Fuel Cells and Hydrogen Joint Undertaking

Main achievements and development perspectives in the frame of Horizon 2020

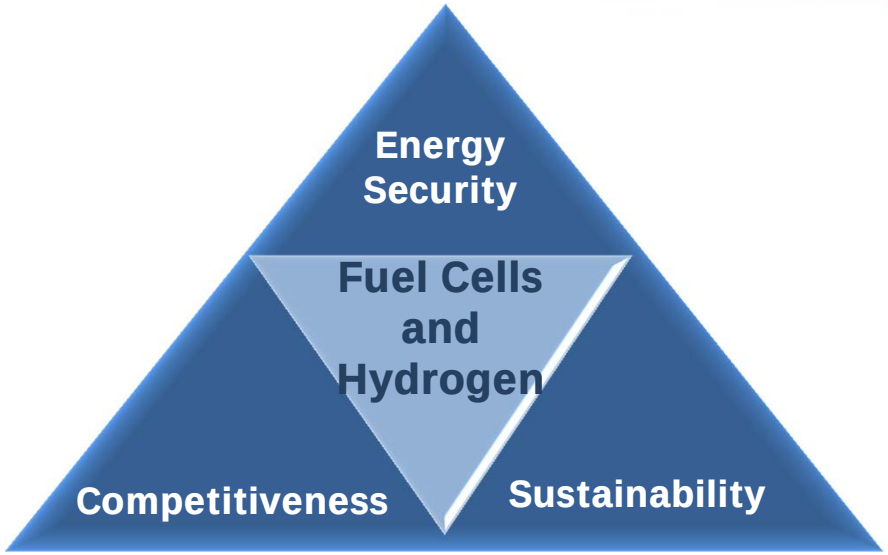
Bert De Colvenaer, Executive Director
Prague, 4 April 2014

Fuel Cells and Hydrogen

technologies can contribute to :

Sustainability

- H_2 is a clean carrier of energy
- Transport and stationary applications, generate electricity and heat
- Storage of renewable energy sources
- Reduction of CO_2 emissions



Energy Security

- Increase independence from unstable outside regions

Competitiveness

- research excellence leading to industry innovation and growth

The FCH JTI in the SET plan

EU targets :

20 % increase in renewables
20 % increase in efficiency
20 % decrease in emissions

Fuel Cell and Hydrogen Joint Undertaking

- FCH JU : community body
- Budget : 940 M €
- FCH JU Programme Office

450 = RTD : 315 ENER : 120 MOVE : 15

Public-Private Partnership

Fuel Cells & Hydrogen Joint Undertaking

Industry Grouping
Over 60 members

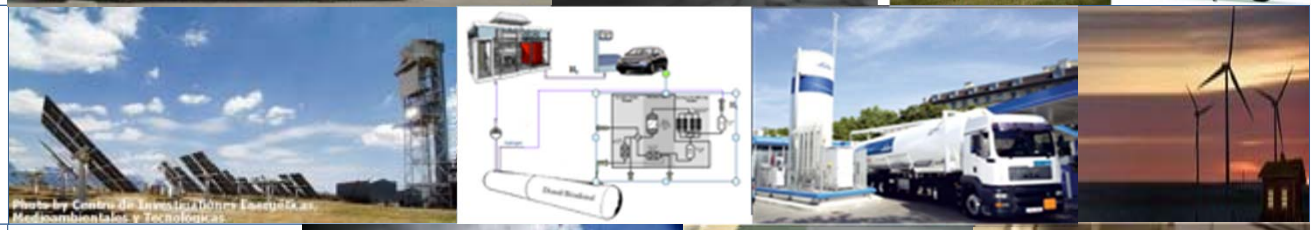
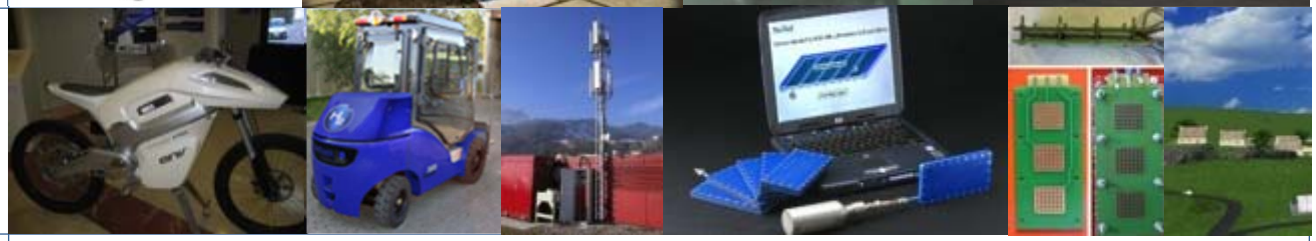
European Union
represented by the European Commission

Research Grouping
Over 60 members

Both the Industry Grouping and the Research Grouping are non-profit organisations with open membership

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

FCH JU portfolio : 127 (+21) projects

TRANSPORTATION & REFUELLING INFRASTRUCTURE	25 projects 8 demo 14 research 3 CSA	
HYDROGEN PRODUCTION & DISTRIBUTION	28 projects 4 demo 24 research	
STATIONARY POWER GENERATION & CHP	36 projects 9 demo 26 research 1 CSA	
EARLY MARKETS	21 project 13 demo 8 research	
CROSS - CUTTING	17 project	RCS, Safety, Education, PNR, …

Clean Hydrogen in European Cities

CHIC

Objectives

- Operation of **26 fuel cell buses** in 5 cities in Europe (**Aargau, Bolzano, London, Milano, Oslo**) and the respective infrastructure for a period of 5 years
- Transfer of learning from cities with experience in operating buses and infrastructure (Hamburg, Berlin, Cologne, Whistler; ~ 30 fuel cell buses) to the 5 cities
- Assessment of the technology with focus on environment, economy and society
- Dissemination to the general public and to cities preparing for the technology in the next step
- 2 filling stations per city
- Demonstration phase 2010-2016
- **Cost 82 M€, 26 M€ funding**

Main Partners

25 partners from cities, consultants and industry:

ATM, BC Transit, BVG, hyCologne, hySOLUTIONS, infraserv höchst, London Buses, Postauto, Ruter, STA, element energy, Euro Keys, HyER, PE International, PLANET, Spilett, University of Stuttgart, Air Liquide, Air Products, Daimler, Linde, Shell, Total, Vattenfall, Wrightbus

HYTEC

The HyTEC project will expand the existing European network of hydrogen demonstration sites into two of the most promising early markets for hydrogen and fuel cells, Denmark (Copenhagen) and the UK (London)

30 new hydrogen vehicles (taxis, passenger cars and scooters

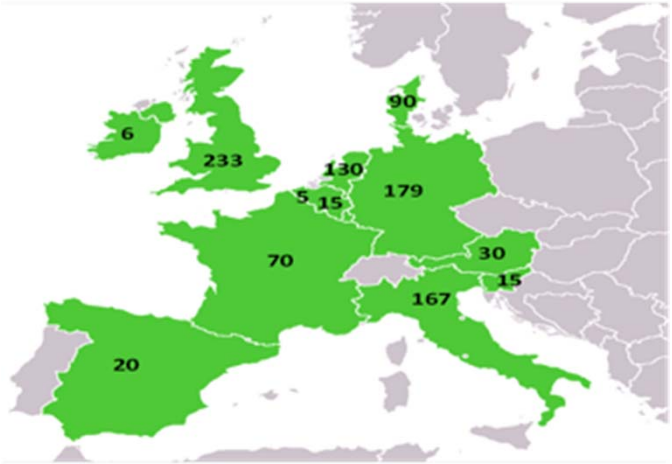
16 partners from 5 countries

2 refuelling stations :

