CaFCP Public Forum – Accelerating Commercialization in California

European Perspectives

April 25th 2017

Intelligent Energy

IE - A long history in hydrogen fuel cell technology

2001
Intelligent Energy established

2005
First purpose built fuel cell motorbike

2007
IE and Suzuki partnership begins

2008
First manned fuel cell aircraft produced by Boeing and Intelligent Energy

2010
First zero-emission PEM fuel cell hybrid taxi

2011
First fully road approved fuel cell scooter

2013
Personal fuel cell energy device

2014
Listed on the London Stock Exchange

2016
Fuel cell drone demonstrated at InterDrone 2016

IE’s technology strengths

Stationary Power

Back-up power and diesel replacement, initially for telecom towers, but also for a range of other sectors

We are pursuing opportunities in a number of countries

Field proven in India, with a tower uptime of close to 100%

Distributed Energy

Global opportunities for hydrogen fuel cells as an element in hybrid and portable systems

Part of global climate change initiatives, supported by a growing financing ecosystem

A desire, by increasing numbers of global multinational corporations, to reduce their carbon footprint directly and throughout their supply chains

Drones

Our technology provides a unique solution

Fuel cells offer extended flight times and quick refuelling

Fuel cells are a natural solution for drone manufacturers moving into larger drones with heavier payloads

We have successfully demonstrated our technology

Suzuki, Automotive and Japan

Suzuki has been critical to the development of our technology and continues to be a key partner

Our expertise, together with that of Suzuki, opens up a range of opportunities in the motive sector, for range extenders and prime power

Asia is also potentially a large market for our products and technologies

AC64 fuel cell stack

The AC64 air cooled fuel cell runs on hydrogen and ambient air to produce clean DC power in a simple, cost-effective, robust and lightweight package.

The modularity of our proprietary product design allows for scaling across 200W to 2.7kW per fuel cell stack to meet precise customer power and form factor requirements.

AC10 fuel cell stack

The AC10 air cooled fuel cell stack runs on hydrogen and oxygen from the air to produce clean DC power in a lightweight and power-dense package.

The AC10 stack can be readily integrated into customers’ systems with minimal balance-of-plant components.

Where IE operates

With headquarters in the UK, IE has an international presence around the world:

Commercial offices

Loughborough, UK
HQ, main facility

USA
San Jose, California
– Commercial Office

Japan
Osaka
– Commercial Office

Yokohama
– SMILE joint venture

Regional representation

Singapore

Bangalore, India

Shanghai, China

Development centres

Loughborough, UK

Grenoble, France

Merritt Island, FL, USA

UK H_2Mobility (UKH2M): a joint industry-government project evaluating the potential for and rollout strategy for H_2 transport in the UK

UK H_2Mobility Partners

- Government departments + devolved administrations — Department for Business Innovation & Skills; Department for Transport; Department of Energy & Climate Change; The Scottish Government; GREATERLONDONAUTHORITY; Llywodraeth Cymru Welsh Government
- Car OEMs — DAIMLER; HYUNDAI; TOYOTA; NISSAN; HONDA
- Hydrogen providers/ producers and utilities — AIR LIQUIDE; ITM POWER; BOC
- Technology providers — Intelligent Energy; Johnson Matthey
- Public-private partnerships — New Energy World
- Fuel retailers — Sainsbury's

Companies interviewed

- Fuel retailers — MORRISONS; Shell; Sainsbury's; TESCO
- Fleet operators and lease companies — ARVAL; ups; DHL; B&Q; Lex Autolease; Government Procurement Service; BT Fleet
- Grid operator — nationalgrid

Goal

Evaluate the potential for **hydrogen as a transport fuel** and develop a **rollout strategy** that will contribute towards

- Decarbonising surface transport
- Creating new economic opportunities
- Diversifying energy supply
- Reducing local environ-mental impacts

UK H_2 Mobility

UKH2M purpose: create a sound analytical basis to provide a long-term vision for a hydrogen rollout strategy for the UK

1 Consumer perspective

- Market research shows that **consumers are receptive to functionality of FCEVs**
- However, high **TCO** and lack of **HRS infrastructure** are **significant barriers** to adoption
- **Early adopters** of FCEVs (~10%) are environmentally motivated and technology-savvy
- **Fleets** show **high interest** in FCEVs but limited willingness to pay a TCO premium

2 FCEV

- **Demand forecast** suggests highlight the long-term potential of hydrogen mobility, with 1.6 million FCEVs expected in the UK by 2030, subject to step changes in costs after 2020

3 HRS

- Early HRS deployment will be phased, with 10-20 stations in key regions by 2015 (such as London and the South-East England), increasing to ~65 by 2018/20 across the country
- Later **rollout** would follow **hydrogen demand** as vehicle fleet increases
- New **HRS can be profitable** up from 2020s as part of a **continuous rollout of vehicles**

4 Production Mix

- **Hydrogen** will be produced from **a mix of ultra-low carbon and conventional sources,** delivering a 75% CO_2 saving compared to a conventional diesel vehicle by 2030
- **Water electrolysis** can provide **additional benefits** to the wider energy system, thereby reducing cost of hydrogen production by 15-20%

