Programme Review Days 2015

Fuel Cell Buses in the FCH JU: A success story?

Carlos Navas, Project Manager – FCH JU

Strong Public-Private Partnership with a focused objective

Industry-led Public-Private Partnership (PPP)

Fuel Cells & Hydrogen Joint Undertaking

Industry Grouping
Over 90 members
~ 50% SME

European Union
represented by the European Commission

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

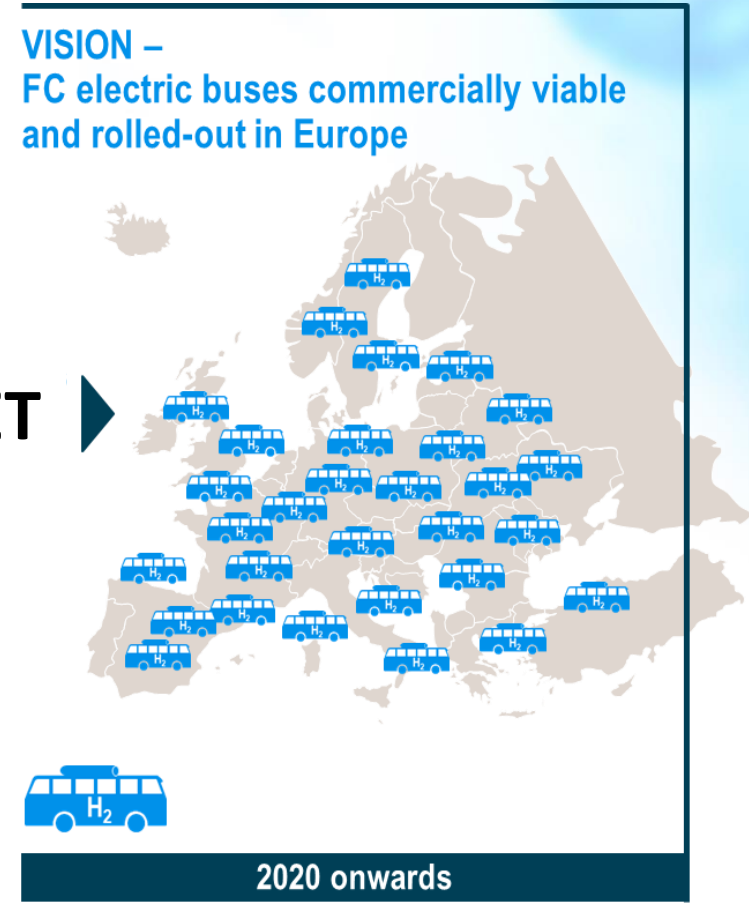
Vision for Fuel Cell Bus Market

SUPPLY (Tech push)