- London
- Copenhagen

Ene.field project

- Demonstration of up to 1000 residential fuel cell µCHP (1-5 kW) units from 9 manufacturers in 12 EU member states
- Establish supply chains, validate new routes to market, stimulate cost reduction for final commercial deployment



FCH JU Target	State of the Art	Expected performance
Electrical efficiency (min) 35%	30 %	35 % – 50 %
Overall efficiency > 85% (LHV)	70 % – 85 %	Up to 90 %
Lifetime : of 8 - 10 years	3 years	Up to 8 years

HyLIFT DEMO

HyLIFT
Clean Efficient Power
For Materials Handling
www.hylift.eu

European demonstration of fuel cell powered materials handling vehicles including infrastructure

Objectives

- demonstration of 30 fuel cell forklifts
- demonstration of hydrogen refuelling infrastructure
- performance of accelerated durability tests
- preparation of market deployment from 2013 on

ludwig bölkow systemtechnik
DanTruck
DTU
EHA EUROPEAN HYDROGEN ASSOCIATION
FAST Federazione delle associazioni scientifiche e tecniche fondata nel 1897
HyRaMP
H2 Logic
JRC EUROPEAN COMMISSION
ie Institute for Energy
Linde
SINTEF
TÜV

PURE

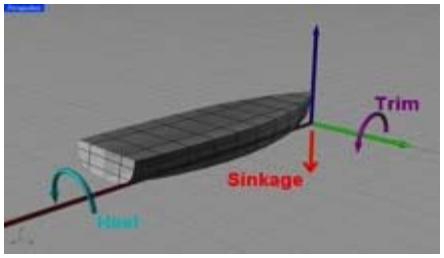
APU for recreational yachts

Objectives :

- Electrical output between 50 W and 500 W_e
- Demonstrate electrical efficiency of 30%+
- 1,000 h lifetime with 100 start-stop cycles
- Size < 50 l/kW, weight < 35 kg/kW
- Demonstrating a cost < 5,000 €/kW

Challenges :

- Salty environment (air)
- Sea movements



Damen FCS 1605

FCH JU Main Achievements

- **Transport sector :**
  - 49 buses, 37 passenger cars, 95 mini cars
  - 13 new refuelling stations
  - FC Bus H_2 consumption halved
  - H_2 cost < 10€/kg
- **Stationary sector :**
  - 1000 domestic Combined Heat & Power generators
  - Cost - 50%, efficiency 90%, lifetime up to 8 years
- **Early markets sector :**
  - 9 fork lifts, 1 tow truck
  - 19 back up power units

- **For the European FCH community :**
  - Strong, visible and coherent
  - Consensus strategy (MAIP/AIP)
  - Pre-competitive collaboration
  - 430 participants in 127 projects
  - SME participation 23%

Fuel Cell and Hydrogen Community

+10%

average increase of annual **turnover** (on a 2012 total of €0.5 billion)

+8%

average increase of **R&D expenditures** (2012 total €1.8 billion)

+6%

average increase of **market deployment expenditures** (2012 total €0.6 billon)

+6%

growth in **jobs** per year (~4,000 FTE in 2012) while average EU job market has contracted

+16%

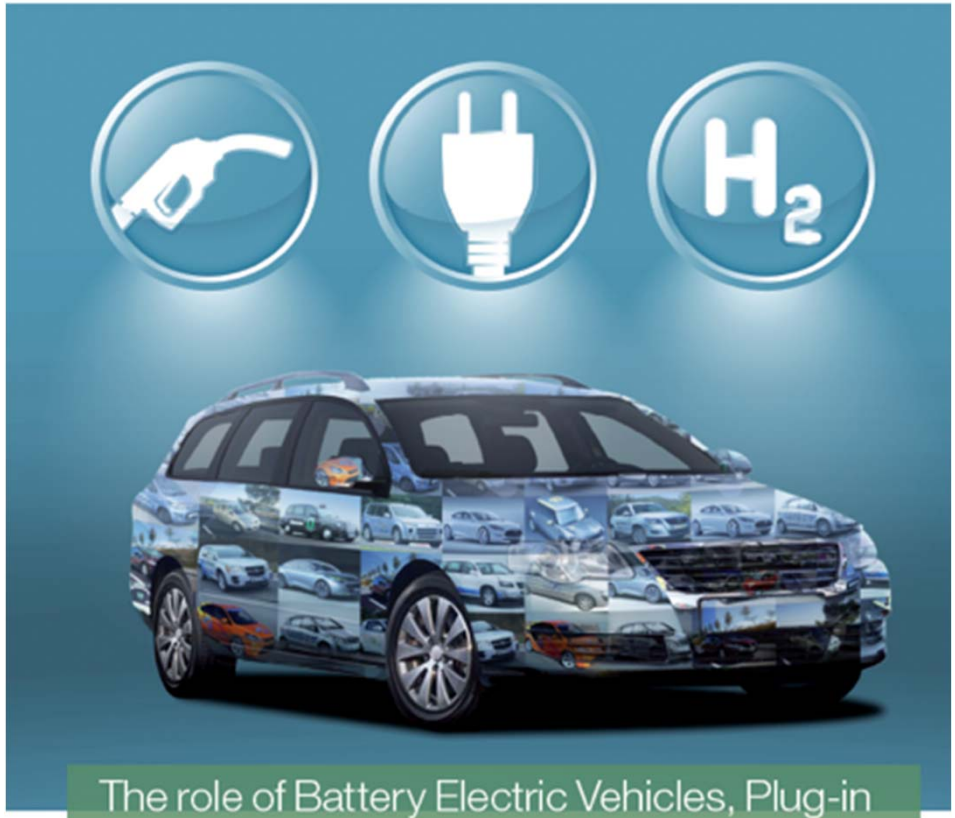
annual increase in **patents** granted in the EU to European companies (average 1.5% for all European industries)

Source: Trends in investments, jobs and turnover in the Fuel cells and Hydrogen sector, 2012

