Tees Valley Multi-Modal Hydrogen Transport Hub Masterplan

Overview

This document provides an overview of the Masterplan for the creation of a set of facilities for the production, storage and distribution of green hydrogen to supply a network of refuelling stations and support operational trials of hydrogen powered vehicles across transport modes and use cases. The facilities also include a a Research & Development (R&D) campus for the creation, sharing and exploitation of knowledge. Collectively this is called a Hydrogen Transport Hub and is to constitute a living lab to understand the viability of hydrogen as part of the energy transition in the transport sector and act as a catalyst for further scaling, subject to the trials' outcomes. The Masterplan is a blueprint for the Hub and has specifically considered its location in Tees Valley – a region with existing capability and infrastructure of relevance. It is vital that this blueprint is taken forwards from 2021, seeking opportunities for early operation of smaller-scale trials as soon as possible, prior to a fully operational Hub from 2025 onwards which will support the primary operational trials outlined in this document.

On 30 September 2020[1], the Secretary of State for Transport announced the Government's ambition to develop a multi-modal **Hydrogen Transport Hub**, with the prospect that this be located in Tees Valley – a region of the UK steeped in industrial heritage and which currently produces more than half of the UK's commercially available hydrogen[2]. Mott MacDonald was commissioned by the Department for Transport to develop a vision and masterplan for the Hub. Support and input were also provided by Aspinall Verdi, RAND Europe and SOIF (School of International Futures).

The study has centred upon Tees Valley to ensure the work is spatially specific rather than abstract. However, **the resulting masterplan can be considered a transferable blueprint** for such a Hub to be located anywhere in the UK. It has focused upon determining a design that is **suitable** (able to support fulfilment of the vision), **acceptable** (able to meet stakeholders' expectations) and **feasible** (able to be delivered, in a timely fashion).

The Hub will be comprised of a set of facilities for the production, storage and distribution of green hydrogen[3], linked to a network of hydrogen refuelling stations that will service **operational trials across transport modes in the period 2025-2030**. Prior to this, opportunities should be taken to introduce "pop-up" demonstrators to test and learn from hydrogen-transport technologies and prepare the Hub for operation. The Hub will also include facilities for knowledge creation, sharing and exploitation as it acts as a living lab that forms part of a national and international network of research and innovation for transport decarbonisation through use of hydrogen.

The Hub will establish the UK as a leader in hydrogen technology and its application in transport. Ultimately the purpose of the Hub will be to deliver evidence to support the use of hydrogen for transport that will inform the DfT's long term strategy, and the role it may play in supporting the decarbonisation of the transport sector in the UK.

Vision

The vision that has informed the Masterplan is as follows:

The Hydrogen Transport Hub will be a living lab (drawing upon the UK's national pool of science and technology talent) of regional, national and international significance that acts as a catalyst for the fulfilment of green hydrogen's role in decarbonising transport across modes. This will establish the region as an exemplar in the development of education, training and skilled employment surrounding green technology that builds upon industrial heritage and which contributes to inclusive green growth and positioning the UK as a global leader in energy transition.

Masterplan

Hydrogen Demand

The facilities in the Masterplan are based upon an estimated total demand for green hydrogen of 12-13,000 kg/day during the primary operational trial period of 2025-2030, the equivalent of 60,000-65,000 litres of diesel or 125-175 tonnes of carbon. 1kg of hydrogen is roughly equivalent to 0.75 gallons/3.4 litres of petrol or diesel.[5]

Table 1 provides a breakdown by mode of demand to form a recommended set of operational trials for 2025-2030 of a scale and nature that are suitable, acceptable and feasible. Demand per vehicle per day is indicative. It would depend upon the specific nature of use cases and vehicle types involved. This would require further, more detailed examination to ensure appropriate hydrogen supply capability is designed and built.