5 Economics & sustainability

- The financing need to seed the early HRS network is ~60m before 2020
- A national infrastructure deployed by 2030 would need HRS investments of ~400m, though much of this could be financed conventionally based on future fuel retailing profits

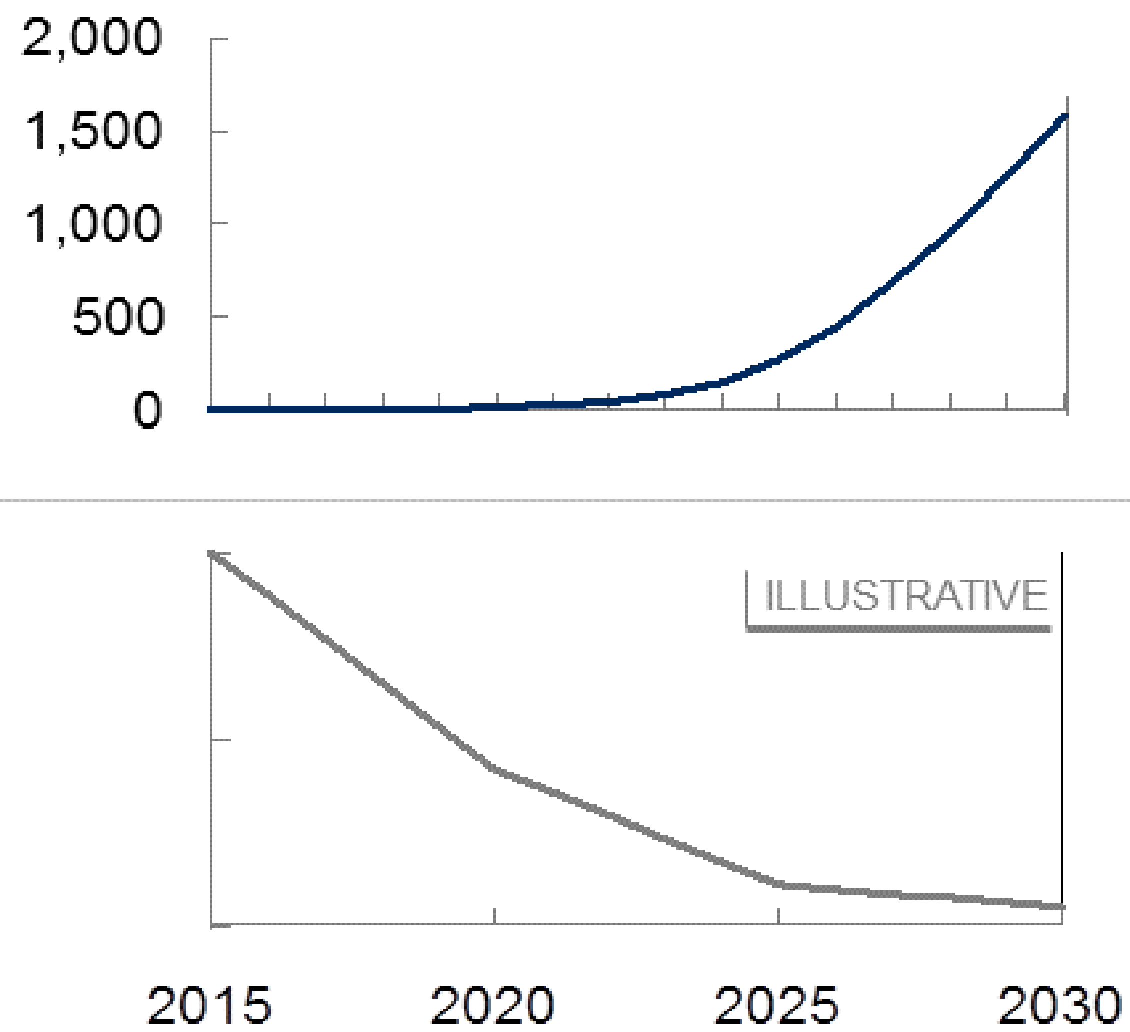
6 Benefits

- Hydrogen transport provides several benefits to the UK, including:
  - **CO_2 abatement** of >30 mn tonnes annually by 2050 and **avoidance of local emissions**
  - **Improved energy security** (>GBP 1 bn per year balance of payments benefits in 2030)
  - **Economic advantages for the UK** as it becomes a leading global H_2 market

UKH2M Demand forecast shows that a cumulative FCEV fleet of ~1.6 million FCEVs could be reached by 2030 as ownership costs decline over time

FCEV car parc (cumulative)
Thousands

FCEV ownership cost premium (illustrative)