+ **=** **MARKET**

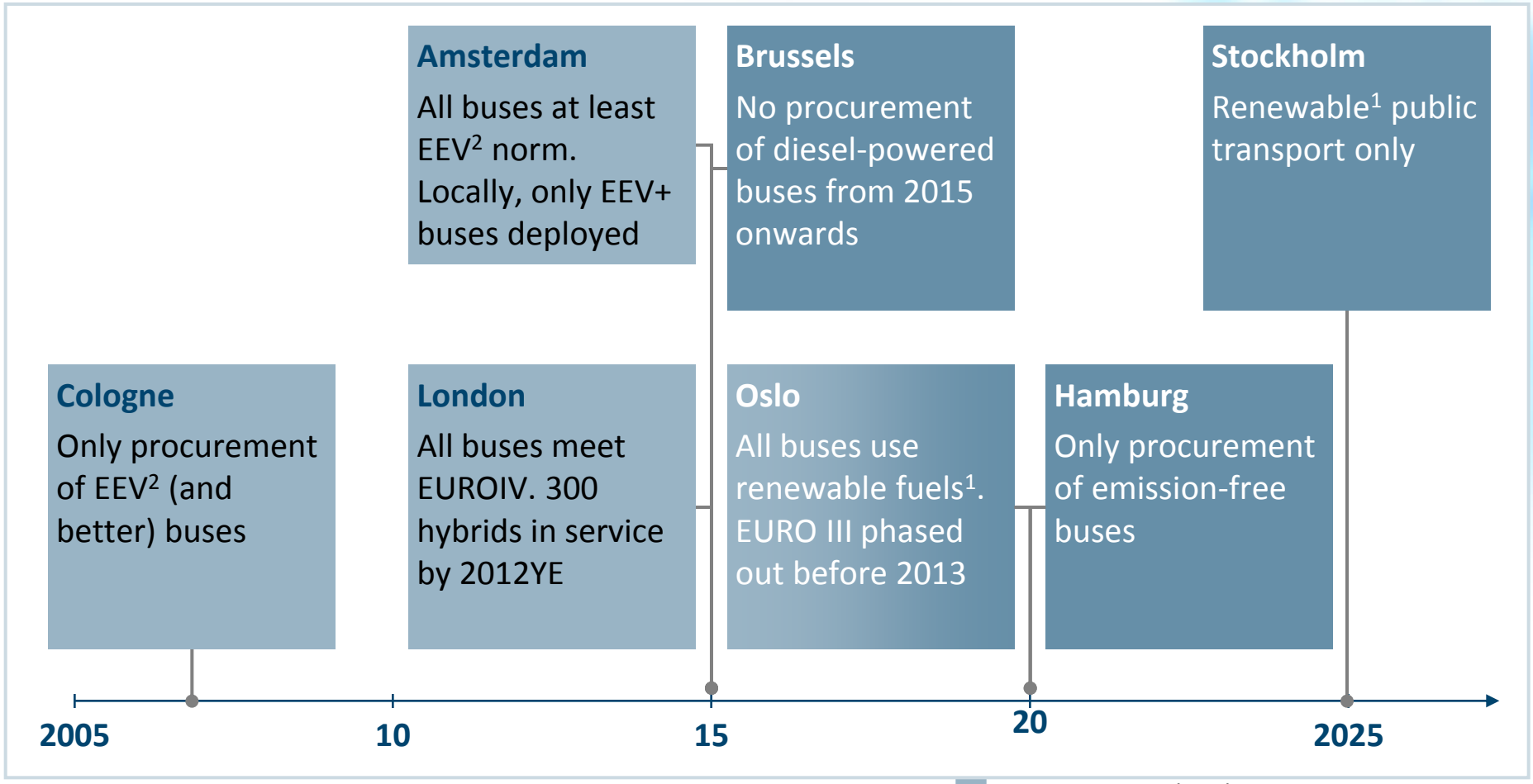
DEMAND pull from Bus operators

Motivation/Business case?



Motivation: Cities are taking action towards cleaner public transport

Europeans perceive major environmental problems to be caused by the transport sector and want local authorities to solve them



1 Includes biofuels
2 EEV: Enhanced Environmentally friendly Vehicle is a EURO norm in-between EUROV and EUROVI

SOURCE: Roadmap 2050; Dieselnet; Local city websites; 2001/81/EC; team analysis

Steps from FCH JU to prepare market entry

1. Bring stakeholders together: supply and demand
2. Reach agreement on:
   - Roadmap: techno-economic assessment + business cases
   - Level of interest/commitment
   - Potential for cost reductions for FCBs and HRS/H2
3. Commitment from supply and demand
4. Organise:
   - National clusters
   - Additional co-financing sources
   - Joint procurement
5. Implement

FCH JU: Bringing stakeholders together and drafting a roadmap to commercialisation

ROADMAP

A

Create independent fact base and confirm feasibility along value chain

Milestone go/no go

B

Create European rollout scenario based on typical business cases

Milestone go/no go

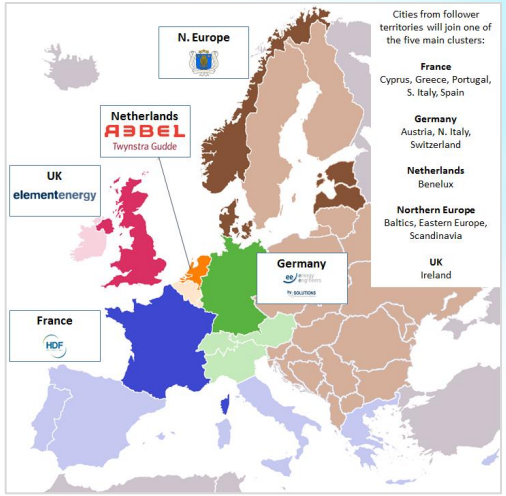
C

Develop frameworks , investment guidelines, and communication tools

EXECUTION

Study issued: 6/12/12

Study issued: 16/10/15



Ongoing work:

- Joint procurement
- Secure co-financing
- Further outreach

The "Urban Buses: Alternative Powertrains for Europe" coalition consisted of more than 40 companies and organizations

Publication: 6 December 2012

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

Bus manufacturers

VANHOOL, HESS MOTION & EMOTION, APTS, VDL BUS & COACH, EvoBus, SOLARIS, IVECO, MAN

Technology providers

SIEMENS, ENERDEL, VOITH, BAE SYSTEMS, NJCELLSYS, BOMBARDIER, PM PROTON MOTOR, HYDROGENICS Advanced Hydrogen Solutions, Škoda, UTC Power A United Technologies Company, vossloh, ZF, BALLARD, ABB

Other organizations

EnergieRegion.NRW Cluster Nordrhein-Westfalen, HyER, New Energy World JU fuel cells & hydrogen for sustainability, elementenergy, NOW Nationale Organisation Wasserstoff- und Brennstoffzellentechnologie

