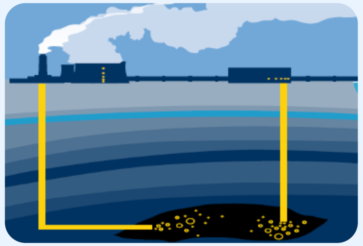

The challenges of hydrogen delivery to support heavy duty vehicle decarbonisation

Safety and Loss Prevention Special Interest Group

16th June 2021

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Project Introduction

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- This summary is part of a much larger project Element Energy is conducting on behalf of the GB and Ireland GDNs and National Grid
- The project was NIA (Ofgem) funded
- The project was completed in January 2021 and the final report can be found using the link at the bottom of this page
- The project built a detailed narrative of the transition of the GB economy to net-zero by 2050
- The report highlights the key technical and legislative barriers to meeting net-zero under different scenarios
- A key outcome of the project was to understand the role of different fuels, green gas (biomethane, bio-SNG and hydrogen) and electricity in this transition
- A key focus of the work was to understand the role of transport as an early catalyst for low carbon fuel production and distribution

Steering Group

Cadent

Gas Networks Ireland

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The project explored decarbonisation pathways across the whole economy with a focus on the role of heavy duty vehicles in accelerating decarbonisation

Project Approach

- The project looked at the role of electricity, hydrogen and biomethane as decarbonisation vectors across transport, residential heating, non-residential heating and industry
- Demand for electricity, hydrogen and biomethane were modelled from the bottom up based on consumer/industry choice as a function of cost
- The work focused on heavy-duty vehicles (trucks, buses, coaches, etc.) to understand their role in scaling up demand and driving down costs
- The work modelled two core decarbonisation pathways (High Electrification and High Hydrogen), with additional sub-scenarios to explore the role of biomethane, for practicality, emissions and cost to government

High Electricity	High Hydrogen
Low electricity prices supported by smart RES and demand integration and low-cost storage drives uptake of electricity as the dominant clean fuel	Rapidly increasing H_2 production scale brings down costs. H_2 similarity in use to fossil fuels means it is popular with end users

Narrative Key Findings

Timeline

HGVs could be an important early H_2 user helping to boost production/distribution scale, while also acting as an anchor load for cars, vans & buses

H_2 HGVs start with a commercial demonstration, transition to back to depot medium haul applications and then enter the long-haul market with public refuelling

H_2 HGVs directly displace biomethane HGVs in the long-haul stock between 2035–2045. At the same time, the public refuelling infrastructure could be converted

Impact

Increasing H_2 demand in transport builds scale and brings down costs, making H_2 and H_2 derived fuels more accessible to decarbonise other sectors

H_2 HGVs can operate on longer routes in the 2030s when BEV are still technology constrained, helping to accelerate decarbonisation

Large HGV HRS need piped H_2 and can act as a purification and distribution center for other H_2 transport demand decreasing overall costs

Challenges

The largest 10% of HGV HRS will be between 5-20t/day and will dispense 32% of HGV H_2. These stations can only be fed by pipeline

Pipeline H_2 contains contaminants meaning the H_2 must be purified before it can be used in a vehicle. The purification process needs further development

To succeed H_2 requires scale which relies on success across sectors. This means H_2 requires diverse stakeholders to work towards a common goal

HGV: Heavy Goods Vehicle. BEV: Battery Electric Vehicle. HRS: Hydrogen Refuelling station

A major part of this work looked at delivering hydrogen refuelling stations for HGVs and the possibility of converting CNG/LNG stations over to hydrogen as the market shifts

Hydrogen refuelling stations

- Hydrogen refuelling stations today are designed for cars or buses and are much smaller (<1t/day) than those potentially needed for HGV (up to 20t/day)
- The advantage of bigger stations is reduced cost per kg of hydrogen dispensed
- The drawbacks include:
  - Distributing hydrogen becomes very complex (we assume distribution by compressed tube trailer is practical up to a station size of 3t/day)
  - On-site storage requirements can exceed COMAH limits requiring increased safety standards
  - Distribution by pipeline requires hydrogen purification before use in a vehicle

CNG station conversion to hydrogen

- We have explored the following areas:
  - Land
  - Site Preparation
  - Equipment
  - Operations

To answer the question: does a network of CNG stations facilitate the transition to hydrogen station?

