NewBusFuel

New Bus ReFuelling for European Hydrogen Bus Depots

Summary of NewBusFuel

The NewBusFuel project (2015-2017) has received funding from the FCH-JU under the European Union's Horizon 2020 Programme under Grant Agreement nr. n°671426

FUEL CELLS AND HYDROGEN
JOINT UNDERTAKING

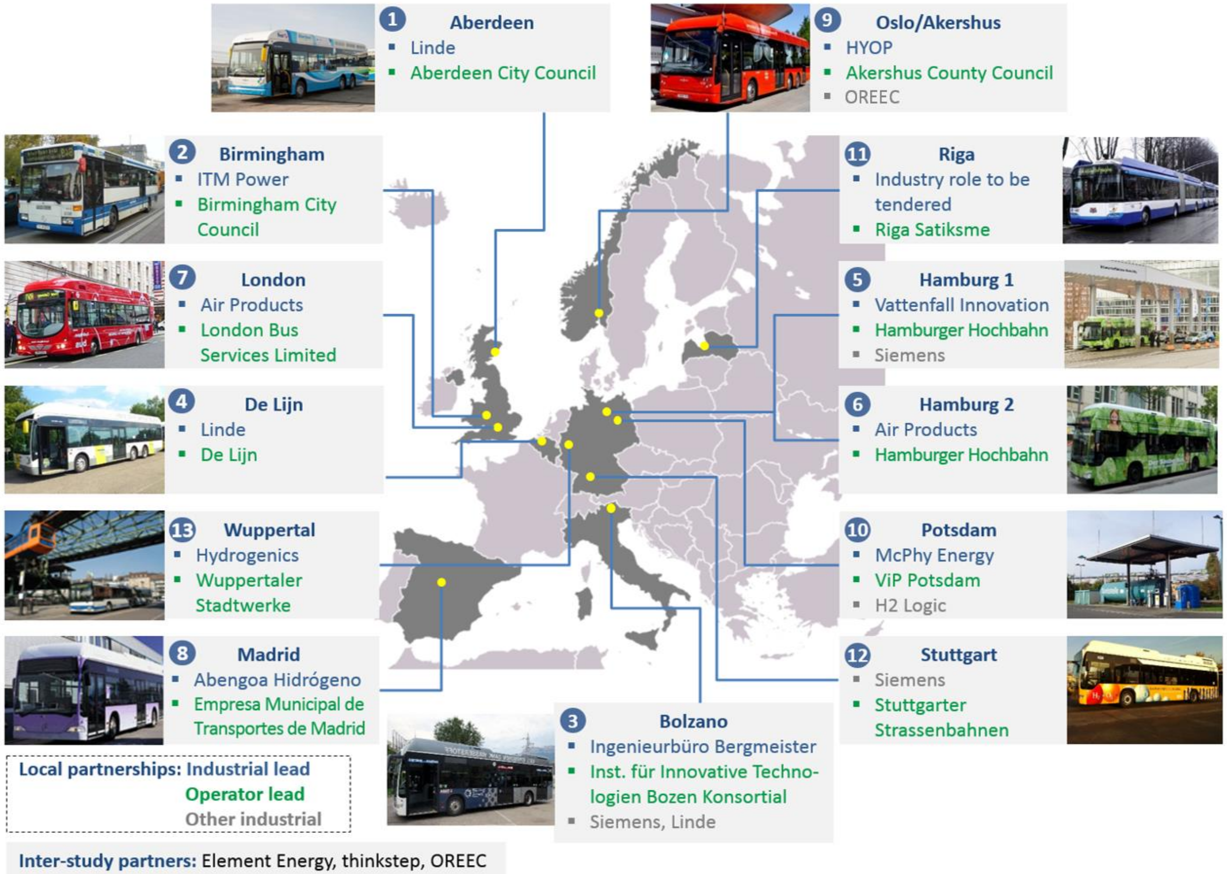
Goal of the project:

- **Resolving the knowledge gap** for the establishment of large scale hydrogen refuelling infrastructure for fuel cell buses

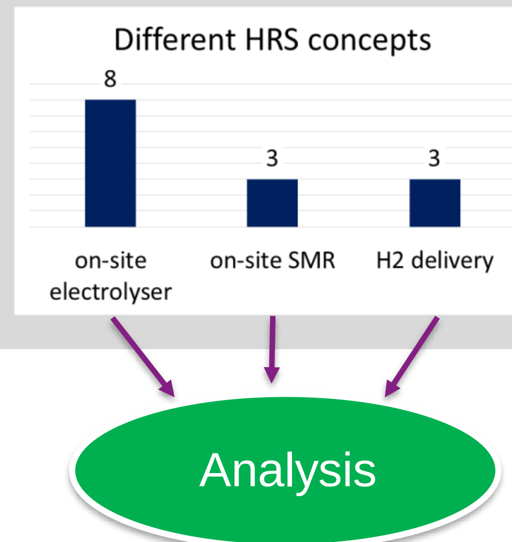
- Key challenges:
  - Scale: throughputs in excess of 2,000 kg H_2/day
  - Reliability: close to 100% reliability to refuel
  - Refuelling time: window for refuelling usually only 4 – 6 hours/day
  - Footprint: limited space availability in urban bus depots
  - Storage demand: need for multi-day storage (usually >2 t H_2)
  - Business models: novel partnerships between suppliers and bus operators

- General approach:
  - Bringing together experts from hydrogen fuelling station providers, equipment suppliers and bus operators in 13 city bus infrastructure studies, defining optimal designs, hydrogen supply routes, commercial arrangements and practicalities for a hydrogen station capable of providing fuel to a fleet of fuel cell buses (75-260 buses).

