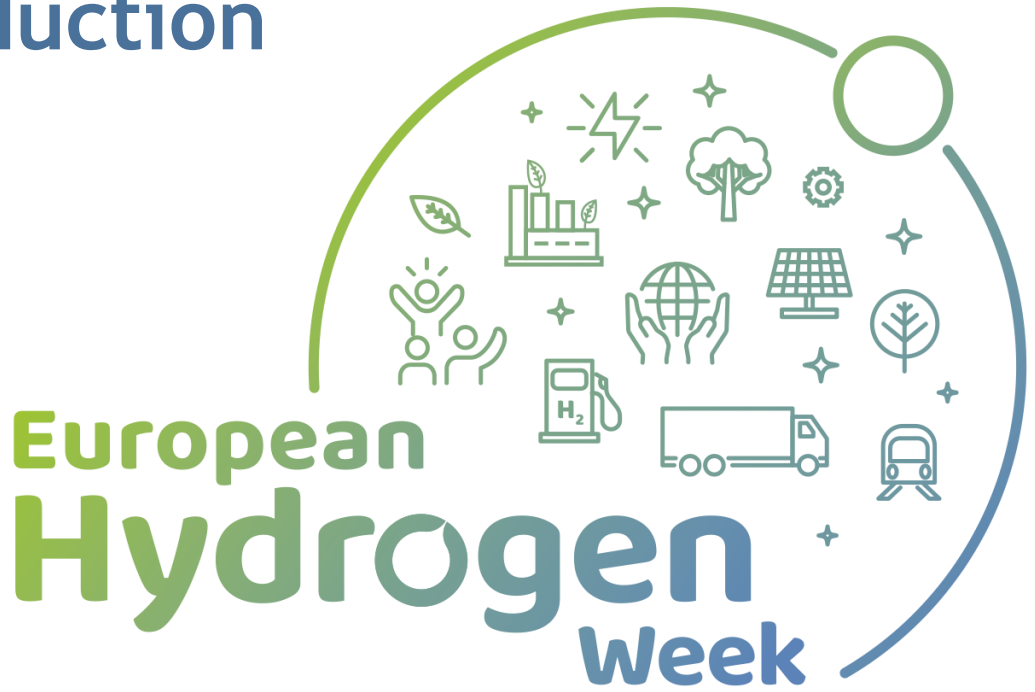
Hydrogen Production



N. Lymperopoulos

Project Officer

#EUResearchDays
#PRD2022
#CleanHydrogen

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EU Research Days & Programme Review