A portfolio of power-trains

for Europe

A portfolio of power-trains for Europe:
a fact-based analysis



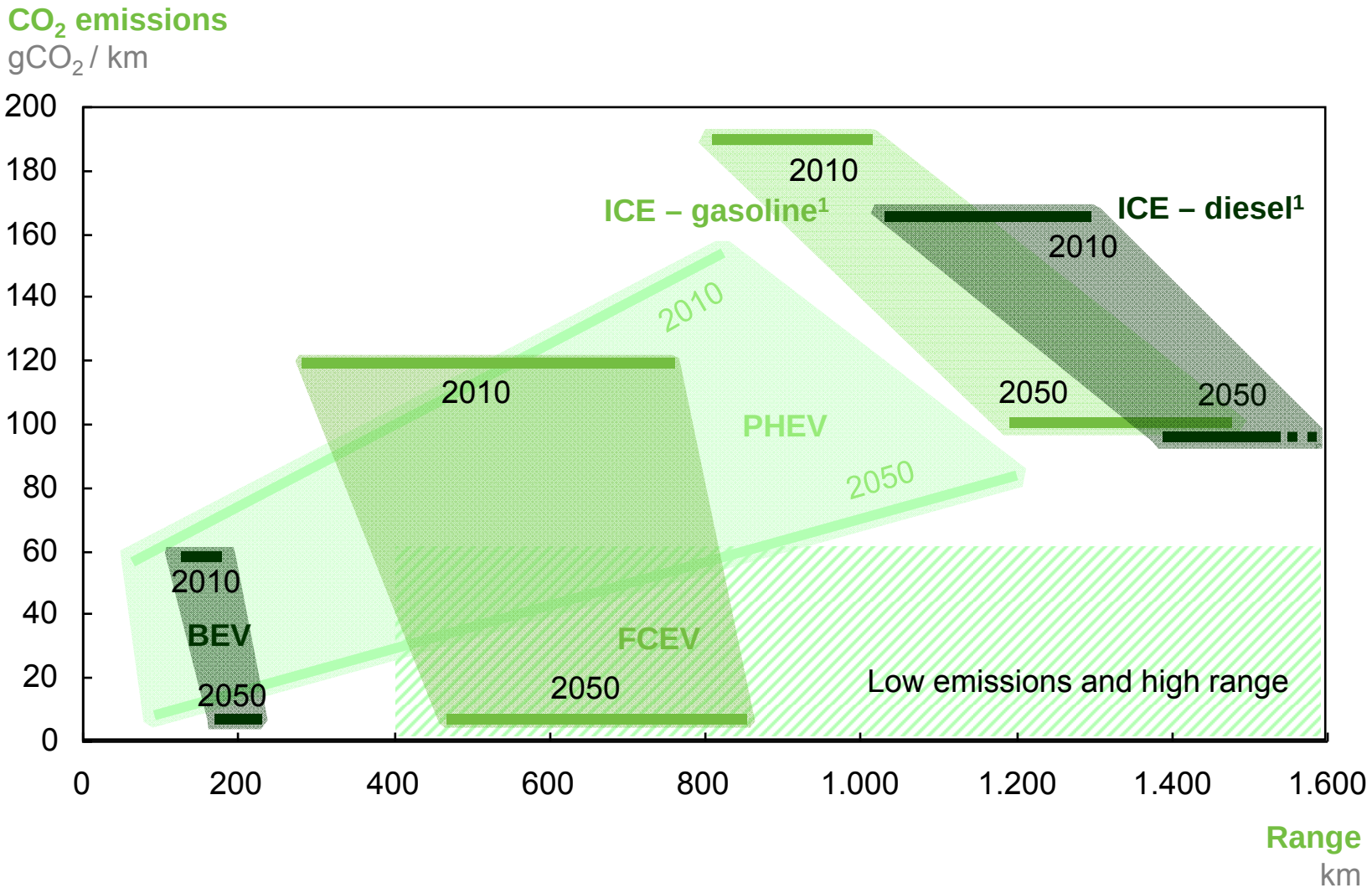
Industry participants	
Car OEMs	DAIMLER, HONDA, HYUNDAI, KIA MOTORS, NISSAN, Ford, RENAULT, VW, BMW, TOYOTA
Oil and gas	Eni, OMV, Shell, TOTAL, galp energia
Utilities	EnBW, VATTENFALL
Industrial gas companies	AIR PRODUCTS, AIR LIQUIDE, Linde
Equipment OEMs	INTELLIGENT ENERGY, Powertech
Wind	NORDEX
Electrolyser companies	HYDROGENICS, PROTON ENERGY SYSTEMS, ELT Elektrolyse Technik, Hydrogen Technology
NGOs, GOs	European Climate Foundation, NOW, New Energy World

Publication: 8 November 2010

Available on **http://fch-ju.eu**

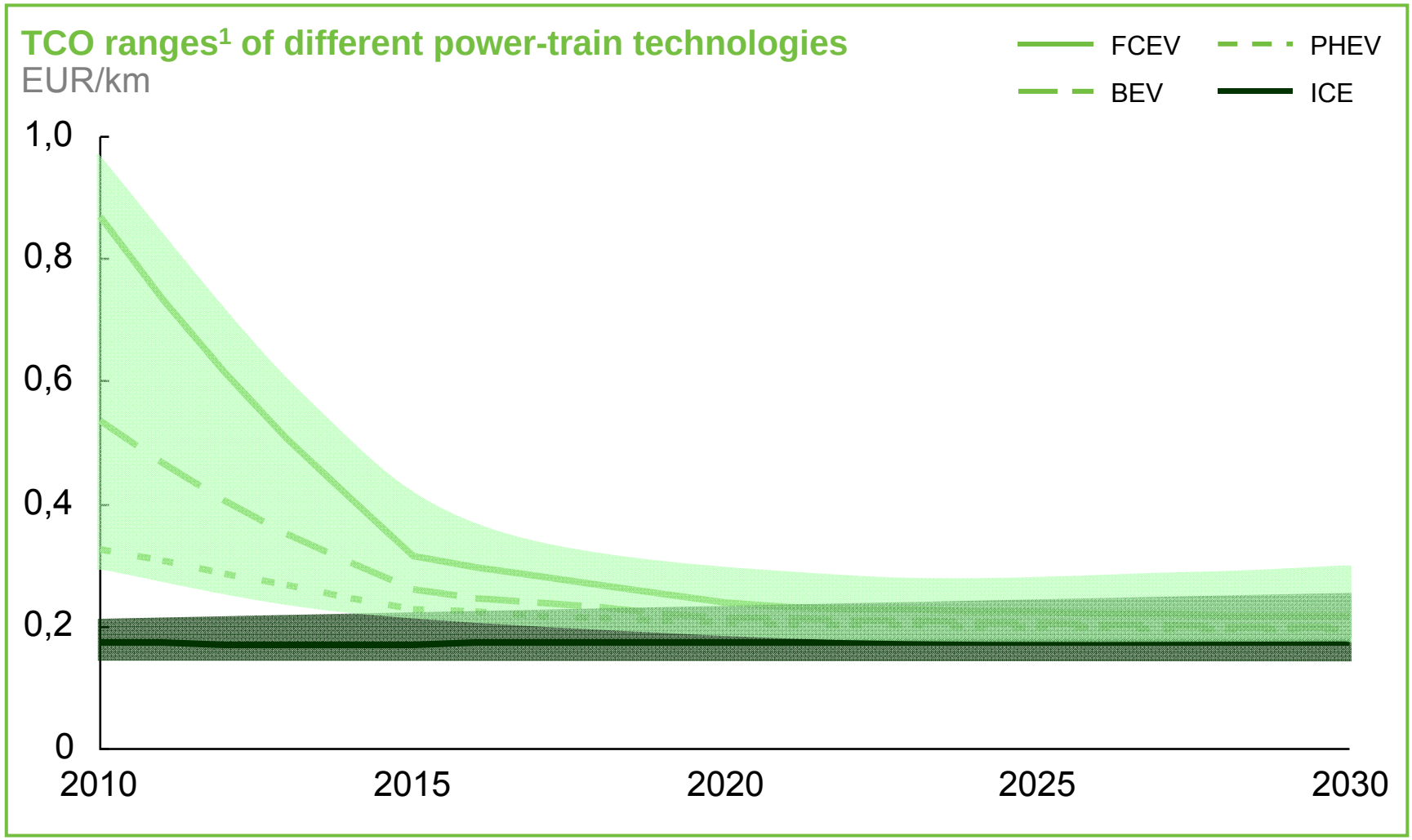
Battery and fuel cell vehicles can achieve low emissions

