Green Hydrogen Production through electrolysis

Bart Biebuyck, Executive Director

Hybalance electrolyser factory acceptance
Oevel, 13 February 2017

FCH 2 JU: Strong Public-Private Partnership with a focused objective

Industry-led Public-Private Partnership (PPP)

Fuel Cells & Hydrogen Joint Undertaking (FCH2 JU)

Hydrogen Europe
Industry Grouping
Over 100 members
~ 50% SME

European Commission

N.ERGHY
RESEARCH ON FUEL CELLS & HYDROGEN
Research Grouping
Over 60 members

The Joint Undertaking is managed by a Governing Board composed of representatives of all three partners and lead by Industry.

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

Legal basis:
Council Regulation: 559/2014 of 6 May 2014 (H2020)

FCH-JU objectives

H_2 STORAGE FOR GRID BALANCING

Demonstrate on a large-scale hydrogen's capacity to harness power from renewables and support its integration into the energy system

GREEN HYDROGEN PRODUCTION

Increase efficiency and reduce costs of hydrogen production, mainly from water electrolysis and renewables

CLEAN TRANSPORT

Reduce fuel cell system costs for transport applications

HEAT & ELECTRICITY PRODUCTION

Increase fuel cell efficiency and lifetime

MINIMAL USE OF CRITICAL RAW MATERIALS

Reduce platinum loading

Recent Energy Union initiatives

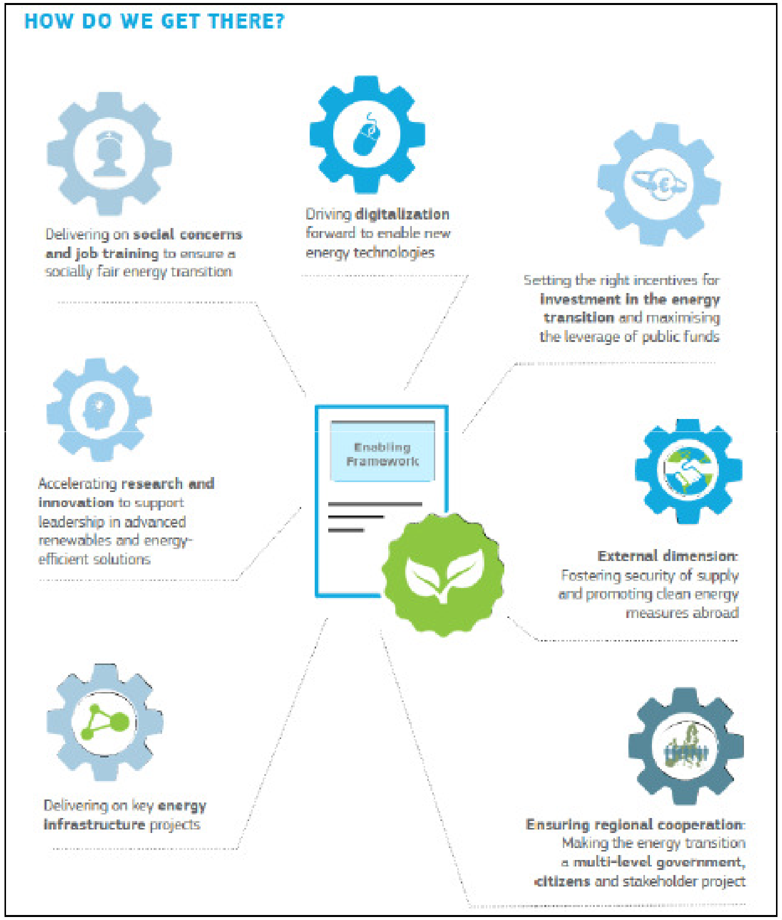
A. Energy package "Clean Energy for all Europeans" *COM(2016)860*

3 leading principles:

- *Putting energy efficiency first*
- *Achieving global leadership in renewable energies*
- *Providing a fair deal for customers*

http://ec.europa.eu/energy/sites/ener/files/documents/energy_union_package_factsheet_i_v2.pdf

