FUEL CELLS AND HYDROGEN
JOINT UNDERTAKING

European Developments in Electrolyser Technology: *Technical and Economic Outlook*

N. Lymperopoulos

POWER TO GAS
Conference
Antwerp, 7 June 2018

Strong public-private partnership with a focused objective

EU Institutional Public-Private Partnership (IPPP)

Fuel Cells & Hydrogen Joint Undertaking (FCH 2 JU)

Hydrogen Europe

Industry grouping
More than 130 members
50% SME

European Commission

Hydrogen Europe Research

Research grouping
over 60 members

To implement an *optimal research and innovation programme* to bring FCH technologies to the point of market readiness by 2020

FCH JU programme implementation

Energy

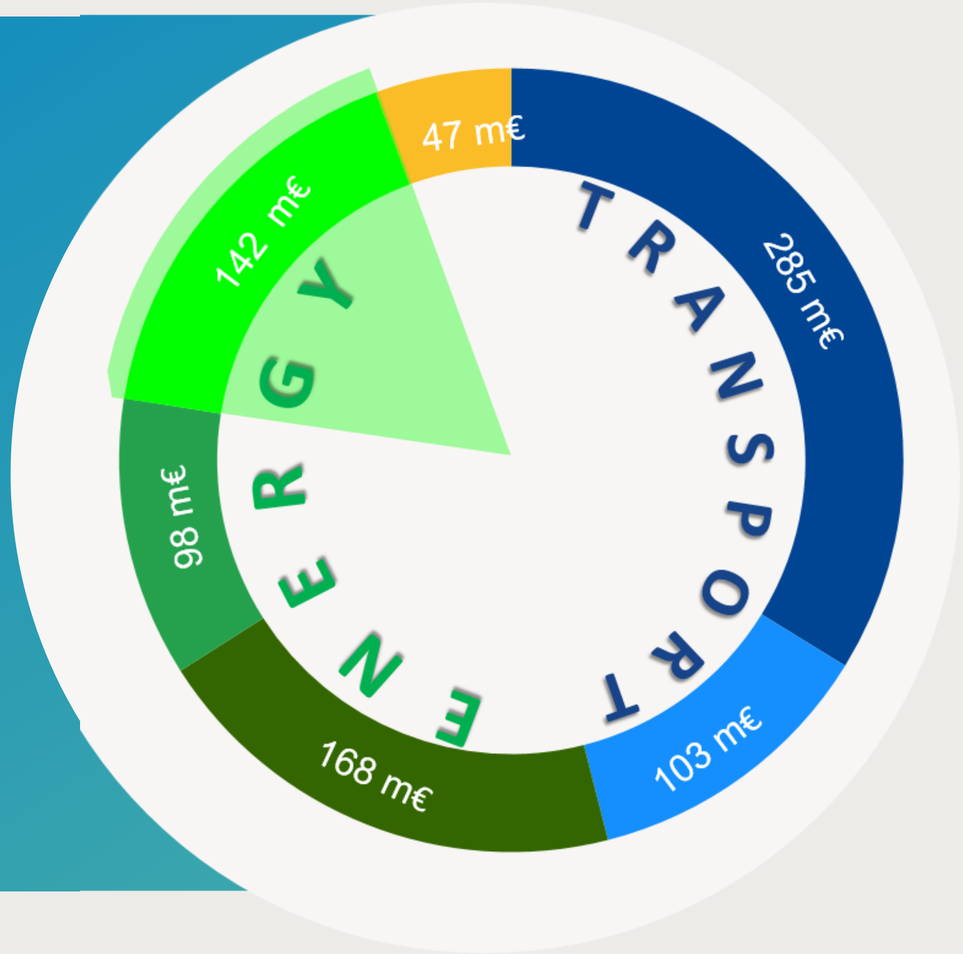
- Hydrogen production and distribution
- Hydrogen storage for renewable energy integration
- Fuel cells for power & combined heat & power generation

Transport

- Road vehicles
- Non-road vehicles and machinery
- Refuelling infrastructure
- Maritime rail and aviation applications