Annual FCEV sales
Thousands

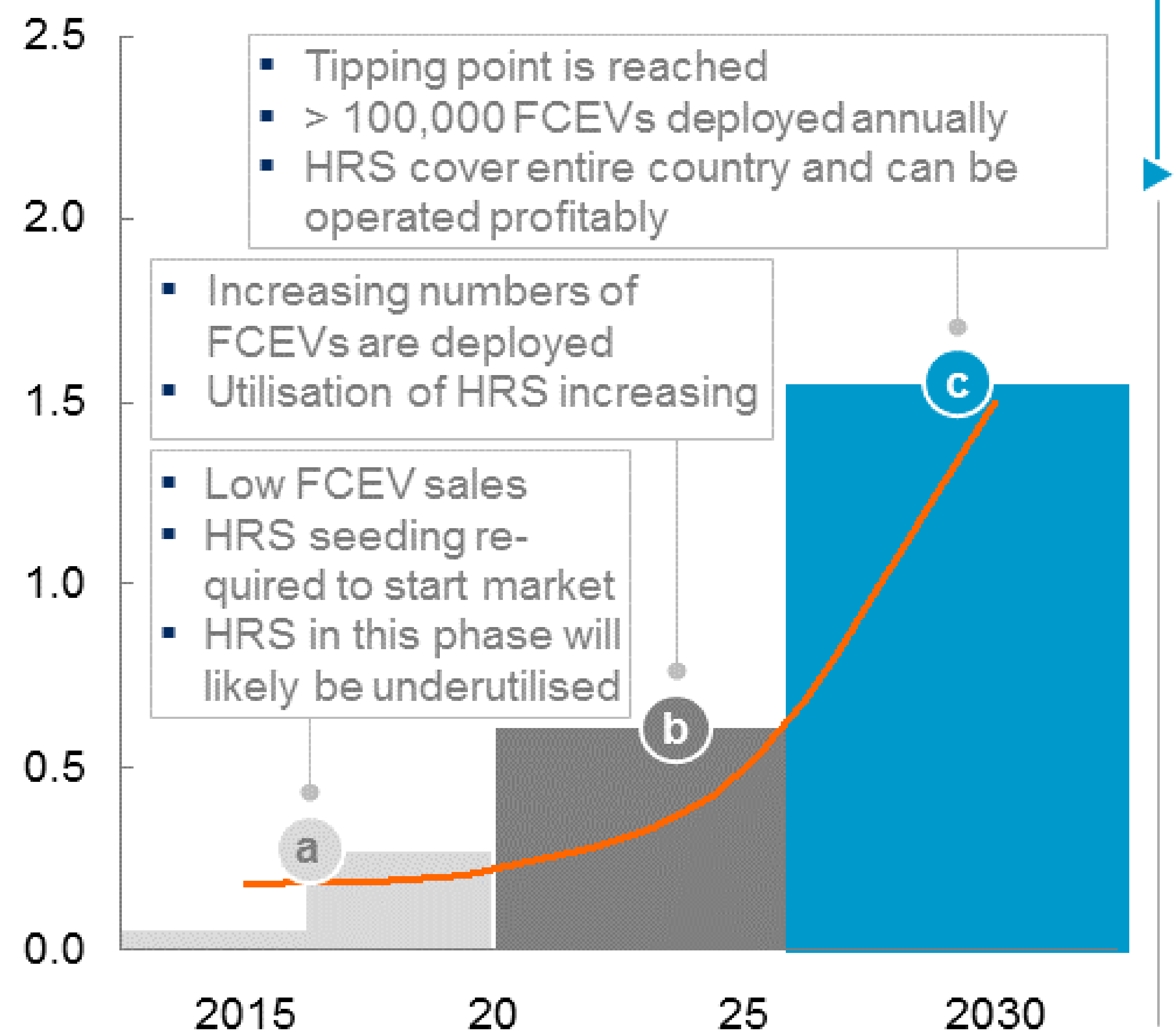
	2015	2020	2025	2030
Annual FCEV sales (Thousands)		~ 10	> 100	> 300

FCEV ramp-up

- Demand projections based on **FCEV price estimates** provided by OEMs through a **Clean Team**
- **First series-produced FCEVs** will come to market in 2015
- **Early phase will require support** to meet price requirements of early adopters or fleet users
- **Mass market deployment during 2020s,** as 2nd generation FCEVs are expected to bring significant cost reductions

The rollout of FCEV and HRS in the UK is likely to be characterised by 3 very distinct phases requiring tailored action

Cumulative FCEV car parc
Units millions



Potential success factors

a

- Mechanisms need to be found to de-risk investment into underutilised 'seed' HRS
- Support for early vehicle and HRS rollout is required due to high cost early on
- HRS in this phase will be phased, for example with a strong regional focus for the earliest stations
- Coordination of rollout necessary to maximise coverage for a given no. of HRS