Table 1: Operational Trial Demand by Mode

Mode	Primary Operational Trial	Kg/day demand	Total demand by mode for trial (kg/day)
Light road vehicles	Two in-region trials – LGVs and intensively used passenger vehicles, circa 130 vehicles	5.00[4]	650
Buses	Selected routes with full depot conversion, circa 60 buses	20.00[4]	1200
Coaches	Two corridor long-distance trial (allied to HGV trial below) – assume 10 coaches	20.00[4]	200
HGVs I – long distance	Three corridor long-distance trial using existing hydrogen refueling locations outside Tees Valley – 100 artic HGVs	20.00*	2000
HGVs II – intra region	Expansion of short-distance 'shunts' to cater for additional operators - circa 300 rigid vehicles	7.00*	2100
	Expansion of short-distance 'shunts' to cater for additional operators - circa 30 artic vehicles	20.00*	600
HGVs III – local authority fleets	Full HGV vehicle replacement in single district for short journeys – circa 60 rigid vehicles	7.00*	420
Rail	Conversion of all local Tees Valley rail routes to, from and through and construction of a new depot/stabling facility – circa 15 trains	300.00[4]	4500
Domestic shipping	Land-based port vehicles & plant	1.00**	150
	2 river based small vessels	70.00**	140
Domestic aviation	Airport equipped to be 'hydrogen ready' and in use by airlines developing small aircraft. Trial of land-based specialist vehicles.	400.00	400

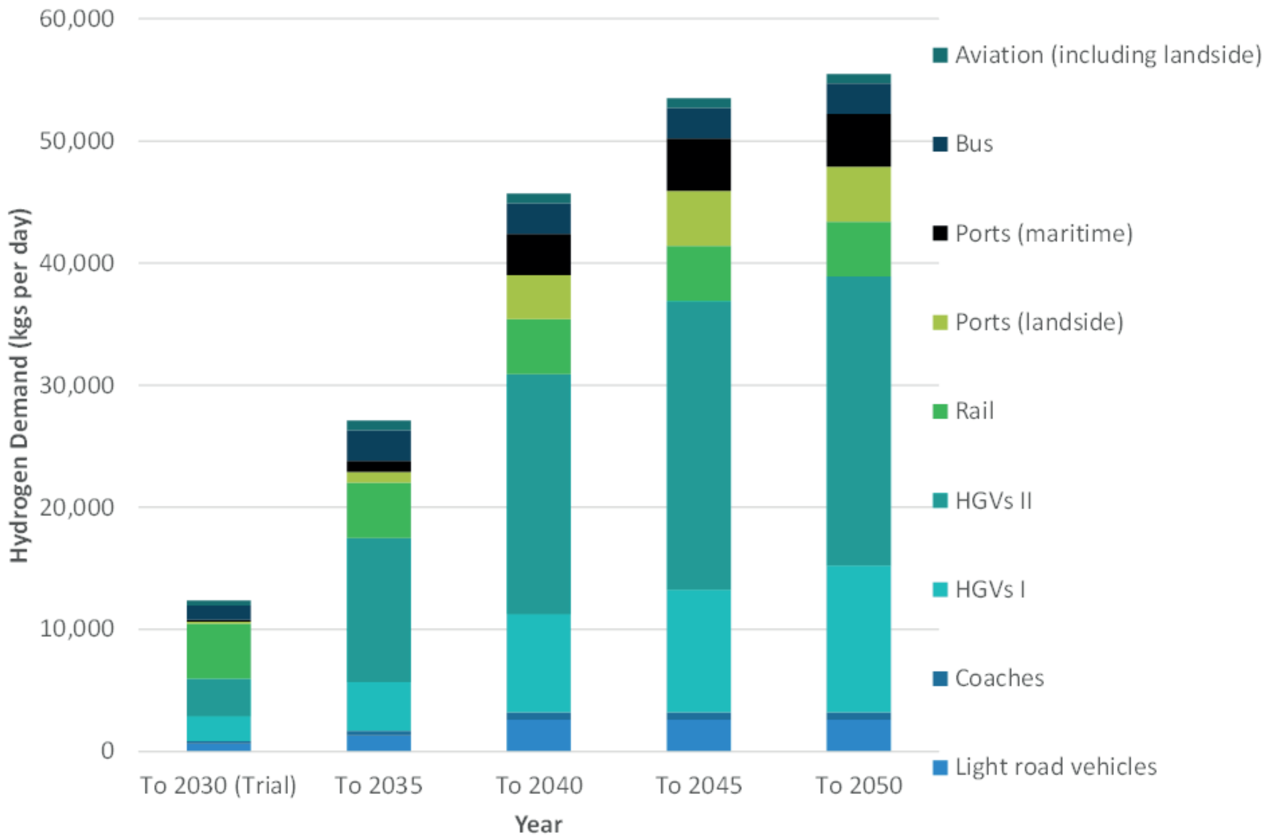
**Assumptions for HGVs are based on DfT Road Freight Statistics (Table RFS0112 and Table TSGB0304 (ENV0104)) and assume 10 downtime days per annum:*