13 design studies with following partnership:



- 13 design studies in 12 cities in 7 countries
  - 4 cities new to H_2/FC technology
- Considered technologies:



Data analysis team (thinkstep) have evaluated each study to produce a **techno-economic summary** and a **guidance document** to help new bus operators understand the sector and inform complex procurement decisions for initiating a fuel cell bus project.

NewBusFuel

Scope of analysis and main deliverables:

- **Capture key lessons learned from** the individual **design studies**
- Information has been aggregated and anonymised and data collected from each study to produce:

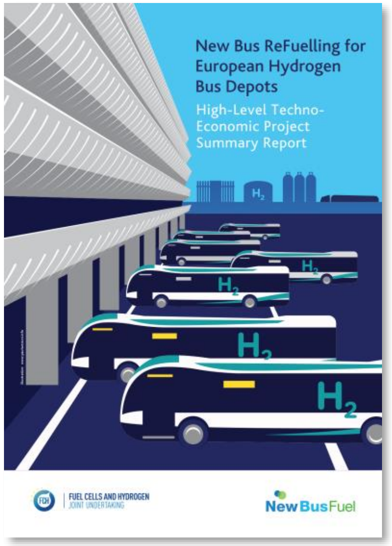
A **Guidance Document** on Large Scale Bus Refuelling

- Target audience: bus operators / transport agencies, specifically project managers tasked to set up an HRS
- Provides insight on learning and know-how created as well as indicative quantitative values for design parameters from the design studies

B High-Level **Techno-Economic Summary Report**

- Analysis of the project results
- Deriving recommendations for three stakeholder groups: bus operators, policy makers and industry

Both documents available at www.newbusfuel.eu



A - Guidance document

Summary

- HRS design, operation, business model need to be chosen individually for each HRS

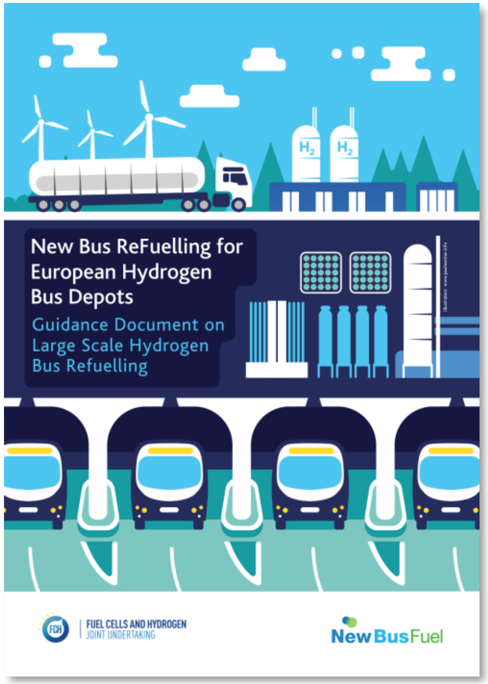
  → bus operator, authorities, infrastructure supplier need to cooperate for finding the ideal solution

  → HRS station design requires new business models and adds complexity, but:

  → recommended framework helps to approach the relevant questions

  → provided indicative values for the different design parameters help to get a first idea about the requirements and options for the future HRS

  → more information in the **Guidance Document on Large Scale Hydrogen Bus Refuelling**

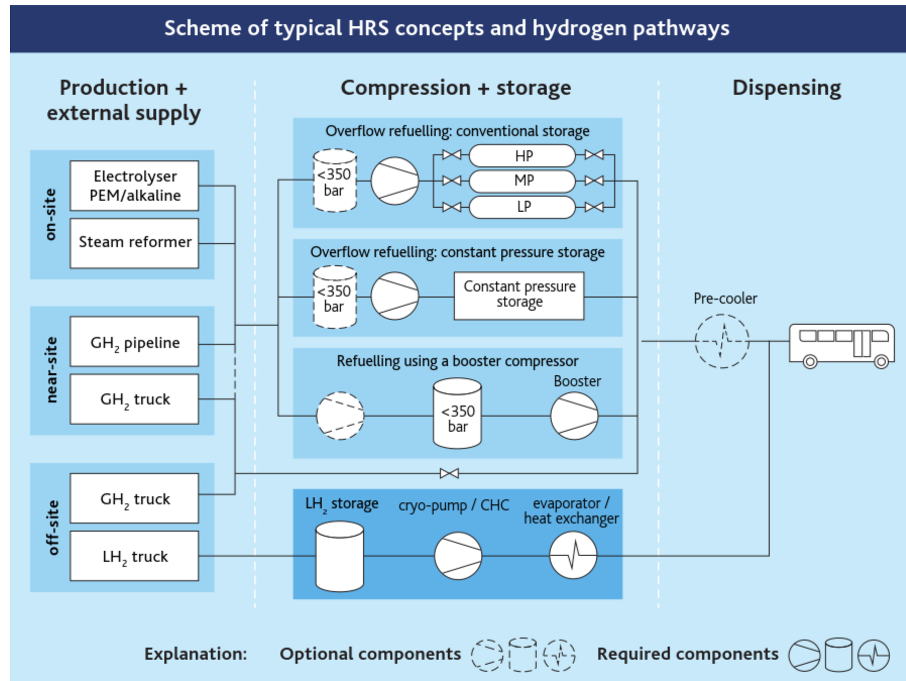


A - Planning of right concept & design

Hydrogen refuelling station (HRS) concepts

There are 2 states of hydrogen (H_2) supply: - **gaseous** (GH_2) - or - **liquid** (LH_2)

