FCH2 JU: Making hydrogen and fuel cells a reality in Europe

Congress Hydrogenregion 2.0, Antwerp,
25 October 2016

Bart Biebuyck – Executive Director

http://www.fch.europa.eu/

Background: The Energy Union

(European Commission Communication Feb.2015)

The 5 Pillars of the Energy Union:

1. Security of supply
2. Integrated European energy market
3. Energy efficiency
4. Decarbonisation
5. **Research and Innovation => SET-Plan**

Strategic Energy Technology Plan

The FCH 2 JU in the SET plan to realize EU 2030 targets

EU 2030 targets*:

27 % increase in renewables

27 % increase in efficiency

40 % decrease in emissions

Fuel Cells and Hydrogen Joint Undertaking

- FCH JU - EU body
- Budget: 1.4 bill.€ (2014-2020)**
- FCH JU Programme Office

*European Council, October 2014

** continuation of previous program for 2008-2013 with a budget of approx. 1 bill.€

Fuel Cells & Hydrogen technologies role in the Energy Union

Energy Security

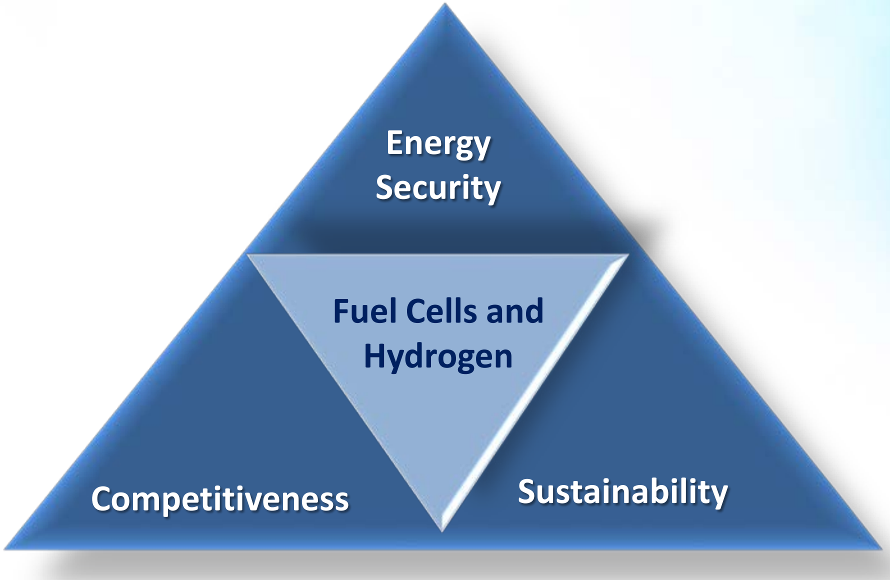
- Increase independence from unstable outside regions

Competitiveness

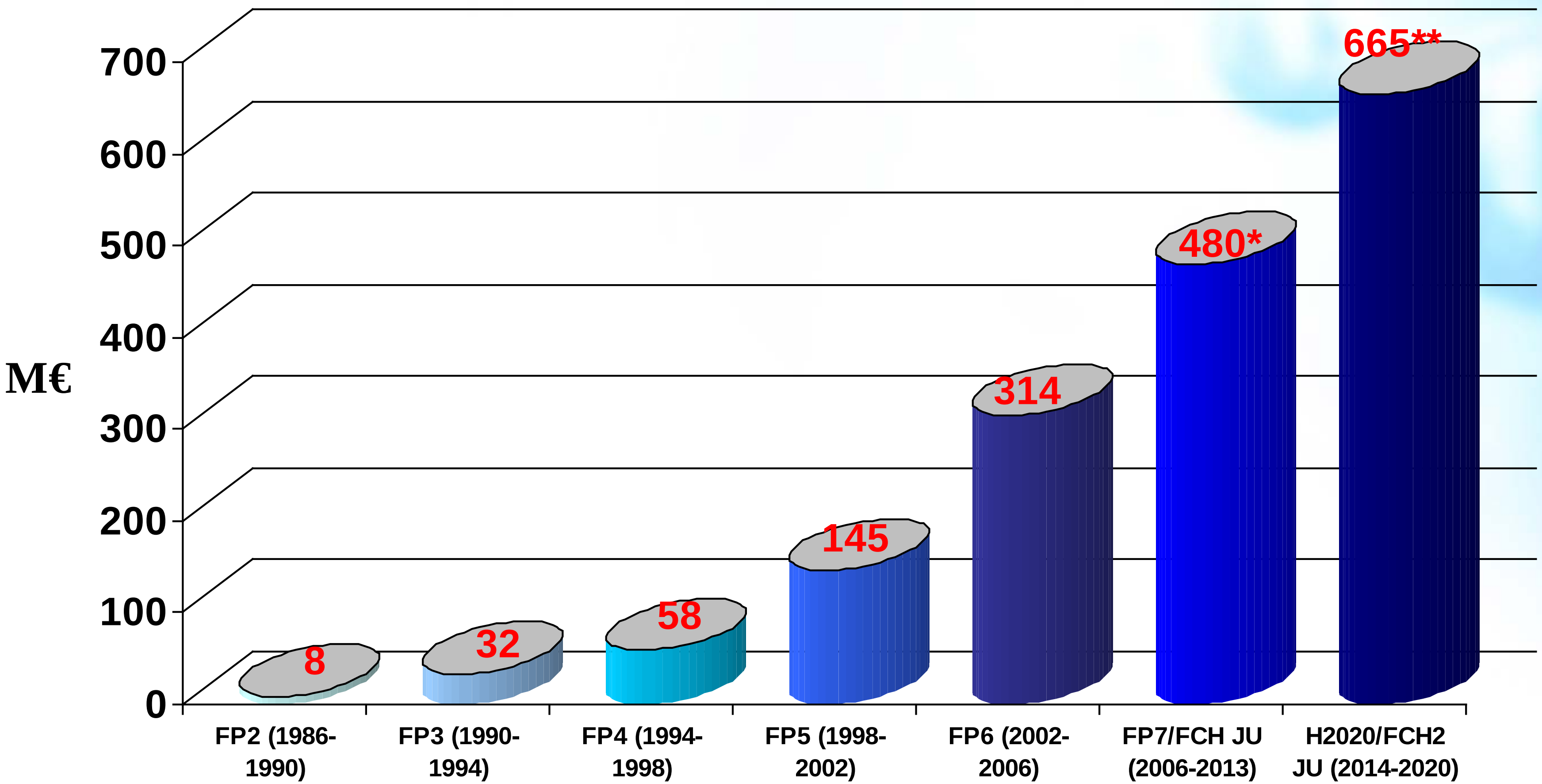
- research excellence leading to industry innovation and growth

Sustainability

- H_2 is a clean energy carrier
- Transport and Energy applications, generate electricity and heat with very high efficiency
- Possibility for storage of renewable energy sources
- Reduction of CO_2 emissions



Continuous Support in the EU Framework Programmes



** 470 mill EUR implemented by FCH JU + about 10 mill EUR already spent from EU 2007 budget, before FCH JU in place*
*** 665 mill EUR only to be implemented by the FCH2 JU + additional budget from EU programmes for low TRL (basic research) and structural funds/smart specialisation*

TFCH2-JU is strong Public-Private Partnership with a focused objective

Fuel Cells & Hydrogen Joint Undertaking (FCH2 JU)

Hydrogen Europe
Industry Grouping
Close to 100 members
~ 50% SME

European Commission

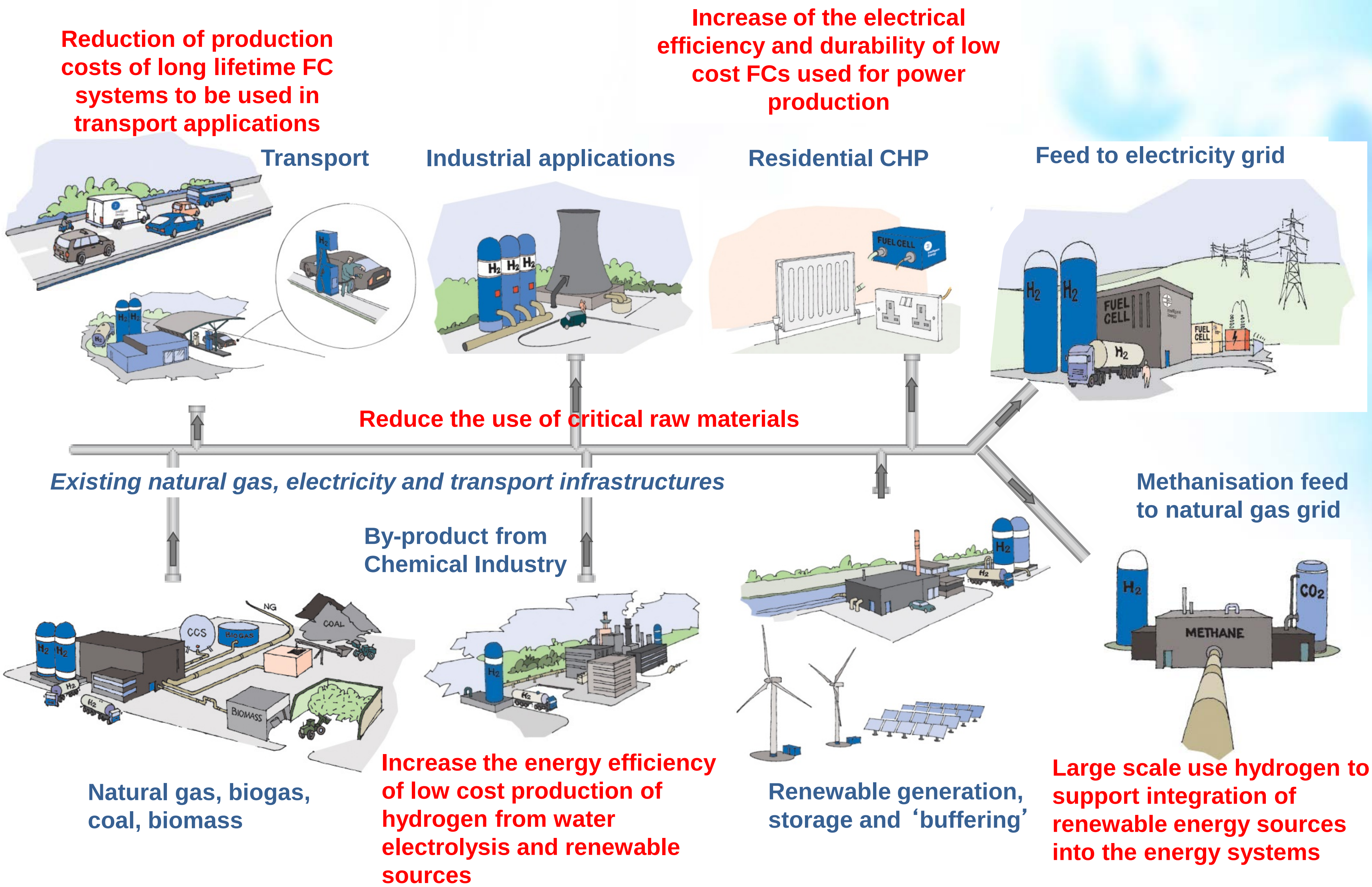
N.ERGHY
RESEARCH ON FUEL CELLS & HYDROGEN
Research Grouping
Over 60 members

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

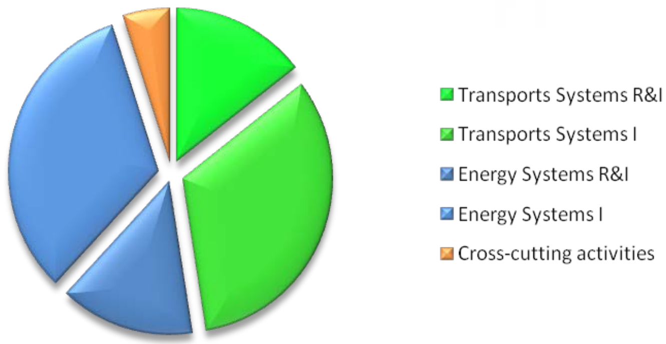
To accelerate the development of technology base towards **market deployment of FCH technologies** from 2015 onwards

Legal basis:
Council Regulations:
521/2008 of 30 May 2008 ***(FP7)***
& amendment 1183/2011 of 14 Nov 2011
559/2014 of 6 May 2014 ***(H2020)***

FCH2 JU objectives



Multi-Annual Work Plan, MAWP (2014-2020)



Estimated budget of €1.4 billion
Strong industry commitment to contribute inside the programme + through additional investment outside, supporting joint objectives.