Parallel Sessions

28th Oct. 09:30 - 11:15

Hydrogen Production

European Hydrogen Week

2022: JU Large electrolyser demos at commissioning stage

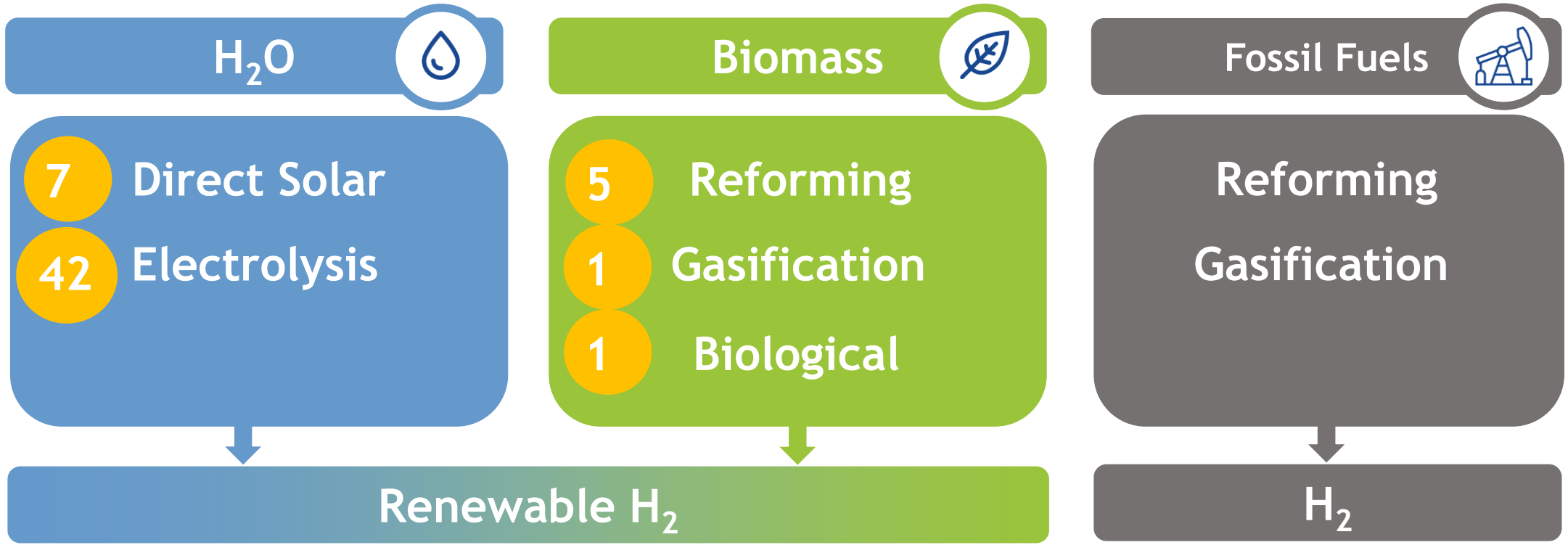
H2AEOLUS

DEMO 4GRID

REFHYNE
CLEAN REFINERY HYDROGEN FOR EUROPE

Hydrogen Production Technical Coverage

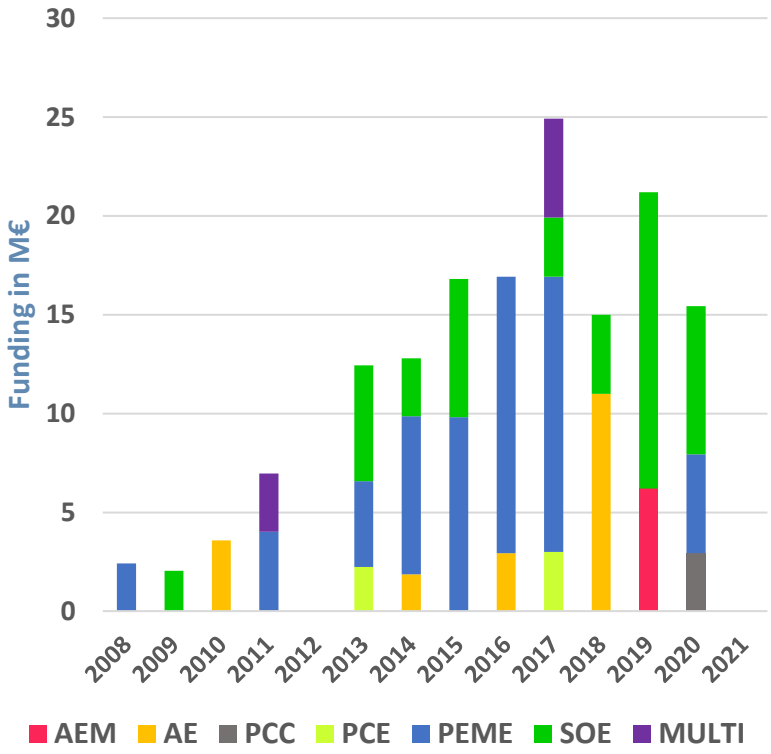
56 projects, 180 M Euro, 16.7% of Clean H_2 JU support. Only renewable H_2