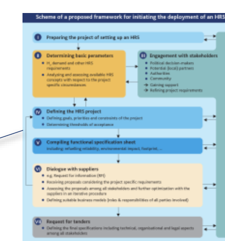
- On-board storage in bus always as gaseous
- 3 main supply routes
- 4 compression + storage concepts



HRS projects can become complex

- They involve many stakeholders
- Need to address several different constraints and goals – footprint, regulations, codes & standards…

→ A structured framework is created to provide assistance for efficient HRS project implementation (p. 43 in Guidance Doc.)



A.2 Technical aspects in NBF

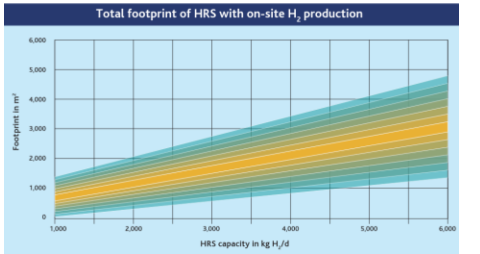
Determination of H_2 demand, HRS footprint and power supply

- **Hydrogen demand is** the **most fundamental parameter** for HRS design -**Data and indicative values** for the different design parameters from NBF design studies give guidance and **enable first quantitative estimations** on H_2 demand

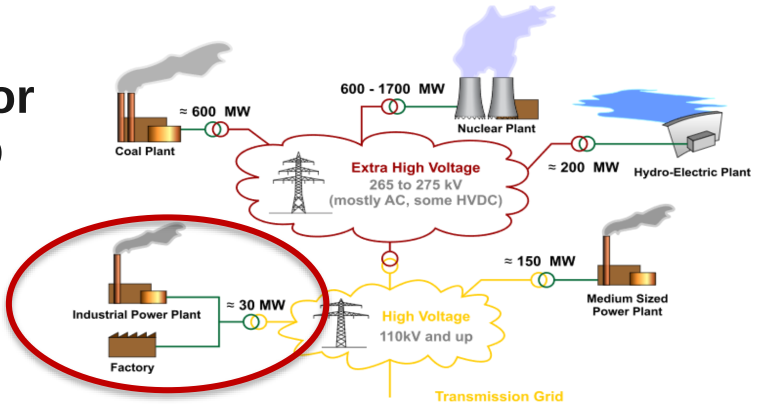
Parameters determining the amount of required hydrogen per FC bus

Parameter	Typical range	Min/Max values
Assumed consumption of a 12m bus	9 – 10 kg H_2/100 km	8.5 / 12 kg H_2/100 km
Assumed hydrogen consumption of a 18m articulated bus	12 – 15 kg H_2/100 km	11.5 / 15.6 kg H_2/100 km
Required daily operating range of a fuel cell bus	200 – 300 km	155 / 450 km
Typical range of daily hydrogen consumption per bus	20 – 30 kg H_2	15 / 36 kg H_2

- **Space constraints** for HRS at the bus depot can be crucial
- **HRS footprint** depends on deployed technology and RCS
- Capacity dependent indication on HRS footprints is provided in the guidance doc. (chapter 5.1)



- **On-site electrolysis requires large capacity for electric power supply** e.g. for 120 FC buses @ 25 kg H_2/d > 12 MW power demand for on-site electrolysis and compression

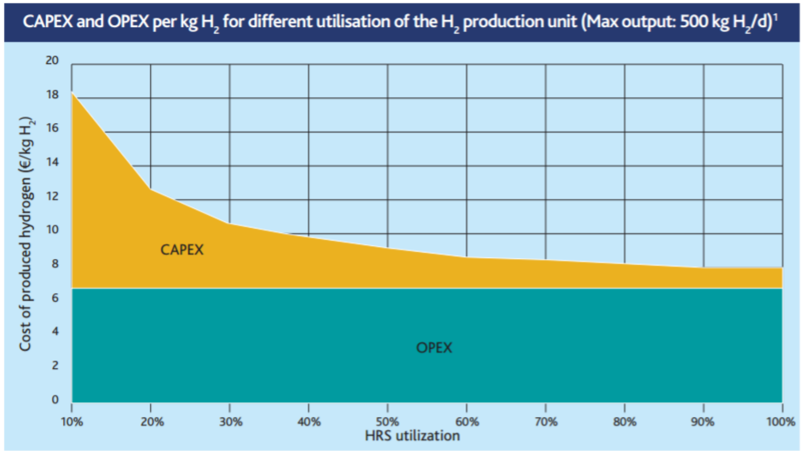


Source: Wikipedia

A.3 Economic aspects in NBF (short summary)

Capital expenditure (CAPEX):

- High overall investment (both for on-site electrolysis and steam reforming)
- Assumed lifetime of components 20 years, electrolyser: 1 stack change
- H_2 production using an electrolyser re quires a significant investment
- At the same time per kg H_2 dispensed, CAPEX contribution is rather small