TRANSPORT

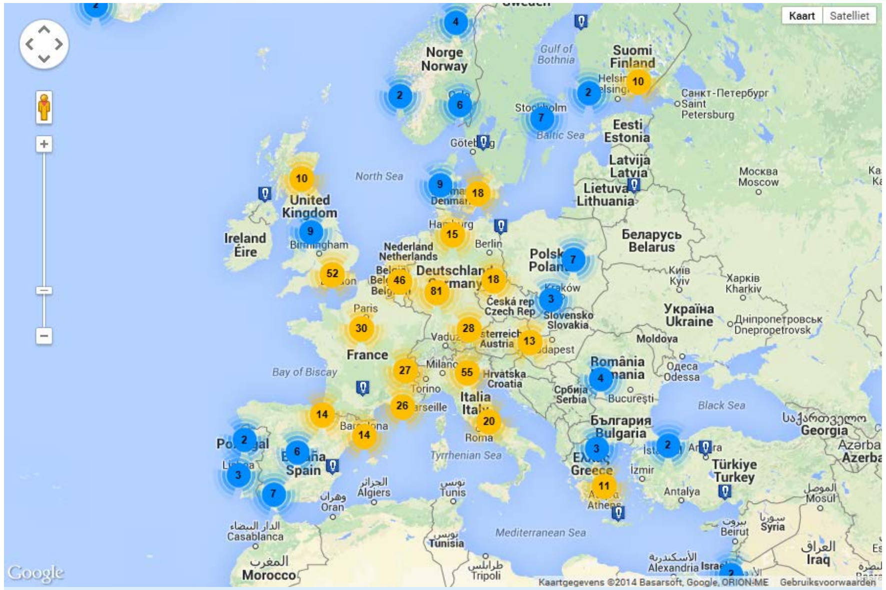
- Road vehicles
- Non-road vehicles and machinery
- Refuelling infrastructure
- Maritime, rail and aviation applications

ENERGY

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

Cross-cutting Issues
(e.g. standards, consumer awareness, manufacturing methods, …)

Strong FCH community in Europe
Projects involving 23 EU Member States



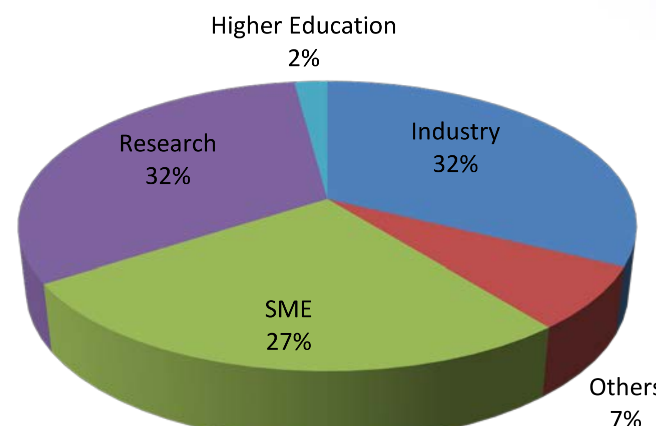
571 Beneficiaries:

- 35% Industries
- 28% SMEs
- 27% Research Organizations
- 4% High Education Institutions
- 6% Others

Incl international cooperation outside EU

(Additional non-EU countries: CH, NO, IL, TR, IS, RS, CN, RU & US)

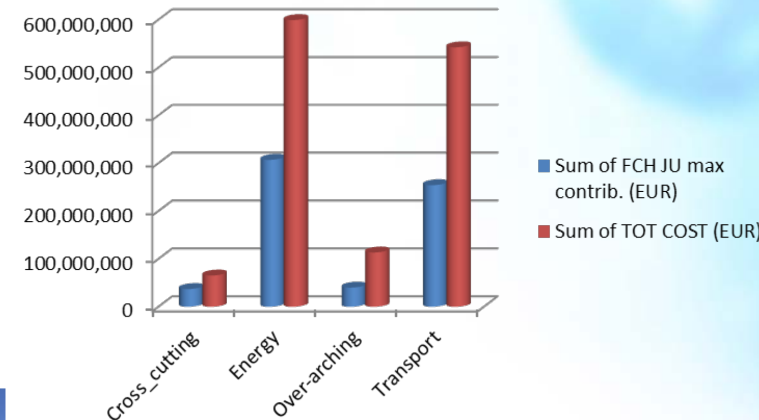
Funding of beneficiaries categories

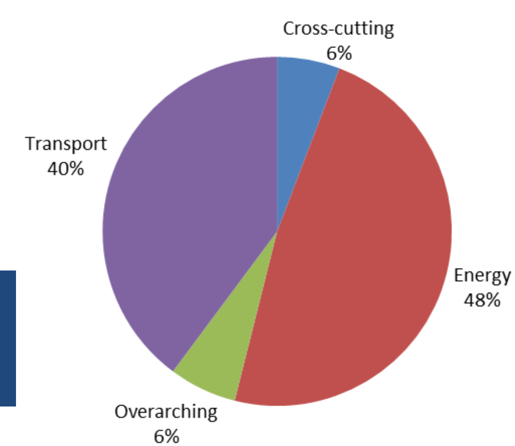


FCH2 JU portfolio of projects

185 projects supported for about 638 mill €

50/50 distribution between Energy and Transport pillars

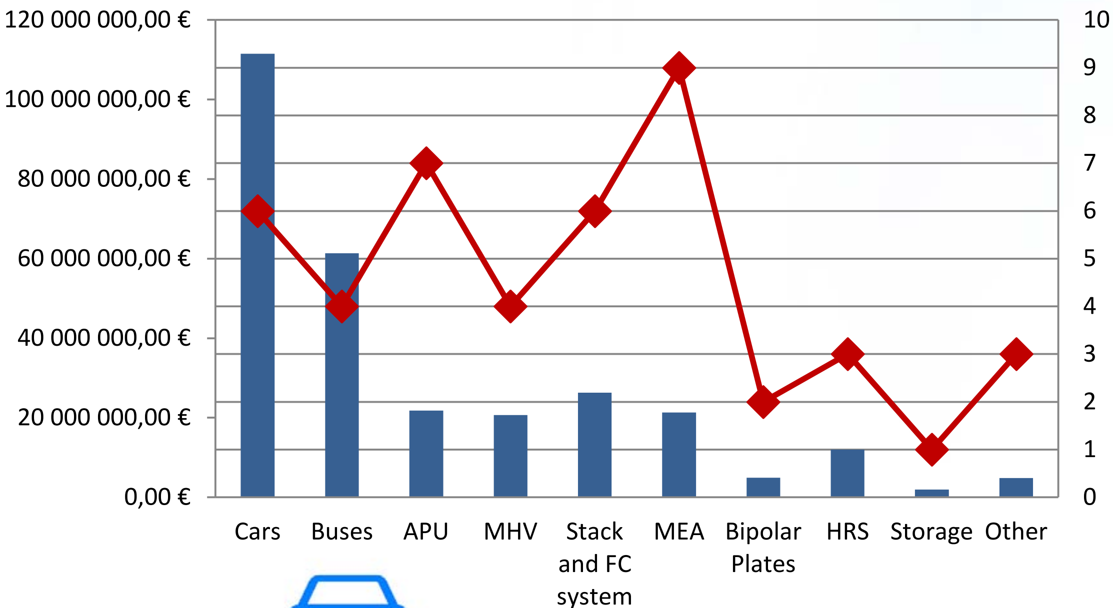




Similar leverage of private funding: 682 mill €

Continuous/constant annual support (through annual calls for proposals)

Transport portfolio

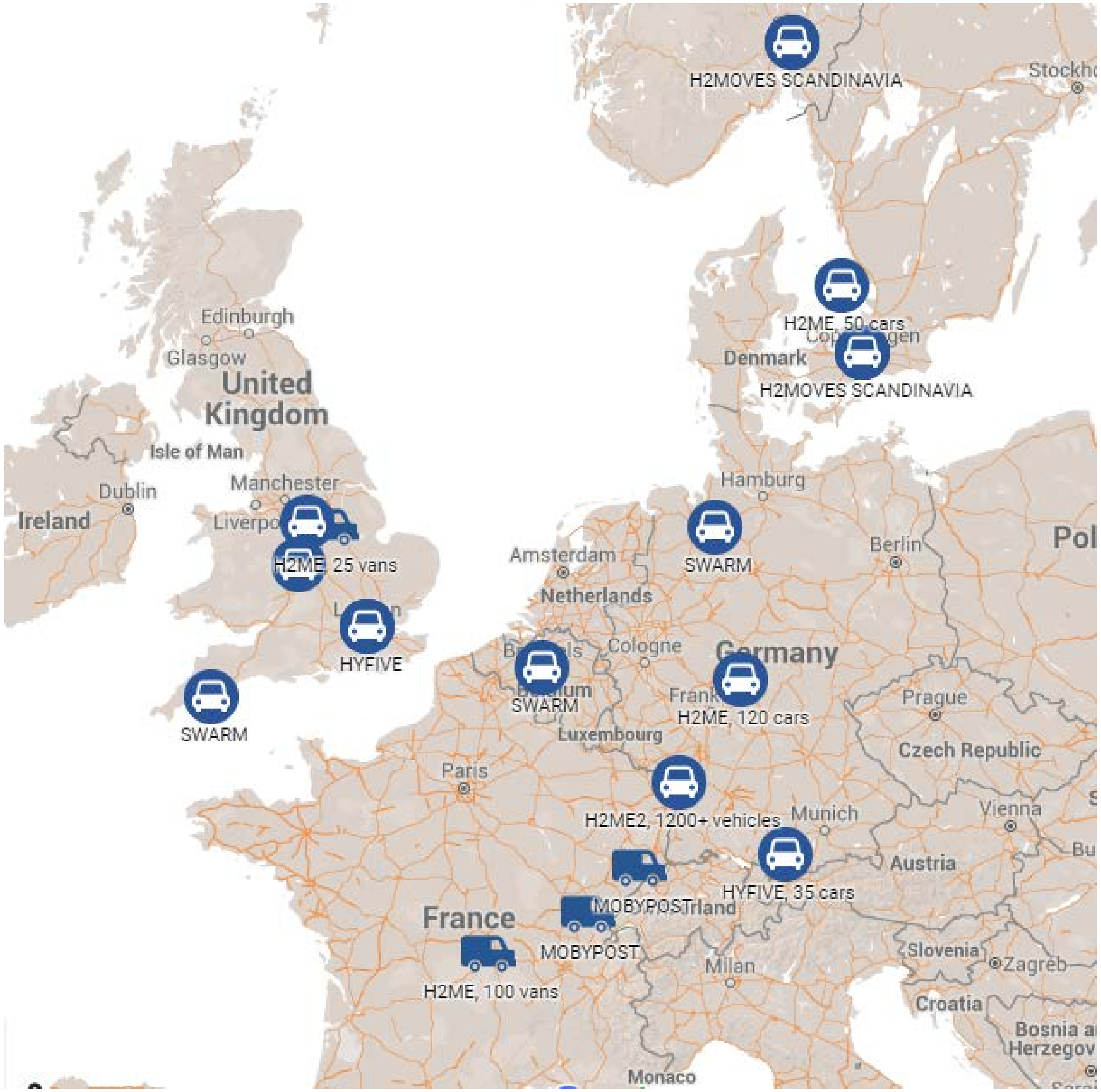


Total FCH JU support:
- **286.6M€ for 45 projects of which 215.3M€ for demos (incl. 21.8M€ APUs)**