3 relevant documents for H2&FC: see next 2 slides



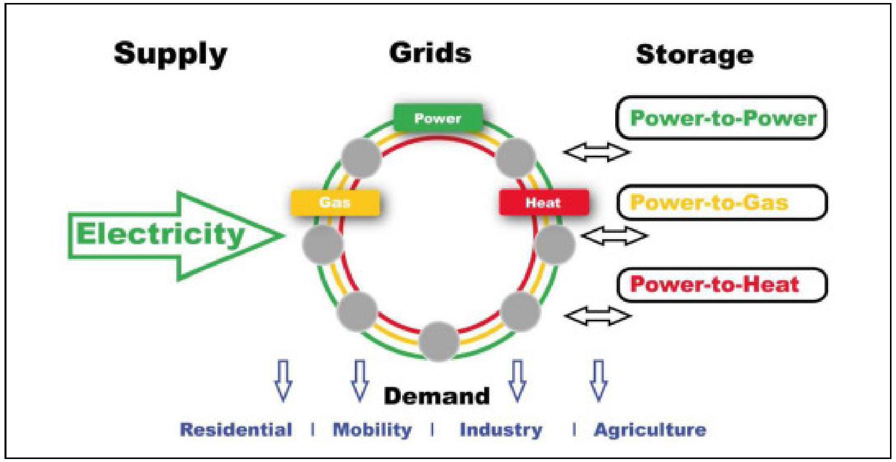
Recent Energy Union initiatives

A.1 Electricity Market Design Directive *COM(2016)864*: attention to flexibility options, a.o. storage, ***hence relevant for H2 and FC***

- Definition of energy storage:

  "energy storage in the electricity system means the deferring of an amount of the energy that was generated to the moment of use, either as final energy or converted into another energy carrier"

- Staff Working Document Energy Storage SWD(2017)61 – *elaboration of role and potential of H2 storage to contribute to flexibility by integrating sectors and thereby enable further decarbonisation of transport, industry, buildings and agriculture*



Recent Energy Union initiatives

A.2 New Renewable Energy Directive (RED II) *COM(2016)767*: how to achieve binding target of 27% RES by 2030; covers electricity, transport and heating and cooling sectors; ***relevant for market uptake of renewable H2 and of Power-to-X***

A.3 Accelerating Clean Energy Innovation *COM(2016)763*

4 technology focus areas identified, ***2 are relevant for H2:***

- Strengthening EU leadership on renewables:

  Intensify the development of solutions to increase the production and integration of renewables, in particular of variable renewables, into the energy system including the transport sector, through thermal and chemical storage (power-to-gas, power-to-liquids)

- Developing affordable and integrated energy storage solutions:

  accelerate full integration of storage devices (chemical, electrochemical, electrical, mechanical and thermal) into the energy system, at domestic, commercial and grid scale

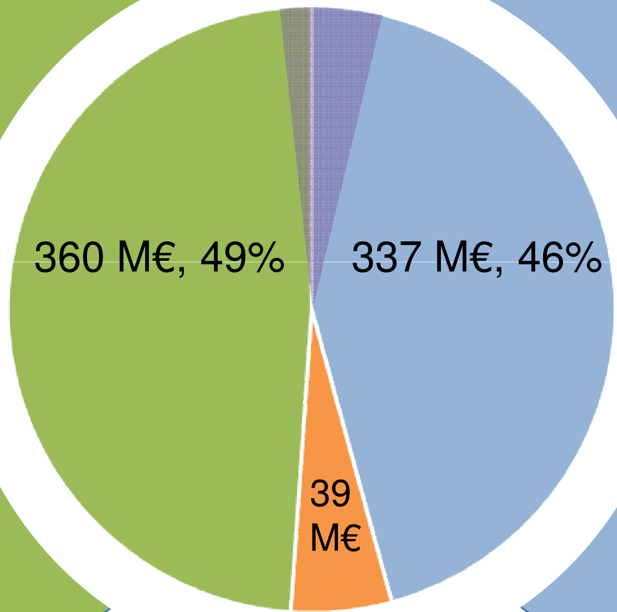
  - Batteries, hydrogen and other storage applications – both mobile and stationary – play a larger systemic role for RES integration and optimisation of operations.
  - creation of favourable market conditions for increased dissemination of storage solutions at both consumer- and grid level, including building bridges between the electricity grid, natural gas grid and the transport system as a precondition for a fully renewables-based power supply.