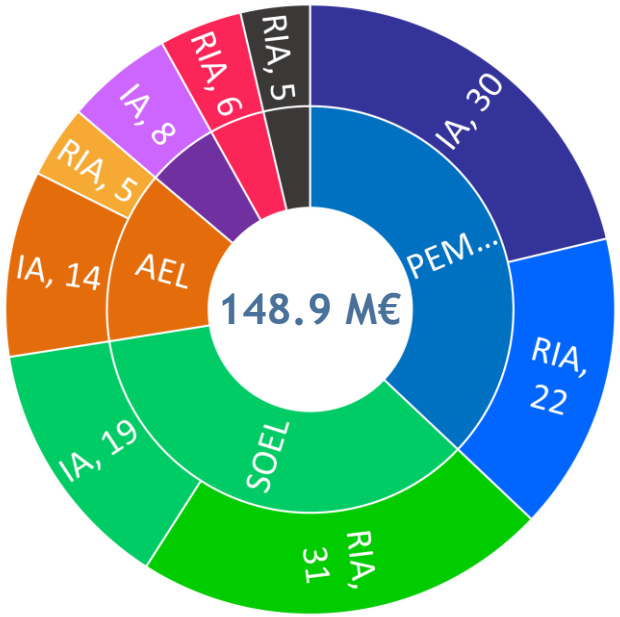
Electrolysis Research and Demonstration

Support increasing annually, covering different types of electrolysers

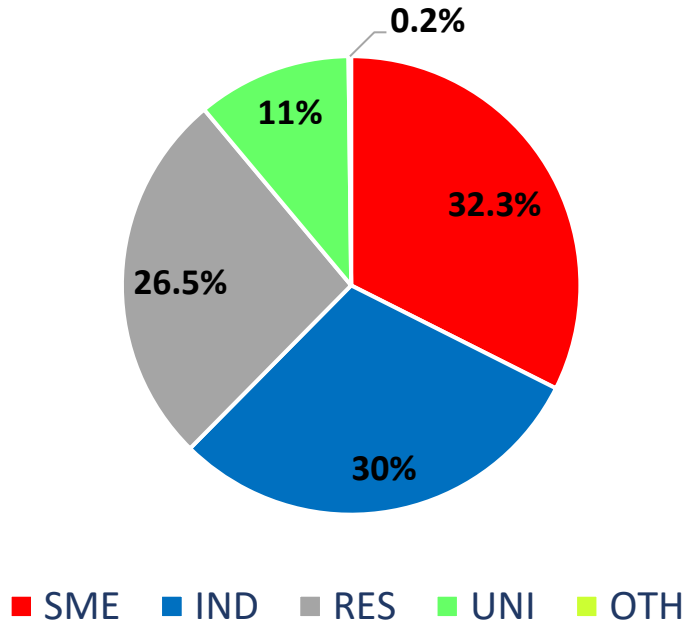
JU funding per technology



Electrolysers, M€ JU support



JU contribution per type of Beneficiary



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

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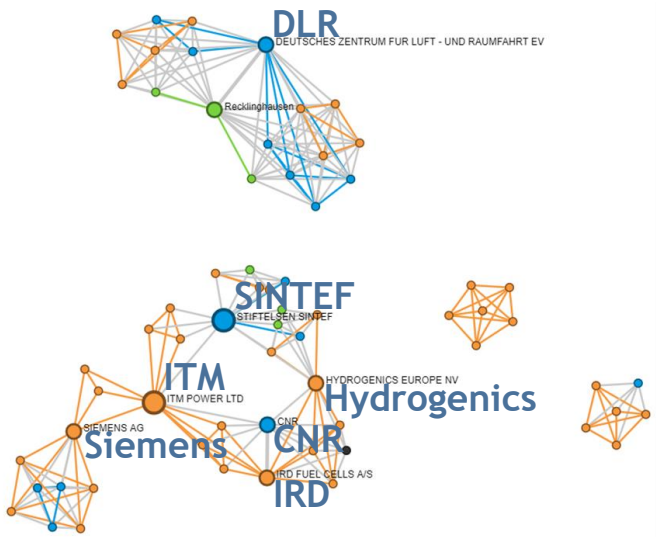
Electrolysis Research and Demonstration