HGV: Heavy Goods Vehicle. CNG Compressed Natural Gas

While bigger vehicles and greater hydrogen demand offer better economics they also pose major challenges for safety

- CNG/LNG stations already exist in the middle of this size range capable of delivering ~50t/day
- HRS installed today are mostly for buses and cars and are much smaller than those presented here
- Proposed Nikola HRS in USA, supplied by Nel, will start at 8t/day with the option to expand up to 32t/day

	Number of Large HGVs Refuelling (refuel/day)	CNG/LNG Station Size (t/day)	Hydrogen Station Size (t/day)	Notes
Small	100	13	4	
Small	200	26	8	*Proposed in USA*
Small	300	39	12	
Large	400	52	16	*Today's in UK*
Large	500	65	20	*Today's in UK*
Large	600	78	24	
Large	700	91	28	
Large	800	104	32	

We looked at a number of different HRS designs to understand if they impact the station conversion success

The gas station is converted in **one go or over a 5 to 10 year period**, keeping some gas dispensing capacity during the transition into a hydrogen refuelling station. The period length will vary with station size: ca. 5 years for small station, ca. 10 years for large stations.

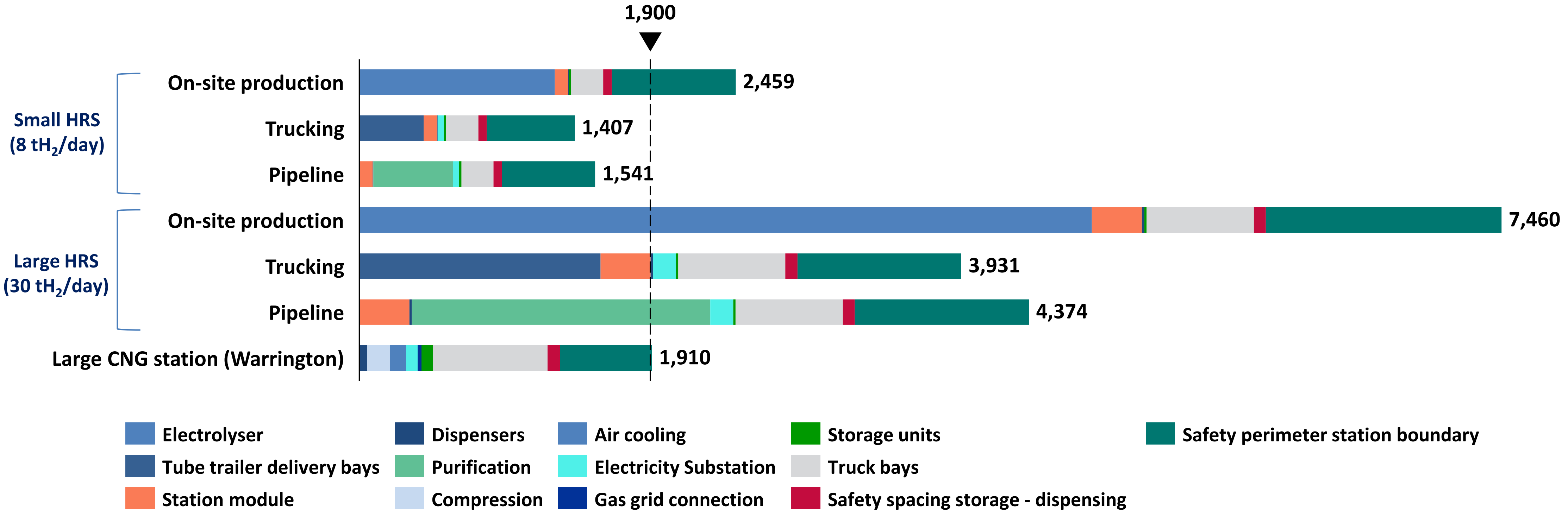
The HRS designs we included in this study were:

HRS design	**Current deployment**
hydrogen is **produced on-site using an SMR, fed with biomethane**, and is dispensed at 350bar	None in UK but technology exist
hydrogen is **produced on-site using an electrolyser** and is dispensed at 350bar	Common current approach
hydrogen **arrives on-site through the gas grid, the hydrogen is separated and purified** before being dispensed at 350bar	At R&D stage
hydrogen is **trucked to the station in tube trailers** and is dispensed at 350bar	Common current approach

Comparison of the station footprints show that a large CNG station site only has space for a small HGV hydrogen station

Station Area

- On-site production is characterised by large footprints associated with the footprint of the electrolyser arrays, which is unfeasible for large scale stations.
- Trucking of hydrogen brings slight footprint reductions as it avoids the need for large purification set-ups that would be needed for cleaning hydrogen delivered by pipeline.

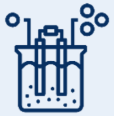
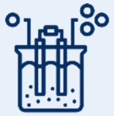
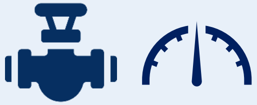
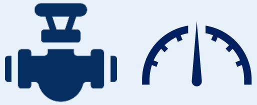


Summary of the main benefits and drawbacks of the different pathways

Benefit/ Drawback	On-site Electrolysis	On-site SMR	Trucked Hydrogen	Hydrogen by Pipeline
Option is available in the near term	✓	✓	✓	✗
Option works at large station scale	✓	✓	✗	✓
Option can be scaled across the industry	✓	✗	✗	✓
Reuse gas grid connection	N/A	✓	N/A	✓
Reuse electricity grid connection	✗	✓	✓	✓
Easy to meet H_2 purity needs	✓	✓	✓	✗
Large on-site hydrogen storage requirements	✓	✓	✗	✓
Large station footprint	✗	✗	N/A	✓
Can meet net-zero well to wheel emissions	✓	✗	✓	✓