Rigid = 49 daily average miles @ 9.2 MPG with 0.75 imperial gallons = 1kg of hydrogen[5]

Artic = 133 daily average miles @ 9.0 MPG with 0.75 imperial gallons = 1kg of hydrogen[5]

*** Determined through discussions with stakeholders in Tees Valley*

Chart 1: Cumulative demand by mode through to 2050 Source: Mott MacDonald Limited



The purpose of the trials is to test all aspects of the assumptions made in this document, and in future iterations, to enable finalisation of the Masterplan to a greater level of detail. It should be noted that there are a number of variables which could impact upon the demand assumptions in this document which would need to be considered in more detail as part of the next stages of work:

- Use of the modes – Utilisation of vehicles will vary by mode depending upon factors such as their purpose, movement pattern and refuelling habits. For example buses may run for longer hours with a stop-start pattern, compared to HGVs which are required to factor in break time for drivers and are likely to have longer periods without fuel consumption during loading and unloading.
- Daily demand during the trial – It is anticipated that the operational trials will ramp up at different speeds by mode, with some modes being fully operational earlier than others and the potential for some to not be fully realised as suggested. There is scope within the total demand presented for flexibility across the modes in terms of their take up.
- Electrolyser capacity – The proposed modular approach for increasing the capacity of the electrolyser allows for greater flexibility to respond to changes in demand. It is important that the trial period utilises the initial electrolyser capacity efficiently and does not generate demand above this which may require a further electrolyser to come online before there is the demand for this to operate at a viable capacity.
- Technology – Assumptions in this document are based on the capabilities of current technology. It is expected that future development of hydrogen technology will improve over time and support greater efficiencies across the sector, having an impact upon demand across the modes.