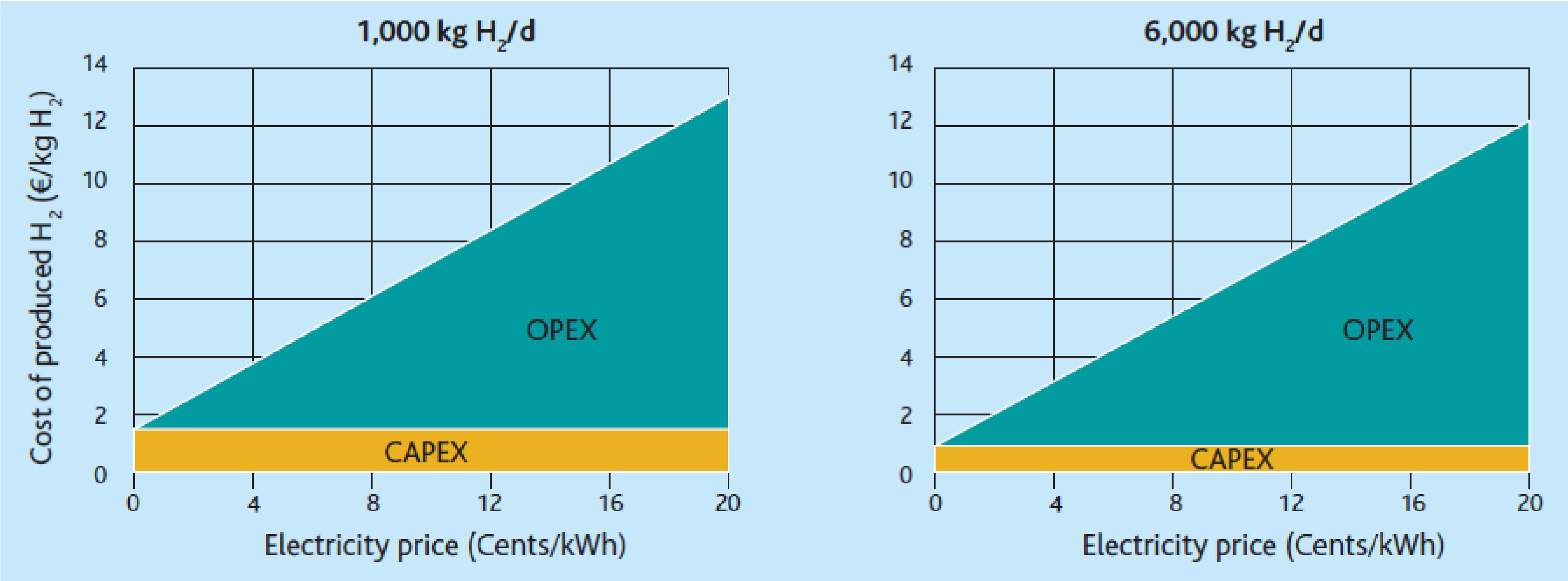
Operational expenditure (OPEX):

- Different parameters related to energy sources (electricity vs. natural/ biogas) create large difference in cost scenarios

A.3 Economic aspects in NBF

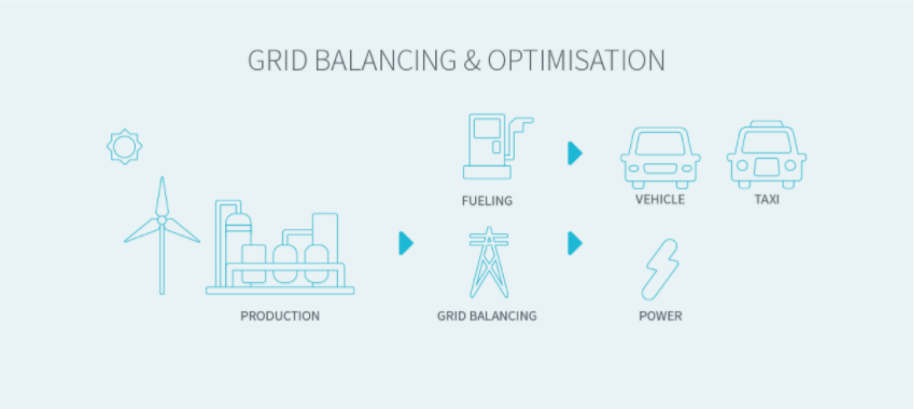
Electricity prices

- The plots below show the cost per kg of producing hydrogen at well-loaded hydrogen refuelling stations at varying electricity prices
- As is demonstrated below, costs of ~4 – 8 Cents per kWh are required to produce hydrogen within the targeted range
- Therefore in order to produce hydrogen at prices appropriate for today's bus fleets, access to low cost electricity is essential



Ongoing steps for reducing hydrogen costs
H2ME2 Wp4

- There is further ongoing work to understand how grid balancing services could be used to reduce the cost of electrolytic hydrogen production
- In Hydrogen Mobility Europe 2 (H2ME2), electrolysers will be aggregated and used to provide grid balancing services at the HRS deployed in the project



- This will be a novel step - demonstrating the potential of a new revenue stream for electrolytic hydrogen production
- A series of services will be tested, demonstrating the potential for electrolysers to provide frequency response and reserve services

This project has received funding from the **Fuel Cells and Hydrogen 2 Joint Undertaking** under grant agreement No 671438 and No 700350. This Joint Undertaking receives support from the **European Union**'s Horizon 2020 research and innovation programme, the New European Research Grouping on Fuel Cells and Hydrogen ("**N.ERGHY**") and **Hydrogen Europe**.