- Total of 1,785 passenger cars in 6 projects
  - Of which 1,123 with FCs as range extender
- Total of 62 refuelling stations

- Total of 67 buses from 4 projects in 12 locations

Cars - Situation in FCH JU projects:
295 cars in operation or about to start



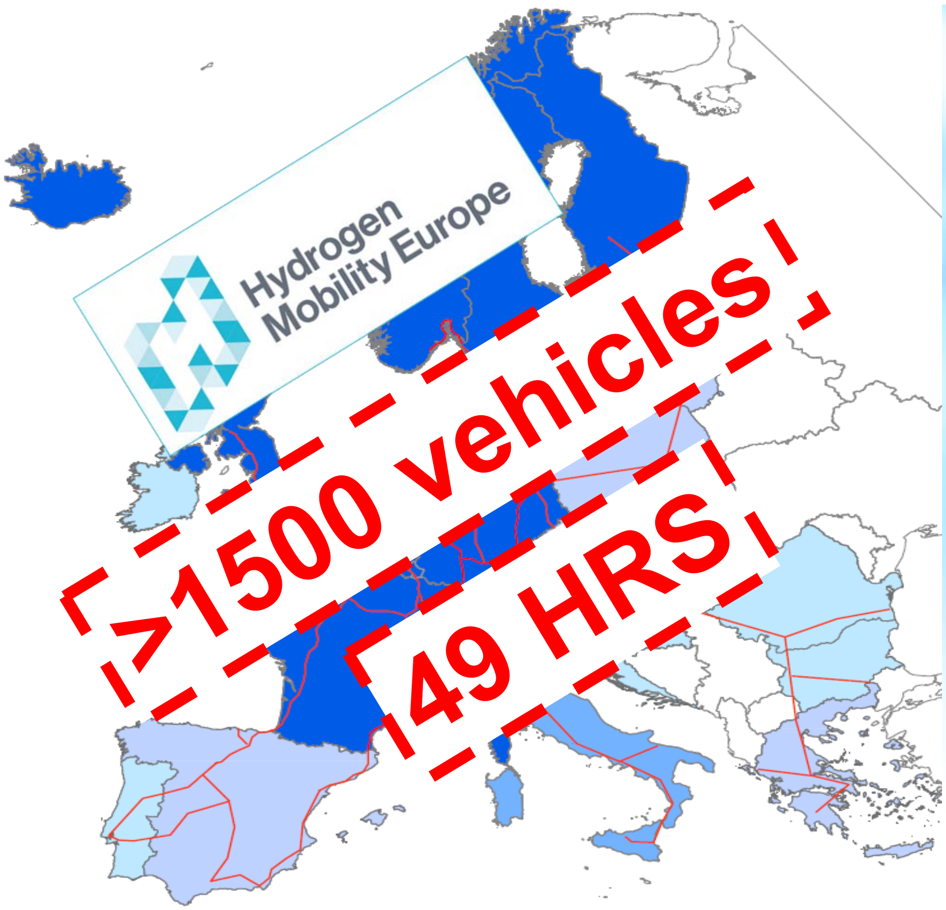
#FCEVs	Project
17	H2moves.eu SCANDINAVIA
24	HYTEC
2	SWARM
114	hyFIVE
138	Hydrogen Mobility Europe

11 HRS deployed

Cars: from MS plans to a EU perspective

Advanced FCEV and HRS programs

- **France** – a large private consortium has agreed a strategy based on a transition from captive fleets to nationwide infrastructure for FCEVs.
- **Germany** –
  - 50 H2 stations by end of 2015 under the Clean Energy Partnership. Government and industry invest jointly over 40 M€.
  - the H2Mobility project has already signed a “term sheet” linking six industrial players to deploy 100 stations by 2017 and 400 by 2023 for 350 M€.
- **Scandinavia** – An initial network provides coverage for FCEVs, which can be purchased at equivalent ownership cost.
- **UK** – a consortium with significant Government presence has agreed a strategy based on seeding a national network of 65 stations by 2020. 7.5M£ have been committed by the Government for 15 HRS by 2015.



Similar initiatives are starting or running in other countries: **Austria, Belgium, Finland**, **Netherlands**, **Switzerland**.

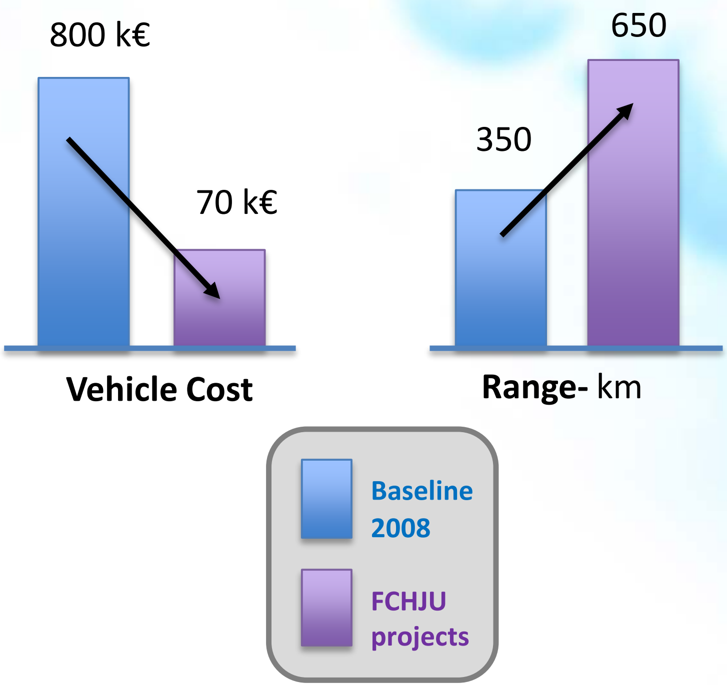
Cars: Achievements and Challenges

111M€ for 1,785 vehicles from 6 projects with 62 stations

Contributions of FCH JU demo projects

Achievements

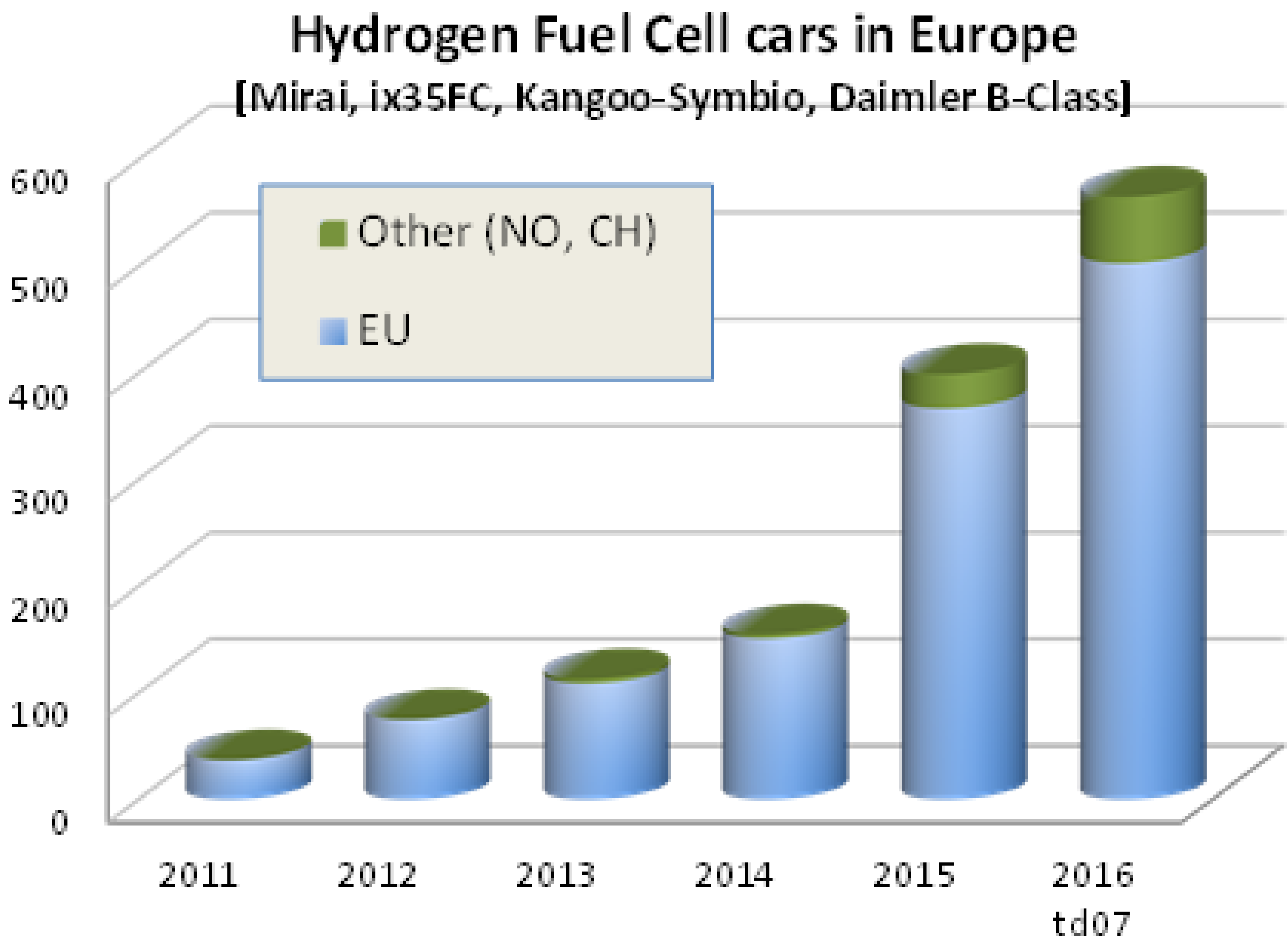
- Product ready for commercialization
  - Cold start solved
  - Refilling time solved
  - Range equivalent to incumbent technology
  - High availability
- Cost reduction
- New concepts



Challenges

- Infrastructure:
  - Availability
- Vehicles:
  - Few choices in the market
  - Cost

