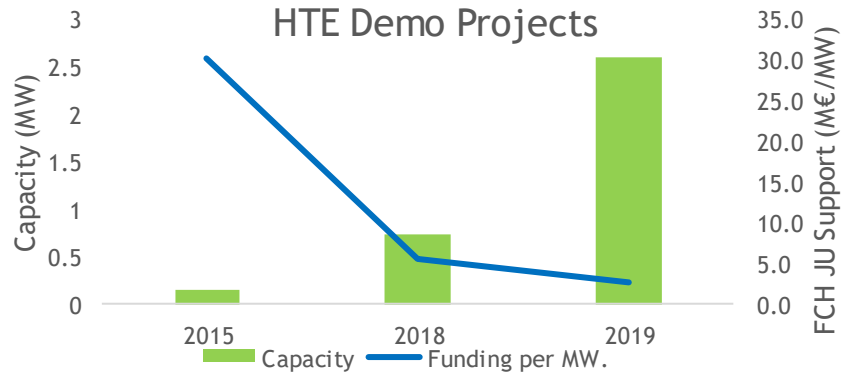
PAUL WURTH BECOMES NEW LEAD INVESTOR AND TECHNOLOGY PARTNER OF SUNFIRE

Salzgitter
Iron and Steel Works
2018
720kW
GrInHy2.0
Green Industrial Hydrogen

Salzgitter
Iron and Steel Works
2015
150kW
GrInHy
Green Industrial Hydrogen

Rotterdam
Neste Biorefinery
2019
2.4MW
MULTIPLHY

NESTE INVESTS IN SUNFIRE



In 5 years capacity increased >10x and support reduced by 5x

PRD 2021

#PRD2021
#CleanHydrogen

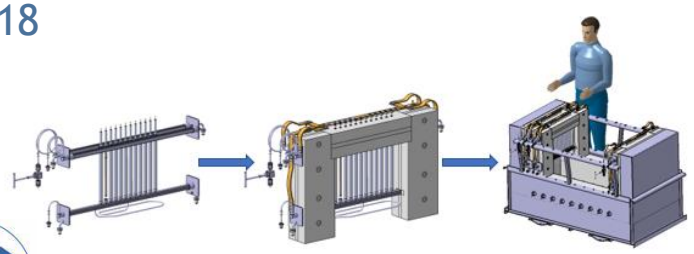
FCH

European Commission

HT Electrolysis R&I projects

Higher efficiencies, improved durability, innovative concepts

2018



GAMER

PCE, tubular cells
Pressure 10 bar

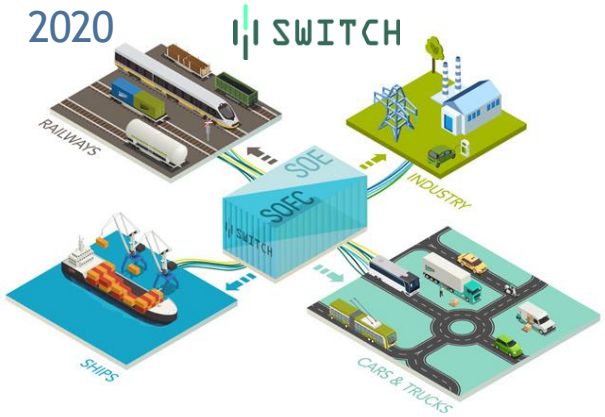
2018

RE FLEX

2019

Prod loss < 0.4%/kh

2020



Electricity consumption
< 40 kWh/kg

CAPEX < 4,500 €/kg/d

Availability >95%

Current density 1.25A/cm²
Steam conversion rate > 85%

#PRD2021
#CleanHydrogen

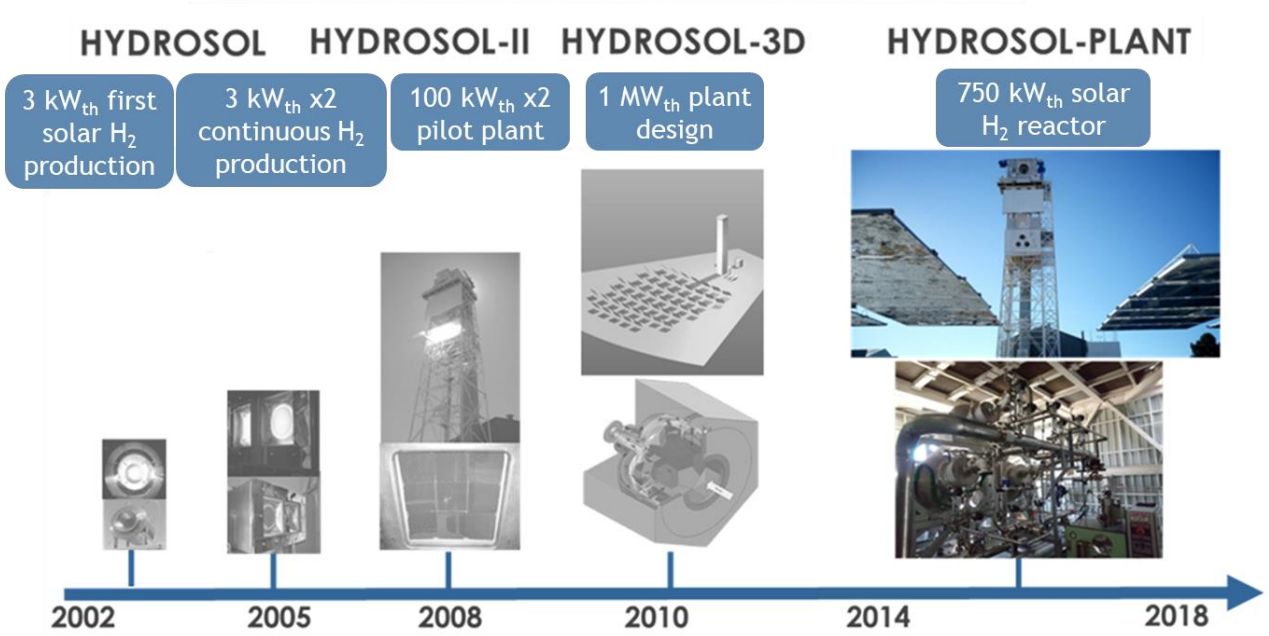
FCH

European Commission

HT Direct production of H_2 from sunlight

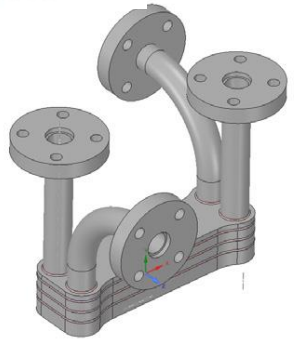
Large improvement of redox thermochemical cycles for water dissociation using concentrated solar-thermal power

Previous HYDROSOL-projects



- Production of structured redox materials and aging > 150 cycles (out of 1000)
- Improvements of the reactor design for laboratory efficiency of ≥10%
- Demonstration of efficiency >5% in the field tests of the 750 kW_{th} plant

hydrosol beyond



#PRD2021
#CleanHydrogen

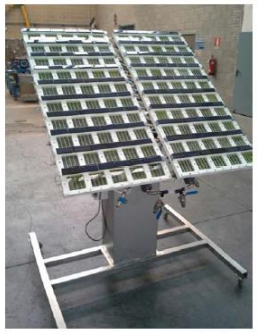
European Commission

LT Direct production of H_2 from sunlight