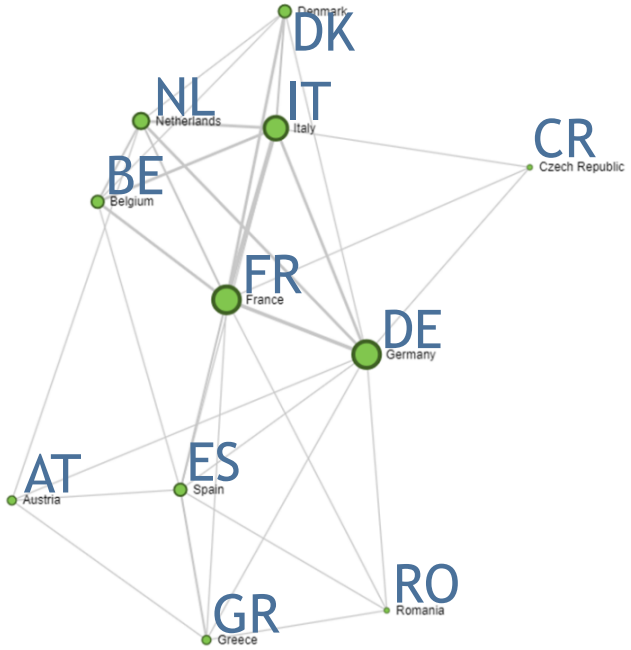
JRC TIM analysis for 2021 **LT** Electrolysis – 11 projects



- Private Company
- Public Institution
- Research Centre
- Higher Education
- Other

Top Participants

Participant	Number of projects
SINTEF, ITM	3
Multiple participants	*2*



Member State	Number of projects
France	7
Germany	7
Italy	6
Netherlands	4
Spain, Belgium, Denmark	3

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

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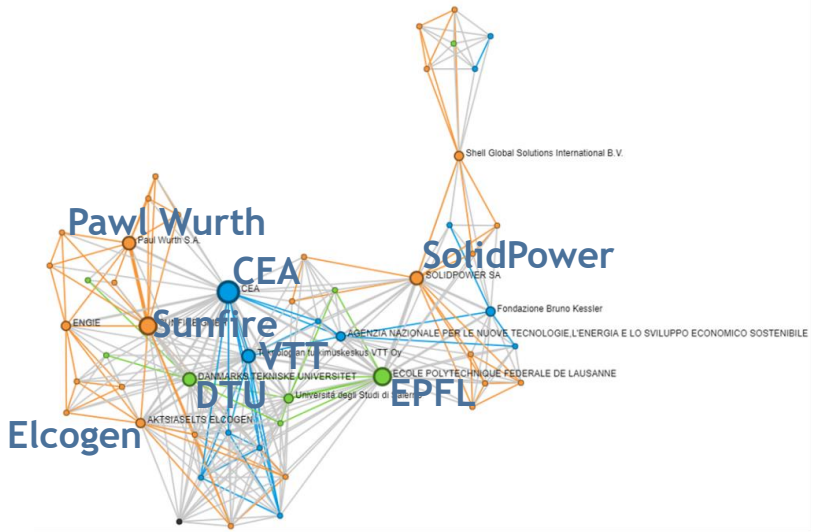
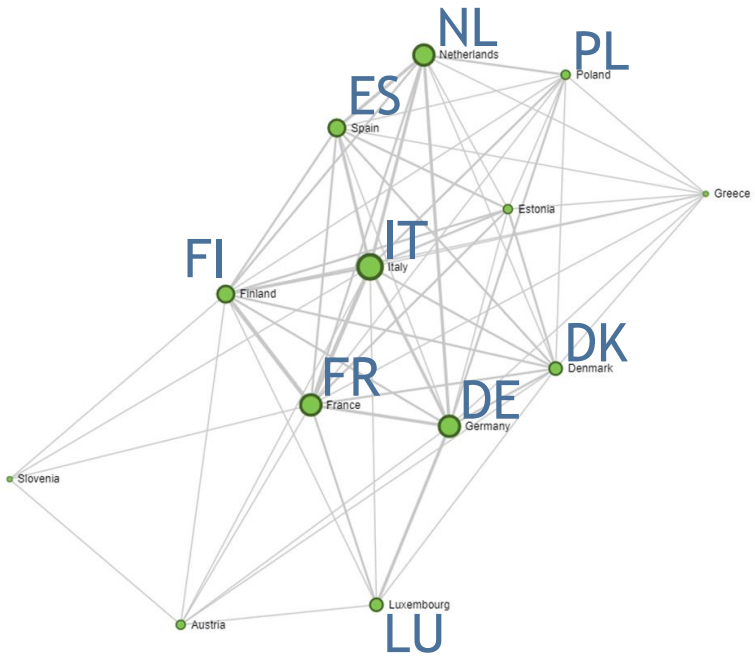
Electrolysis Research and Demonstration