204 projects supported for 737 M€

Similar leverage of private funding: 782 M€

ENERGY
117 projects

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



TRANSPORT
53 projects

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

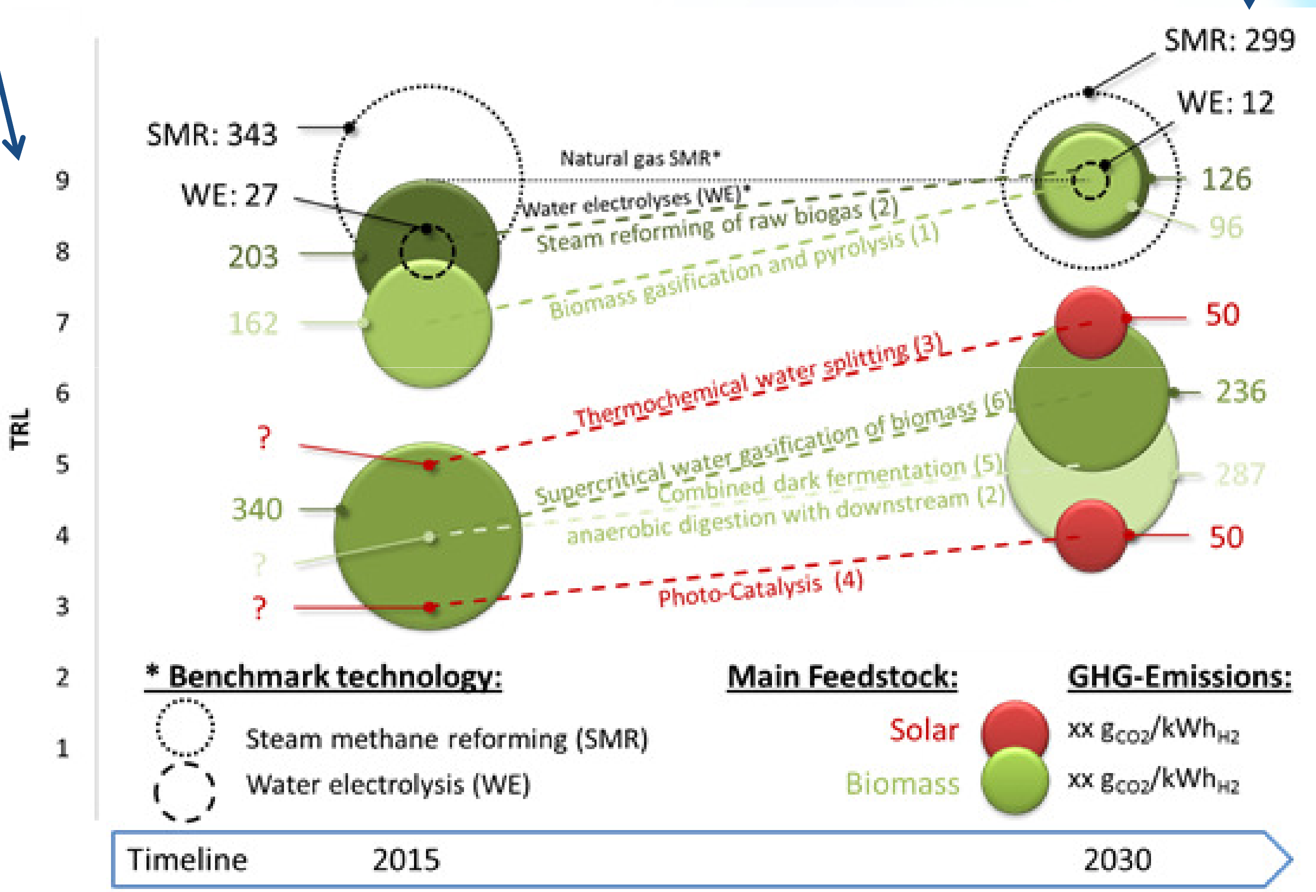
Cross-cutting, 34 projects

(e.g. standards, safety, education, consumer awareness, …)