b

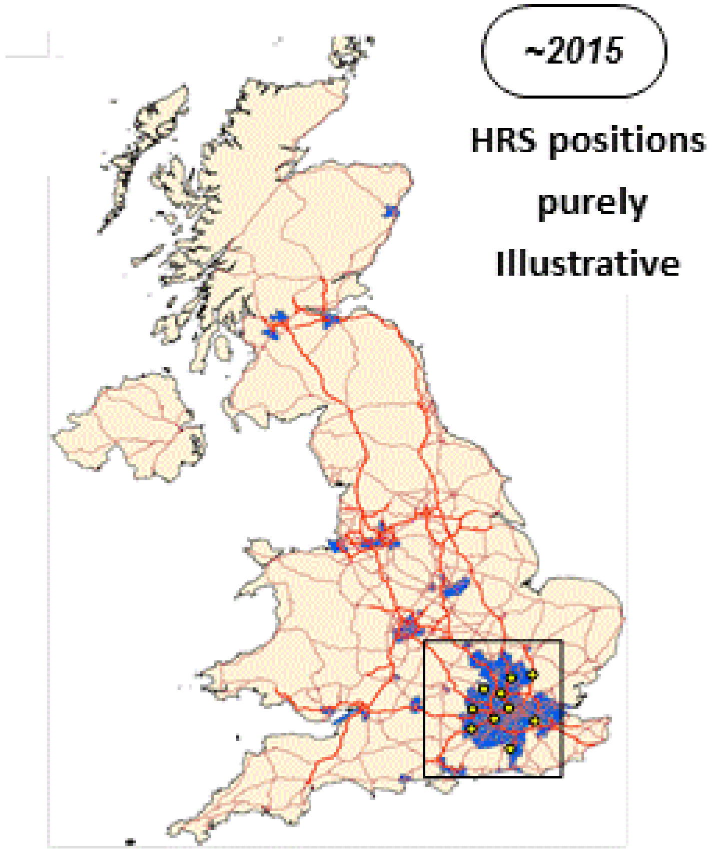
- As FCEVs become price competitive, infrastructure rollout needs to accelerate
- Policy uncertainty should be avoided as market starts to pick up

c

- As FCEV become suitable for the mass market, HRS could become very profitable
- Potential for taxation without harming the infrastructure and vehicle case is potentially established

Deployment of HRS in the UK would follow a 3-step approach, with HRS locations reflecting customer demand and local initiatives ('nucleation' not 'highways')

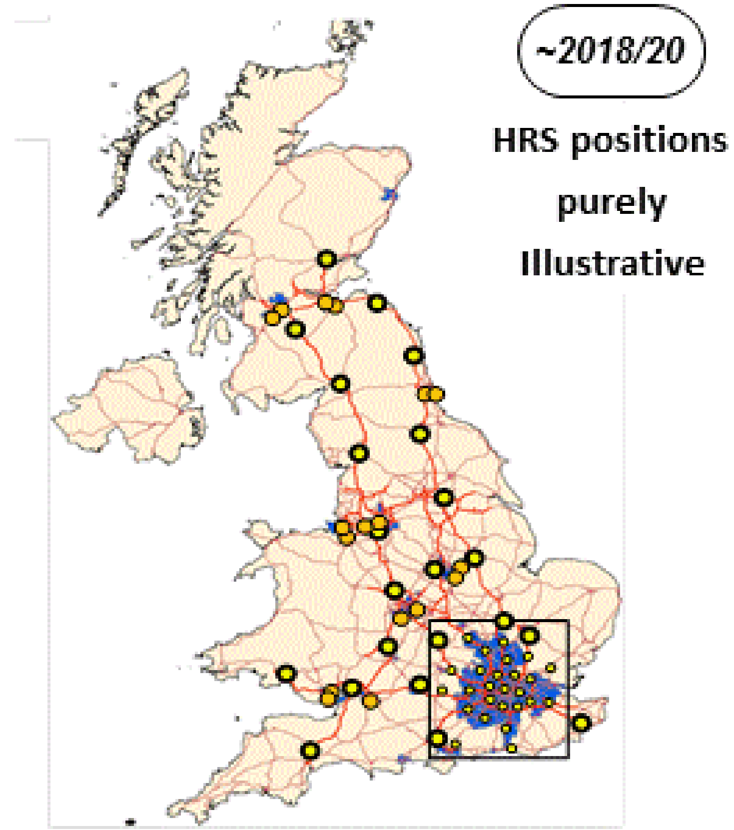
First coverage provided in targeted launch areas



# of HRS: ~10

Strong regional focus for earliest HRS e.g. London and South-east England

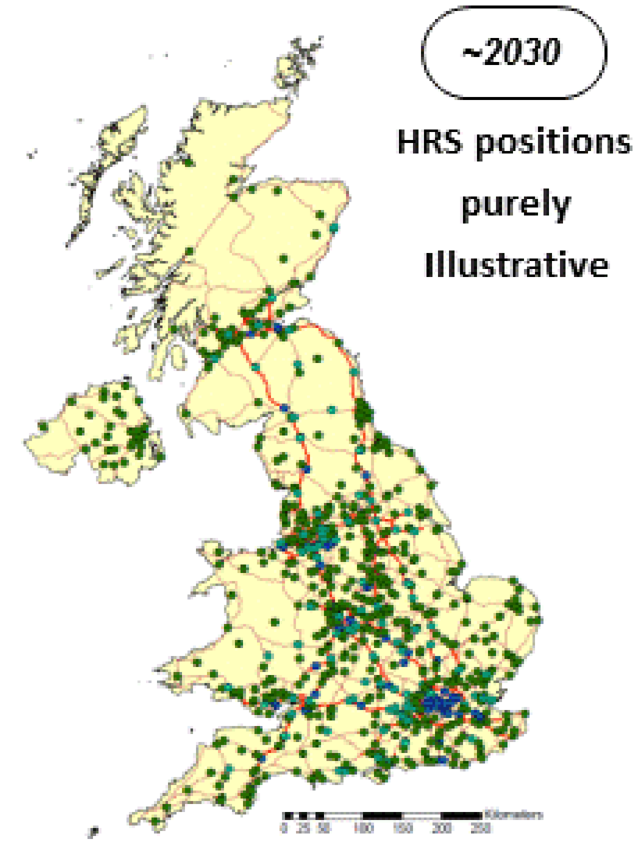
Additional clusters and basic national driving covered