Infrastructure providers

AIR PRODUCTS, Linde, BOMBARDIER, ABB, H2 Logic Hydrogen Fuel Cell Motive Power Solutions, HYDROGENICS Advanced Hydrogen Solutions, Ballast Nedam, AIR LIQUIDE

Operators

GVB, RET, RIJK, HyCologne, Transport for London, HOCHBAHN, Ruter#, BVG, TMB, VRR, MIVB STIB, BOGESTRA

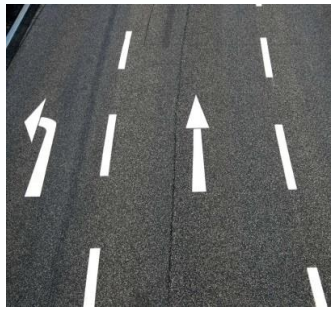
1 Bombardier, Hydrogenics and ABB participate in both the Technology Providers and the Infrastructure working groups
2 These bus OEMs manufactured approximately 70% of the new busses in Europe in 2011

SOURCE: Urban buses - alternative powertrains for Europe, McKinsey

FC buses: as clean as (battery) electric, as flexible as diesel buses

High daily ranges

… of 300 km on average without refuelling – Extension possible



Full route flexibility

… not bound to any required infrastructure on the route

Performance

… comparable to diesel buses, e.g. acceleration or gradeability

Fast refuelling

… down to 7 minutes possible – Also several refuelling cycles per day possible

High passenger comfort

… due to reduced noise levels and smooth driving experience

Close to technology maturity

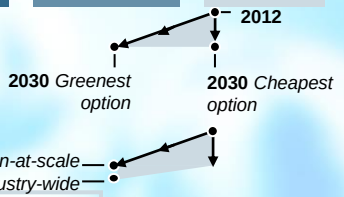
… with more than ten years and 5.5 m km of operational experience in Europe

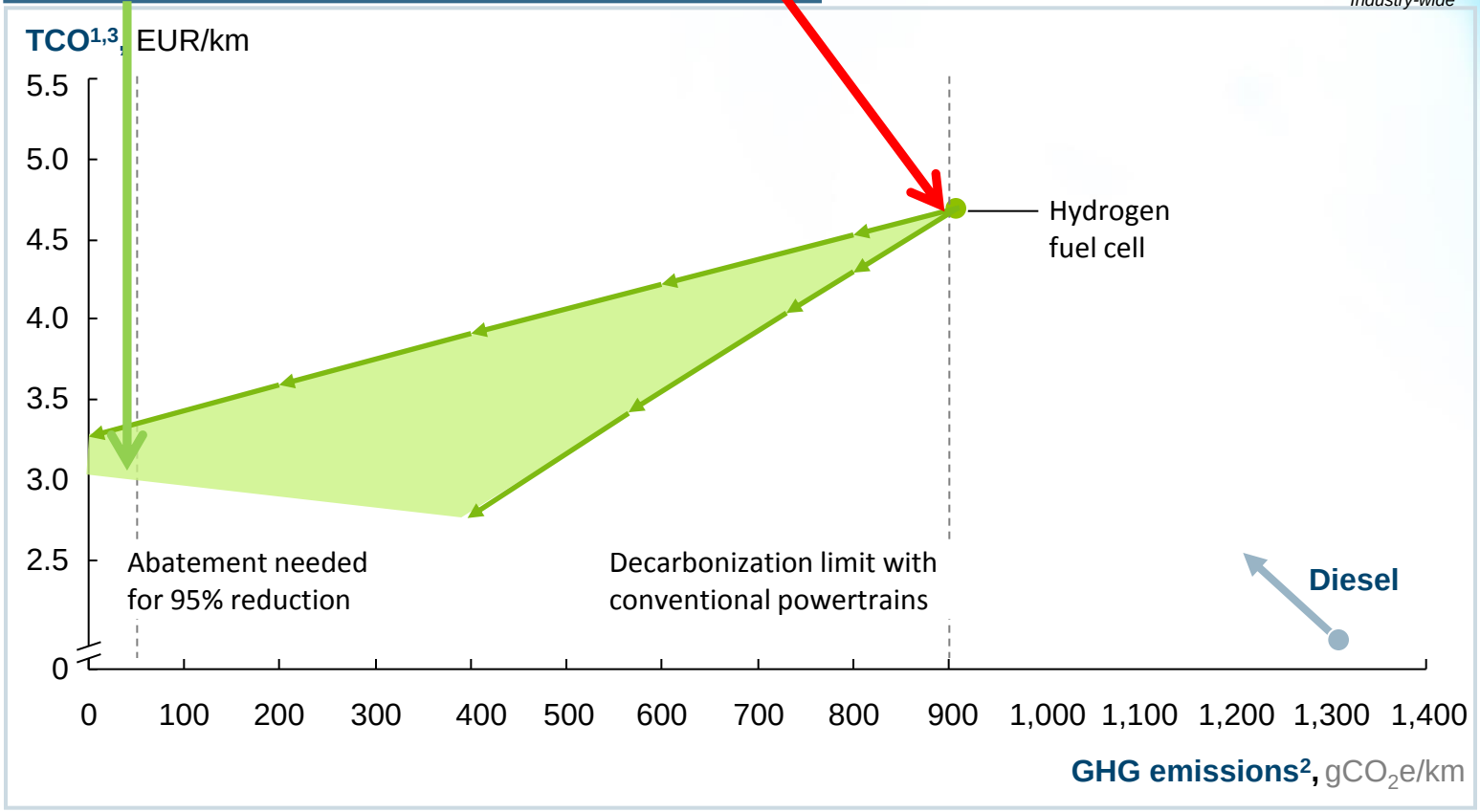
Note: For a comparison of different alternative powertrain solutions please refer to the study "Urban buses: Alternative powertrains for Europe"