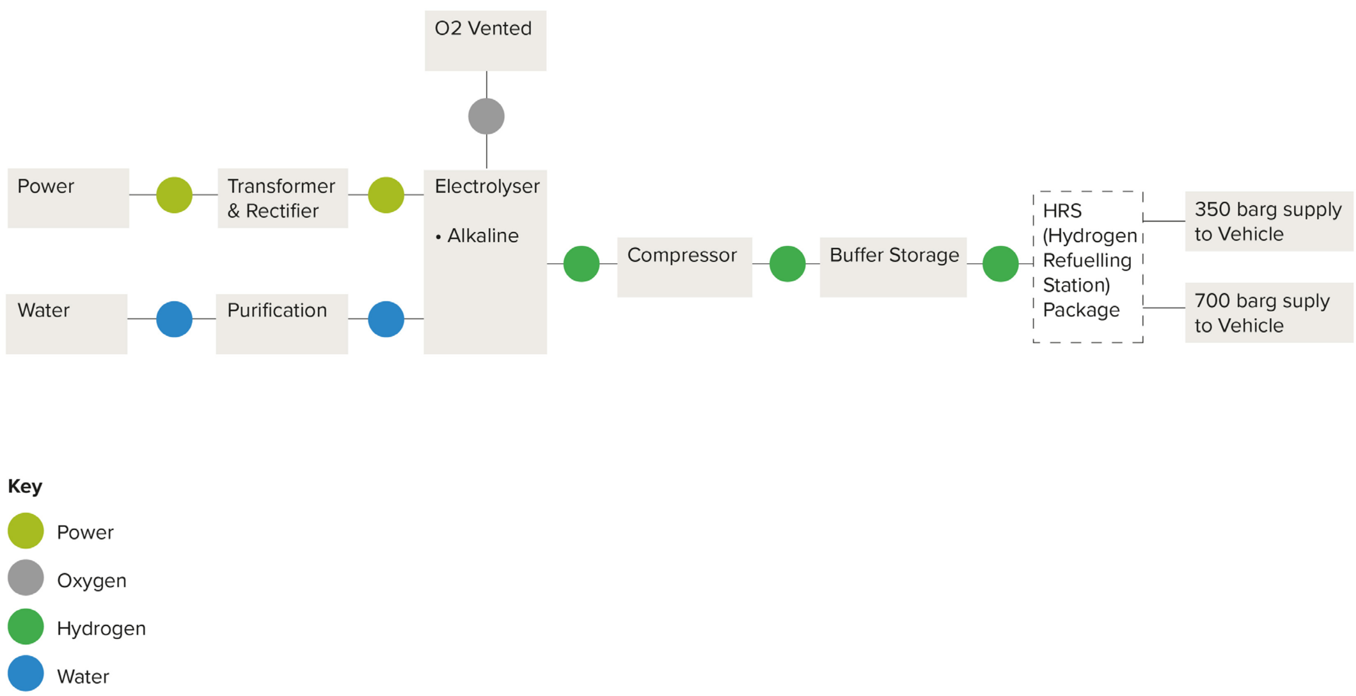
Hydrogen Production

A prerequisite for the Hub is that hydrogen produced must be green hydrogen (notwithstanding scope to consider earlier use of grey hydrogen if helpful to the build-up to a fully operational Hub by 2025). In addition to this it is also important that the infrastructure is proven and reliable and capable of rapid roll out to maintain market confidence. The demand as shown for the operational trials in Table 1 suggest enough initial demand to justify the development of an industrial scale centralised hydrogen production facility, with the ability to allow additional electrolysers to be easily integrated as the demand increases (potentially four blocks of 26 MWH2 HHV (Higher Heating Value) each). It is assumed that the “power” for the electrolyser be sourced from renewables in order to meet the requirement / definition of green hydrogen. Typically, the oxygen produced by the electrolyser would be vented to the atmosphere, however this is potentially a valuable product, and its potential to improve the overall economic performance of the Hub should be considered.

Desirable characteristics and facilities for a centralised electrolyser facility include:

- COMAH (Control of Major Accident Hazards) upper tier status;
- existing energy generation capability and access to utilities;
- access to existing pipe networks;
- lack of environmental constraints and supportive planning framework;
- site security and safety
- on site fire services
- existing transport connections via road, rail, sea; and
- adjacent space for expansion.

Figure 1: Hydrogen Supply - Configuration of the Centralised Production Facility



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Hydrogen Storage

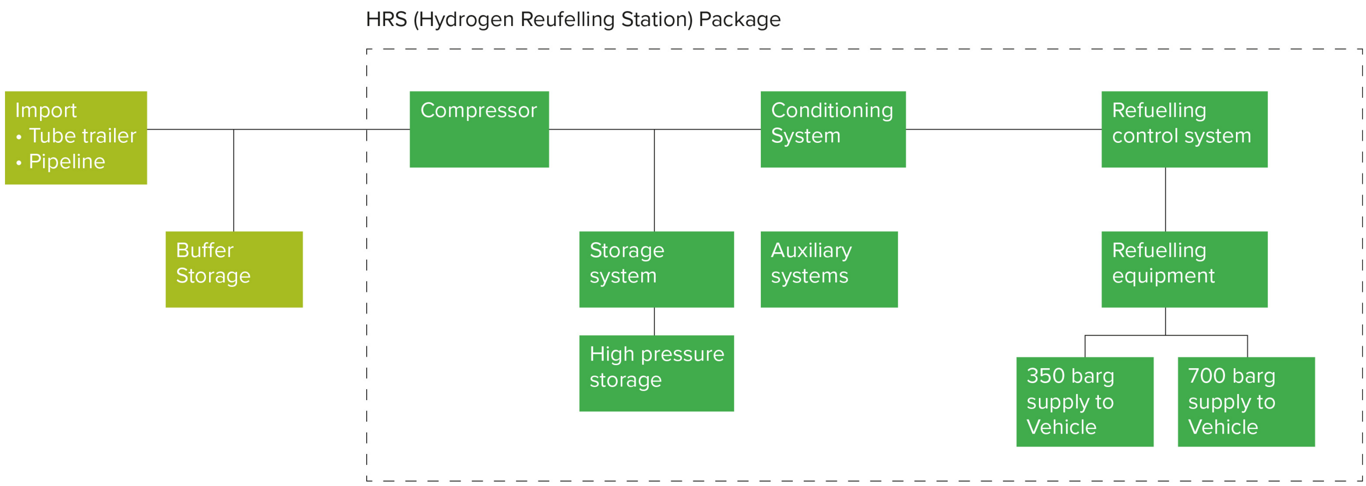
To allow for downtime and changes in daily and seasonal demand, hydrogen storage is proposed for the Hub. Security of supply is the critical factor for a transportation related project, therefore **storage equal to one week's demand has been assumed**. Salt cavern storage is cost effective when storing large volumes of hydrogen and two smaller salt caverns are suggested (as opposed to one larger cavern), one at the start of the project, then one later around 2035 once demand growth had been confirmed.