Cross-cutting

- E.g. standards, safety, education, consumer awareness …



Hydrogen Production, Distribution & Storage

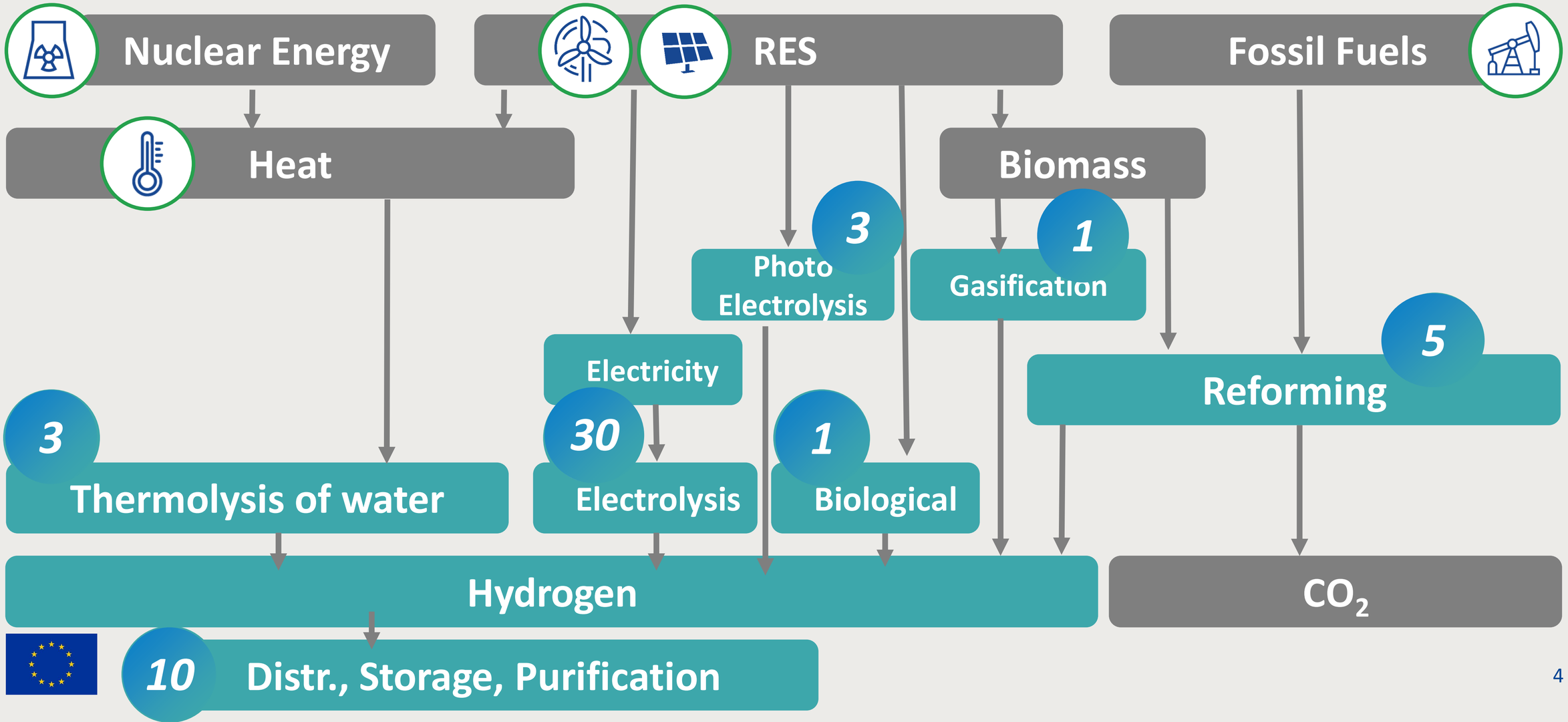
16.8%

142 M€

53 Projects

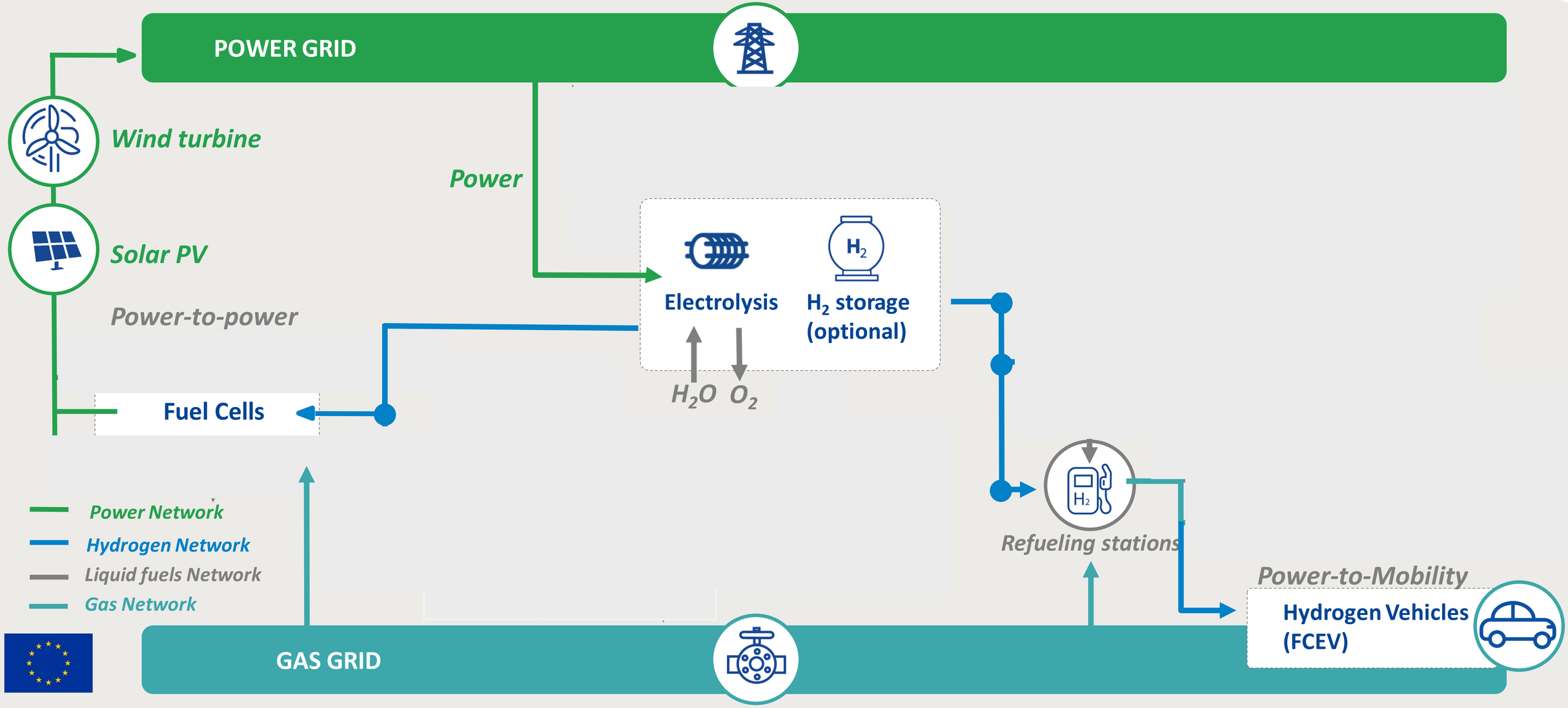
Hydrogen Production Technical Coverage

95% of FCH JU support to green Hydrogen production



What's New in H_2: Riding the "P2H & H2X" wave

Greening industry, providing electricity grid services, injection in the NG grid



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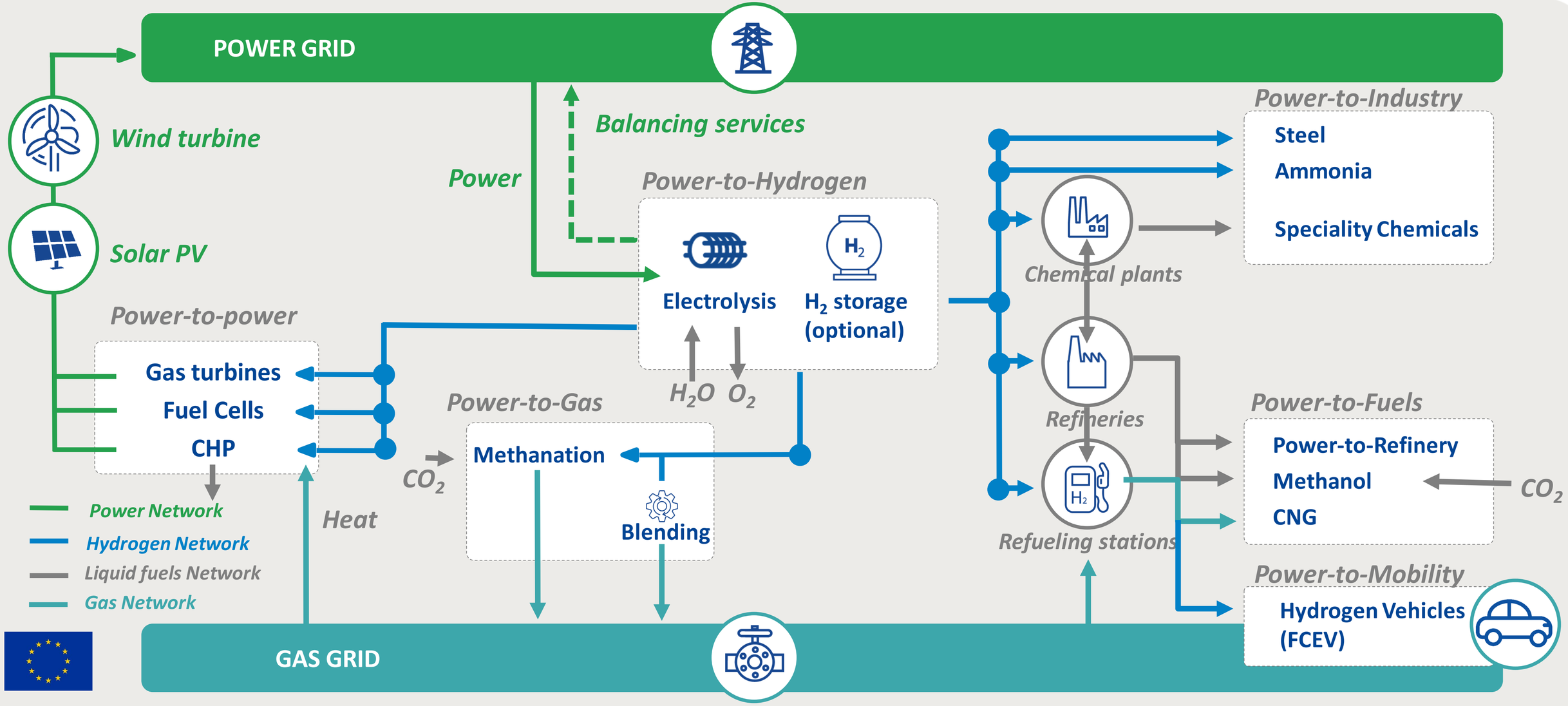


Electricity grid congestion drives Early business cases

Low electricity cost, demand for H2, provision of grid services, injection in NG grid – Short Term potential of 2.8 GW of electrolysers by 2025

Bankable business cases were found in the best locations

WACC on CAPEX: 5% Project lifetime: 20 years	SC mobility (Albi, France)		Food industry (Trige, Denmark)		Large industry (Lubeck, Germany)	
	2017	2025	2017	2025	2017	2025
Primary market H2 volume (t/year)	270	950	900	900	3 230	3 230
Average total electricity price for prim. market (€/MWh)	44	45	38	47	17	26