FCH JU Green Hydrogen Study: Main findings

TRL

g_{CO2}/kWh_{H2}



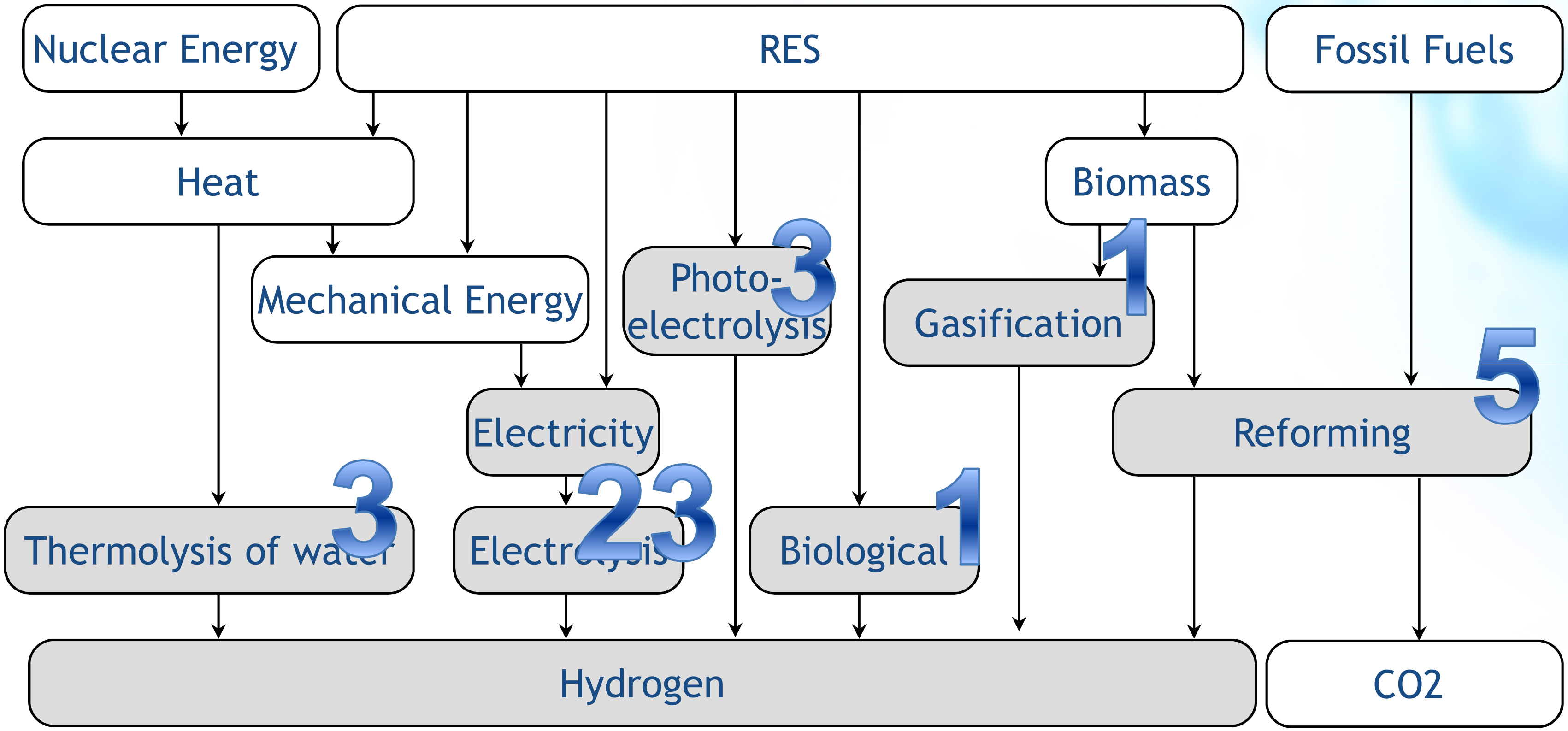
Pathways

(2) Raw biogas reforming
(1) Biomass gasification
(3) Thermo-chemical cycles
(6) Supercritical H2O gasification
(5+2) Fermentation
(4) PEC