C/D SEGMENT



After 2025, costs of all power trains converge

C/D SEGMENT



H2 Mobility in Germany

AIR LIQUIDE DAIMLER THE LINDE GROUP

NOW OMV TOTAL

H_2 Mobility initiative

Leading industrial companies agree on an action plan for the construction of a hydrogen refuelling network in Germany

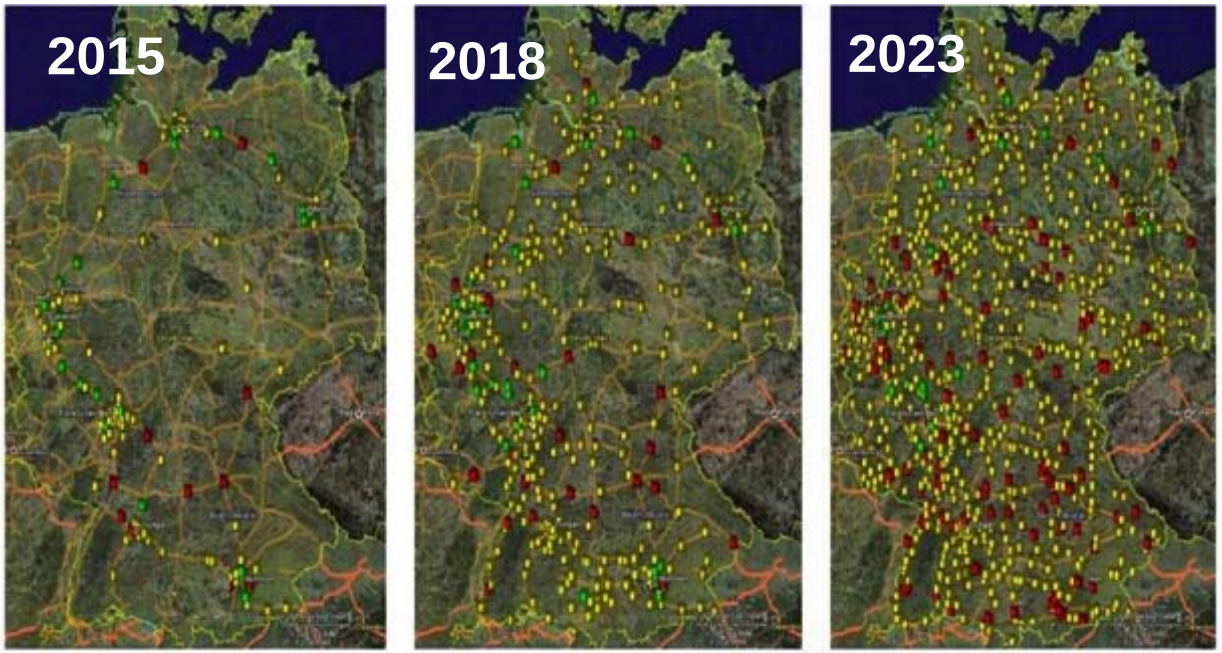
- **Hydrogen refuelling network to grow to about 400 filling stations by 2023**
- **Precondition for the market success of fuel cell powered electric vehicles initiated**
- **Overall investment of around €350 million planned**
- **Development plan represents the benchmark at international level**

Stuttgart, 30 September 2013 – The six partners in the "H_2 Mobility" initiative - Air Liquide, Daimler, Linde, OMV, Shell and Total – have set up upon a specific action plan for the construction of a nationwide hydrogen refuelling network for fuel cell powered electric vehicles. By the year 2023 the current network of 15 filling stations in Germany's public hydrogen infrastructure shall be expanded to about 400 H_2 filling stations. As a first step the deployment of 100 hydrogen stations in Germany over the next 4 years is intended. This would ensure a need-related supply for fuel cell powered electric vehicles to be introduced into the market in the next years. An agreement in principle has been signed by representatives of all the partners involved.

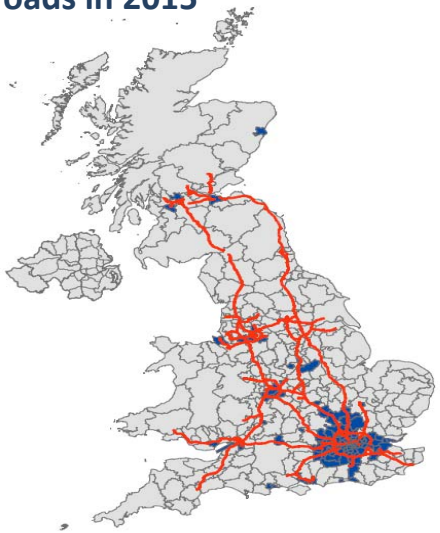
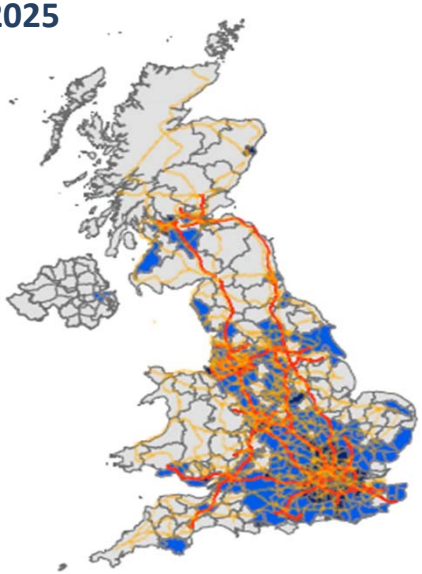
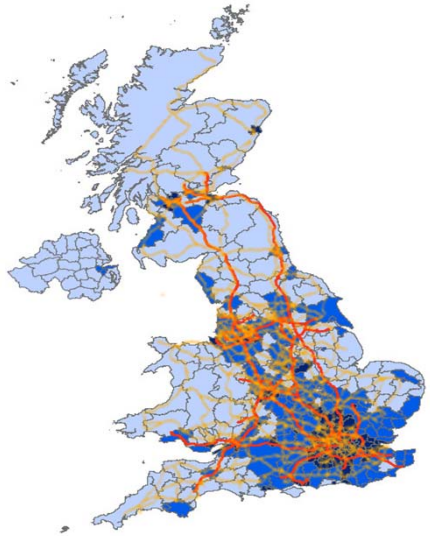
In addition to plans for a nationwide filling station network, the agreement includes the principles for the procurement and distribution of the necessary hydrogen and a request for support to the German Federal Government. Following the foundation of a joint venture (subject to necessary regulatory approvals), gradual expansion of the national filling station network will commence next year. This means that an H_2 supply suitable for everyday use shall be created not only for densely populated areas and main traffic arteries, but also for rural areas. The objective is to offer an H_2 station at least every 90 kilometres of motorway between densely populated areas. According to this plan in metropolitan areas, drivers of fuel cell powered vehicles will have at least 10 hydrogen refuelling stations available each from 2023. Thus zero tailpipe emission H_2-mobility is becoming increasingly attractive for customers. The "H_2 Mobility" initiative expects that a total investment of around €350 million will be required for this future-oriented infrastructure project.