Net margin without grid services (k€/MW/year)	39	71	228	248	-146	30
Net margin with grid services (k€/MW/year)	159	256	373	393	-13	195
Share of grid services in net margin (%)	75%	72%	39%	37%	-	85%
Payback time without grid services (years)	11.0	9.0	4.6	3.7	-	8.4
Payback time with grid services (years)	8.0	4.5	3.4	2.7	-	3.5
Key risk factors	• Taxes & Grid fees • H2 price • Size of fleets • Injection tariff • FCR value		• H2 price • Taxes & Grid fees • FCR value		• Taxes & Grid fees • FCR value • Carbon price	

Profitable stand-alone primary applications have a payback time ranging between 4 and 11 years.
Providing grid services can reduce payback time by 30-50%.

EU-28 market potential	Cumulative market size	Market value	H2 Volume
2017	1500 MW	2.6 B€	200 ktons/year
2025	2800 MW	4.2 B€	400 ktons/year

Integration of Renewables in the Power Sector

Hydrogen can be produced from excess renewable energy and used outside the power sector – Long term potential of 170GW of electrolysers by 2050

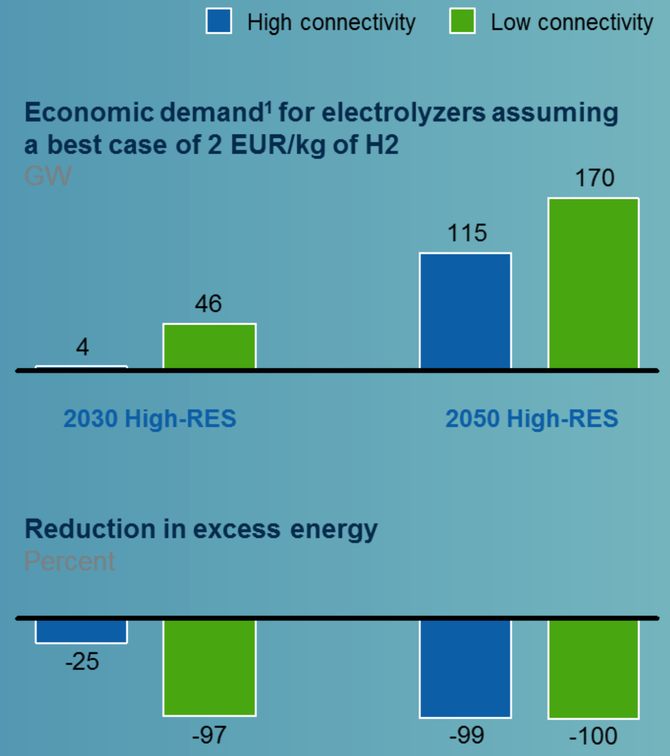
CONTEXT: There are 4 main options for integrating renewables, but all the options have significant limitations