JRC TIM analysis for 2021 **HT** Electrolysis – 9 projects



Top Participants

Participant	Number of projects
CEA	5
Sunfire, EPFL	4
DTU, VTT, SolidPower, Paul Wurth	3



Member State	Number of projects
Italy	6
Germany, France, Netherlands	5
Spain, Finland	4

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

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

1.2 MW

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

2.5 MW

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

3.2 MW

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

6.0 MW

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

10 MW

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

Djewels → Scale-up → HEAVENN

20 MW → 60MW

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

Date: **2021**
Funding: ≈30 m€

European Commission

3x100 MW

PEMEL

AEL

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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
- EU electrolyser OEMs collaborating on safety with EHSP

H2FUTURE
Green Hydrogen

- 6MW atmospheric PEMEL feeding steel industry
- η=83%$_{HHV}$, purity 99.9%
- Operating range 15-150%
- H_2 production costs 25-50% lower
- >800t H_2 produced

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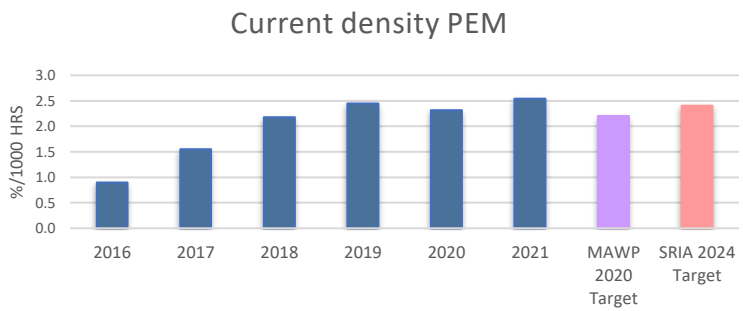
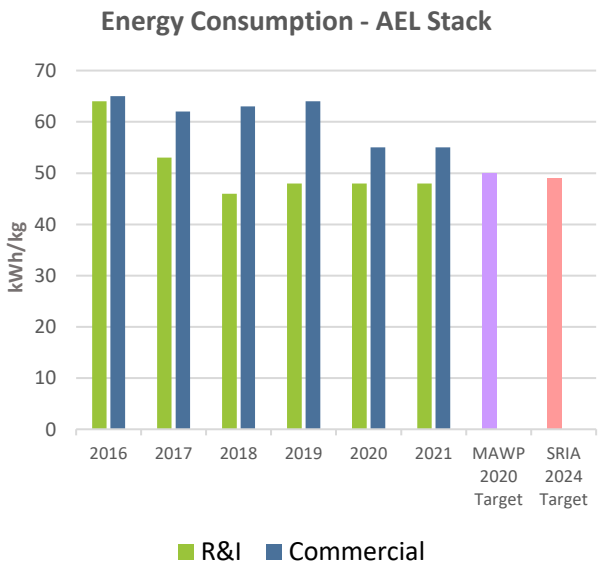
LT Electrolysis R&I projects