The launch of fuel cell powered production vehicles on the German market has been announced by first manufacturers for 2015. In addition to attractive procurement and

- Initiative gathering the German government and 6 major industrial companies
- 400 hydrogen stations by 2023
- Investment of € 350 million
- Benchmark at international level



H_2 Mobility in UK

	Seeding of Tier 1 regions[1] – major cities and connecting roads in 2015	**Coverage extended to Tier 2 regions and all major roads <2025**	**Full population coverage by 2030**
			
# of HRS	~65	~330	~1,150
	Initial seeding in **major population centres**	Extend coverage to enable close-to-home refuelling to **50% of the population** and long distance **travel**	Extend close-to-home refuelling to the **whole of the UK,** including less populated regions

1 Defined as most attractive regions for FCEV deployment based on vehicle density and per capita income

Strong International Momentum

Current state of initiatives

H2Mobility Germany:
Recent announcement made - 350M€ for 400HRS by 2023

H2 Mobilité: Government and **industry** partners building common strategy

UK H2Mobility: Government and 11 companies developed common strategy

Business case in development

Danish Government has announced an Energy Plan 2020 that includes a **range of initiatives for** hydrogen infra-structure and FCEVs, amongst which are significant incentives

Government and **13 compa-nies** announced program for FCEV **mass production** and **100 HRS** by 2015 **connecting** 4 metropolitan areas

Government announced program to finance and deploy **100,000 FCEV** and **170 HRS** by 2020

Demo initiatives in California and East Coast H_2 Highway; partially funded by DoE.

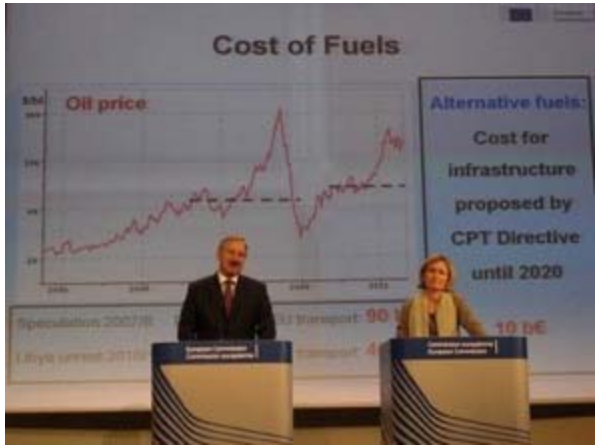
New **"Clean Fuels Outlet" regulation** in **California** requiring deployment of HRS (to avoid penalties).

California Fuel Cell Partnership announced roadmap to **rollout 68 stations by 2015**

H2USA started

Clean Power for Transport Package

- Proposal for Directive on the deployment of alternative fuels infrastructure
  - Build a competitive and resource efficient transport system.
  - Establish long term fuel strategy.
  - Remove technical and regulatory barriers.
  - Facilitate a single market for alternative fuels vehicles and vessels.

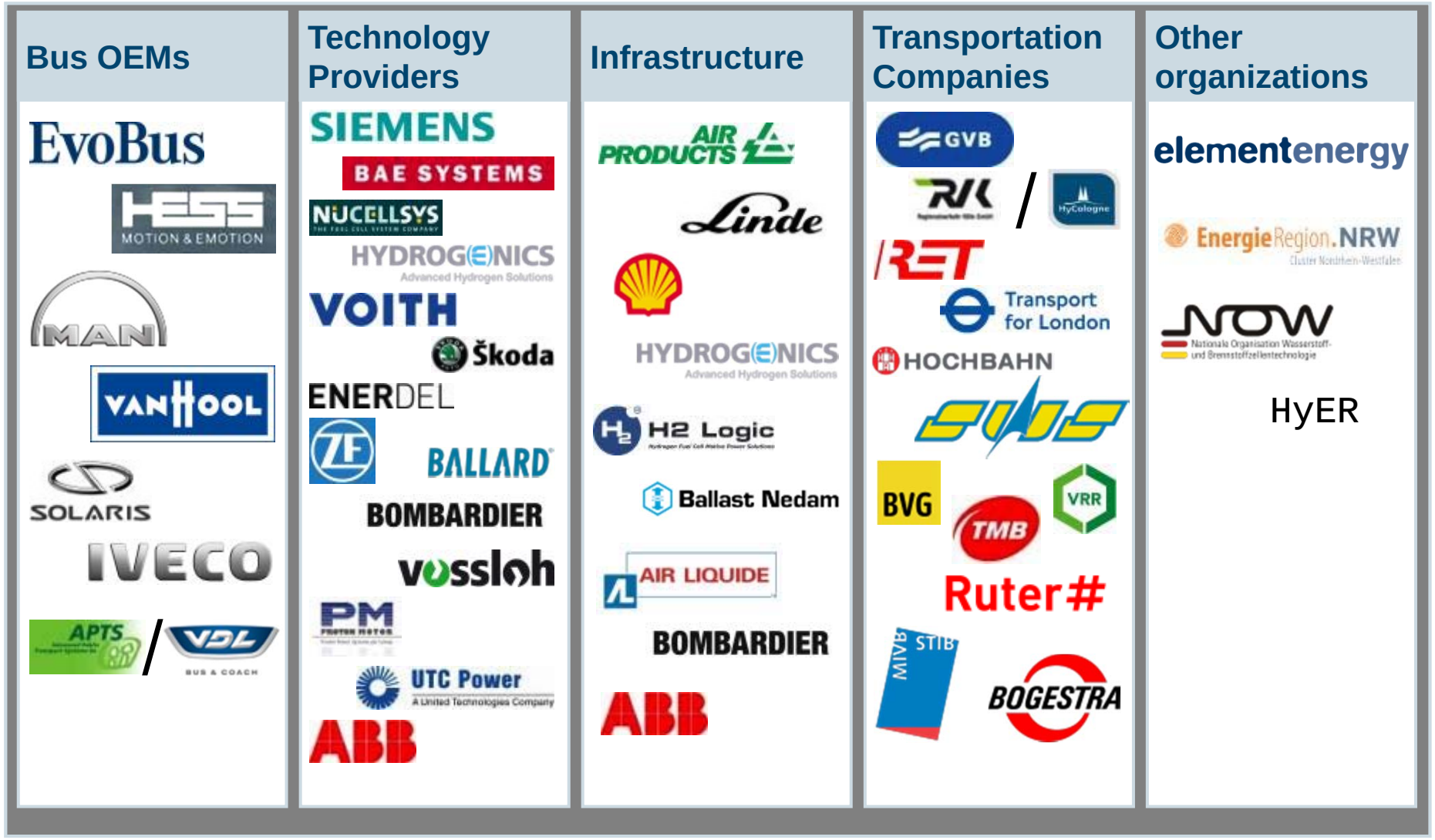


- Associated costs:
  - Electricity = 8 M charging points = 8 B€
  - LNG Waterborne =139 refuelling points * 15 M€ = 2,1 B€
  - LNG trucks = 144 refuelling points * 0.4 M€ = 58 M€
  - CNG road = 654 refuelling points * 0.25 M€ = 164 M€
  - **Hydrogen = 77 refuelling stations * 1.6 M€ = 123 M€**

Urban buses: alternative powertrains for Europe

A fact-based analysis of the role of diesel hybrid, hydrogen fuel cell, trolley and electric powertrains