Commercialisation pathway needed for larger volumes

NOTE: RANGE ALSO SHOWS EFFECT OF ALTERNATIVE PRODUCTION SCENARIOS | WELL-TO-WHEEL | 12 M BUS | 2012-30

How do we get from here to there? Volumes





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
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: Study analysis

Views from users and suppliers as of 2013

Suppliers

Clear motivation, but:

- Level of interest from potential buyers?
- Size of market?
- History indicates limited follow-up from demo projects

- To what degree should we invest in this technology?

Transport Operators

Clear future technology potential, but: issues remain:

- FCBs:
  - Reliability
  - Cost
  - Availability of spare parts
- HRS/H_2:
  - Price of (clean) H_2
    - Also unclear for large fleets
  - Ability to fuel a large depot (back-to-back refuellings, footprint,...)

- Are suppliers ready to invest to develop cost-effective technology solutions?

Fundamental questions on confidence & commitment

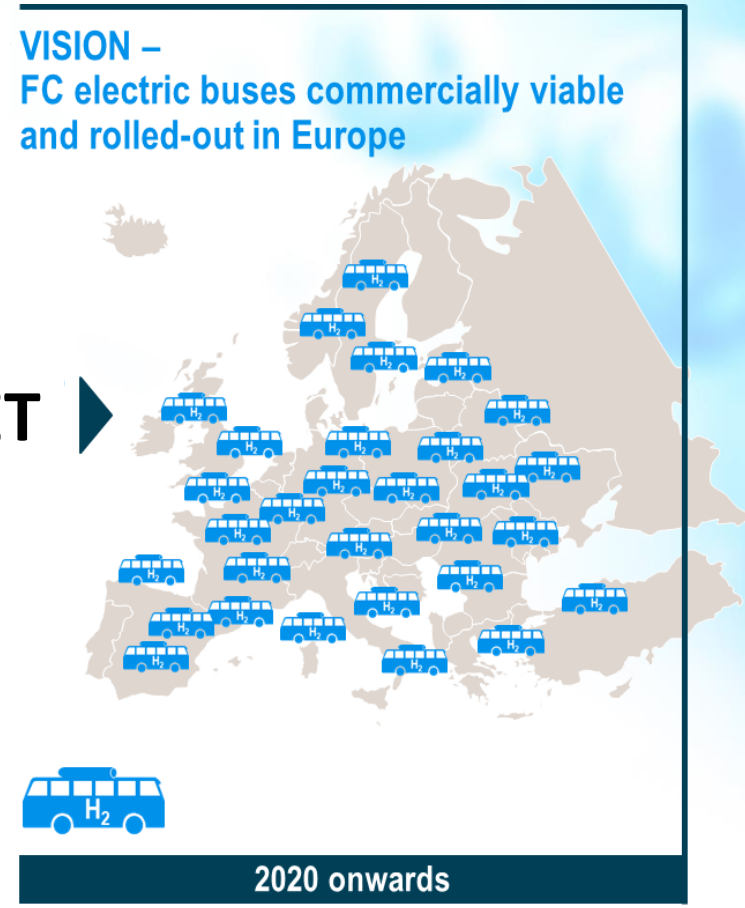
Must define volumes that enable commercial market and pathway to achieve them

Early indications from supply side indicate need to reach 500-1000 FCBs for market

How to get close to those figures (see FCH JU objective) within the H2020 programme?