RES integration solution	Deficit solved?	Surplus solved?	Residual load[1]	Limitations
0 Base case situation			Deficit / Surplus	
1 Dispatchable generation (hydro, bio-mass, fossil)	✓	✗	Deficit / Surplus	▪ Hydro and biomass quantity is limited ▪ Fossil fuels generate CO_2 emissions ▪ No utilization of excess energy
2 Transmission and distribution expansion	✓	✓	Deficit / Surplus	▪ Ineffective if RES production correlated over large area ▪ Hampered by permitting issues and long construction times
3 Demand side management	✓	✓	Deficit / Surplus	▪ Limited by amount of demand that can be shifted and time for which it can be delayed
4 Energy storage – Power-to-power	✓	✓	Deficit / Surplus	▪ *Focus of this study* ▪ *Technologies considered in the study included:* – *Batteries (Li-ion, NaS, Lead-acid, Flow-V)* – *Mechanical storage (pumped hydro, compressed air, liquid air)* – *Hydrogen power-to-power storage* – *Heat storage* – *Hydrogen for use outside of power sector*
4 Energy storage – Conversion to heat and heat storage	✓	✓	Deficit / Surplus	
4 Energy storage – Conversion to Hydrogen for use outside power sector	✗	✓	Deficit / Surplus	

1 Difference between demand and intermittent RES production

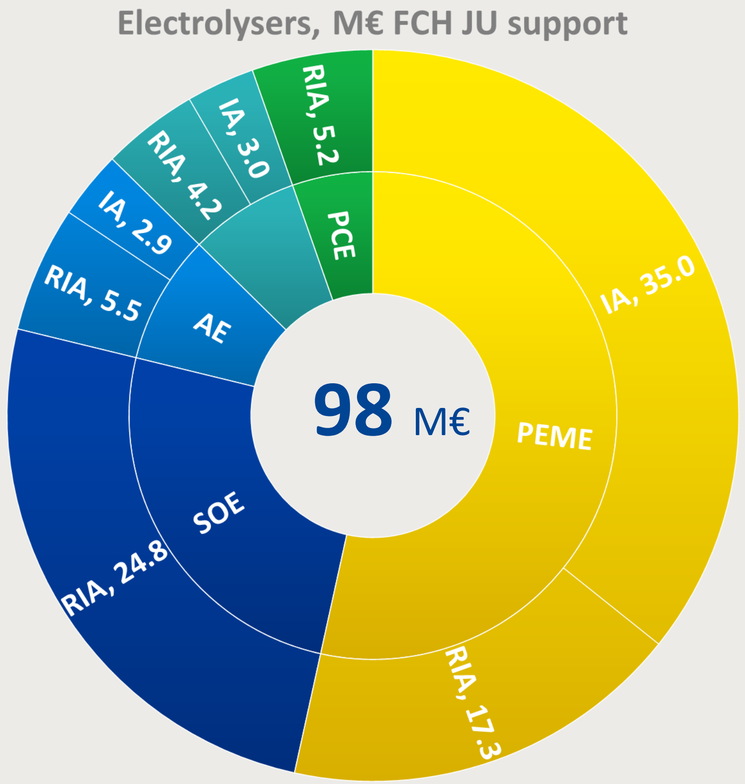
All of these option come at a cost to society

2



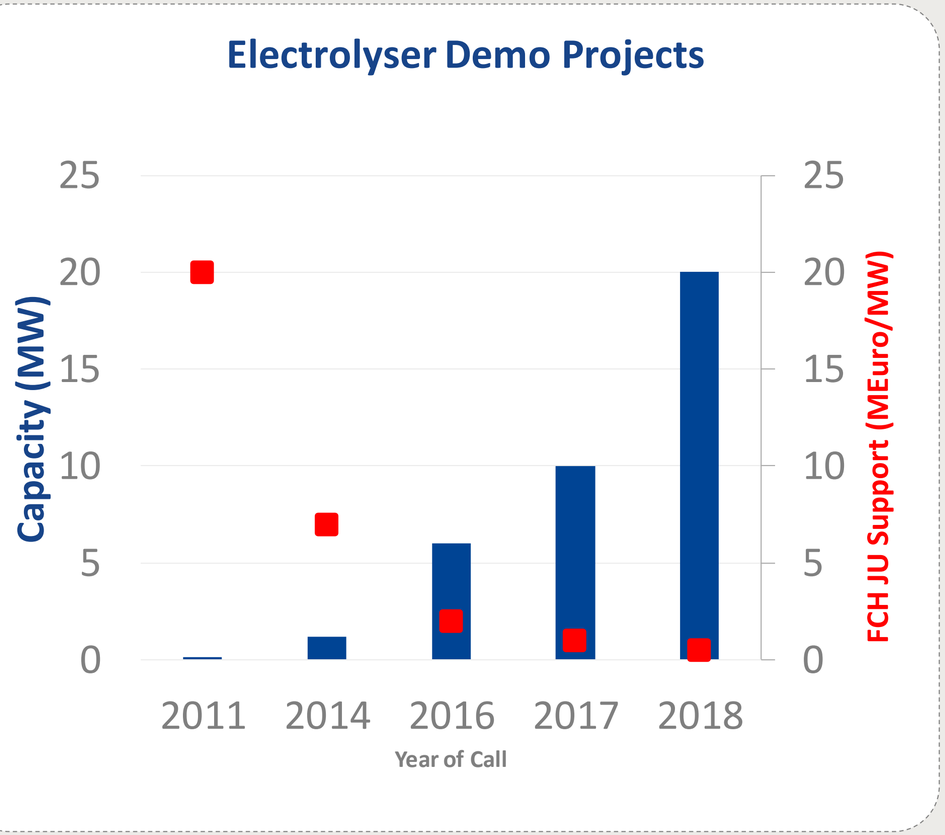
Electrolysis Research and Demonstration

The potential of Hydrogen for the greening of industry has lead to fast capacity increase and cost reduction