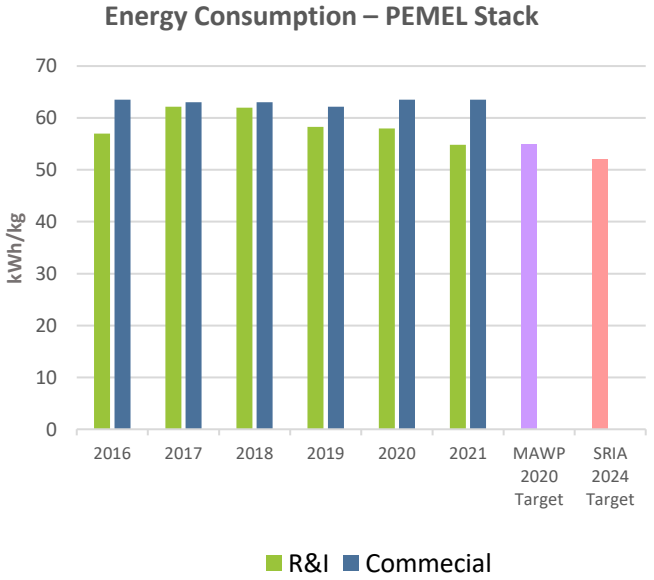
Achievement of MAWP targets safeguards Europe's leading position

PEM Current density > 2.4 A/cm2

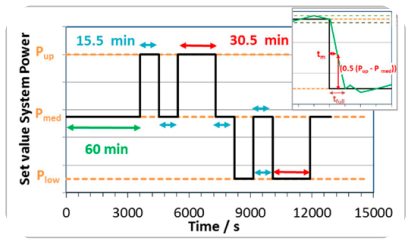


Energy cons. @ system level <55 kWh/kg

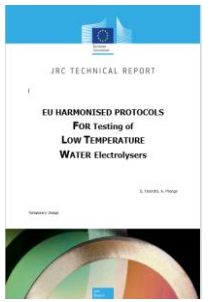




Standardised Testing Protocols



QualyGridS



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LT Electrolysis R&I projects

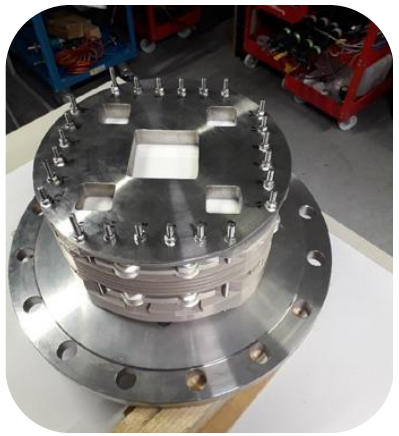
2018: 2 projects on game-changer low temp electrolysers

NEPTUNE

- 25kW, 100bar self-pressurising PEM electrolyser with simplified BoP
- @ 90 °C, cell voltages of 1.74 V @ 4 A cm^{-2} and 1.98 V @ 8 A cm^{-2}
- η degradation rate 0.23%/1,000h

PRETZEL

- 25 kW, 90bar PEM electrolyser system
- Cell η=77%, Ti PTL 6 A·cm-2 @ 90C, non-precious metal coatings
- 2,000h test @ 100bar



LT Electrolysis R&I projects

2019: 3x Anion Exchange Membrane electrolyser projects

ANIONE

- 2 kW AEM electrolyser
- 1.75V @ 1 A/cm^2; 0.1M KOH
- Reinforced AEMs, no CRM electrocatalysts

CHANNEL

- 2 kW AEM electrolyser
- 1.8V @ 1 A/cm^2; 0.1M KOH
- P2D S/W model

NEWELY

Next Generation Water Electrolyser

- 2 kW AEM electrolyser, hydraulic compression
- 2V @ 1.8 A/cm^2; 0.1M KOH
- AEMs reinforcement using covalent bonds

- H_2 & O_2 evol catalysts @ 0.1 M KOH
- Functional materials to be validated @ stack level
- AEMEL Testing protocols
- AEMEL hub

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LT Electrolysis R&I projects

2020: Marinisation & H2 for Underground storage

OYSTER

- Marinisation of 1MW PEMEL
- Near-shore operation
- W/T following
- Integrated desalination

hypster Hydrogen Storage

- 1MW PEMEL
- Providing H_2 to regional clients
- Cycling of H_2 salt cavern

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HT Electrolysis Demonstration projects

HTELs finding their place in the industrial courtyards, facilitating strategic partnerships