# of HRS: 65

Extend coverage to additional urban clusters, enable basic national driving

Transition to full population coverage by 2030



# of HRS: 1,100

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

Confirmation that Hydrogen transport can provide a set of important national benefits to the UK

	Long-term benefits of hydrogen infrastructure
A CO_2 emissions	▪ FCEV CO_2 emissions ~75% less than equivalent diesel car in 2030 ▪ CO2 abatement between ~10 mn and ~30 mn tonnes of CO2/year possible by 2050
B Local emissions	▪ FCEVs have no harmful tailpipe emission and could lead to significant health benefits ▪ Air quality damage costs could be reduced by ~100-200 mn GBP/year in 2050[1]
C Energy security	▪ Domestic energy activities could increase by up to 1.3bn GBP/year by 2030, improving the UK's balance of payment
D Economic effects	▪ Setting up FCEV and H_2 production in the UK could provide high-skilled jobs and additional value creation ▪ UK could become international lead market for hydrogen transport if skill base and competitiveness develops

+ Wider benefits

- Hydrogen transport could provide **additional benefits** to society such as reduced noise levels, reduced health care cost due to reduction of ultrafine particles and reduced cost for cleaning public places from exhaust emissions, etc.

1 Based on calculations using Defra's Air Quality Damage Cost Guidance

UKH2Mobility outcome: a deployment strategy, with government support, to allow a transition from the earliest adopters to national hydrogen mobility

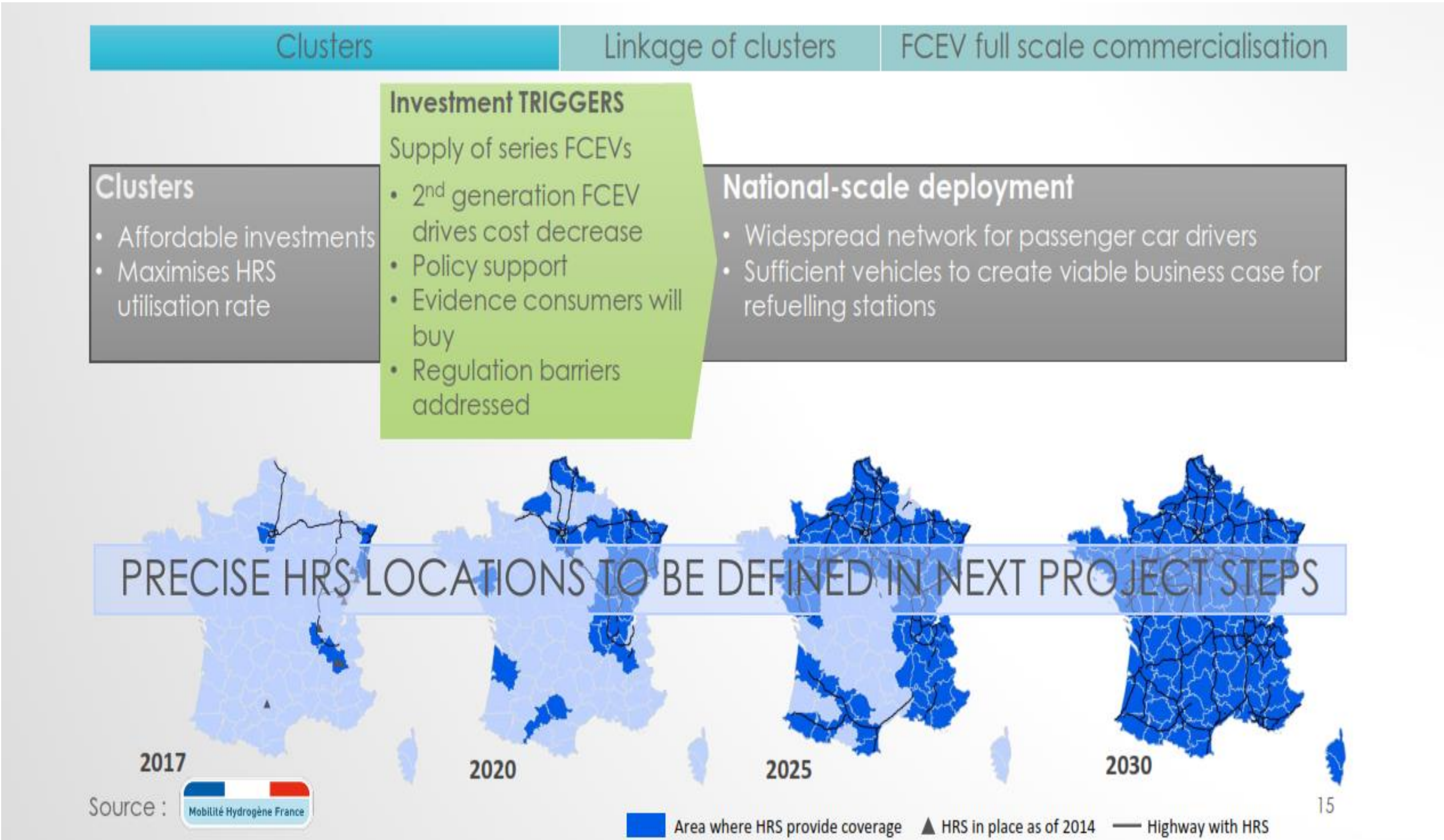
Short term deployment and business structure