Criteria

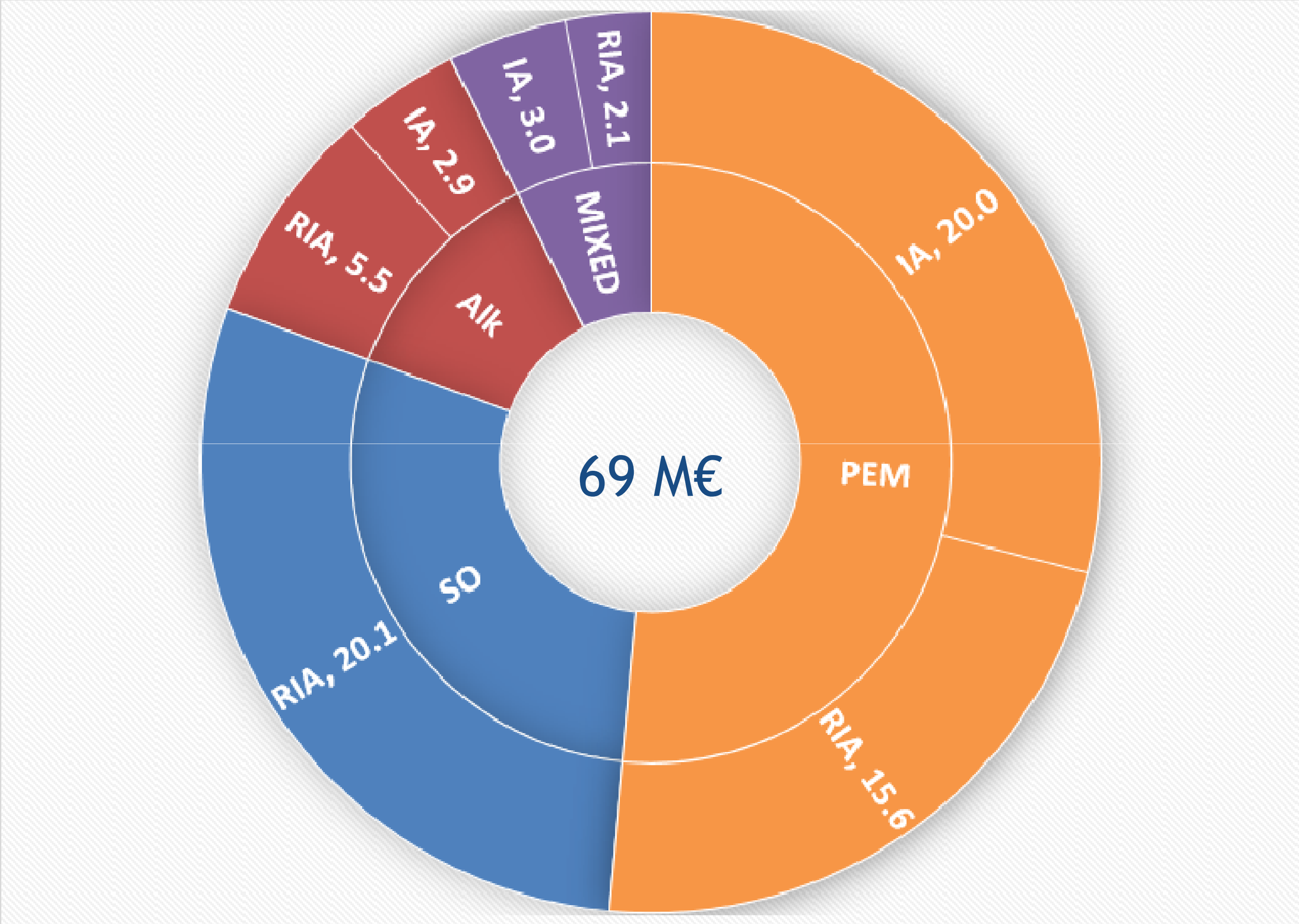
- TRL
- Feedstock
- GHG-emissions

FCH 1&2 Hydrogen Production Technical Coverage



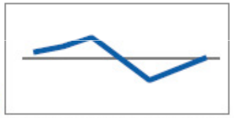
- 36 projects
- 93 M€ FCH JU support

FCH 1&2 JU Support to electrolyser projects (M€)



FCH JU Energy Storage Study: Main findings

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 ⊖	

All of these option come at a cost to society

1 Difference between demand and intermittent RES production

7

FCH JU Energy Storage Study: Main findings

At realistic values of hydrogen, large installed electrolyzer capacity would be viable and able to utilize nearly all excess RES energy in the 2050 horizon