Scale-up and outdoor demonstration of a photo-electrochemical (PEC) system with an PV area exceeding 10 m²

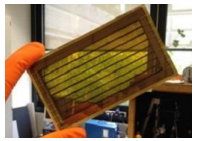
Artiphyction

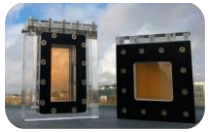
- 1.6 m² irradiated surface (η=3 % STH)



PEC DEMO

- Hybrid PEC-EV
- η =9 % STH
- 4x50 cm²





PECSYS

- PV-electrolyser concept
- 10 m² prototype
- η =9 % STH
- LCOH = 4 - 10 €/kg

2011 — **2013** — **2016**

- Demonstration of 10 m² direct coupled PV-EC device
- Efficiency record of 14 % for SHJ PV-PEM electrolyser
- 6 €/kg achievable with integrated PV-EC approach
- Constraints in scaling-up an integrated PV-EC device

#PRD2021
#CleanHydrogen

FCH

European Commission

Biomass gasifiers & reactors; Biogas reformers

Singular projects on biomass; Recent emphasis on **raw** biogas compact reformers

Dry biomass: H_2 <5 €/kg from biomass gasification

2012

UnifHy 1MWth plant – 500kg/d

Wet biomass: Dark fermentation at lab scale

2012

HYTIME 1MWth plant – 1 kg/d

Biogas without CO_2 prior removal

100kg/day H_2 Conversion η = 71.5%

2015

BIONICO

2017

BioRobur plus

#PRD2021
#CleanHydrogen

FCH

European Commission

European Hydrogen Week

Conclusions

- Best in class electrolysers have met 2020 KPIs
- FCH JU projects proved electrolysers as a reliable enabler for Sectorial Integration and helped bring renewable H_2 to the centre of EU energy policy
- More ambitious cost and performance targets, improvements in manufacturing & recyclability coming up to keep EU leadership
- Alternative routes for renewable H_2 production have moved from lab to field, further improvements required for market readiness