The coalition of more than 40 industrial companies and organizations



1 Bombardier, Hydrogenics and ABB participate in both the Technology Providers and the Infrastructure working groups

SOURCE: FCH JU; McKinsey

In depth analysis of 8 different powertrains for standard and articulated bus

1. Diesel powertrain

- **Conventional** diesel combustion engine

2. CNG powertrain

- **Conventional** CNG combustion engine

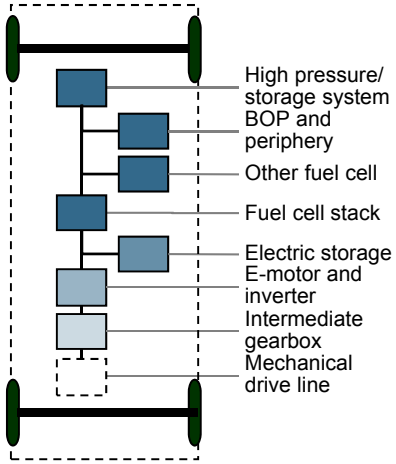
3. Parallel hybrid powertrain

- **Parallel** hybrid configuration of electric and ICE drive
- Fully electric driving for **smaller distances** (<2 km)

4. Serial hybrid powertrain

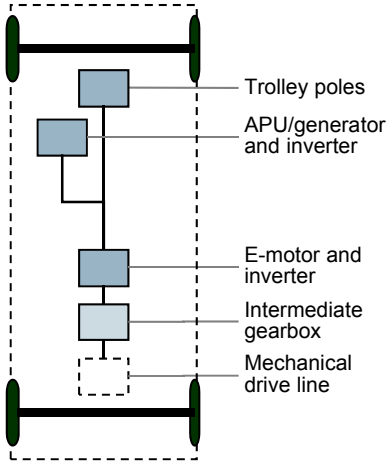
- **Serial** hybrid configuration of dominating electric system
- Fully electric driving for **smaller distances** (<10 km); larger range possible depending on capacity of battery

5. Hydrogen fuel cell powertrain



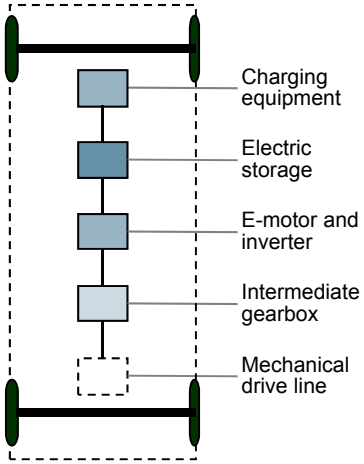
- **Serial hybrid** configuration of fuel cell system and electric drive
- Hydrogen tank pressure typically 350 or 700 bar

6. Trolley powertrain



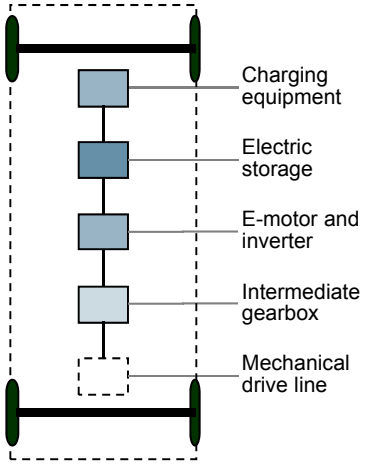
- **Purely electric** drive
- Electric energy taken **from the overhead wiring** while driving

7. Opportunity e-bus



- **Purely electric** drive
- Only charging of battery **from the grid** while stationary at intermediate stops (e.g. via an overhead catenary system)

8. Overnight e-bus



- **Purely electric** drive
- Only charging of battery **from the grid** while stationary at the depot

ICE powertrain | Transmission | Electric powertrain | Battery or supercaps | FC powertrain

SOURCE: Study analysis

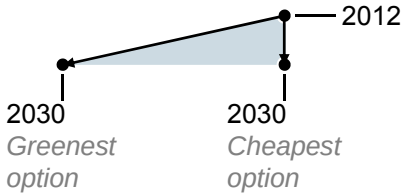
E-bus opportunity and hydrogen fuel cell expected to be the cheapest zero local-emission standard bus by 2030

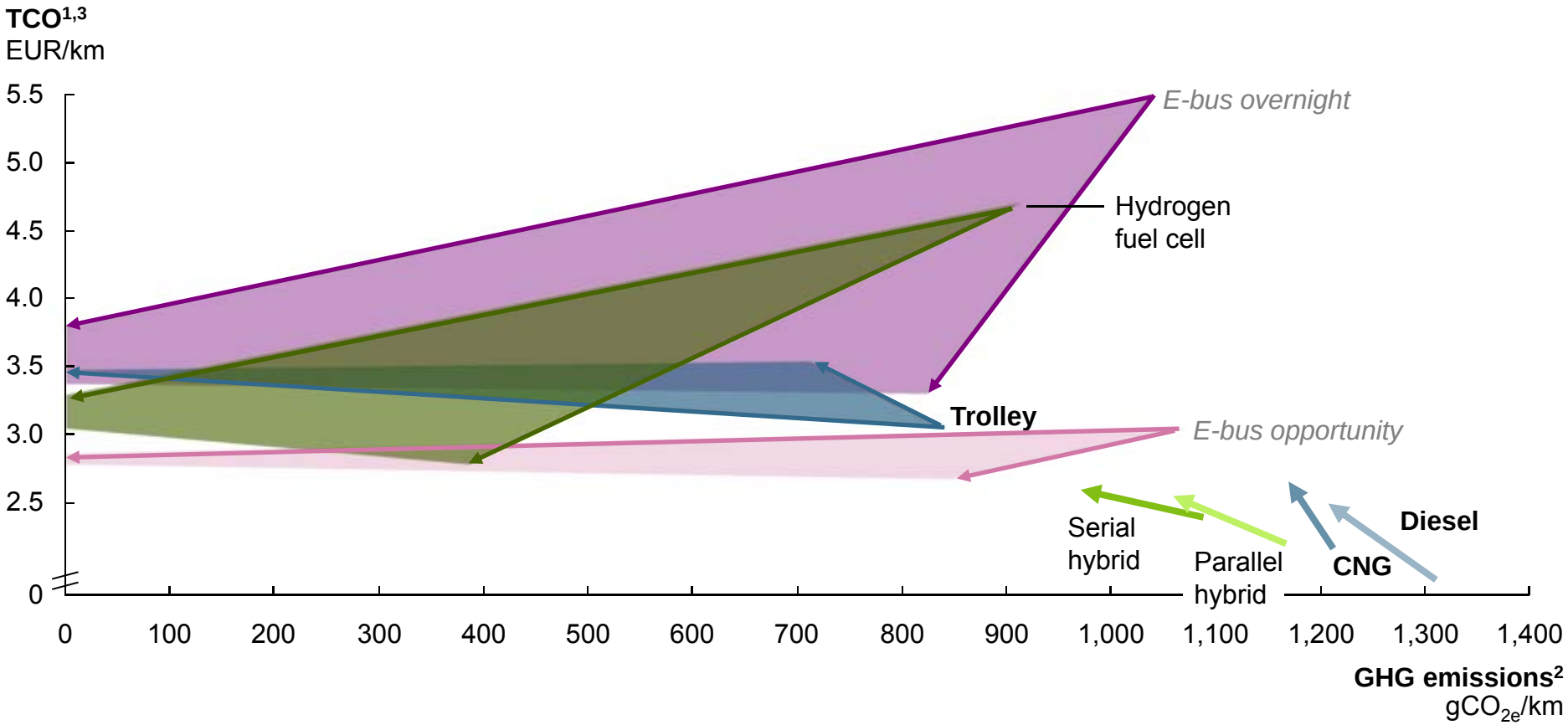
WELL-TO-WHEEL

STANDARD

Labeling of powertrain according degrees of operational experience (kilometers driven):