Non-hydrogen P2P and heat storage will only be able to absorb a small part of the excess energy generated, resulting in the necessity of curtailment – from societal point of view, such electricity could be used at close to zero cost

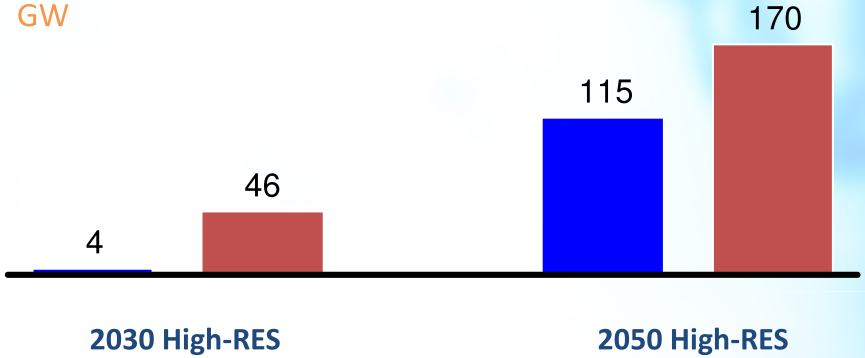
The excess energy can be used to produce hydrogen via water electrolysis for re-electrification or use outside of the power sector

If the value of hydrogen at the point of production can reach a price in the range of 2-4 €/kg very large installed electrolyzer capacity would be economically viable and able to utilize nearly all of the excess electricity

Such use of the excess electricity would create value for the society and the surplus could be divided between the electricity and hydrogen producer

High connectivity | Low connectivity

Economic demand[1] for electrolyzers assuming a best case of 2 EUR/kg of H2
GW



Reduction in excess energy
Percent

Germany archetype

1 Installed electrolyzer capacity achieving 60 EUR/installed kW per year of benefits at given hydrogen plant gate cost – this corresponds to 370 EUR/kW capex, 8% WACC, annual opex at 1.2% of total capex and 10 years lifetime (FCH JU 2014)
Assumes electricity for free, no grid connections fees and no time-shift storage is in place.

FCH JU Early business Cases Study:

#	Business cases	Regions	Main factors
1	Merchant – On-site General case	1. Denmark (2017/2025) 2. France (2017/2025)	High merchant price Low electricity price
2	Mobility – On-Site	1. France (2017/2025) 2. Denmark (2017/2025) 3. Germany (2025) 4. Great Britain (2025)	
3	Mobility – Semi centralised	1. France (2025) 2. Denmark (2025) 3. Germany (2025)	Low electricity cost Injection and Grid services
4	Large industry - Refinery	1. Denmark (2025) 2. Germany (2025)	Asymetric reserve in DK & DE

TRACTEBEL ENGIE

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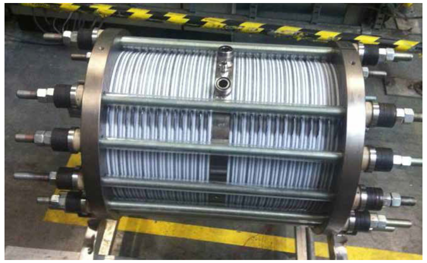
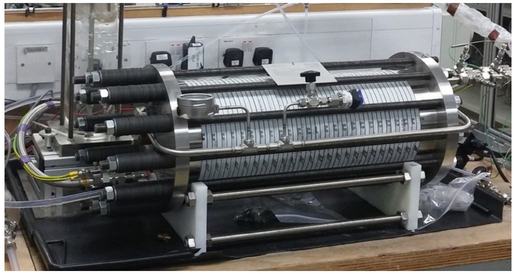
FCH JU Support to Research Projects