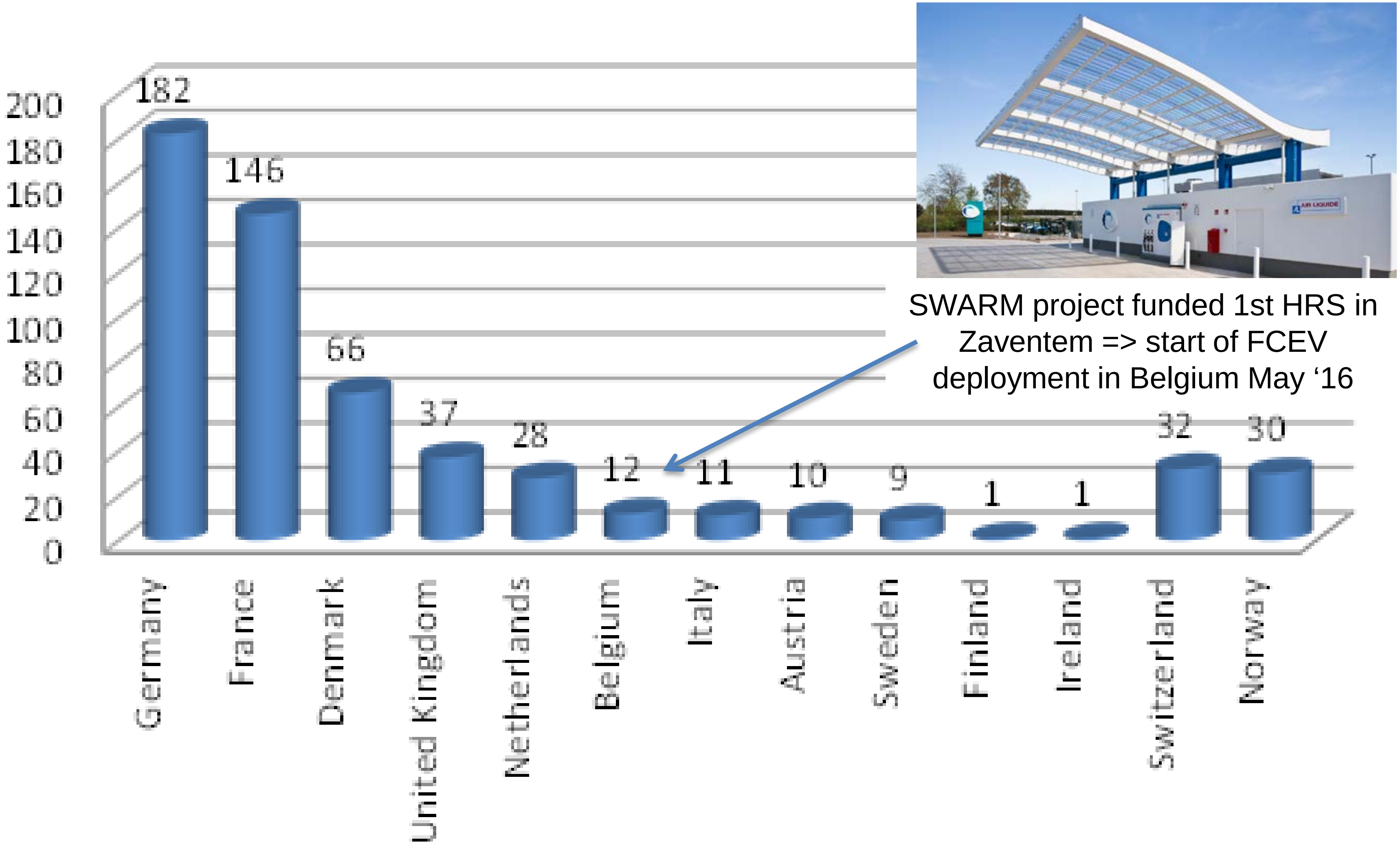
Large validation projects
Increase HRS usage
New models expected



In 2016 there will be over 500 FCEV’s on EU road

Total number of Fuel Cell cars sold by July 2016 in Europe since 2011 (tot. = 565)

[Mirai, ix35FC, Kangoo-Symbio, Daimler B-Class]



FCEV already available in 13 European countries.

Buses - Situation in FCH JU projects: 67 buses in operation or about to start

Ongoing EU-funded fuel cell bus projects

CHIC

- ✓ Aargau, CH –5 FC buses (2011)
- ✓ Bolzano, IT– 5 FC buses (2013)
- ✓ London, UK – 8 FC buses (2011)
- ✓ Milan, IT – 3 FC buses (2013)
- ✓ Oslo, NO – 5 FC buses (2013)

- ✓ Cologne, DE* – 4 FC buses (2011/14)
- ✓ Hamburg, DE* – 6 FC buses (2011/2015)

High V.LO-City

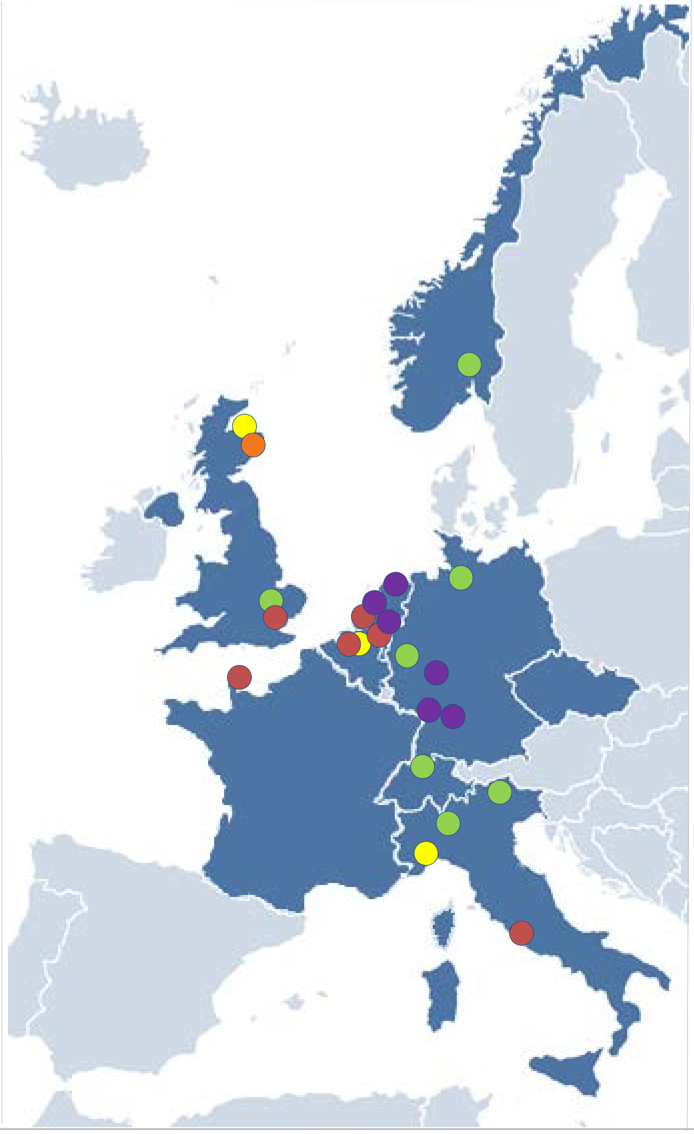
- ✓ San Remo, IT – 5 FC buses (2016)
- ✓ Antwerp, BE – 5 FC buses (2015)
- ✓ Aberdeen, UK – 4 FC buses (2015)

HyTransit

- ✓ Aberdeen, UK – 6 FC buses (2015)

Legend

- ■ Countries with (upcoming) fuel cell buses
- ✓ In operation
- ✓ Planned operation
- (2015) Operation start/planned start
- * Co-financed by regional/national funding sources



Ongoing EU-funded fuel cell bus project

3Emotion

- ✓ Cherbourg, FR – 5 FC buses (2017)
- ✓ South Rotterdam, NL – 2 FC buses (2017)
- ✓ South Holland, NL – 4 FC buses (2017)
- ✓ London, UK – 2 FC buses (2017)
- ✓ Antwerp, BE – 3 FC buses (2017)
- ✓ Rome, IT – 5 FC buses (2017)

Current national/regional-funded fuel cell bus projects

- ✓ Karlsruhe, DE * – 2 FC buses (2013)
- ✓ Stuttgart, DE * – 4 FC buses (2014)
- ✓ Frankfurt, DE * - 1 FC bus (2016)
- ✓ Arnhem, NL* – 3 FC buses (2017)
- ✓ Groningen, NL* – 2 FC buses (2017)
- ✓ North Brabant, NL* – 2 FC buses (2016)

Last update: May 2016

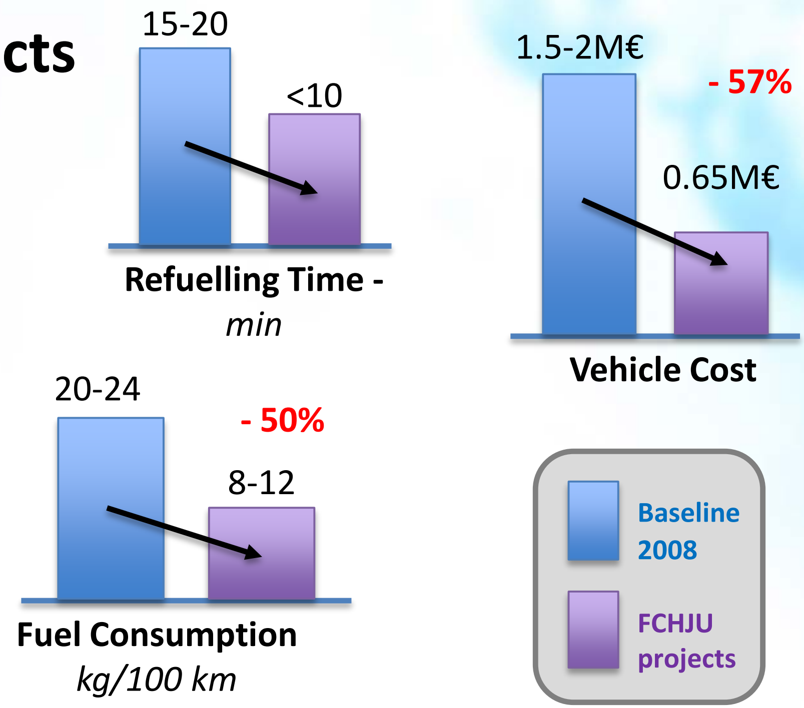
Buses: Achievements and Challenges

61M€ for 67 buses from 4 projects in 12 locations

Contributions of FCH JU demo projects

Achievements

- As flexible as diesel buses
  - Full operations: 12-20hr daily shifts
  - Short refuelling time
- Cost reduction
- Efficient electric drivetrain



Challenges

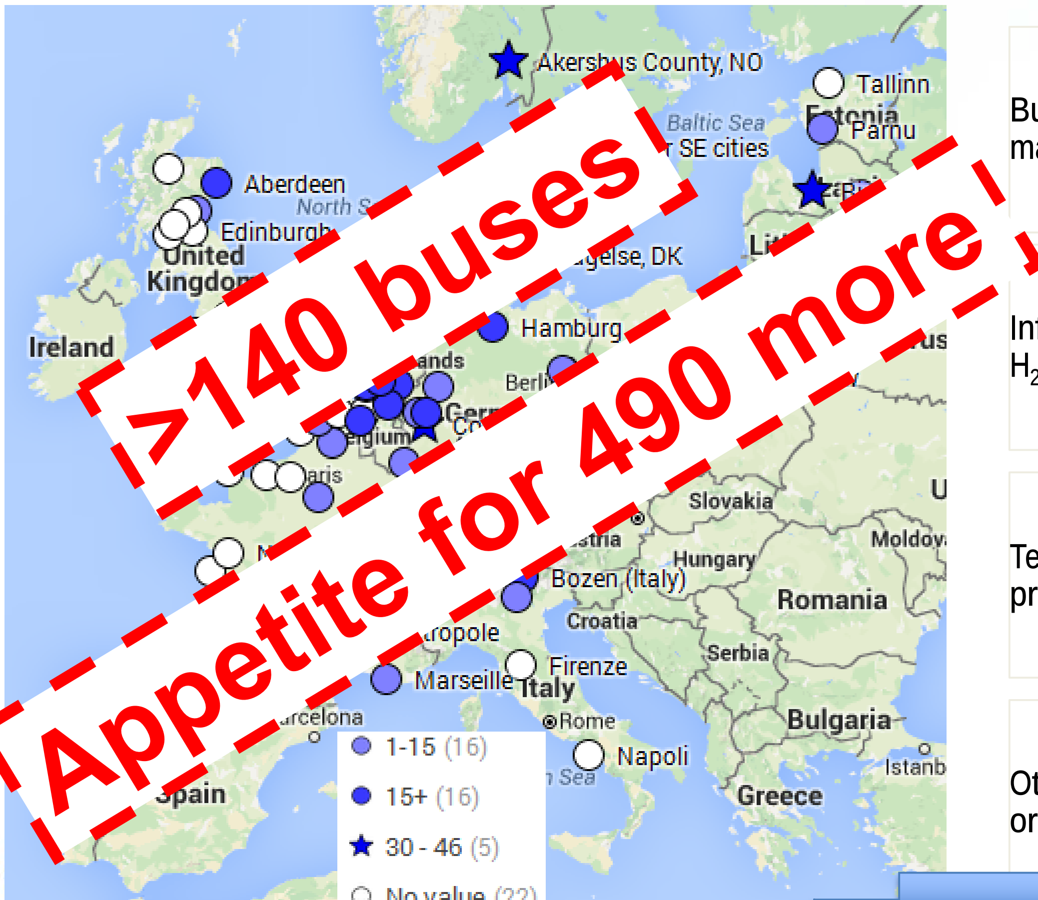
- Availability
- Spare parts
- Time to repair
- Trained staff
- Cost of FCBs, Infrastructure/H2