- **Commercial solution (>> 100 million km): Conventional, trolley**
- Test fleets (> 1 million km): Diesel hybrids, fuel cell
- *Prototype phase (< 10 thousand km): E-buses*





1 Total cost of ownership for a 12m bus including purchase, running and financing costs based on 60,000km annual mileage and 12 years bus lifetime – not all powertrains available for articulated buses therefore articulated buses not shown

2 Total CO_{2e} emissions per bus per km for different fuel types from well-to-wheel

3 Electricity cost for e-bus and water electrolysis part of hydrogen production based on renewable electricity price with a premium of EUR50/MWh over normal electricity

SOURCE: Clean team; working team analysis

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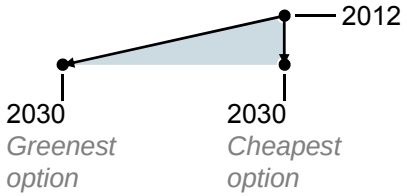

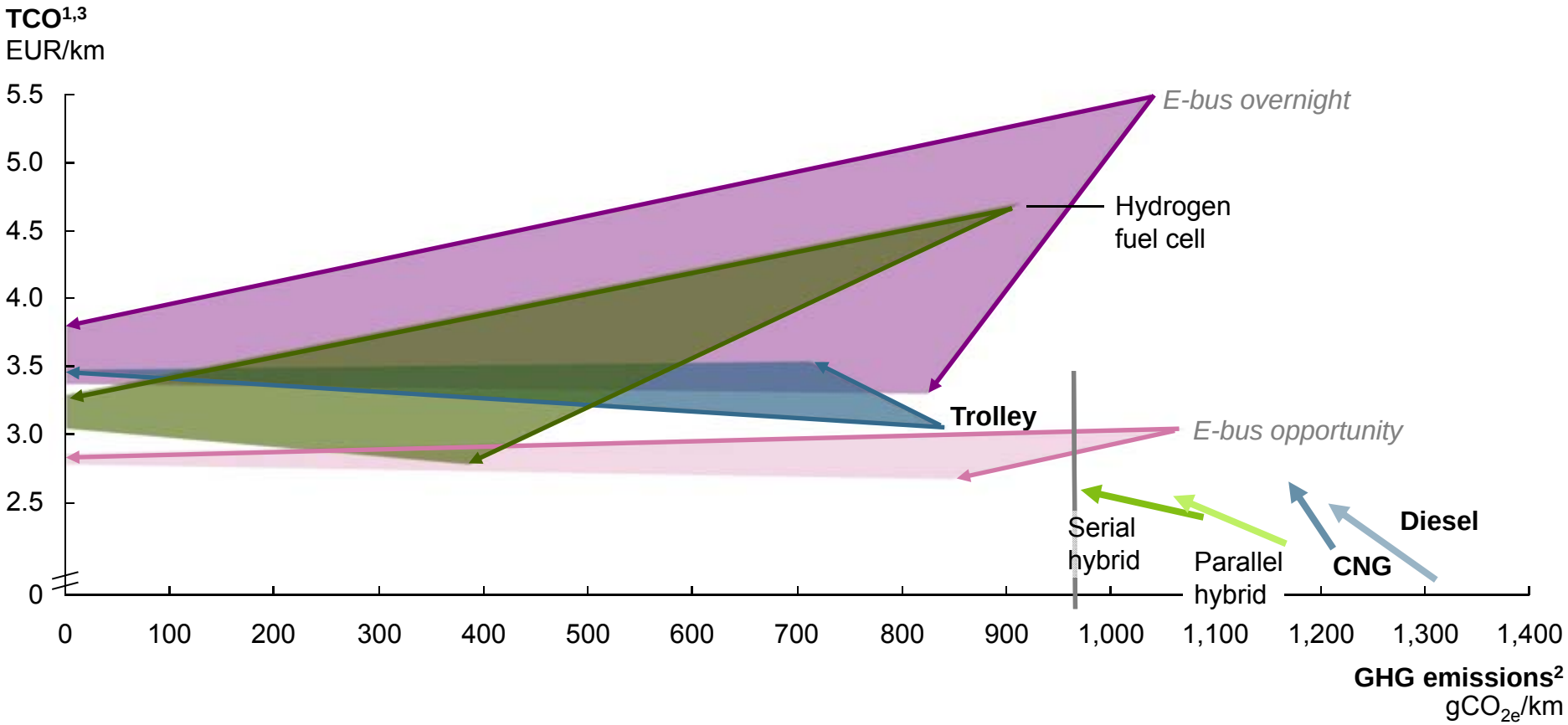

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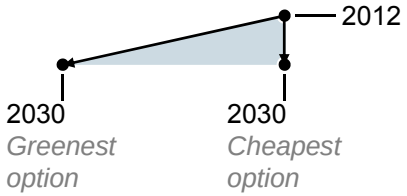