Must gauge purchase appetite as costs decrease to avoid valley of death and obtain commitments thereof

MARKET



Commercialisation Study

Study launched: Stakeholders mobilised

A broad stakeholder coalition of >80 organisations has been established including operators and local governments from 45 locations

Participating locations

Industry coalition members

Bus manufacturers

VANHOOL, MAN, SOLARIS, ŠKODA, EvoBus, APTS, VDL BUS & COACH

Infrastructure/ H_2 providers

H2 Logic, Shell, Ballast Nedam, Linde, AIR LIQUIDE, ITM POWER, AIR PRODUCTS, SIEMENS, HYDROGENICS, McPhy

Technology providers

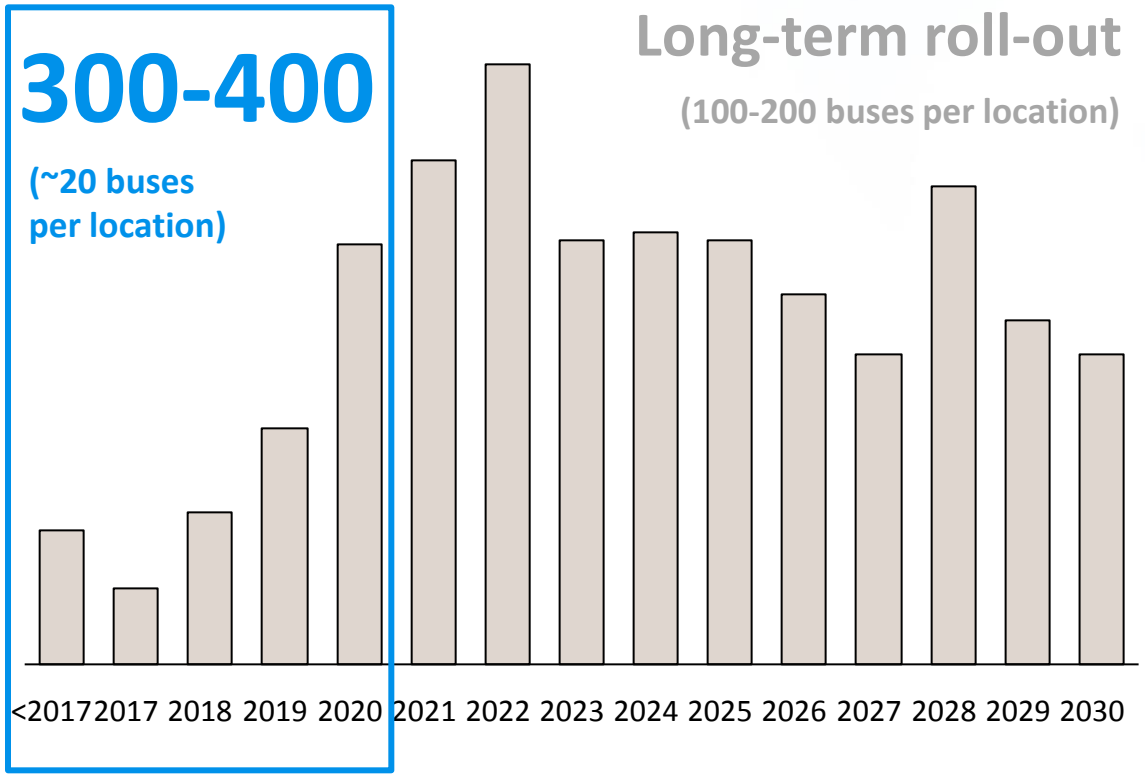
HYDROGENICS, BALLARD, SIEMENS, PM PROTON MOTOR, Intelligent Energy

Other organisations

Government of the Netherlands, VRR, NOW, hySOLUTIONS, VDV Die Verkehrsunternehmen, HyCologne, EnergieRegion.NRW, iit

Strong interest from operators to deploy soon

Deployment plans of participants indicate that at least
300-400 FC buses can be deployed to kick-start the market



Overview FC bus deployment potential

INDICATIVE

> Current planning indications given by participants show that deployment of at least 300-400 FC buses is feasible as part of the initiative

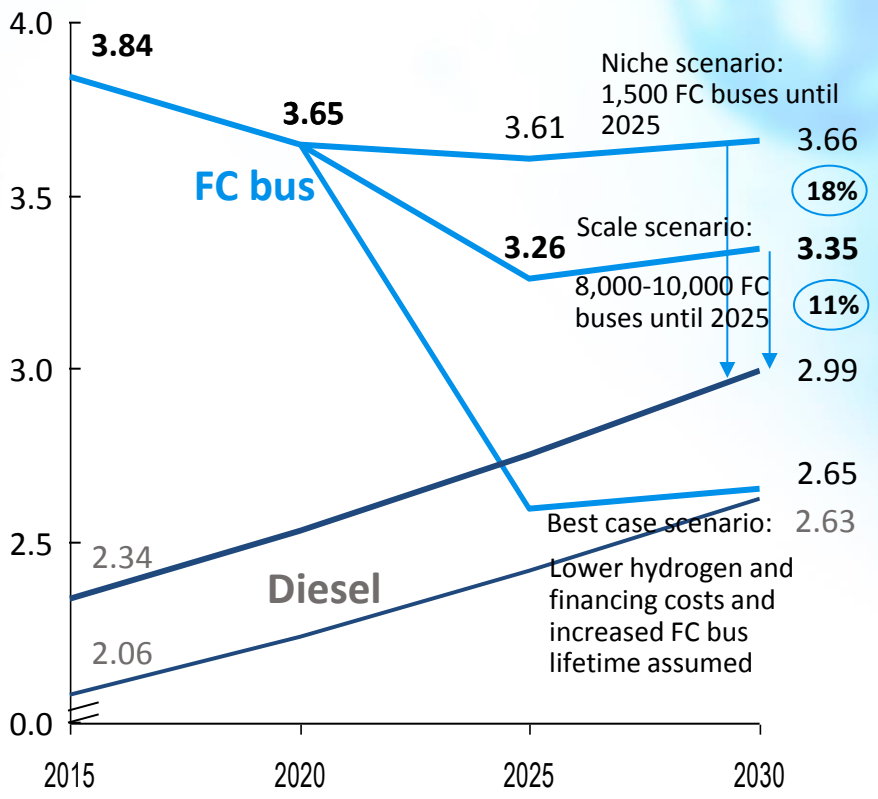
> Additional potential exists with a number of locations that have not yet taken final decisions and with ongoing mobilisation