Volumes bring lower costs and mature supply chain

Buses: from demo to a 1.5 B€ market appetite

A broad stakeholder coalition of 82 organisations established within studies – Operators and local governments have grown now to 64 locations

Participating locations



Commercialization Study – Industry members

Bus manufacturers: Van Hool, MAN, Solaris, Škoda, EvoBus, APTS, VDL

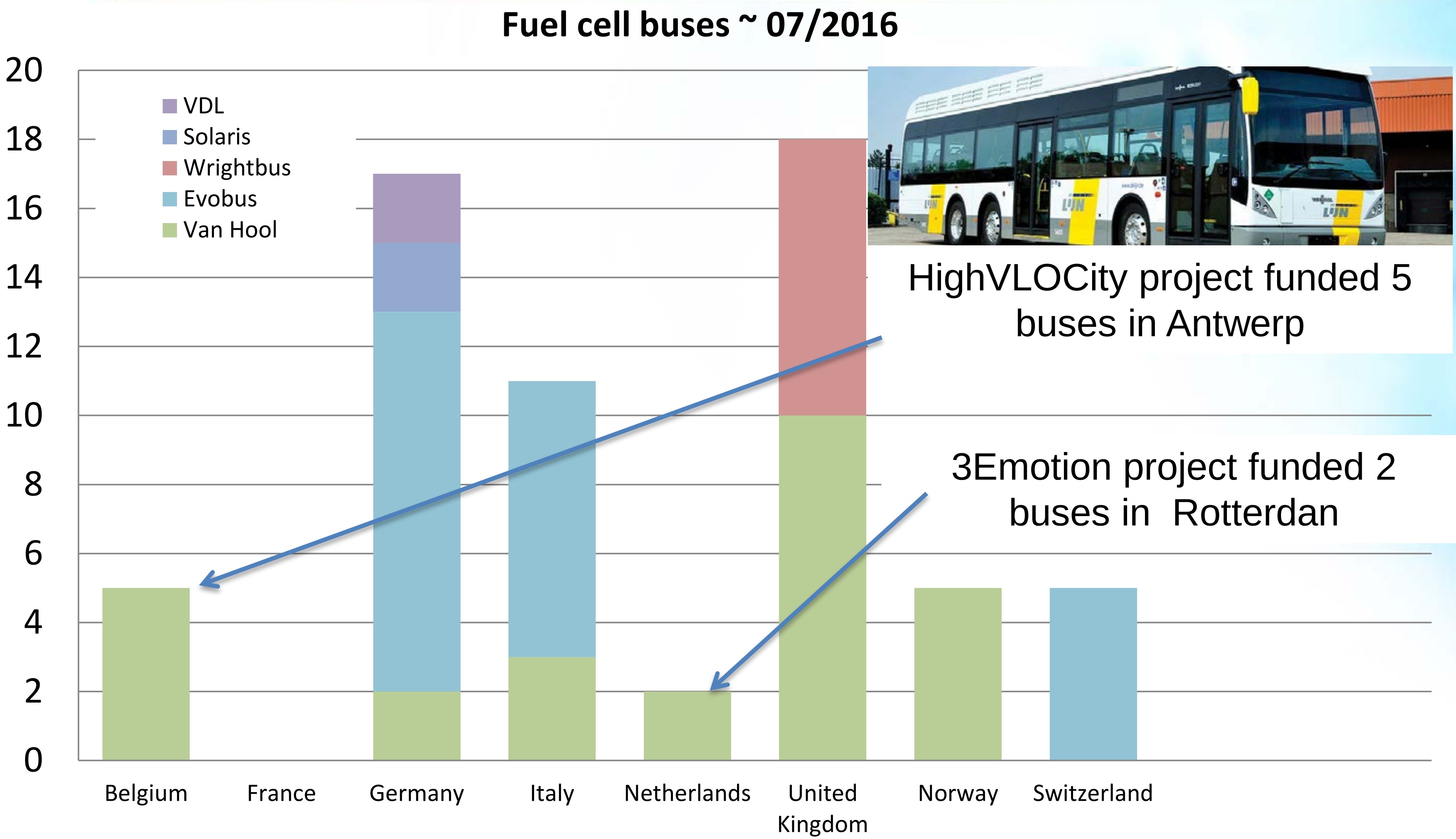
Infrastructure/ H_2 providers: H2 Logic, Shell, Ballast Nedam, Linde, Air Liquide, ITM Power, Air Products, Siemens, Hydrogenics, McPhy

Technology providers: Hydrogenics, Ballard, Siemens, PM, Intelligent Energy

Other organisations: Government of the Netherlands, VRR, NOW, hy Solutions, VDV Die Verkehrsunternehmen, EnergieRegion.NRW

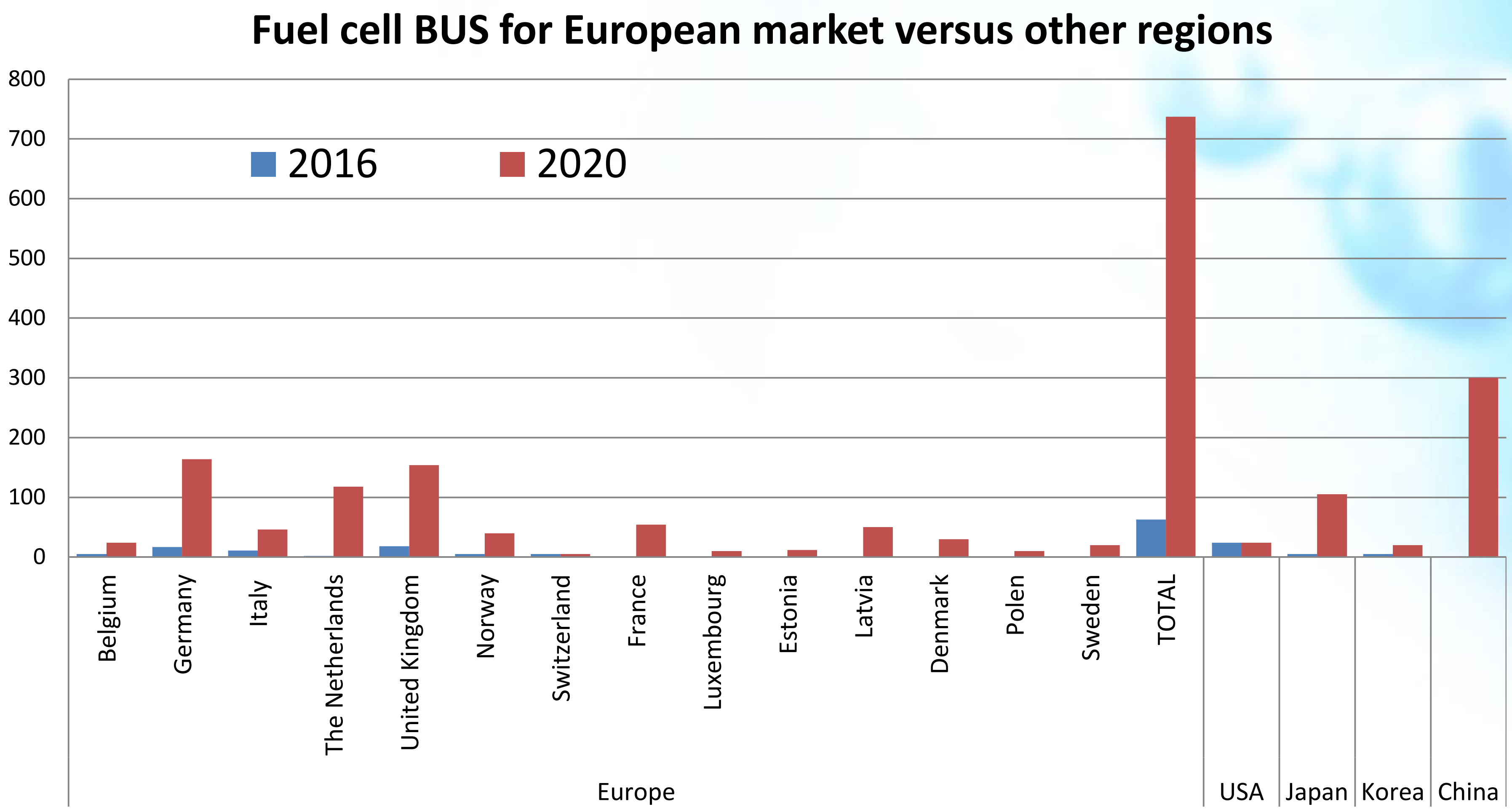
Secured commitments for roll-out and large scale demos

Buses produced for European market per country



7 Member states have H2 busses, total >60 busses. UK leading!

Buses: Status in 2016 and prediction for 2020



From 7 to 14 different member states to have H2 buses
>700 buses in 2020 = worldleader

MHVs and APUs

MHVs

Status:

- 20.7M€ in 4 projects
- Two large demonstration sites
- First 100% greenfield FC site
- 113 units deployed
- Generating the business case

Results:

- >22,000 refuellings
- >5,500kg delivered
- >112,000hrs of FC operation
- >90% reliability

APUs

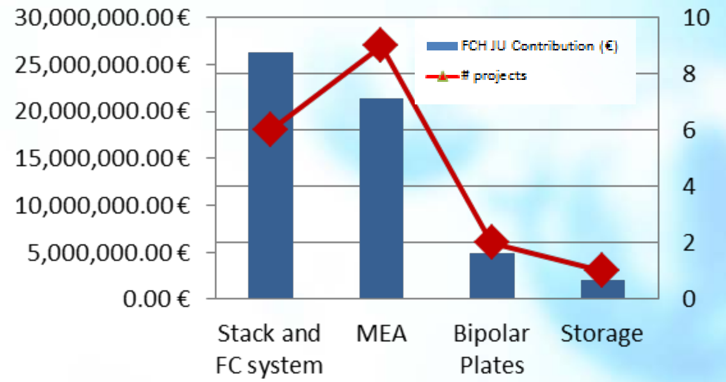
Status:

- 21.8M€ in 7 projects
- Variety of APU applications: trucks, maritime, recreational, air
- Prototypes evaluated
- Technical challenges remain
- Business models to be proven
- Each application deals with different technical/business challenges