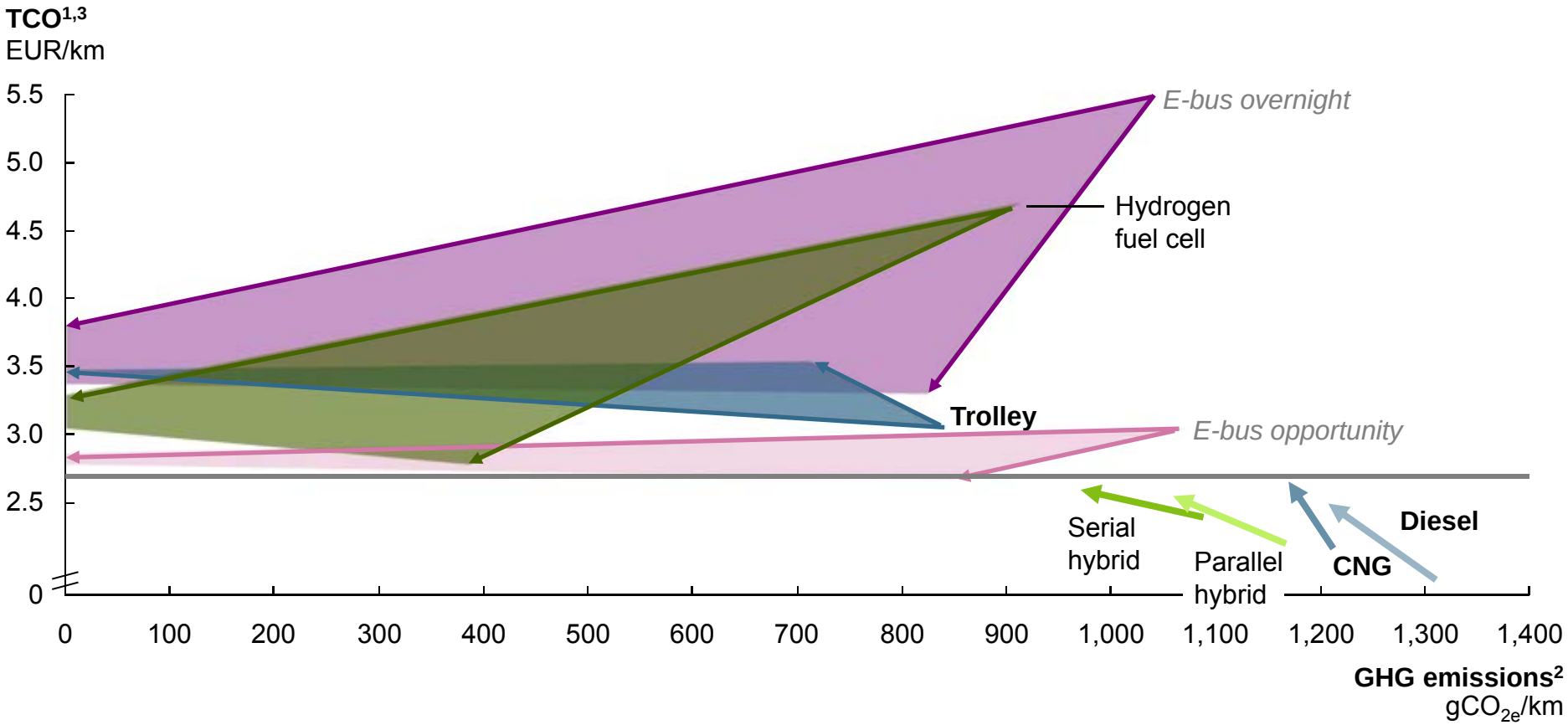

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SOURCE: Clean team; working team analysis

Fuel Cell Urban Buses : next steps

Objectives

Explore and accelerate the commercialization of fuel cell city buses in Europe by:

In a **first** phase,

- Aligning a **coalition** of private and public stakeholders to allow the development of a large scale FC Bus commercialization project
- Developing a functional specification of a **commercial scale FC bus project** and scoping city level FC bus business cases

In a potential **second** phase,

- Develop the basic and detailed engineering of the **hydrogen infrastructure** and developing national ramp up scenarios

In a potential **third** phase,

- Detail the business cases to be **implement**ed
- Developing an **EU vision** for zero emission public FC bus transport and agree on a regulatory framework and funding in support of the commercialization of fuel cell buses

Fuel Cell and Hydrogen 2 Joint Undertaking

General objectives

- Contribute to the objectives of the Joint Technology Initiative on FCH
- Development of **a strong, sustainable and competitive FCH sector**

Specific Objectives

- Reduce **cost** of fuel cell systems for **transport** applications, while increasing their **lifetime**
- Increase the electrical **efficiency** and the **durability** for **power** production, while reducing costs
- Increase the energy **efficiency** of production of hydrogen from **electrolysis** while reducing capital **costs**
- Demonstrate **integration** of renewable energy sources through **H2 storage**

➔Adopted by the Commission on 10 July 2013 as part of the Innovation Investment Package (Horizon 2020)

Fuel Cell and Hydrogen 2 Joint Undertaking

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

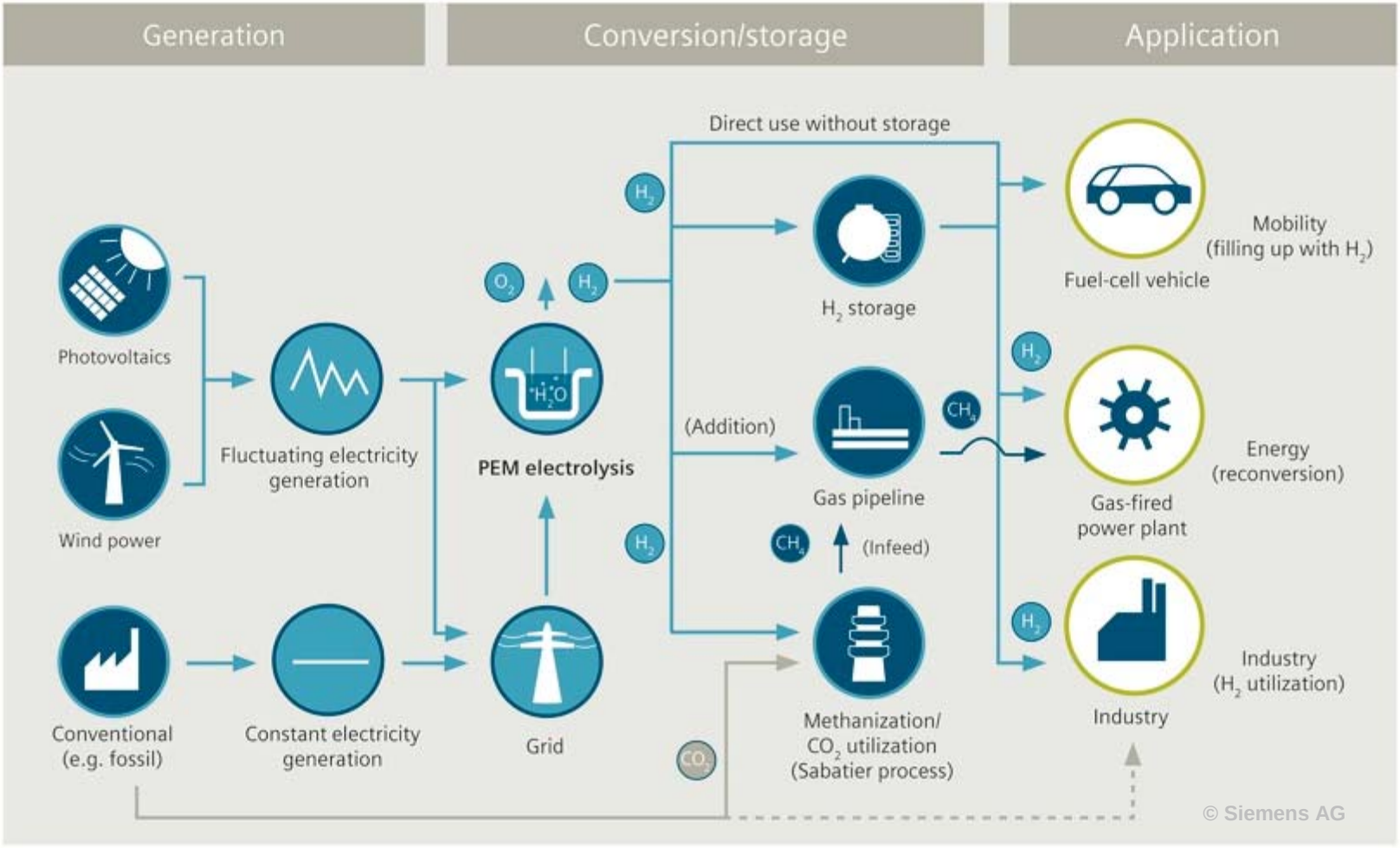
Cross-cutting Issues

(e.g. standards, consumer awareness, manufacturing methods, ...)

- More demonstration and market updake (60 %)
- Increased EC contribution (700 M€)

Hydrogen as “smart link”

Conversion of electrical into chemical power



Applications and examples of use of hydrogen electrolysis

Thank you for your attention !

Further info :

- **FCH JU : http://fch-ju.eu**
- **NEW-IG : http://www.fchindustry-jti.eu**
- **N.ERGHY : http://www.nerghy.eu**