Hydrogen Refuelling Facilities

The seven initial refuelling locations will be largely dependent on the requirements of the primary operational trials and typically be located near major bus and truck depots, the railway, the port, and the airport. Between 2030 and 2050 it is anticipated that the network would be extended to meet growth in demand with additional refuelling stations (circa 10+) being added.

Modular refuelling stations are quite common, typically coming in convenient incremental capacities. In modular stations the compressor, hydrogen cooling, high-pressure storage, and control electronics are housed in a single container. Using these modules provides a compact refuelling station design, reduces installation time and cost, allows testing at a supplier's factory, and can potentially reduce equipment costs due to the production of standardised units .

Figure 2: Hydrogen Supply - Typical Refuelling Station



Source: Mott MacDonald Limited

Hydrogen Distribution

Distribution of hydrogen to the refuelling stations associated with the Hub is proposed via pipelines. Whilst a pipeline has a high upfront cost and would require time to obtain necessary permits in comparison to transportation by road or rail, once operational, a pipeline network would provide lower operating costs, and better safety and expandability. It is possible that some distribution by tube trailers may be required to support the primary operational trails until demand is increased and the pipelines are available. Distribution of hydrogen by tube trailers on HGVs may also be necessary to serve refuelling stations at locations where it is infeasible to be piped.

R&D Campus

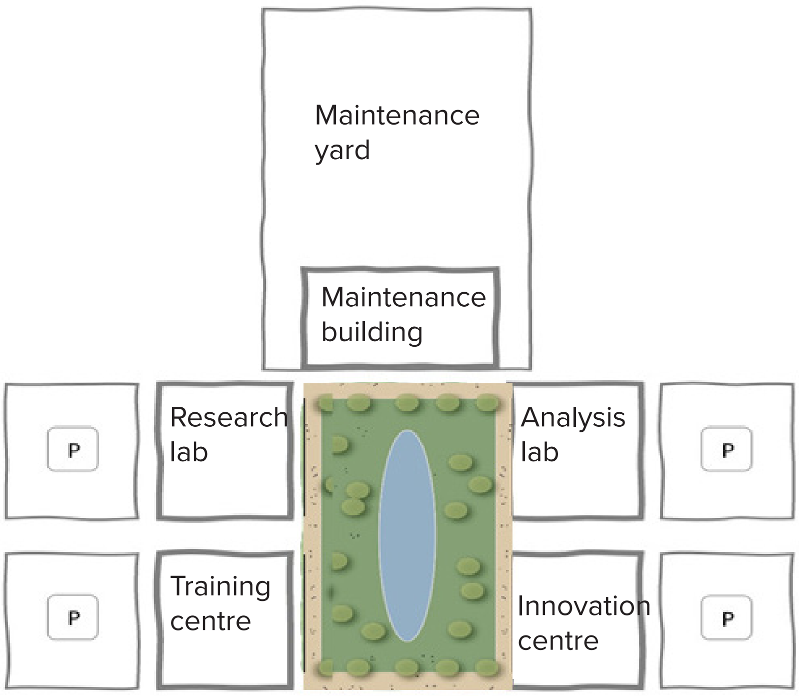
For the Hub to fulfill its function as a living lab[6] it needs to include a range of facilities dedicated to research and development as well as a supportive incubation/ innovation/ acceleration space for entrepreneurs. The design of the Hub's campus therefore needs to support agglomeration, collaboration and creation of a sense of place. Easy access by rail and road would be beneficial.