✓ Benefit ✗ Drawback

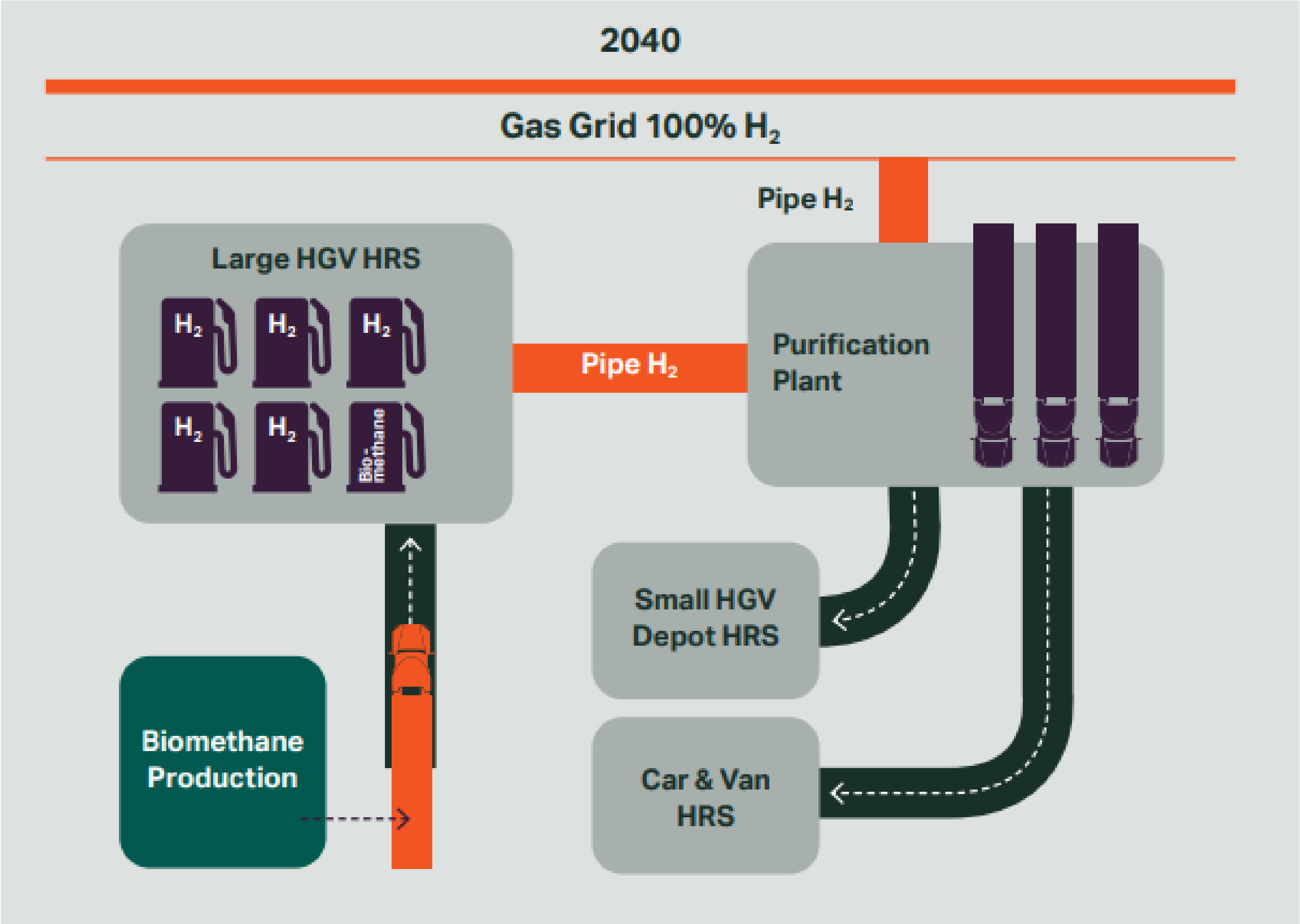
New stations built from 2030 are more and more likely to rely on piped hydrogen as the network is converted

Timeline	HRS Size t/day	HRS Design				
2020-2025	1t/day stations installed to support commercial demonstrations	 Compressed	OR		OR	
2025-2030	Up to 3t/day for early commercial rollout supporting clusters of depots	 Compressed	OR		OR	
2030-2035	Up to 6t/day supporting depot clusters and along motorways	 Compressed	OR	 Blended	OR	
2035-2040	Stations of all sizes up to 20t/day			 Blended Transitioning to Pure H_2		
2040-2045						
2045-2050						

One potential solution would be to locate de-blending and purification hubs on the gas network and then connect to stations by pipe and tube trailer

A possible solution

- Hydrogen purification plants are large and expensive and are best sited next to the gas network to allow non purified hydrogen to be returned to the gas network
- Very high purity hydrogen can be delivered to stations with a short length of new gas pipeline or by tube trailer depending on the size of the station



From this analysis and our database of HGV depots we were able to map the future demand for hydrogen refuelling stations for HGVs across the UK

- The map shows the distribution of stations supplied from the gas network or from hydrogen production sites, either via a direct pipe connection or by trailer delivery from a mother station
- Once the national gas network has been converted to hydrogen most stations can be directly or in-directly fed from the gas network
- To provide full coverage, some less economic locations will need to be served by tube trailer at a significant distance from the mother station
- Some regions in the north and west of England as well as Wales and the Highlands are too far from hydrogen production and would need to be trucked from the network to fill gaps and ensure access to hydrogen for HGVs in every part of the country.

Example results for Cadent's network area in 2050