- **The early rollout will be challenging**, due to limited production volumes and relatively high costs for both FCEVs and HRS
- By following the phased approach outlined above and deploying in selected regions, **funding needs and risks are minimised for all parties**
- By planning all phases and the milestones in advance, **each party has confidence in continued commitments by all others** subject to the agreed conditions being met
- It also gives an opportunity to assess customer demand and the performance of the early network, **allowing refinement of the strategy before follow on investments**
- The strategy is based on **investments by individual organisations, with overall co-ordination** to ensure optimum HRS coverage and a consistent customer experience
- This co-ordinated approach **maximises the benefits of joint working** (e.g. avoided duplication), while avoiding the complexities associated with large joint ventures

Transition to national hydrogen mobility

- Technical analysis and market research carried out by UK H_2Mobility have **highlighted the long term potential for hydrogen mobility in the UK**, as a complement to wider efforts to decarbonise the transport sector
- The deployment strategy proposed will **prepare the UK for the mass market deployment** of FCEVs in the 2020s, by providing a plausible customer offer and basic refuelling network ready for subsequent expansion
- In the long term, it will enable a **profitable and self-sustaining HRS network**, while offering ownership costs similar to conventional diesel cars

H2Mobility France – a focus on back to base fleet vehicles



H2Mobility France – strategy to 2020

HRS + FCEV: NUMBER AND TYPE, PHASES…

- Core Customers identified
- First clusters should be deployed
  - 500-700 fleet Vans
  - Tens of Trucks
  - 15 to 20 HRS
    - Bi-pressure dispensing close to borders
    - 350bar for local fleets
    - Mixture of on-site production and delivered H_2 depending on relative advantages at each site
- Levels of ambition among the regions will determine early locations
- And create trans-border corridors
  - German corridor towards Dusseldorf
  - Belgian corridor towards Brussels and Netherlands

Source : Mobilité Hydrogène France

EARLY CITIES AND FIRST CORRIDORS

26

Hydrogen London – a FCH test bed to achieve multiple objectives

Private sector investment in hydrogen and fuel cells in London has been in the tens of £millions, resulting in a wide range of proven applications, demonstrating the market readiness of the technology:

- Total private sector investment in London has been in the tens of £millions.
- On a global level in 2014, fuel cell sales exceeded $2.2 billion (up from $1.3 billion in 2013)[1] and over 100,000 fuel cells were shipped worldwide.[2]

Construction & specialised applications

- *Unsubsidised, low power fuel cell units are in use in lighting towers, CCTV and road signs across London.*
- *Welfare cabin application has been demonstrated with a fuel cell providing heat and power.*

Lighting towers e.g. for construction

Welfare cabin heat & power

Fuel cell & solar powered lighting for construction at the Olympic park

Transport

- *Hydrogen cars, buses and delivery vans are now on the roads in London.*
- *Fuel cell car costs have reduced by 95% since 2002 and cars can now be purchased for c.£50,000.*[3]

Stations at Hendon and Heathrow; up to five more planned by late 2016

Fuel cell cars in operation e.g. Green Tomato Cars, TfL fleet

Fleet of 10 hydrogen-diesel delivery vans (100% congestion charge exemption)

Fuel cell buses on a dedicated hydrogen route

Fuel cell taxis demonstrated during London 2012

Heat and power

- *London is the European capital for fuel cell combined heat and power (CHP), with the largest installed capacity of any European city.*
- *Gas fuel cell CHP has been installed without subsidy to meet new build planning guidelines.*
  - *In other cities such as Seoul, hydrogen and hydrogen-ready fuel cells are starting to be used for megawatt-scale CHP, showing the potential for London.*