> At most locations, a long-term change of bus fleets is planned towards FC buses and other zero emission options

Cost Analysis: Significant decrease in cost with volumes

- Study considers all components of TCO:
  - Bus depreciation & maintenance
  - Infrastructure and fuel costs
  - Labour
  - Financing
- Purchase price for 12m bus expected to decrease down to 320K-450k€
- Potential synergies with automotive car market may bring cost reductions earlier
  - Dependent on volumes of cars

TCO standard FC bus [EUR/ km]



Users and suppliers agree on the need for action

5 leading bus suppliers and 30 cities/operators have made clear public statements of their commitment to support commercialisation of FC buses

Bus Suppliers Letter of Understanding

LoU presented to demand side representatives in an Handover-Ceremony in Brussels, 12 November 2014

Left to right: First Mayor Olaf Scholz (Hamburg), Deputy Mayor Kit Malthouse (London), Filip van Hool (CEO Van Hool), Dariusz Michalak (Deputy CEO Solaris), Rémi Henkemans (Managing Director VDL Bus & Coach), Gustav Tuschen (Head of Product Engineering Daimler Buses)

Letter of Understanding of Transport Operators and Public Authorities

LoU handed over to the EU Commissioner of Transport at the TEN-T Days in Riga on 23 June, 2015

Left to right: Bert de Colvenaer (FCH JU Executive Director), Pierre-Etienne Franc (NEW-IG Chairman), Nils Usakovs (Mayor of Riga), Els de Wit (Head of Clean Fuels at the Dutch Ministry of Infrastructure and the Environment), Kirsten Holling (Ministry for Building, Housing, Urban development and Transport NRW), Violet Bulc (Commissioner for Transport), Bernard Frois (IPHE Chairman), Catherine Trautmann (European Coordinator North Sea-Baltic Corridor), Kurt Bodewig (European Coordinator Baltic-Adriatic Corridor), Florian Mussner Councillor for Mobility of South Tyrol-Bolzano)

Situation and Outlook:
91 buses in operation or about to start + call 2016(?)

Ongoing EU-funded fuel cell bus projects

CHIC

- ✓ Bolzano, IT– 5 FC buses (2013)
- ✓ Aargau, CH –5 FC buses (2011)
- ✓ 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

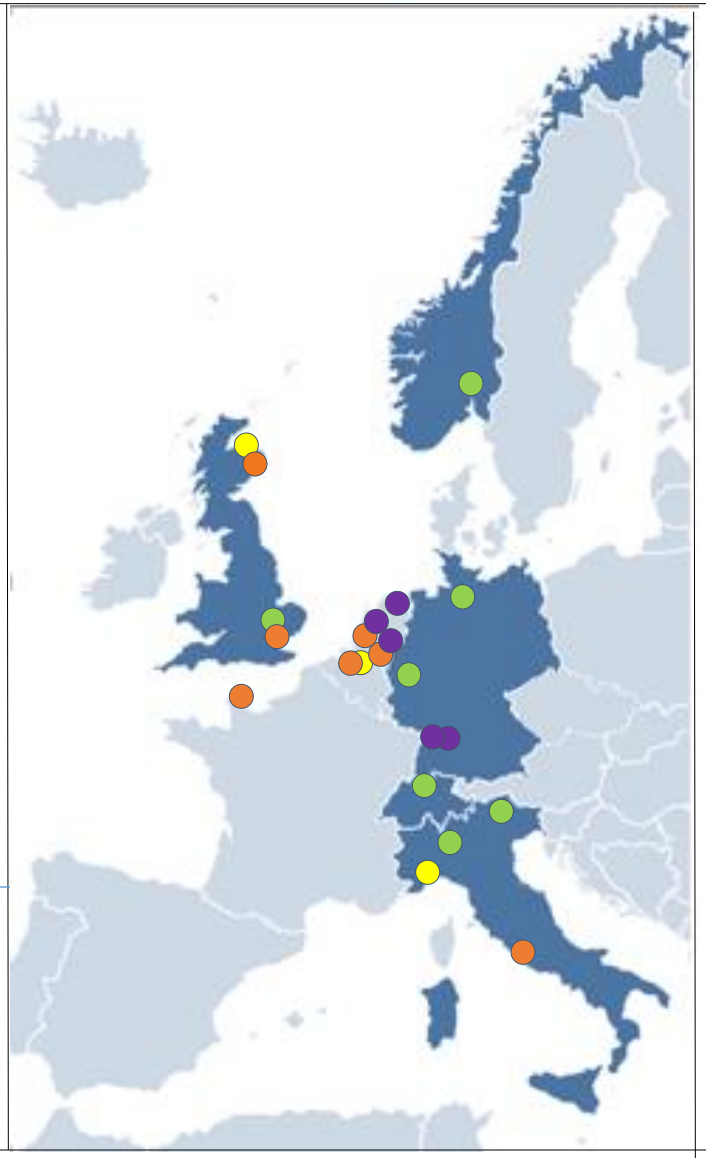
- ✓ Liguria, IT – 5 FC buses (2015)
- ✓ Antwerp, BE – 5 FC buses (2015)
- ✓ Aberdeen, UK – 4 FC buses (2015)