PAUL WURTH BECOMES NEW LEAD INVESTOR AND TECHNOLOGY PARTNER OF SUNFIRE

Salzgitter
Iron and Steel Works
2015
150kW

GrInHy
Green Industrial Hydrogen

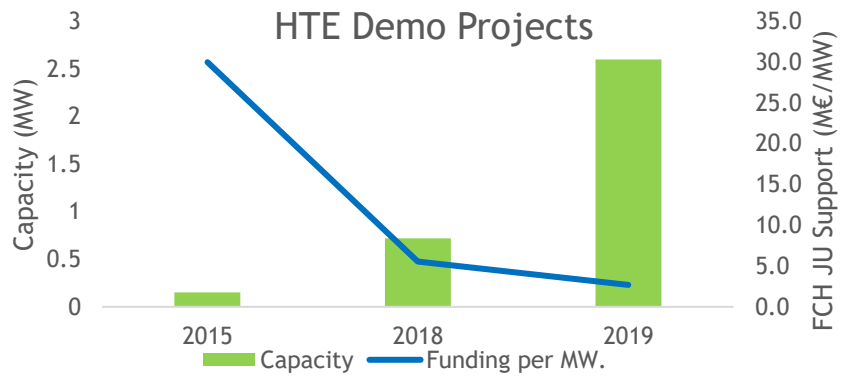
Salzgitter
Iron and Steel Works
2018
720kW

GrInHy2.0
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

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HT Electrolysis Demonstration projects

Total hydrogen production target may not be achieved due to high electricity costs

- Electrolyser OEMs addressing new tecno-economic challenges when operating electrolysers in industrial courtyards
- Industry familiarising with novel electrolysis, updating risk analysis
- Low-cost renewable electricity remaining as a key barrier
- SOEL benchmarked onsite against a PEM equivalent

GrInHy2.0
Green Industrial Hydrogen

- 720kW, 240 stacks atmospheric SOEL feeding steel industry
- η=96%$_{HHV}$, heat input of 6.5kWh/kgH_2
- Current density 0.65A/cm^2
- CAPEX 4,500euros/kg/day
- on track for 15,000h 100 tonnes H_2 by end 2022

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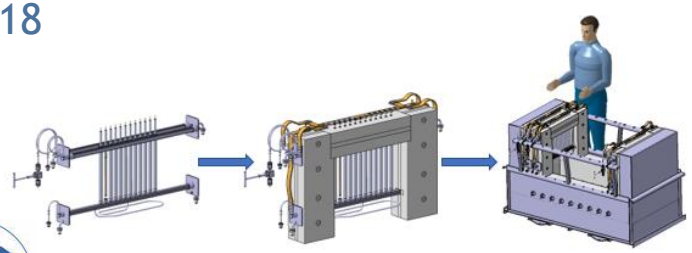
HT Electrolysis R&I projects

Higher efficiencies, improved durability, innovative concepts

2018



GAMER

PCE, tubular cells
Pressure 10 bar

2018

RE FLEX

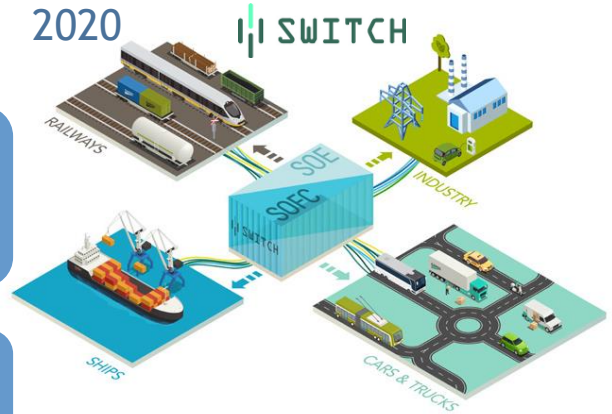
Current density
SOEL 1.25A/cm², SOFC 0.65A/cm²