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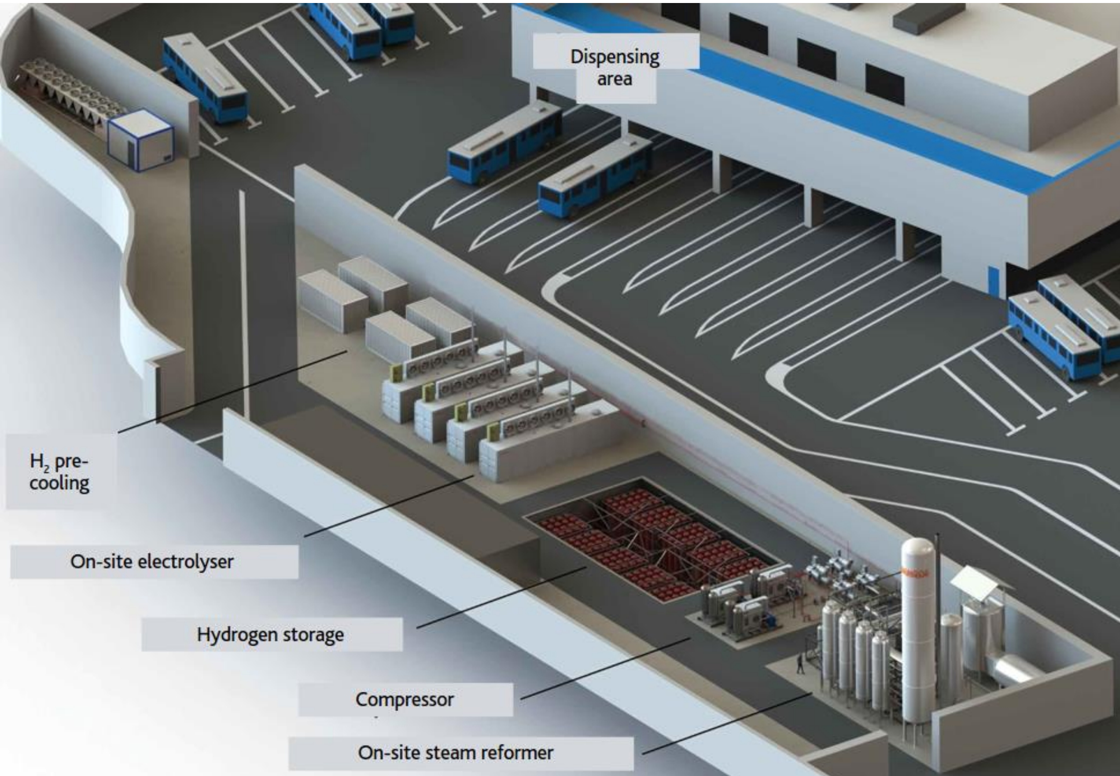
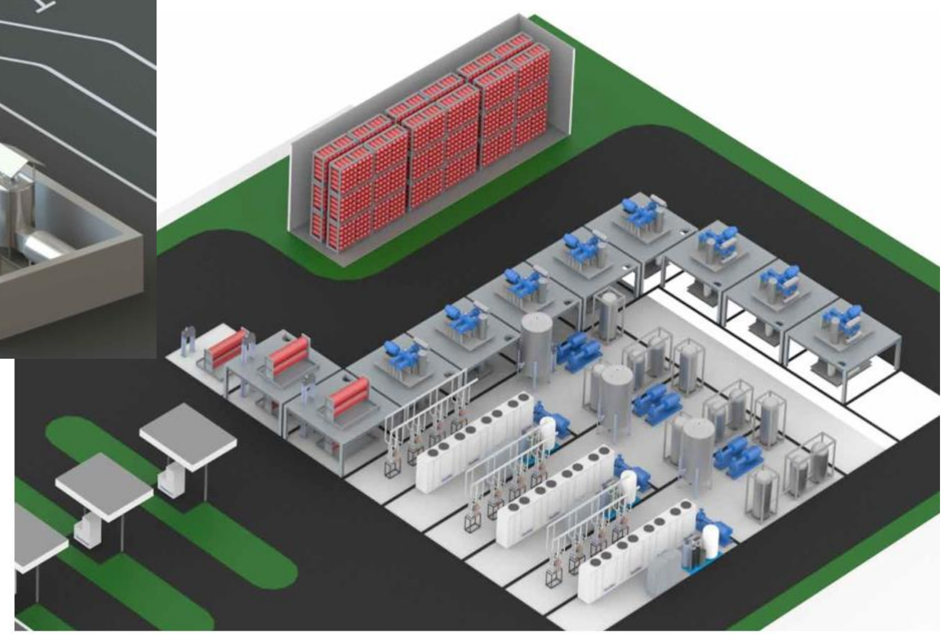
HRS examples from NBF

On-site H_2 generation



HRS with both **on-site electrolysis** and **on-site steam reforming** with a daily capacity of 3-6 t H_2/d (120-240 buses)