HyTransit

- ✓ Aberdeen, UK – 6 FC buses (2015)

Legend

- CHIC countries
- ✓ In operation
- ✓ Planned operation
- (2015) Operation start/planned start
- * Co-financed by regional/national funding sources



Ongoing EU-funded fuel cell bus project

3Emotion

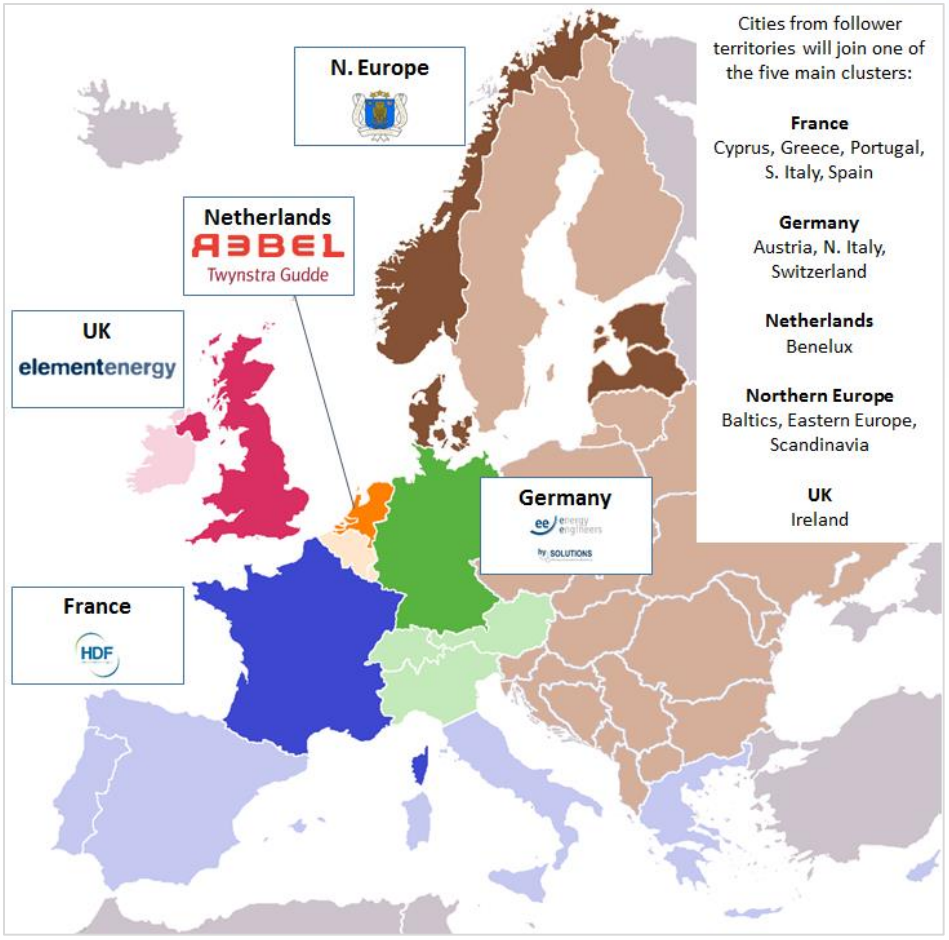
- ✓ Cherbourg, FR – 5 FC buses (2016/17)
- ✓ Rotterdam, NL – 4 FC buses(2016/17)
- ✓ South Holland, NL – 2 FC buses
- ✓ London, UK – 2 FC buses (2016/17)
- ✓ Flanders, BE – 3 FC buses (2016/17)
- ✓ Rome, IT – 5 FC buses (2016/17)