Identification of the requirements for the Campus has been informed by a review of existing examples of similar business and industrial parks in the UK. The key components of the campus are shown in Figures 3 and 4 and considered over two phases:

Campus development – Phase 1 (operational by 2025)

- **Innovation Centre** - provides flexible office, coworking, meeting and conferencing spaces to support businesses and academic institutions who seek to capitalise on opportunities provided by the Hub and seek to test out then scale up their activities
- **Research Lab** - provides large warehousing-type space to support experiments on hydrogen fuelled vehicles and should be specially designed to accommodate all modes of vehicles being considered

Figure 3 – Suggested Campus configuration



Source: Mott MacDonald Limited

- **Analysis Lab** - provides bench space and facilities for chemical engineering research to support trials, researchers, academics and wider research and development activities.
- **Training space** - supports upskilling required in hydrogen-related activities and will support the training of apprentices and professionals.
- **Yard space and maintenance space** - supports specialist maintenance of vehicles involved in the trials. Expansion space will be required as the trials are scaled up.
- **Ancillary development** - A 120 bed hotel to support business travellers to the Hub (and wider regional and national associated undertakings), a small-medium scale conference centre to support exhibitions and events linked to the activities at the Hub and retail space (convenience food retail provided in line with campus development).
- **Phase 1 expansion space** - provides grow-on space for businesses as they move out of the innovation centre but still want to be in the supportive environment of the campus.

Campus development – Phase 2 (as demand dictates)

- **Expansion space and associated development** - expected to accommodate private sector businesses and be built by private developers in line with a masterplan developed during the delivery of Phase 1.