Quadrant 3, Regent Street

TfL's Palestra Building

20 Fenchurch Street

HYDROGEN LONDON working towards a hydrogen economy for London and the UK

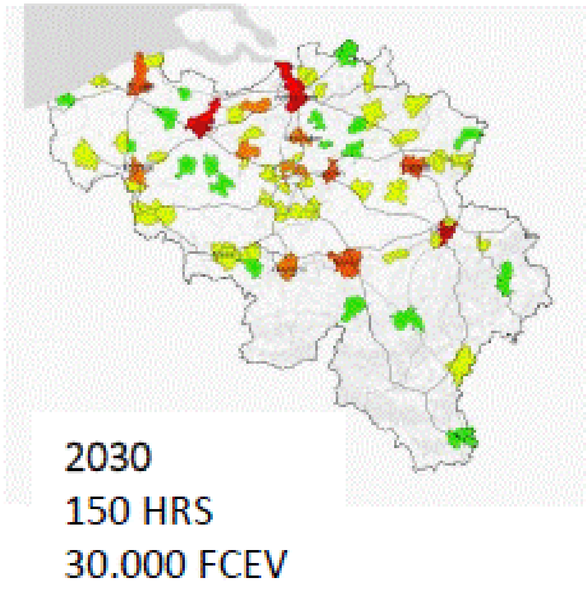
Europe – FCH JU, Hydrogen Europe, TEN-T, EC Directives

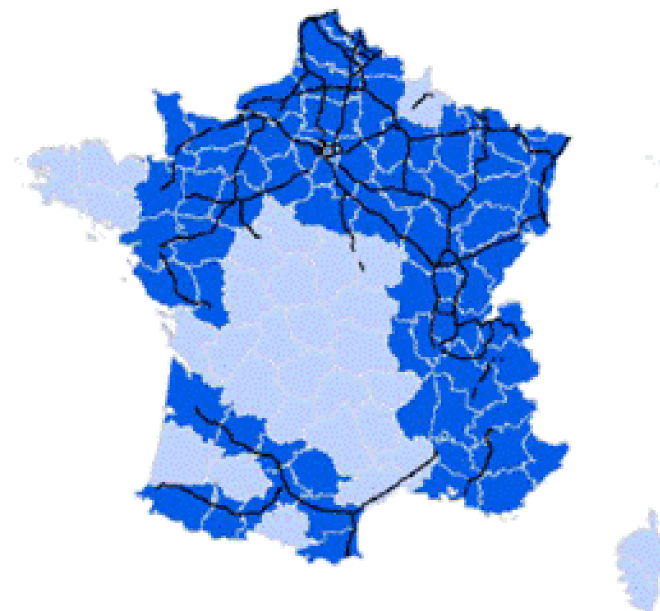
First/Second generation series vehicles from several major OEMs are already or will soon be on the market to start commercialisation of FCEVs in key markets including Europe.

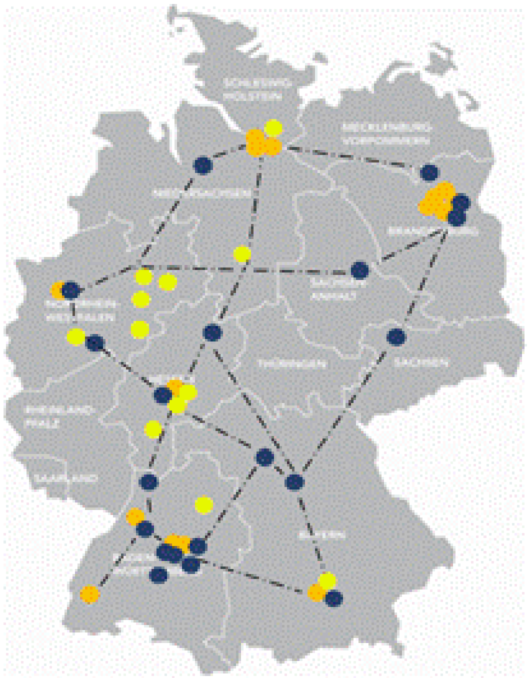
Range extender light duty vehicles are an alternative solution for commercial fleets and for the very first few years

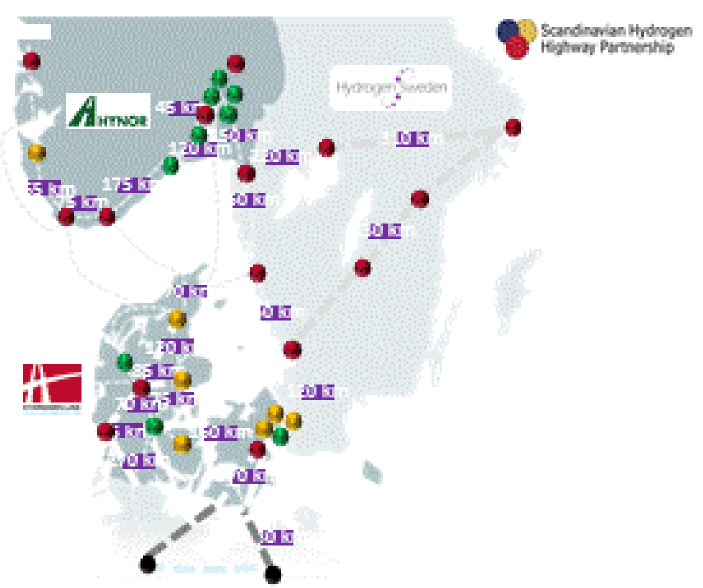
City Busses have been developed by several European OEMs and successfully demonstrated.