1 t H_2/d supplies 40 FC buses @ 25 kg H_2/d



Source: Abengoa Innovación (above) and Hydrogenics (right)

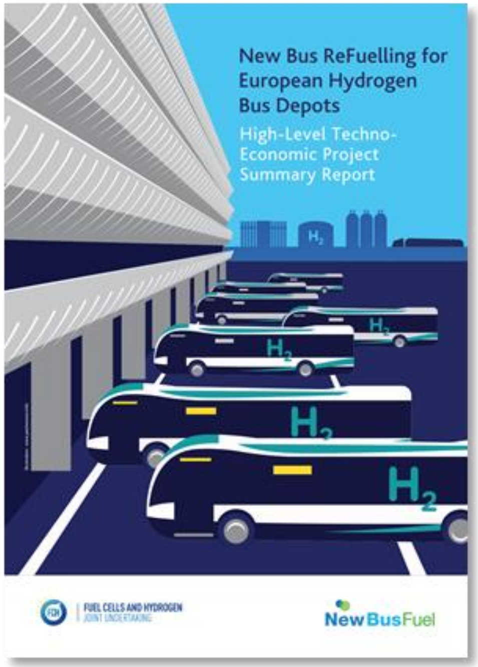
B Techno-Economic Summary report

Summary

- Techno-economic assessment of NewBusFuel design studies for decision makers

- Recommendations for improving technical solutions as well as economic performance addressing three relevant stakeholder groups
  - bus operators
  - policy makers
  - HRS infrastructure suppliers

→ More information and more recommendations can be found in the **High-Level Techno-Economic Project Summary Report**



B.1 Technical analysis
Range of requirements

- NewBusFuel: 12 cities with individual requirements and constraints
  - Bus service characteristics
  - Topography and climate conditions
  - Energy prices, taxes and levies
  - Space constraints at bus depot
  - RCS
  - Political support

- For all design studies, solutions were developed with components and technologies that were achieved today

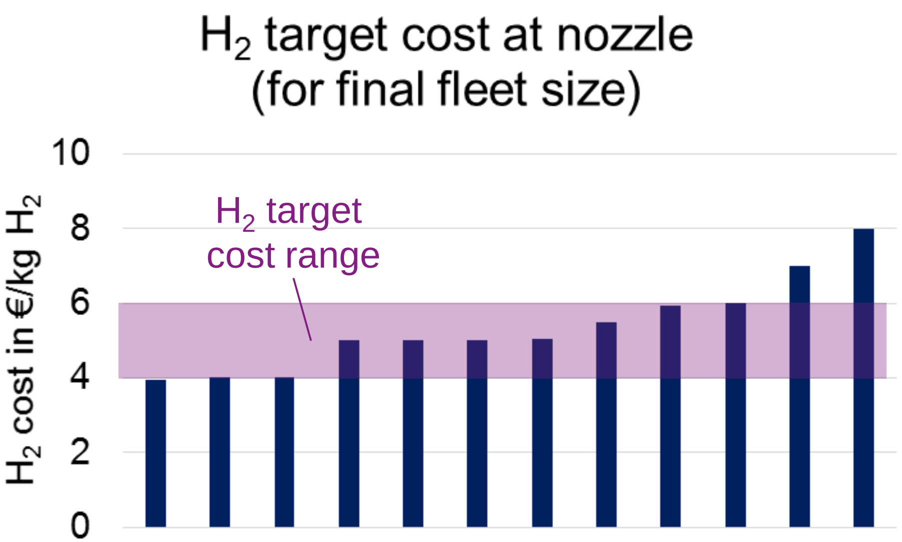
Requirement variation across the case studies conducted within the NewBusFuel project

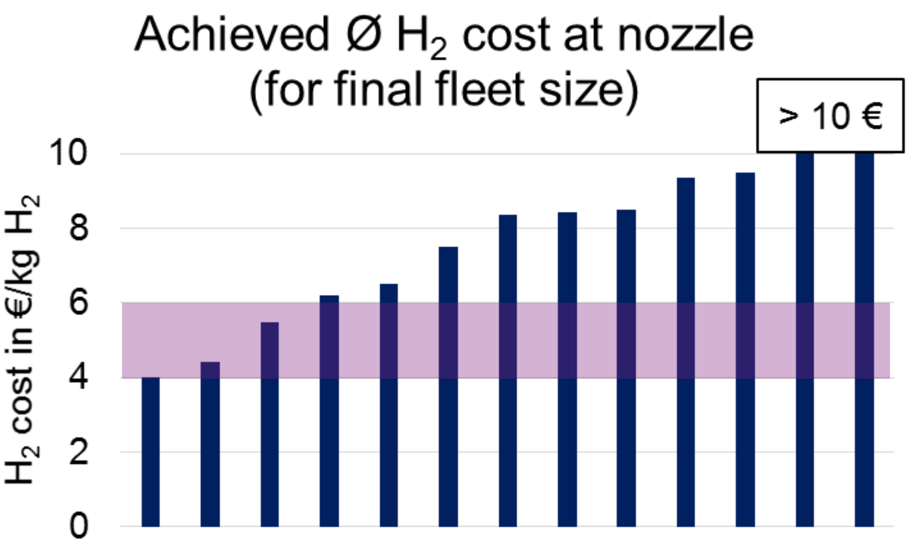
Parameter	Typical range within NewBusFuel	Min/Max
Assumed H_2 consumption of a 12m bus[1]	9 – 10 kg H_2/100 km	8.5 / 12.0 kg H_2/100 km
Assumed H_2 consumption of a 18m bus	12 – 15 kg H_2/100 km	11.5 / 15.6 kg H_2/100 km
Required daily operating range of a fuel cell bus	200 – 300 km	155 / 450 km
Operating days of one bus per year	250 - 350	240 / 365
Number of buses in initial fleet size	10 - 20	3 / 50
Number of buses in final fleet size	50 - 250	40 / 275
Amount of hydrogen required per day (for final fleet size)	1,000 – 6,000 kg H_2	700 / 6,000 kg H_2
Duration of the refuelling window	4 - 6 h	2 / 8 h
Required storage autonomy	1 day - 3 days	0.5 / 4.5 days
Refuelling availability	98 % - 100 %	98 % / 100 %
H_2 cost target	4 – 6 €/kg H_2	4 / 8 €/kg H_2