Figure 4 – Suggested Campus layout

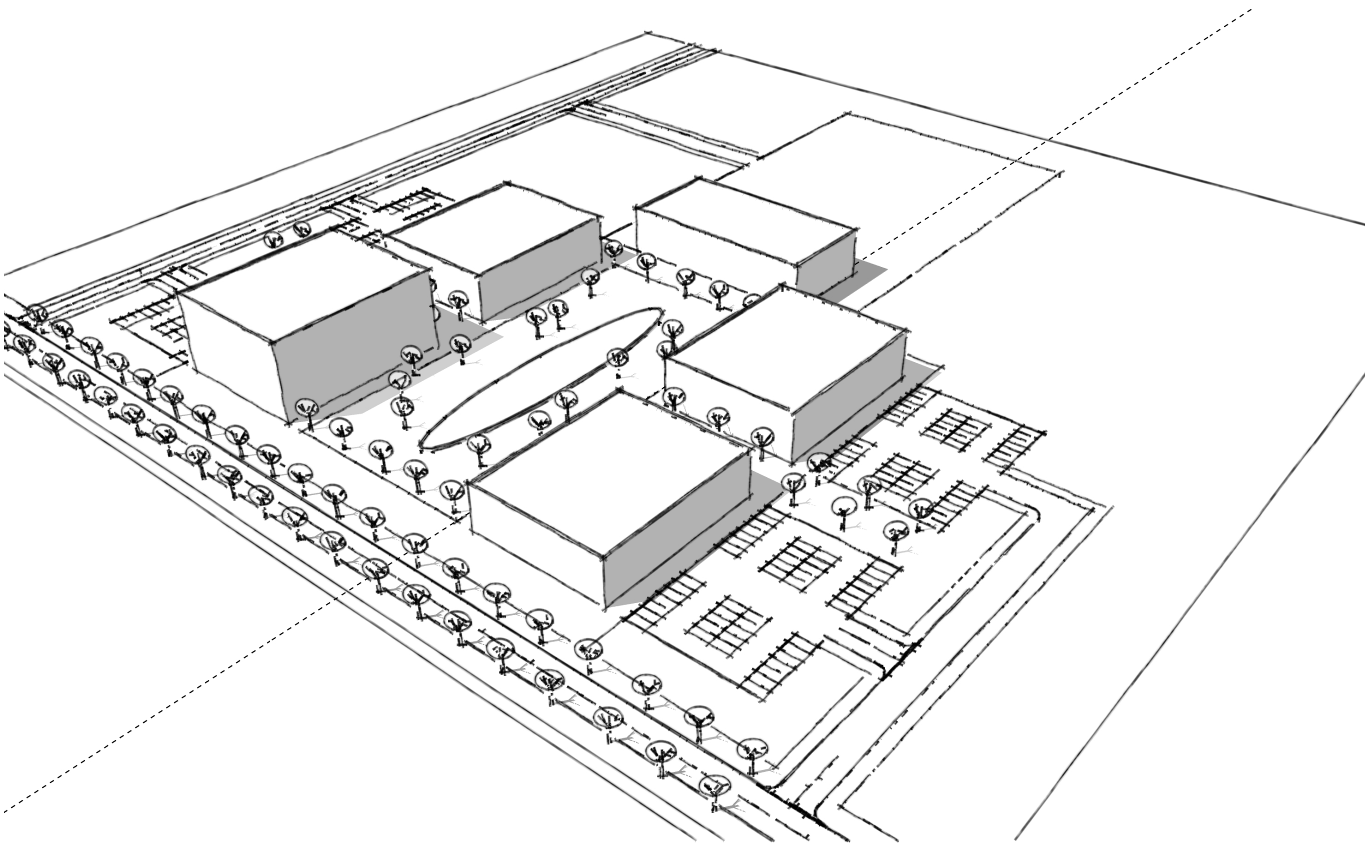
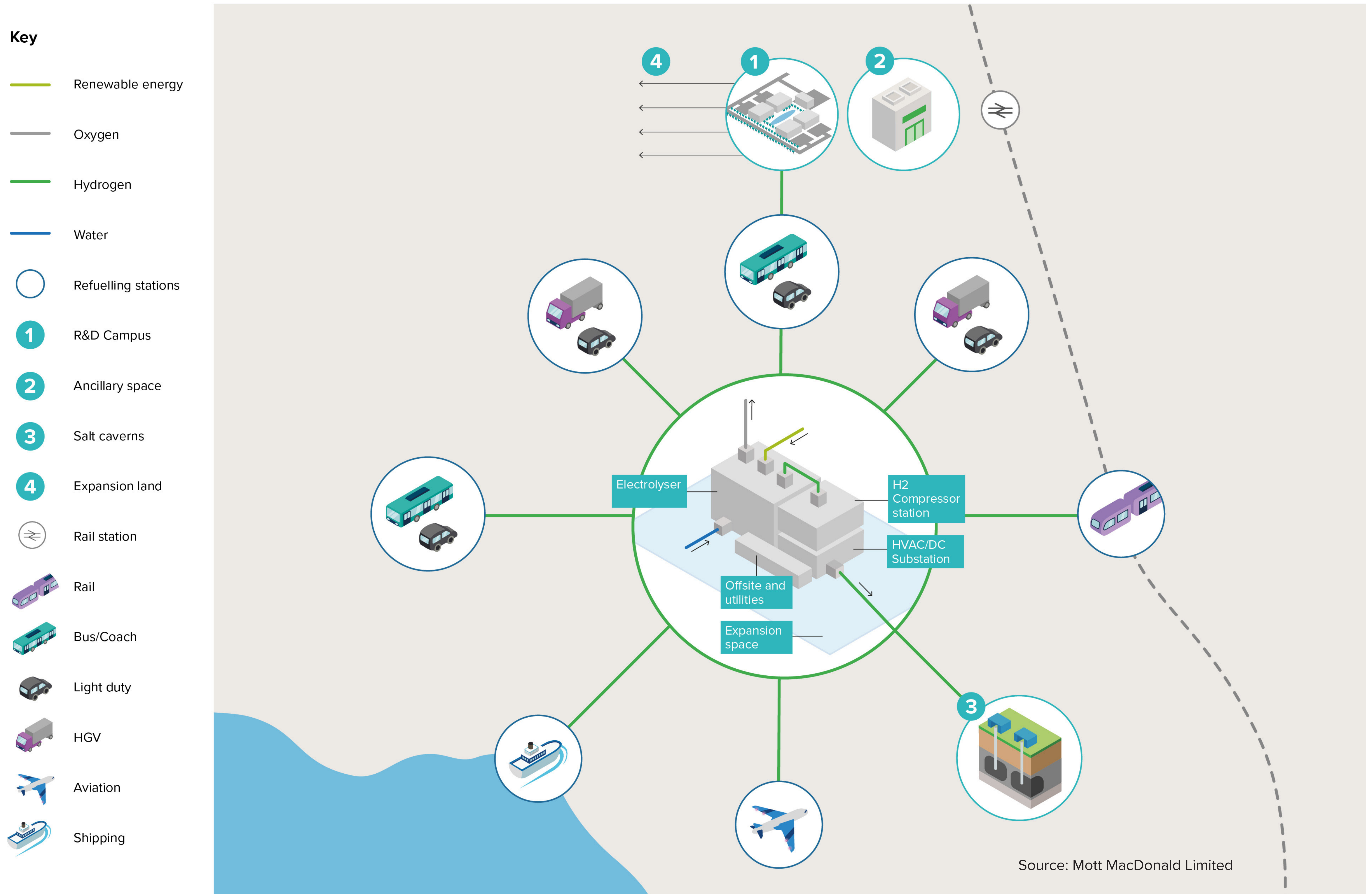