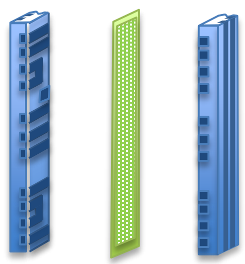
R&D

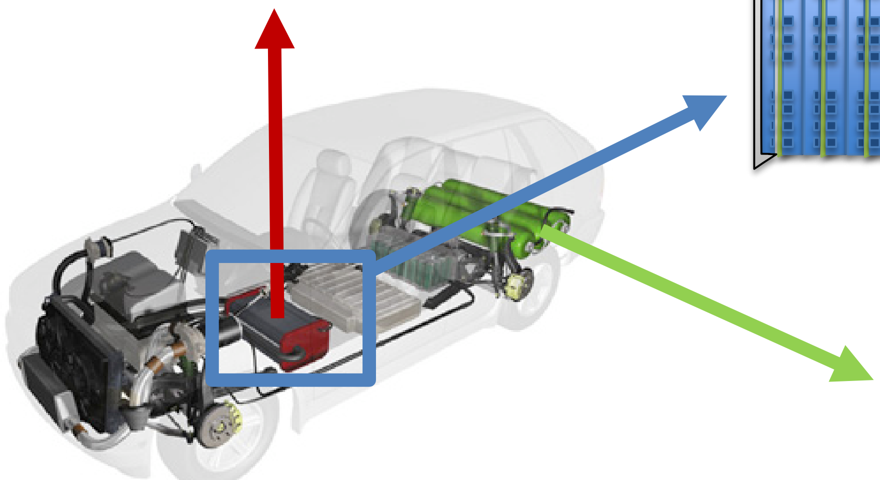
FC Components (26M€/11 projects)

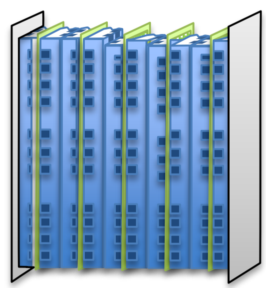
- Membranes: +25% in performance
- GDL: +12% in performance & 7% cost savings
- BPP: Improved corrosion coatings; stable >6,000hrs
- Platinum usage: reduced by 50%



54.6M€ for 18 projects







FC Stacks (26M€/6 projects)

- Good performance in gen 1 (2.8kW/l)
- Expect SoA 3.6kW/l in gen 2
- Cost: <50€/kW @30,000units/yr

H2 Storage (2M€/1 project)

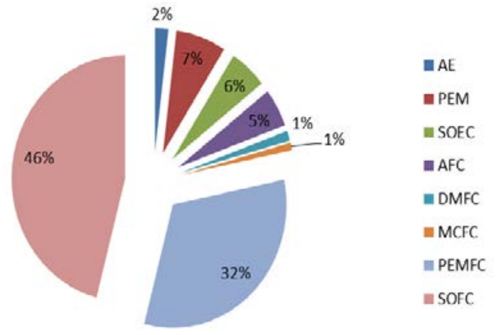
- +22% gravimetric density
- -55% cost savings

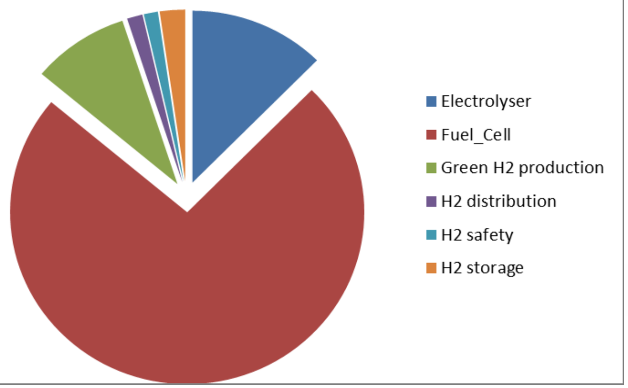
FCH JU Project learnings: Status vs. Targets

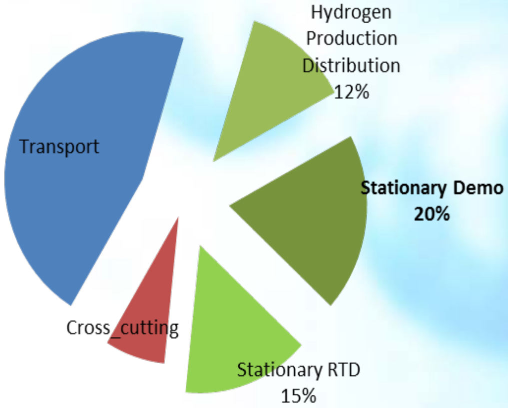
Application	Parameter	Target (2017)	Status
Cars	Cost	70k€	● Available commercially in this price range
	Availability	98%	● >98% achieved
	System lifetime	5000h	Not enough data
Buses	Cost	700k€	● 650k€ being offered
	Fuel consumption	8.51kg/100km	● 8.0-13.2kg/100km
	Availability	90%	● over project lifetime; ● reached in certain locations over last year
Hydrogen Storage	Volumetric capacity	0.022kg/l	● 0.019 kg/l
	Gravimetric capacity	4%	● 5%
	Cost	800€/kg H2	● ca. 2,000-2,500€/kg H2
Hydrogen supply	Price at pump	10-15€/kg (MAIP 2015)	● 10€/kg found at several stations
	HRS cost	1.0-2.5M€	● met and exceeded in some cases (CAPEX, ex. works)

ENERGY portfolio

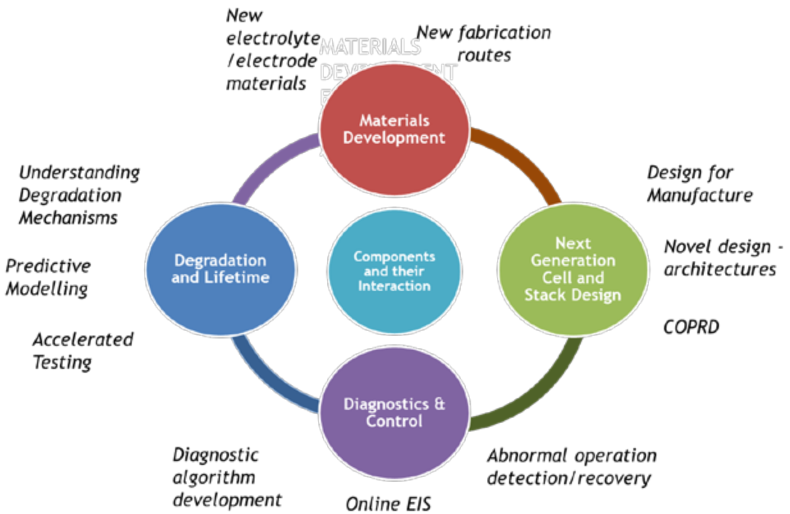
106 projects under Energy pillar, for more than 326 mill €

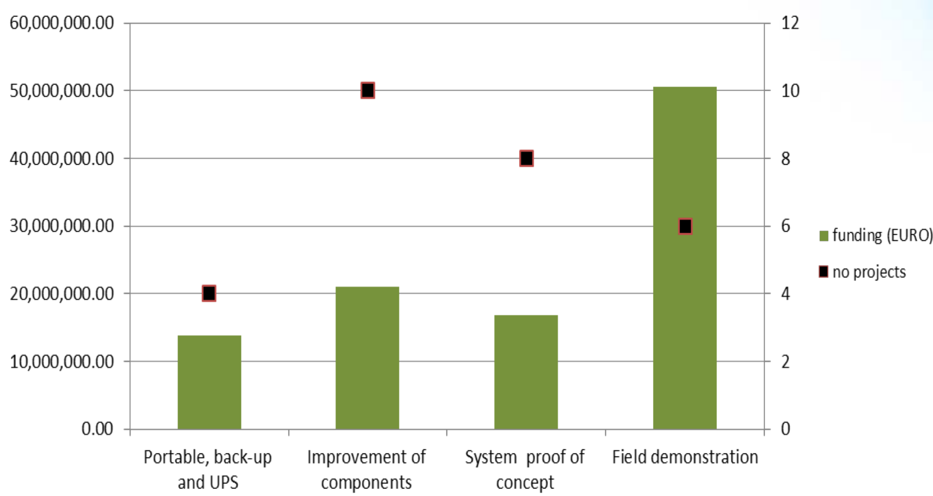






Technology neutral approach, however most support to Solide Oxide and PEM for both fuel cells and electrolyser applications





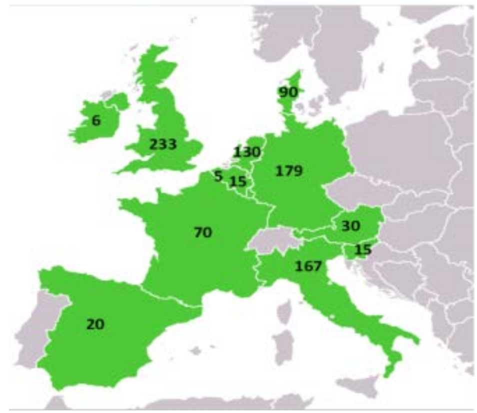
Heat and Power solutions

Higher chance to reach 2030 Energy Goals with Stationary Fuel Cells !

SOFT-PACT

- 65 units Solid Oxide FC mCHP
- 40% $\eta_{electric}$ 79% η_{total}
- 25% cost reduction
- FC system life > 10,000 hours

e·on Ceramic Fuel Cells ideal HOMA



ene.field

- 1,000 units (10 manufacturers) in 11 EU member states
- 30-150 units from each manufacturer

Dachs InnoGen	Cerapower FC10 Logapower FC10	PEMmCHP GS	Elcore 2400	Galileo 1000 N	Inhouse 5000+	ENGEN 2500	BLUEGEN	Vaillant G5+	Vitovalor
LT PEM	SOFC	LT PEM	HT PEM	SOFC	LT PEM	SOFC	SOFC	SOFC	PEM
700W	700W	2kW	300W	1kW	5kW	2.5kW	2kW	1kW	700W
Natural Gas	Natural Gas, Gas	Natural Gas + Biogas	Natural Gas	Natural gas+ Biogas	Natural gas + Biogas + H2	Natural Gas	Natural Gas	Natural Gas	Natural Gas
Floor	Floor	Floor	Wall	Floor	Floor	Floor	Floor	Wall	Floor
SenerTec	Bosch Thermotechnik	Dantherm Power	Elcore	Hexis	RBZ	Solid power	Solid power	Vaillant	Viessmann

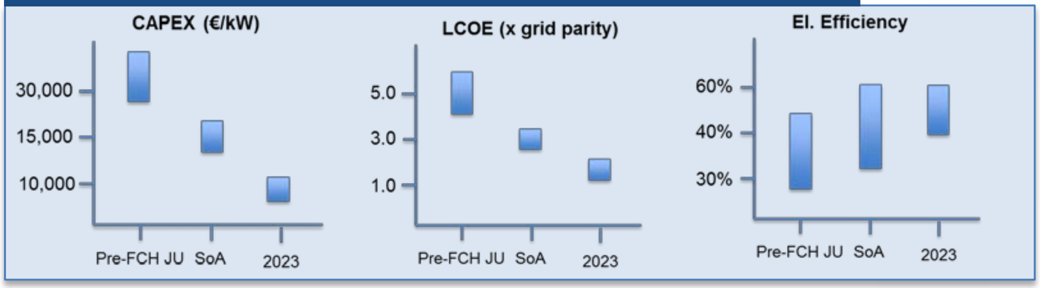
H2 Power-UP

- 240kW
- 61% $\eta_{electric}$
- FC system life > 13,500 hours

AFC energy AIR PRODUCTS innomech Automation Solutions ZBT PAUL SCHERRER INSTITUT PSI FAST EHA EUROPEAN HYDROGEN ASSOCIATION

Accomplishments
(examples of projects achievements)

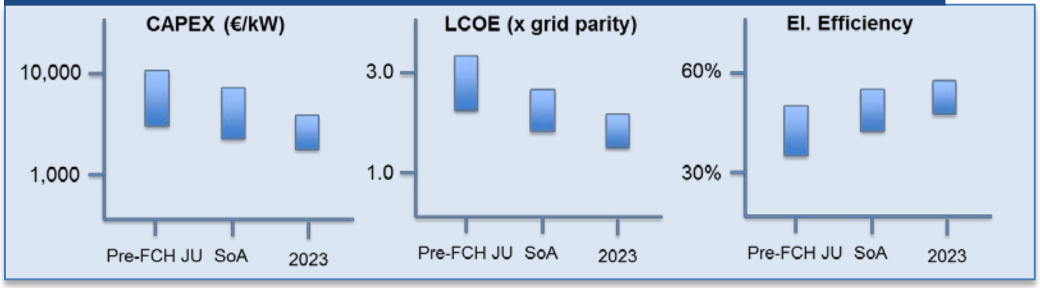
Residential Market Segment (< 5 kW)



ene.field project: more than 500 units installed in 10 countries of Europe, reliabilities confirmed, very good customer satisfaction (70% positive feedback),