Current national/regional-funded fuel cell bus projects

- ✓ Karlsruhe, DE * – 2 FC buses (2013)
- ✓ Stuttgart, DE * – 4 FC buses (2014)
- ✓ Arnhem, NL* – 3 FC buses (2016/17)
- ✓ Groningen, NL* – 2 FC buses (2016/17)
- ✓ Brabant, NL* – 2 FC buses (2016/17)

Last update: October 2015

Situation and Outlook: The FCH JU supports operators in introducing FC buses



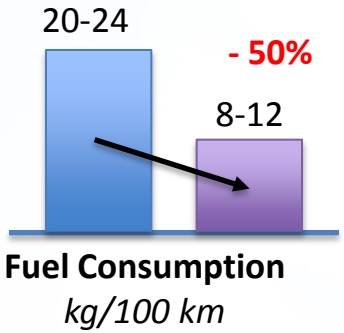
1. **Exchange experience and lessons learnt** with experienced coalition members
2. **Establish contacts in the industry** which can be useful for own concept developments
3. **Partner with other operators** to realise potential cost savings from combined purchases – **joint procurement**
4. Develop a **high-level cost analysis** for your location
5. Find additional **sources of needed co-financing**

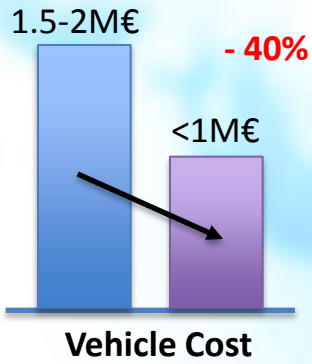
FCH JU Projects: Achievements and Challenges

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

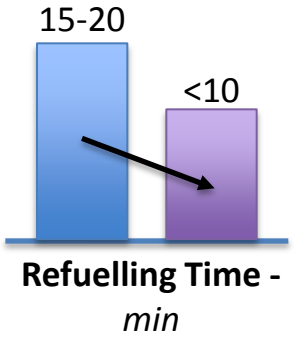
Achievements

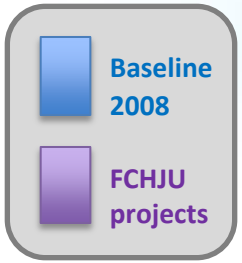
- Efficient electric drivetrain
  - Fuel economy on hybrid bus platforms





- As flexible as diesel buses
  - Full operations: 12-20 daily duties
  - Refuelling time





Challenges

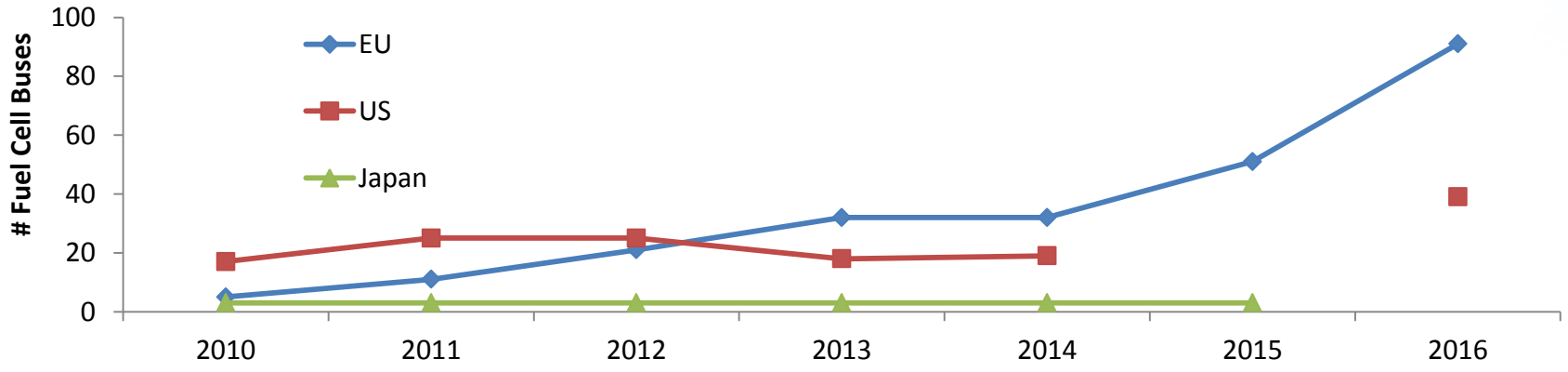
- Availability
- Spare parts
- Time to repair
- Trained staff
- Cost of FCBs, HRS/H2

Volumes bring lower costs and mature supply chain

FCH JU: Are Fuel Cell Buses a success story?

- FCH JU-based platform:
  - Brought key stakeholders together
  - Fostered communication & agreement on roadmap
  - Agreement on demand and supply figures
  - Confidence & commitment from users and suppliers
  - National clusters continue collaboration & foster joint procurement

Established commercialisation pathway



Thank you for your attention

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