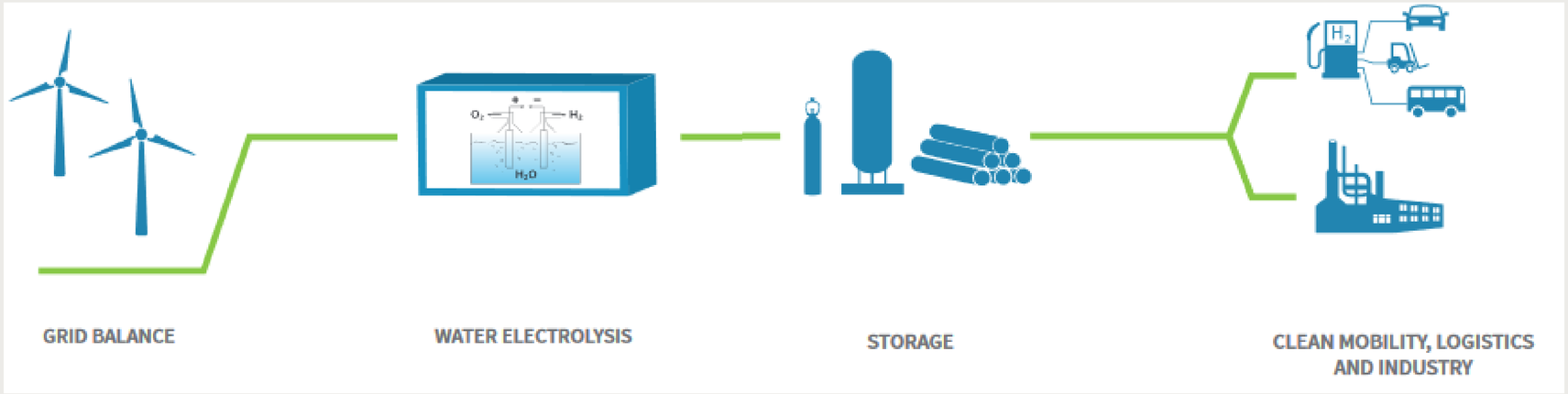
30 Projects

HRS ***Steel industry*** ***Refineries*** ***Food industry***



2014: Greening light Industry & Transport

The Hybalance Project: Producing green H2 from wind, feeding metal industry and bus fleet



HyBalance

Co-ordinated by Air Liquide

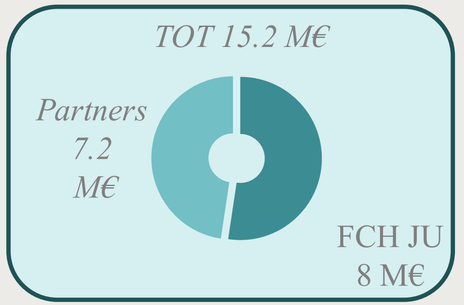
1.2 MW PEM electrolyser by Hydrogenics

Installed in Hobro, Denmark

Commissioned February 2018

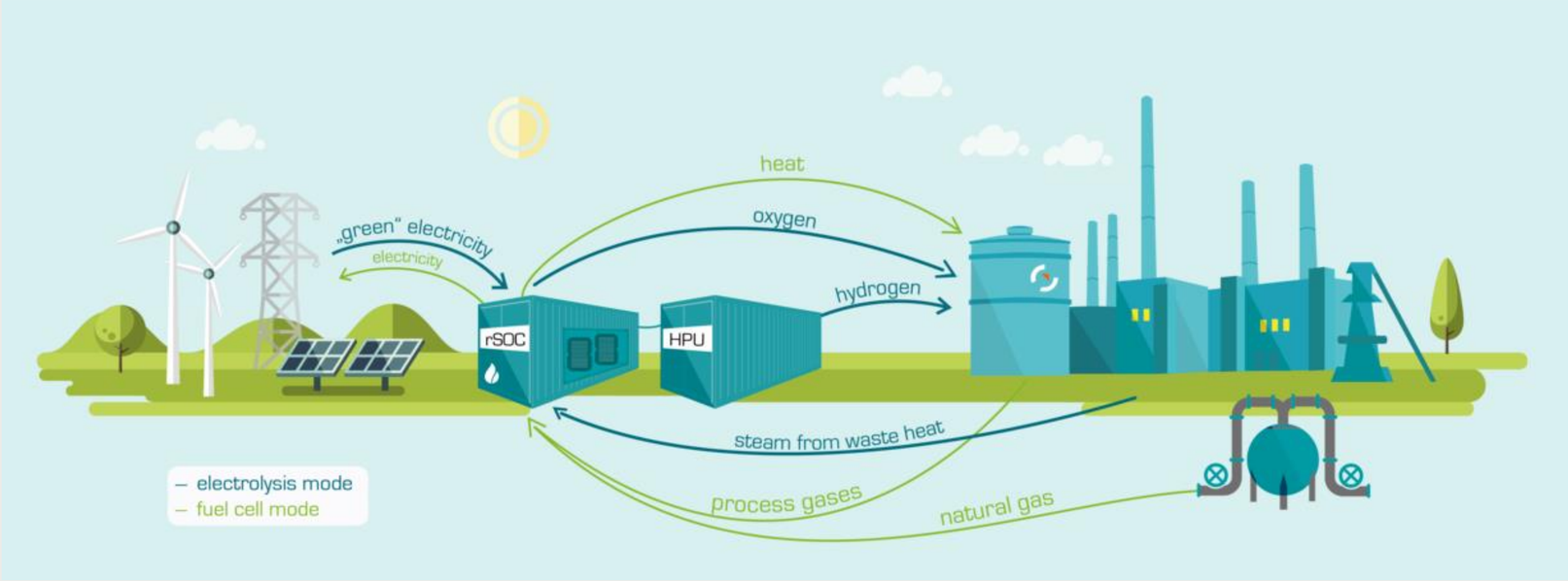
Feeding light industry (sinter metal, Hobro) and buses (Aalborg)