B.2 Economic analysis

Target cost and achieved cost

- H_2 target cost range
  - 4 – 6 €/kg H_2 for most studies
  - was achieved by three studies with different HRS concepts
  - higher H_2 cost tolerable with increasing fuel efficiency of FC bus, i.e. lower H_2 consumption
  - use of renewable energy carriers likely leads to higher H_2 cost





B.3 Recommendations

Stakeholder Groups

- Recommendations derived for three stakeholder groups
  1. Bus operators and transport authorities
  2. Policy makers
  3. Industry

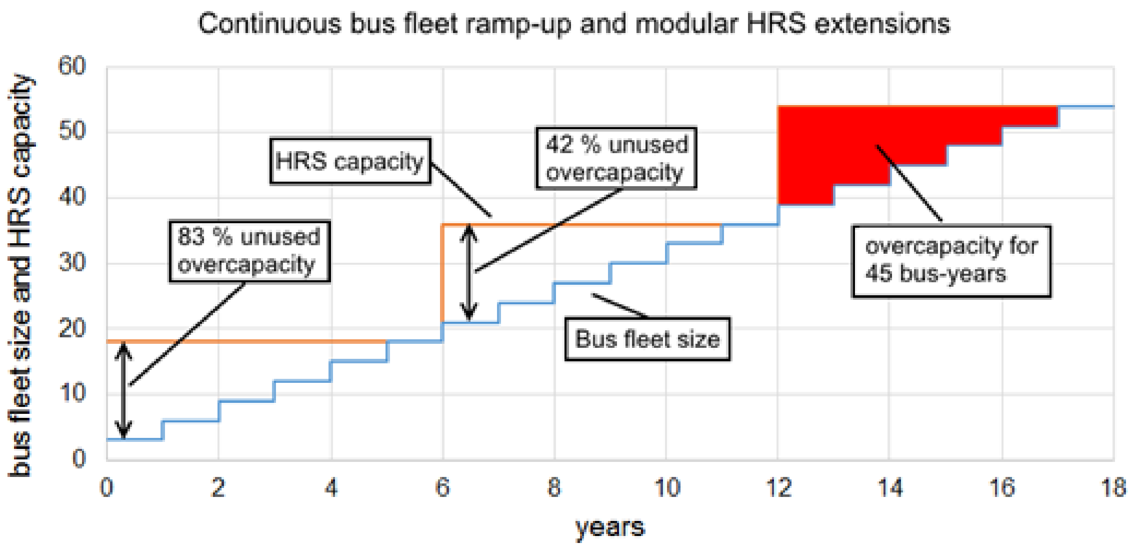
B.3 Recommendations

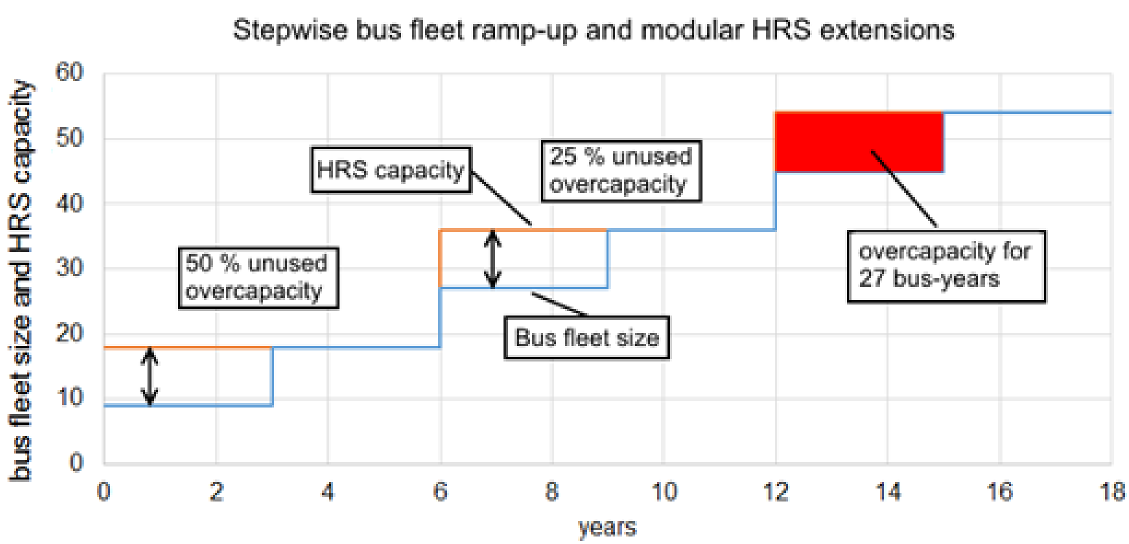
Bus operators: Fleet and HRS size

- Low utilization of the HRS infrastructure leads to high CAPEX contribution

→ Establish an appropriate initial fleet size

→ Ensure infrastructure sizing and procurement is adequately linked to growing bus fleet