SOFT-PACT project: 65 fuel cell systems, electrical efficiency higher than 42 % over lifetime (total efficency higher than 78%), 25% cost reduction

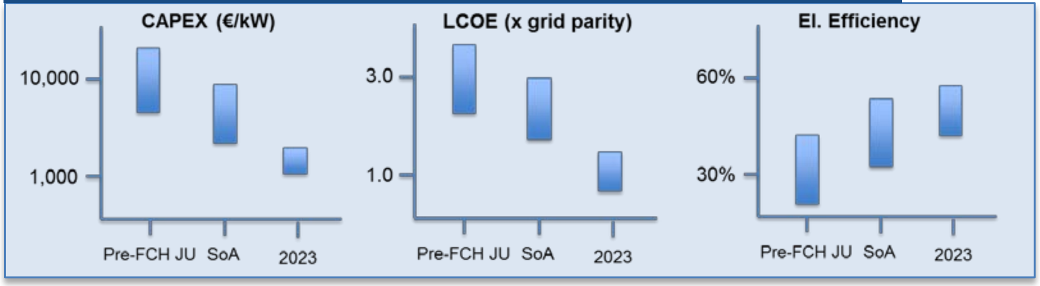
Commercial Market Segment (5-400 kW)



SOFCOM project: proof-of-concept poly-generation SOFC systems fed by biogenous primary fuels (biogas and bio-syngas, locally produced), modular concept, cost driver identified → next step: upscaling to hundreds kW size (DEMOSOFC project)

POWER-UP project: first module of 40kW (out of 240 kW) in the field, 61% electrical efficiency

Industrial Market Segment (0.3-XX MW)



ClearGenDemo project: 1 MW PEM to be installed near Bordeaux, FR on by-product H2 from clori-alkali plant

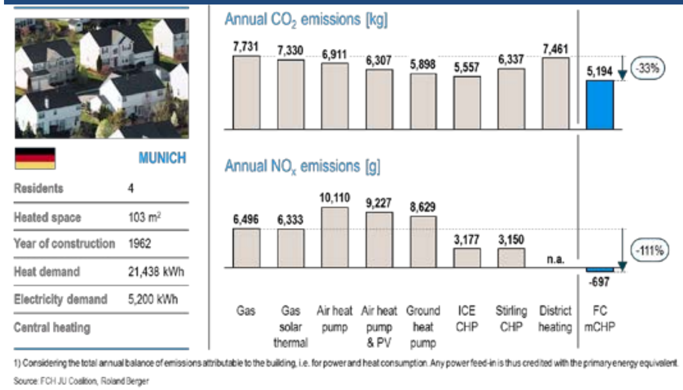
DEMCOPEM-2MW project: 2 MW PEM (European technology) to be demonstrated in China

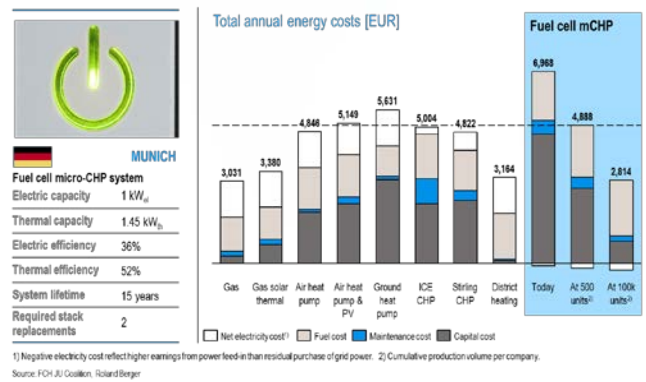
Sources: MAWP, Roland Berger Study, IBZ/Callux

Developing targets/Studies

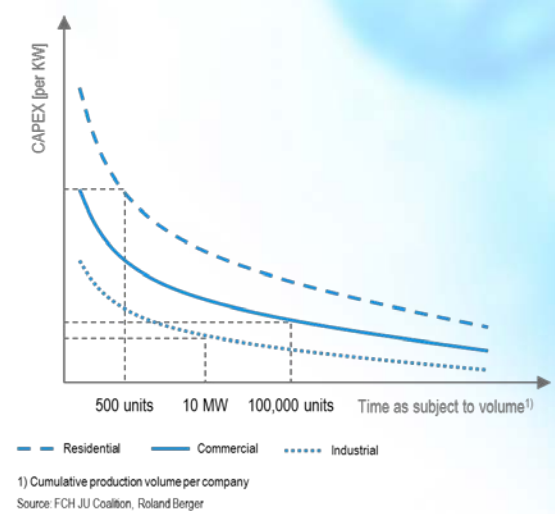
Roland Berger Study: ***Advancing Europe's energy systems: Stationary fuel cells in distributed generation***

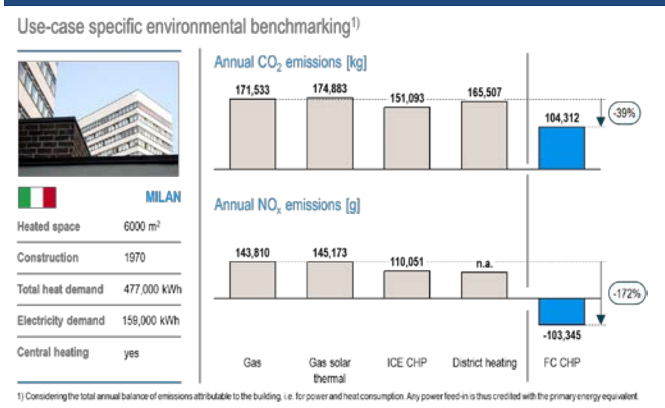
- Industry coalition composed of more than 30 stakeholders – Results reflect common understanding
- The most comprehensive assessment of the commercialisation potential of stationary fuel cells in Europe (4 focus markets, 6 generic fuel cells, 35 years time horizon, 45 different use cases, >30 benchmark technologies, >3 energy scenarios, >34,000 resulting data points)

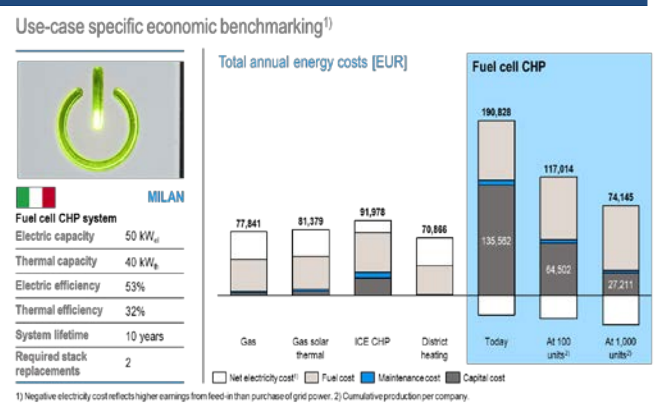




Today FC can reduce CO_2 emissions by more than 30%, while No_x emissions can be eliminated entirely; however, to become economically competitive, capital costs must be reduced substantially by increasing production volumes





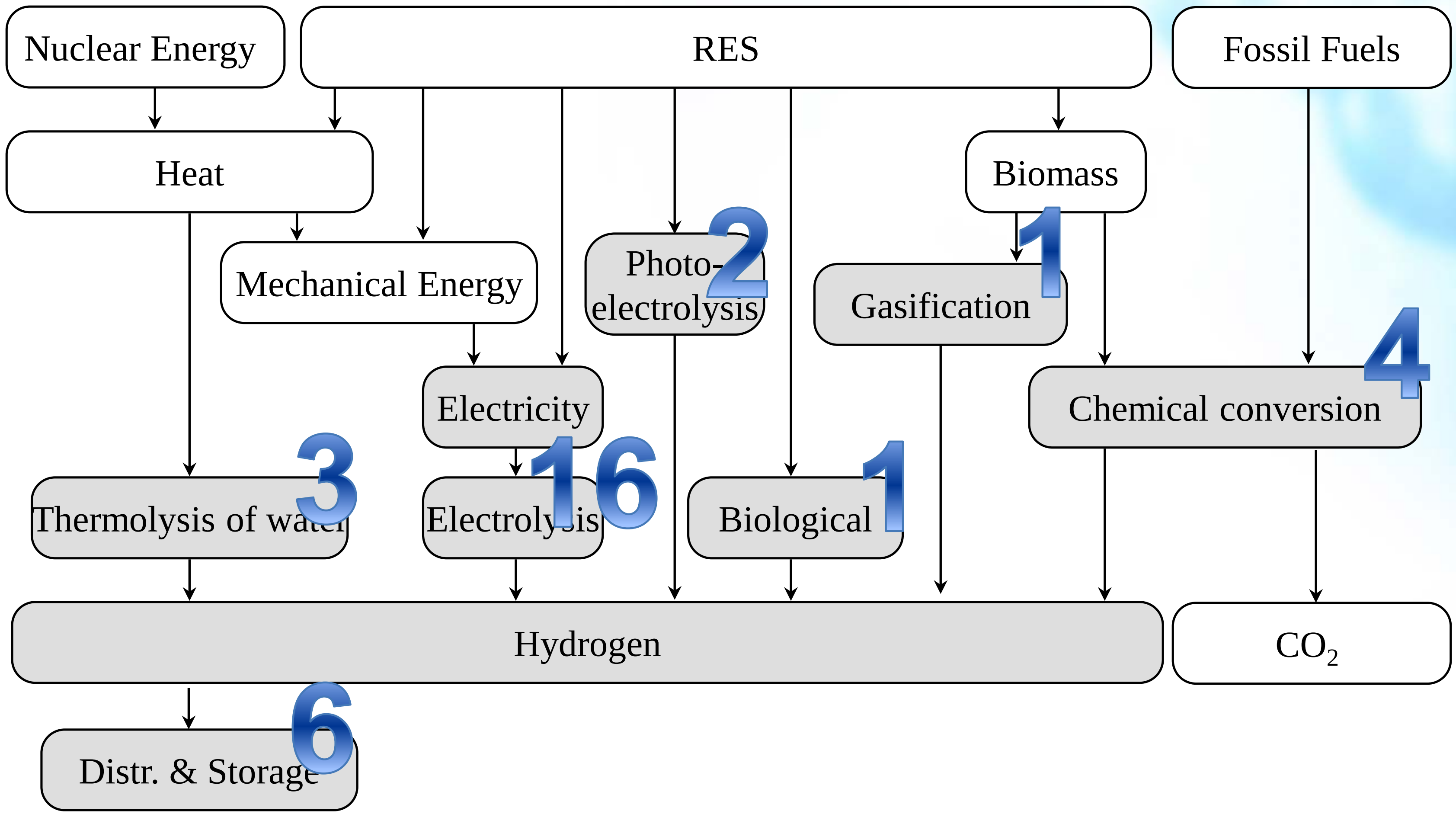


Industry sees ambitious potential (larger volumes allow for automation and bundled sourcing strategies, standardisation must increase within and across technology lines)

Industry is fully committed to decreasing cost with sufficient installation volumes !