Receiving support from the FCH JU but also ForskEL (Danish framework)



2015: Greening steel surface treatment Industry

The GrInHy Project: Green Industrial Hydrogen via Reversible High-Temp Electrolysis



Salzigitter, Germany

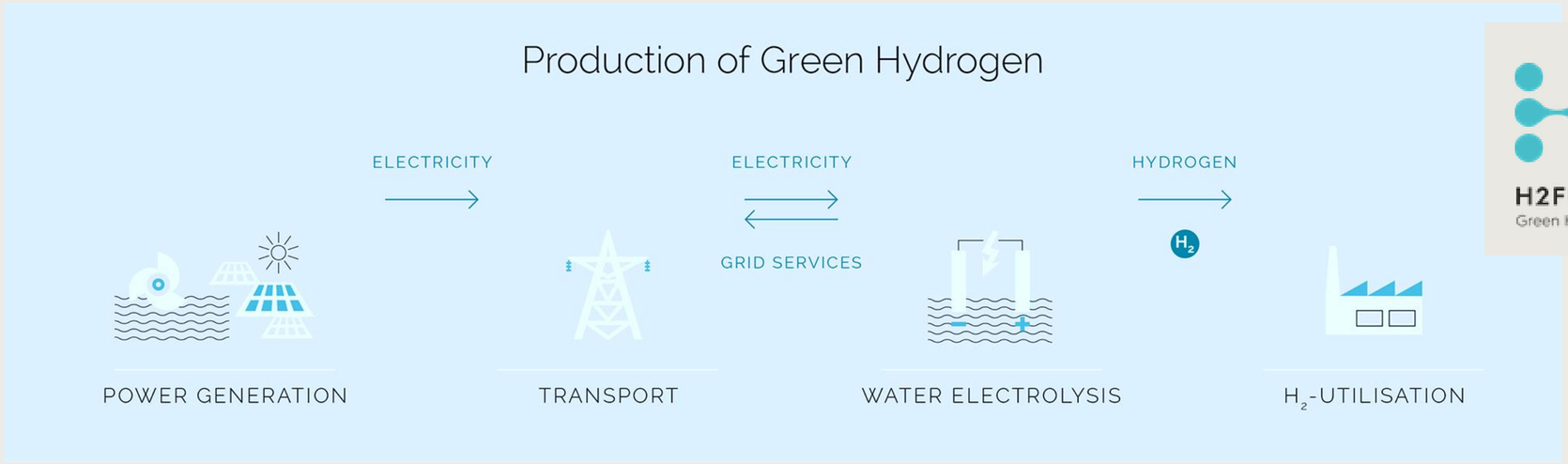
4.5 Meuro, 100% FCH JU funding

150kW Solid Oxide Electrolyser- displace 10% of current consumption of 4MNm3 of H2 per year used in the annealing process presently H2 is provided by tube trailers

Can operate in reverse mode as fuel cell running on NG

2016: Greening the Steel Industry

The H2Future Project: Producing green H2 from hydro power, Injecting in steel industry, providing grid services



Co-ordinated by Verbund (electricity company of Austria)

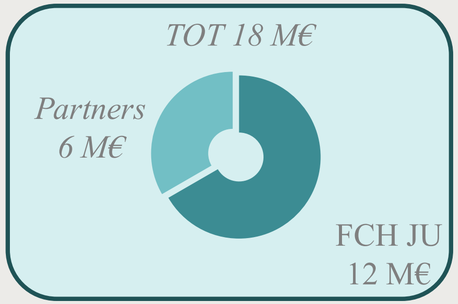
6MW PEM electrolyser by Siemens

Installed in voestalpine (steel industry) in Linz

H2 injected in coke oven gas but view is direct iron ore reduction using H2

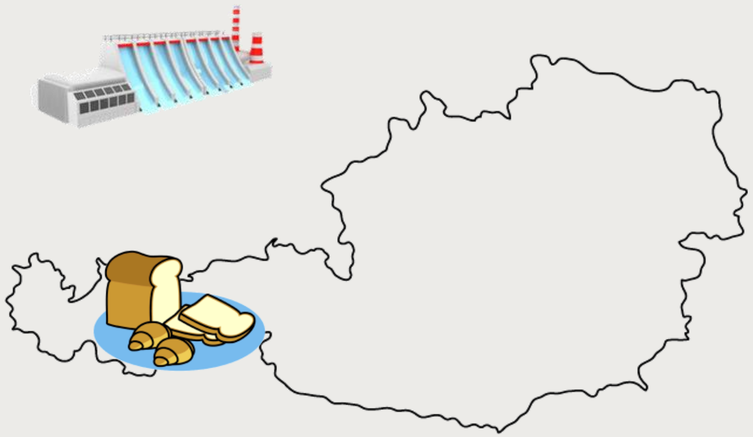
Favourable electricity tariffs in Austria for electrolysers