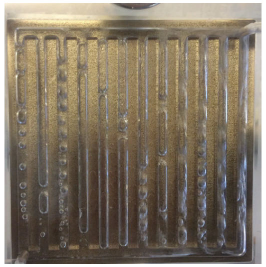
- Electrolysers

Alkaline (AE) and PEM: 2015 data vs 2017 MAWP targets

	FCH JU project results 2015 PEME	FCH JU project results 2015 AE	MAWP target 2017		non-European SoA
CAPEX, M€/(t/d)	⚠	✔	<	3.7	1.7-3.5 @ 1 MW / 500 kg/d
Energy consumption, kWh/kg	⚠	⚠	<	55	65
Efficiency degradation, %/y	✔	✔	<	2	1.1
Min load, % of nominal capa.	✔	-	<	5	0
Max load, % of nominal capa.	⚠	-	>	150	100
Hot start, seconds	✔	✔	<	10	10
Cold start, seconds	⚠	⚠	<	120	300

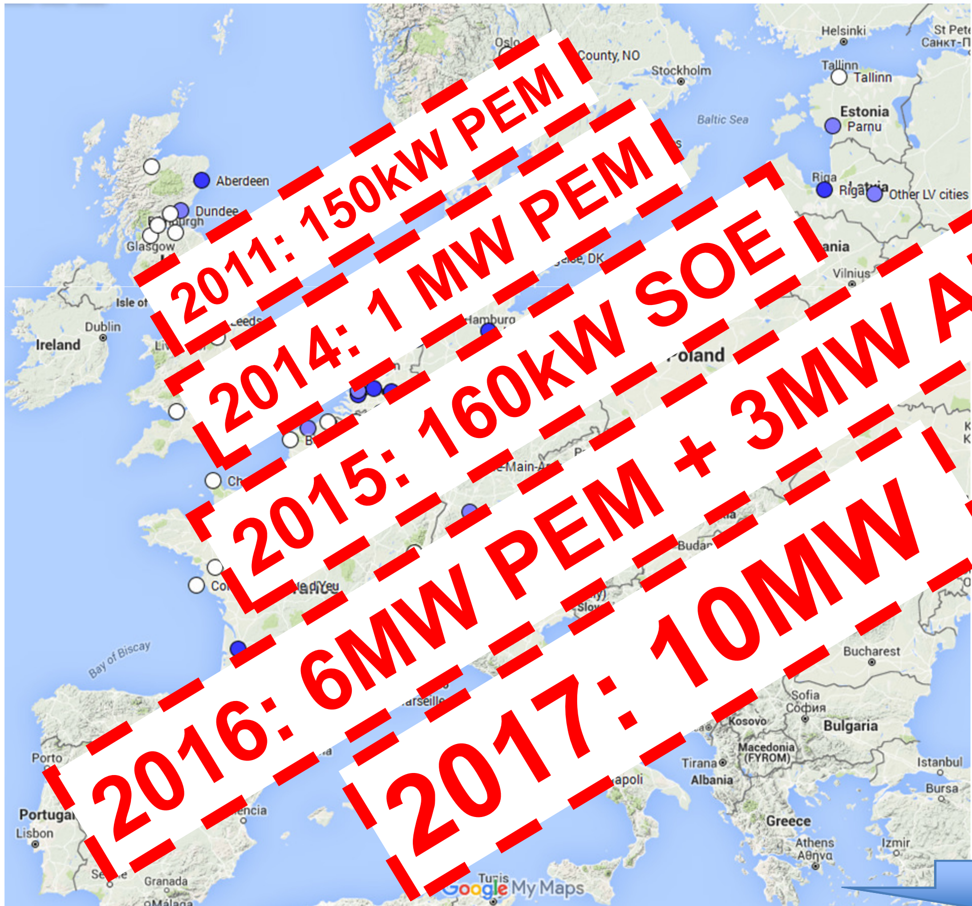






FCH JU support to Demonstration projects

Industry acknowledges the potential of Hydrogen to the greening of industrial products through increased penetration of renewables



DonQuichote — hydrogen out of wind turbine energy

Hybalance

GrInHy — Green Industrial Hydrogen

H2FUTURE — Green Hydrogen

DEMO4GRID

Transport, Steel industry, Refineries, Chemical industry

The Hybalance project is the first and most advanced of the large electrolyser demonstration projects of the FCH JU

- **Duration**: 5 years (1/10/2015-30/9/2020)
- **Budget**: 15.2M€, 8MEuro FCH JU funding + 2.6M€ National funding
- **Scope**: 1MW PEM electrolyser serving industrial and transport markets, providing at the same time electricity grid services