B.3 Recommendations

Bus operators: Overview

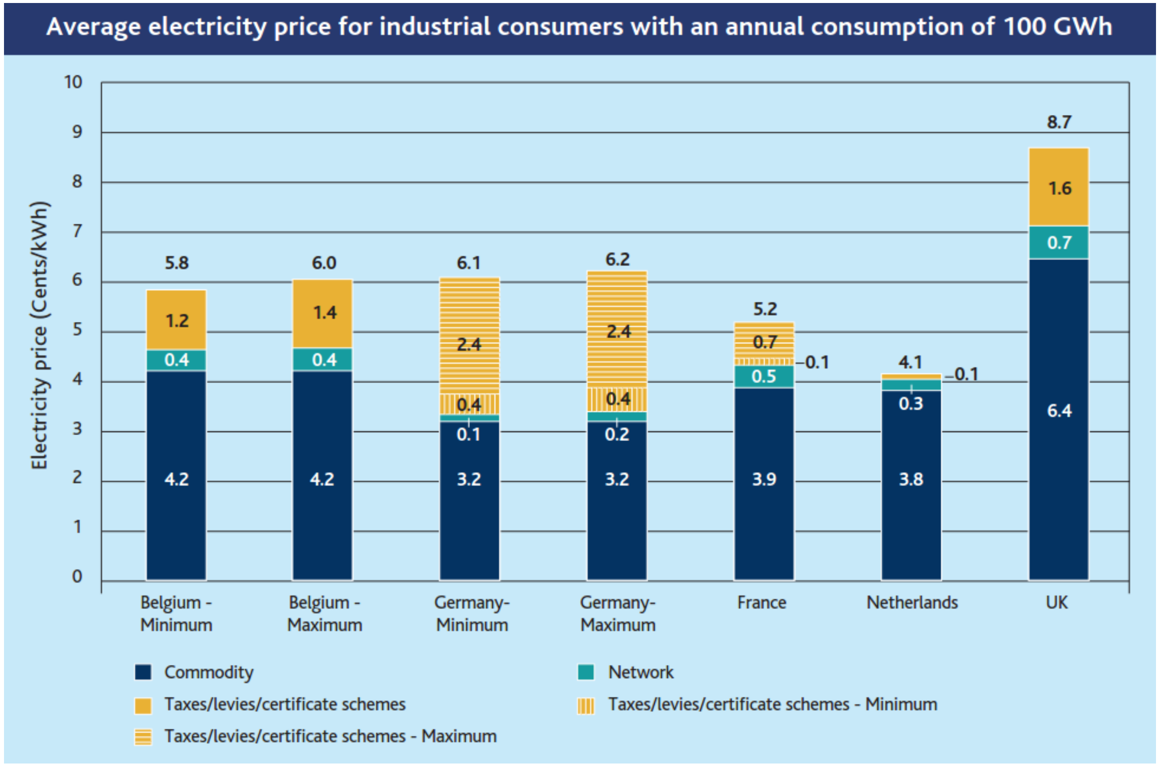
- Take into account the fundamental differences between H_2 and diesel refuelling
- Provide flexibility for HRS design and its operation
- Establish an appropriate initial fleet size
- Ensure infrastructure sizing and procurement is adequately linked to growing bus fleet
- Chose a modular HRS design
- Find appropriate balance between reliability and cost
- Put effort into reducing OPEX
- Try to collaborate with other bus operators for joint procurement of buses and HRS infrastructure
- Confirm procurement process (RFI, RFT etc.)

B.3 Recommendations

Policy makers: Taxes and levies for electricity

- For cost competitive production of H_2 using electrolysis, access to cheap (green) electricity is crucial

→ Revising the additional cost incurred by taxes and levies to decrease cost of H_2 produced by electrolysis



Source: CREG, 2016

B.3 Recommendations

Policy makers: Local air quality regulations

- Reduce taxes and levies for electricity used for hydrogen production
- Extend local air quality regulations and support bus operators during the transition
- Imposing and enforcing stricter air quality regulations: NO_X and PM
- Set a regulatory framework that allows hydrogen to participate in grid balancing services
- Harmonise Regulation, Codes & Standards within EU

→ Demand for using Zero Emission Vehicle Technologies

→ Consistent regulatory framework that considers e.g. societal costs and that imposes e.g. penalties and/ or (partial) bans on polluting conventional vehicle technologies

→ Support bus operators during the required transition, e.g. through financial or organisational resources

Thank you for your attention

This brief presentation of NewBusFuel has been edited by dissemination partner OREEC and summarised from the referenced reports and presentations held at the NBF launch event 15th March 2017 from data analysis partner thinkstep and project coordinator Element Energy.

A big thanks also to all partners in the project consortium for their engagement throughout the project period for their extensive contribution through the studies.

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