Power modulation
50-100% SOFC, 70-100% SOE

Cell active area 200 cm²

Durability 1.2% /1,000h
@ 0.58 A/cm² and SC=68 %

2020



113% stack & 96% system electrical efficiency HHV @ heat demand 7.62kWh/kg

Current density 0.74A/cm²

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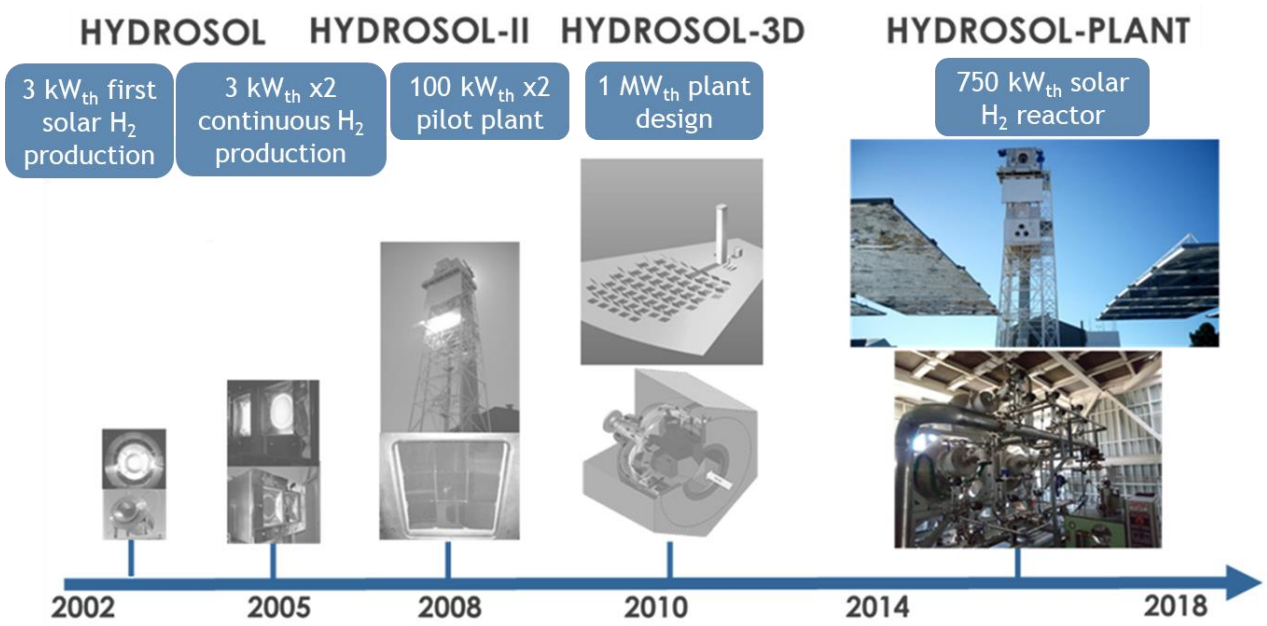
HT Direct production of H_2 from sunlight

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

Previous HYDROSOL-projects



- Production of stable NiFe2O4 lattice structures - 150 cycles
- Heat recovery of high temp heat >60%
- Demonstration of efficiency >5% in the field tests of the 750 kW_{th} plant

hydrosol beyond

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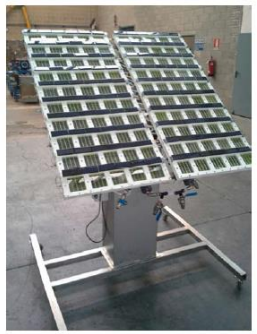
LT Direct production of H_2 from sunlight

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

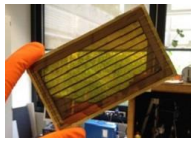
Artiphyction

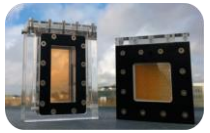
- 1.6 m² irradiated surface (η=3 % STH)



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

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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

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European Hydrogen Week

Conclusions

- R&I: best in class electrolysers have already met 2024 KPIs
- Demo: JU projects proved electrolysers as a reliable enabler for Sectorial Integration and helped bring renewable H_2 to the centre of EU energy policy
- Horizon Europe: more ambitious cost and performance targets, improvements in manufacturing & recyclability coming up to keep EU leadership - ever larger cells, stacks, systems and application areas
- Alternative routes for renewable H_2 production have moved from lab to field, further improvements required for market readiness

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