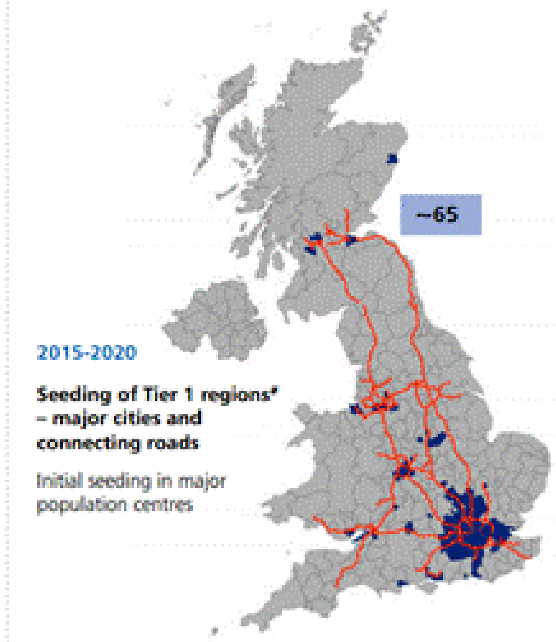
Grouping the existing Hydrogen Mobility plans & initiatives to create the start of a European hydrogen network











Similar plans are starting or being conceived in other countries: eg, **Austria, Italy, Finland, Poland, Hungary, Latvia**

European hydrogen network rationale

European Climate Foundation forecasts: if the European car fleet moves to advanced hybrid, battery electric and FC vehicles (80% of the fleet in 2030, 100% in 2050), impacts on fuel imports, employment and air quality could be significant :

	No further improvement scenario (CO_2 emissions : 135g/km)	Current Policy initiatives scenario (CO_2 emissions target : 95g/km)	Rapid introduction of advanced EV (FCEV/BEV/PHEV) (15/20/45 % of fleet in 2030)
EU fuel bill in 2030	203 Bn€	162 Bn€	136 Bn€
Direct tailpipe GHG emissions in 2050	612 Mt	377 Mt	100 Mt
Direct particulate emissions in 2050	53,2 kt	32,4 kt	3,6 kt
EU job creations in 2030		0,5 M net add creations	1,1 M net add creations

European H2Mobility – Lessons and Leverage

- **There's no single 'solution' for driving H2 Mobility / commercilaisation programmes further or faster forward**

  - Wide variances in industrial (specifically auto makers, H2 gas suppliers and new FCH technology player presence), along with differing political landscapes, have mitigated against seeing a common approach emerge

- **There's been a common theme though across programmes in looking to identify and quantify economic and benefits of transition to Ultra Low and Zero Emission vehicles in national fleets**

  - Each of the mainstream H2Mobility programmes has made a detailed and objective assessment of the underlying economic benefits of FCEVs regarding CO_2 (a mandated control requirement in some areas), NO_2/NO_x, PM and other air quality related emissions, along with health related benefits and energy security impacts
  - This has been seen at multiple local (City or/and Region level), National and wider international (EC) level s

- **Direct governmental involvement sees both upsides and downsides**

  - The upside is that there is potential for directly influencing supportive policies relating to FCEV vehicle and supporting infrastructure introduction through the early roll out stages
  - But the downside is that it requires more time to build the inter-governmanetal consensus and address the use of resources / no 'white elephant' / and 'technology neutrality' concerns across multiple constituencies
  - This is an easier act at the City or/and Regional level than National level

European H2Mobility – Lessons and Leverage

- **Mixture of fleets and vehicles with a typical focus on volume passenger cars**
  - The main H2M programmes have taken the view that preparing for the volume passenger car fleets is the most appropriate target
  - This has in some cases overlooked the benefit and impact of introducing and running smaller bus and commercial vehicles in city based fleets
  - Bus programmes deserve wider recognition and are now reaching a more critical mass in Europe
  - REEVs and H2ICE back to base vehicles may prove to be valuable transitional technologies
- **OEMs are playing a long game in their vehicle technology and product mix**
  - Europe has been the ‘dieselheads’ region with air quality consequences and a background of regulatory control and test issues and more stringent CO2 fleet averages will not necessarily accelerate a transition to FCEVs
  - BEVs have won early stage political support in many European areas against ZEV requirements
- **Green versus Brown H2**
  - There has been considerable analysis of H2 pathways for transport fuels - and overlaps with wider H2 strategies for energy storage, power to gas and grid/network implementation. This has shown real progress in approach and thinking but mandating Green H2 as a transport fuel may be missing the point
- **There’s still a lot to do on immediate RCS issues and legal barriers that European H2M programmes have overlooked**
  - Europe still has much to do at the national and international level on RCS matters, including practical points around FCEV vehicle and HRS infrastructure interfaces and vehicle use (bridges, tunnels, parking and service centres) – and the legal barriers to deployment that remain in national and local legal codes

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