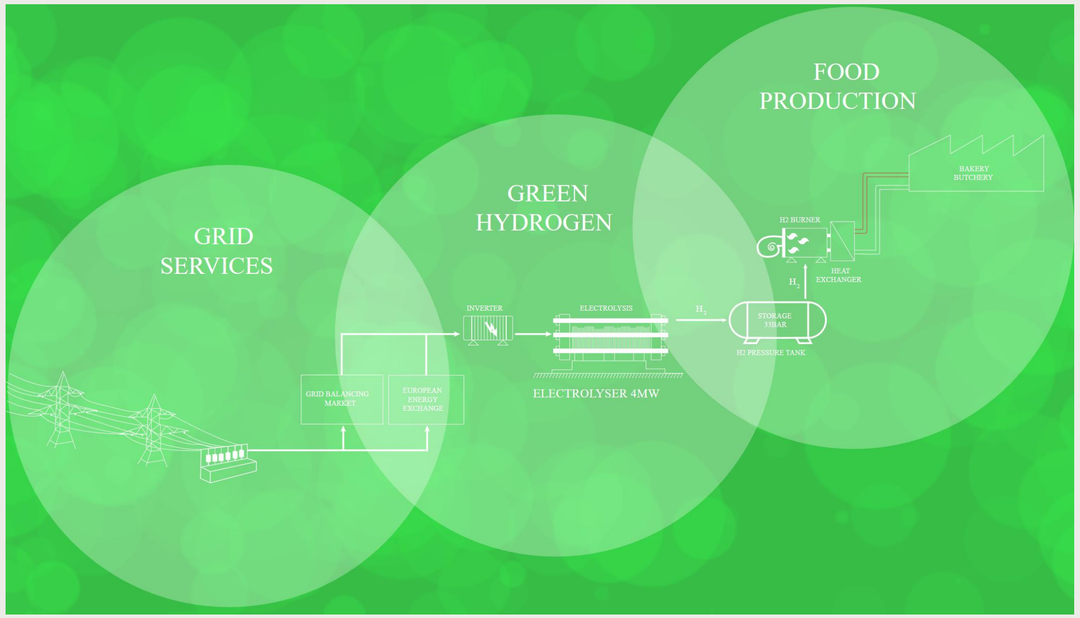
Steel industry a great proponent of green H2 at Commission level



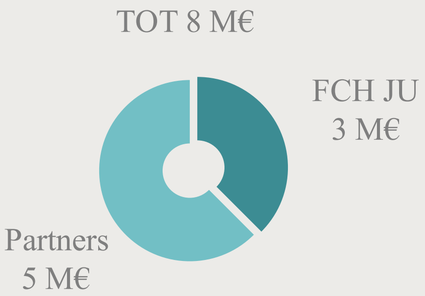
2016: Greening the Food Industry

The Demo4Grid Project: Producing green H2 from hydro power, combustion in boiler of food industry



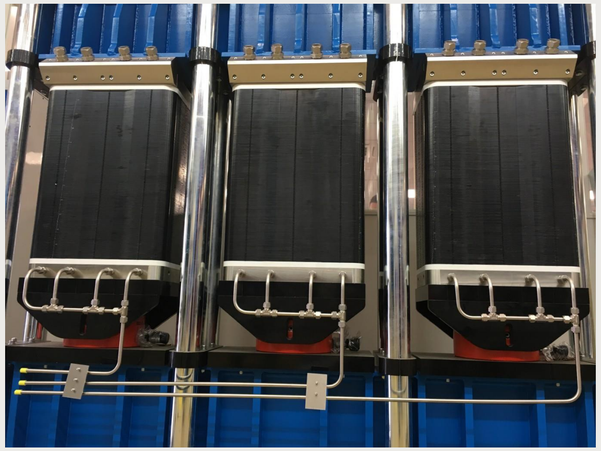


Hosted by Mpreis (food industry, Tirol)
4MW alkaline electrolyser by IHT
Favourable electricity tariffs in Austria for electrolysers
H2 4 Heat



2017: Greening the Refining Industry

The Refhyne Project: Producing green H2 from renewables, displacing grey hydrogen

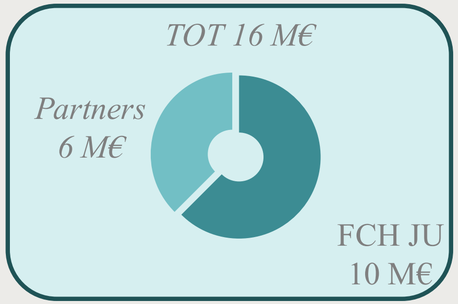


REFHYNE
CLEAN REFINERY HYDROGEN FOR EUROPE

Co-ordinated by SINTEF

10MW PEM electrolyser by ITM Power

Installed in Shell refinery in Wesseling, Germany



Displacing 1% of 180,000 tons annual consumption, supporting the balancing of the grid

2018: Greening the ? Industry

Demonstration of a large-scale (min. 20MW) electrolyser for converting renewable energy to hydrogen

20MW, 11MEuro of FCH JU support

Rapid response for grid services

Minimum footprint

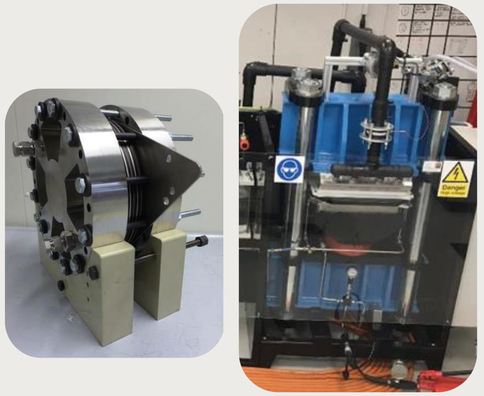
52kWh/kg H2

Steel and refinery industries excluded

Safeguarding Europe's leading position through R&D

Vibrant community of OEMs and R&D institutions

- **Capex targets for AE and PEME < 1.8 k€/kW**
- **Efficiency degradation < 0.8% / yr**
- **Efficiency at system level < 55 kWh/kg**
- **Dynamic performance / Harmonisation of testing**



2017: R&D on Game changer electrolysers

Push the limits of cost, efficiency, lifetime, operability

NEPTUNE project

- self-pressurizing 100 bar PEM electrolyser system of 48-115 kW
- current densities of 4-8 A·cm-2.
- at least 4,000 hours (cumulative, 2000 h steady-state, 2000 h cycled operation))

PRETZEL project

- Cell concept capable of 100 bar, PEM electrolyser system of 25 kW
- current densities of 4-6 A·cm-2, non-precious metal coatings
- at least 2000 h operation