H_2 Production – Present Technical Coverage

95% of FCH JU support on H_2 production goes to renewable pathways

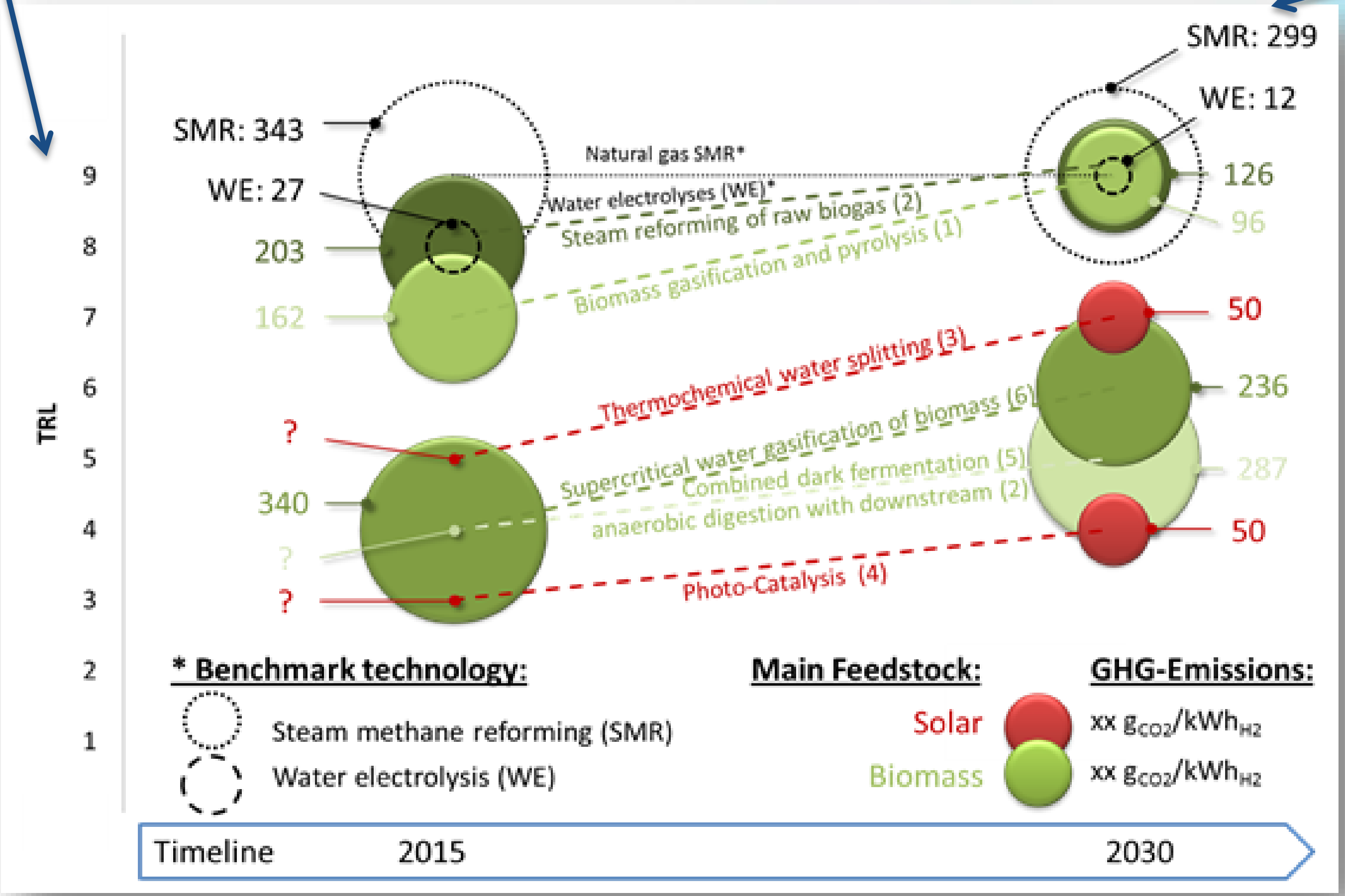


H_2 Production – Strategy

Green Hydrogen Study identified 6 most promising pathways besides RES+WE

TRL

g_{CO2}/kWh_{H2}



Pathways

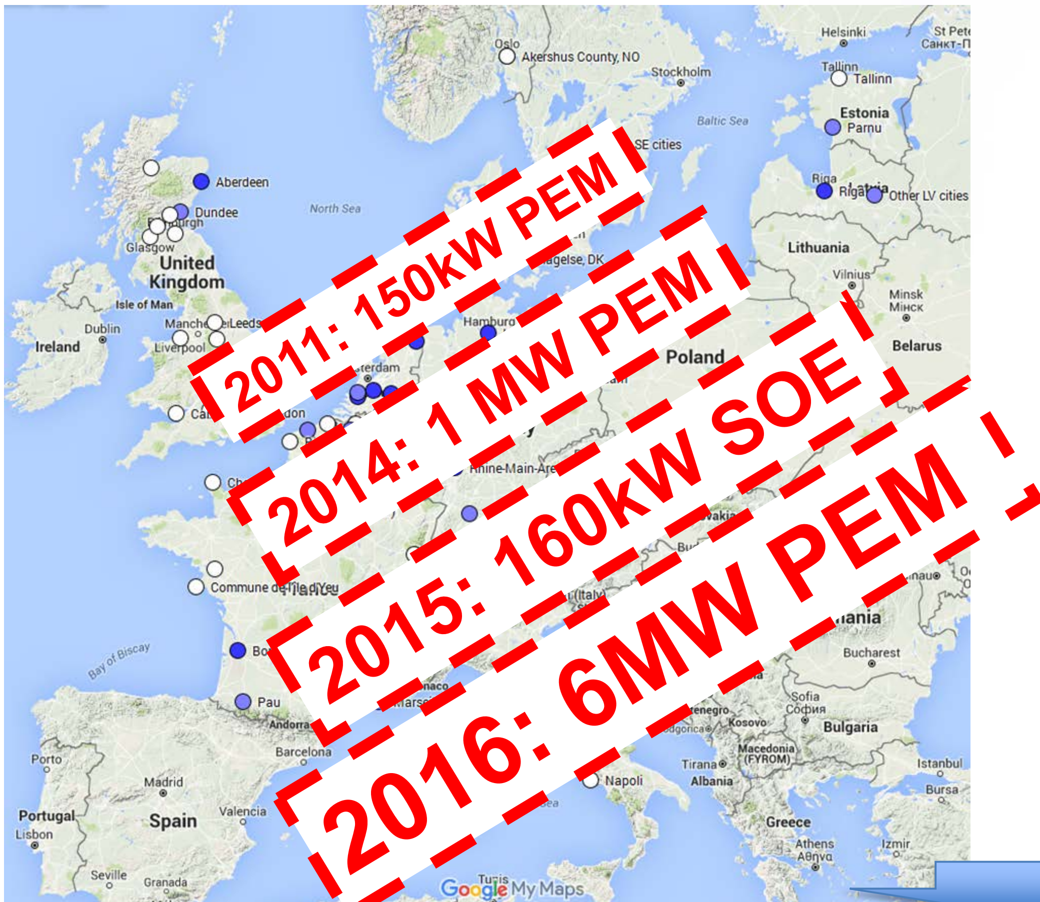
(2) Raw biogas reforming
(1) Biomass gasification
(3) Thermo-chemical water splitting
(6) Supercritical H2O gasification
(5+2) Fermentation
(4) PEC

Criteria

- TRL
- Feedstock
- GHG-emissions

P2H & H2X - from 150kW to 6MW

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



DON QUICHOTE
hydrogen out of wind turbine energy

Hybalance

GrInHy
Green Industrial Hydrogen

Transport, Steel industry, Refineries, Chemical industry

P2H & H2X - Long term prospects

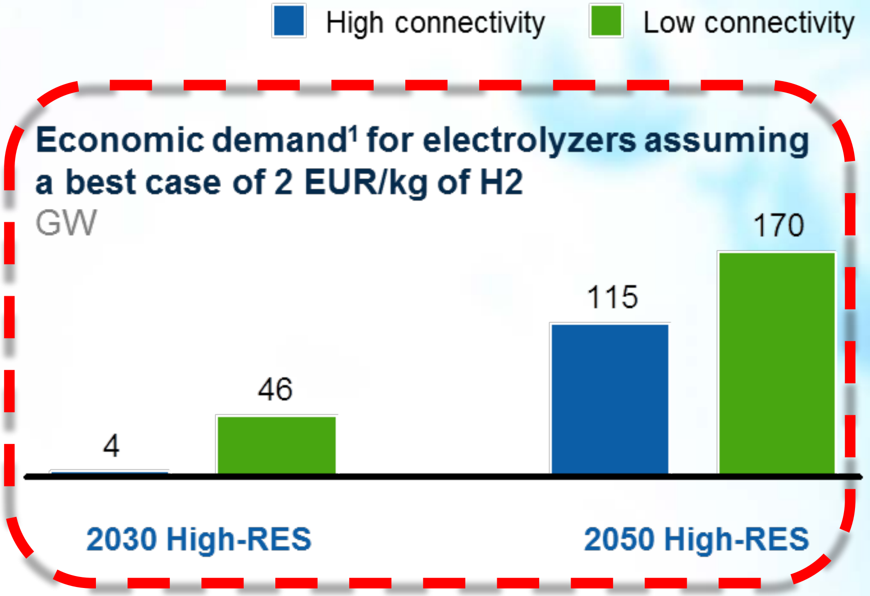
Germany archetype

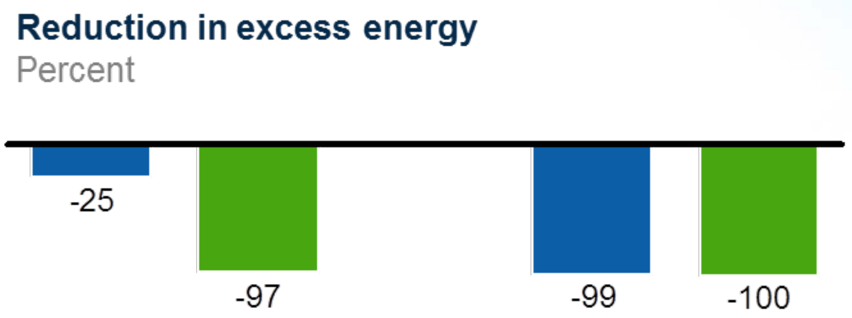
Non-hydrogen P2P and heat storage will only be able to absorb a small part of the excess energy generated, resulting in the necessity of curtailment – from societal point of view, such electricity could be used at close to zero cost

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





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 Achievements

Hydrogen Packard car (1927) - Woikoski

Hybrid FC Buses

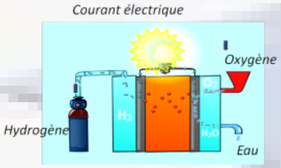
FCEV

FC in commercial planes

Marine & aerospace

Forklifts

FCEV RE



1995 | 2000 | 2005 | 2010 | 2015 | 2020

Backup power

Large scale stationary applications

Energy storage

CHP Systems

Portable applications

The scope of applications is widening with time

The FCH JU is launching an initiative to engage Regions/Cities and Industry to develop FCH Markets

- The FCH JU is launching a large, ambitious study to develop markets, enable solutions and coordinate funding
- We need active collaborations with interested regions/cities in which they:
  - Define product needs
  - Provide input to define business cases for these products
  - Engage directly with a broad spectrum of industry players who can supply the products
  - Help coordinate and maximise funding/financing sources to implement solutions
- We offer:
  - Our commitment to work with you
  - Cover 100% of the costs of external support (consultants)
- We request:
  - Your commitment to provide input and engage actively in the study and beyond in the rollout
  - A vision to include hydrogen-based technologies in the portfolio of solutions to be supported in your community

- As a first step, we are asking interested communities to sign a Memorandum of Understanding (MoU)
  - There will be a symbolic signing ceremony held on November 23 at the FCH JU annual Stakeholder Forum in Brussels

Thank you for your attention !

Further info :

- **FCH2 JU : http://www.fch.europa.eu/**
- **HYDROGEN EUROPE : www.hydrogeneurope.eu**
- **N.ERGHY : http://www.nerghy.eu**