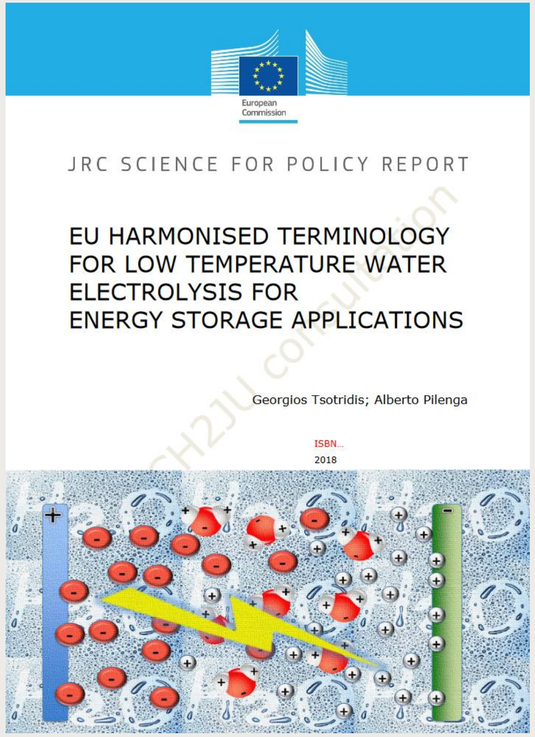
GAMER project

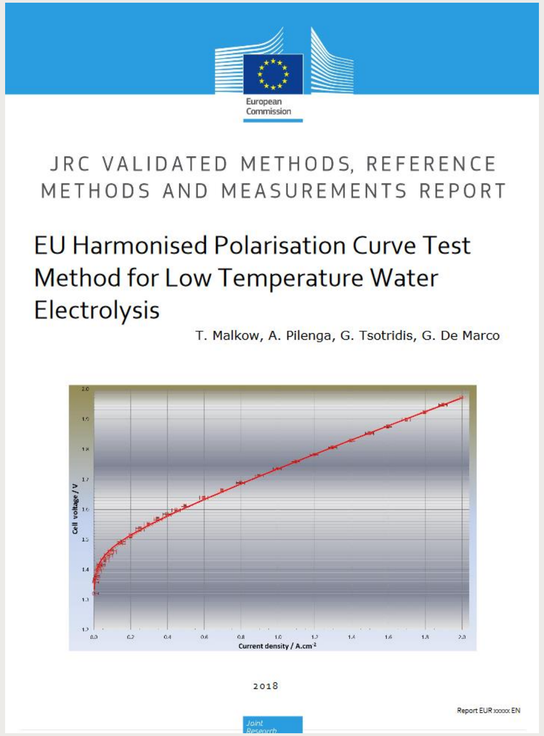
- Tubular proton ceramic electrolyser @ 30 bar, 10kW
- current densities of 4-6 A·cm-2.
- Operation @ 500-700 C

Harmonisation of electrolyser Testing Protocols

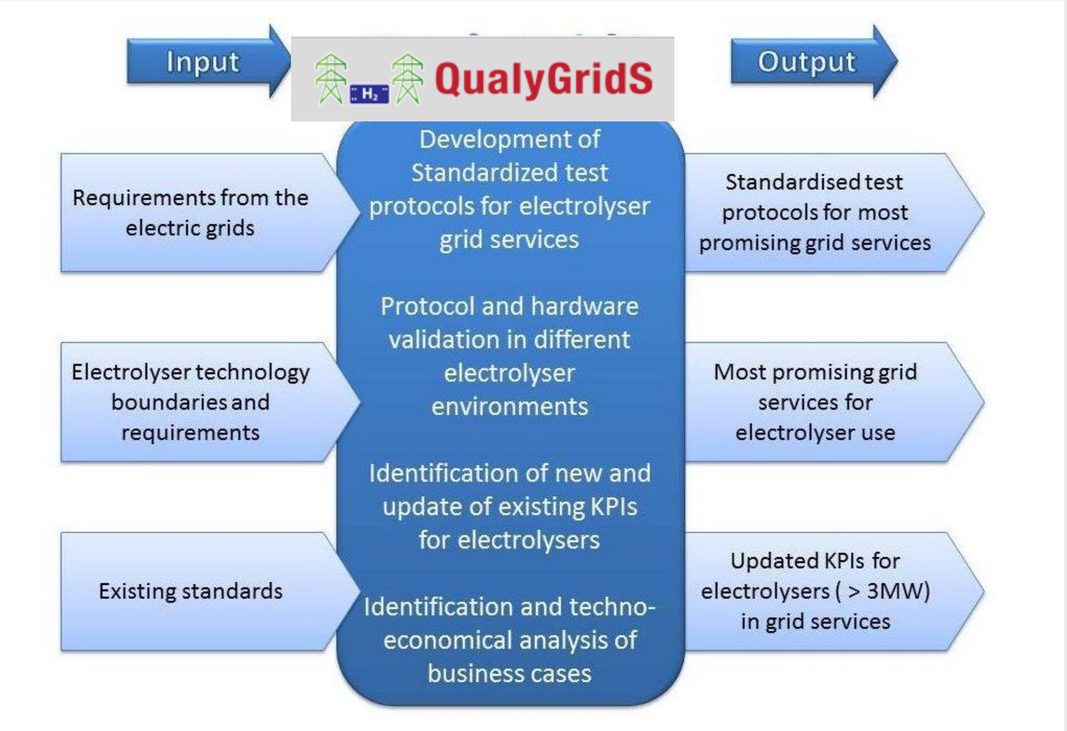
2 parallel efforts

1. JRC standardisation of testing @ cell and stack level: two documents for public consultation





2. QUALYGRIDS project standardisation of testing @ system level



Summary

The FCH JU has consistently provided support to electrolyser development and demonstration

ALK elys @ atm. cost 1,200 – 850 Euro/kw for 1 – 5 MW resp. with 58-52 kWh/kg H2

PEM elys @ 30 bar cost 1,500 – 1,300 Euro/kw for 1 – 5 MW resp. with 63-61 kWh/kg H2

Continued support to RD&D will allow improvements to cost and availability

Considerable prospects for the electrolyser industry, supported by the emerging Power to Gas market for Sectoral Integration

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