Figure 5 – Masterplan Overview (2025-2030)



Source: Mott MacDonald Limited

Costings, benefits and risks

Costings

It is assumed that costs are staggered to follow the expected increase in hydrogen demand. In round numbers the total CAPEX for hydrogen supply infrastructure through to the end of 2050 is about £415m, excluding financing and assuming all equipment is bought at today's prices. The figure for the Campus (Phase 1 only) is about £50m. The annual OPEX is projected to increase over time as capacity is added reaching about £12m in the 2040s (excluding electricity costs).

Table 2 provides a breakdown of CAPEX and OPEX costs over the period of Hub from 2021 to 2050.

Table 2: CAPEX and OPEX costs during the lifetime of the project (4,5)

Description	2021-2025	2025-2030 (Trial Period)	2030-20345	2035-2040	2040-2045	2045-2050	Project total
Required Hydrogen Production (kg/day)	-	12,500	27,500	46,500	54,000	56,000	-
No. of blocks in Centralised production (1)	-	1	2	3	4	-	-
No. of Refuelling Stations	-	7	13	15	17	17	-
CAPEX (£ millions) (2)(3) (Hydrogen Infrastructure)	118	106	117	68	6	0	415
OPEX (£ millions/yr)	-	4	6	10	12	12	-
Campus CAPEX (£millions) (6)	50						50

Notes:

1. Each Electrolyser block will have a capacity of 26 MWH2 HHV. One new block will be installed at the start of each period.
2. Includes pre-investment in pipelines and cavern storage.
3. Excludes cost of land.
4. CAPEX/OPEX does not take into account cost reduction of key elements, financing or stack replacement and electricity, dementalized water and other utility costs.
5. Numbers rounded
6. Campus expansion to be taken forward by SPV/PPP with costs of development considered by partners as demand builds from 2025 with further development being a mix of public and private with mostly private sector investment anticipated. Opex assumed to be covered by operators.

Benefits

In total across Phases 1 and 2 at full build-out the Hub could support 3,900 net direct jobs on-site and in total 5,000 net additional jobs once multiplier effects are included. The net additional GVA pa from net direct jobs supported is around £370m at full build out which results in a **£3.0bn Present Value** benefit when profiled over 30 years based on the likely persistence of the jobs created. This only relates to the jobs on site and within the supply chain, and does not include wider industrial or sectoral growth.

Indicative carbon savings can be estimated by applying a carbon emission factor to the amount of diesel which would be expected to be displaced by the substitution of hydrogen (no account has been taken of embodied carbon or emissions associated with the production and delivery of the fuel). Applying standard conversion factors for hydrogen to diesel, a diesel emission factor of 2.67 kgCO_2/litre of diesel and taking the quantities outlined for the operational demand projection gives a total annual carbon savings of 170kt/yr and 725kt/yr for 2030 and 2050, respectively, based on the demand shown in Chart 1. In cumulative terms the saving would be almost 10 million tonnes of CO_2 over the period 2030 to 2050. Further iterations of this Masterplan will be based on sustainable development principles to support savings through the development and operation of the Hub.

The Hub will support UK leadership in the development of new standards for hydrogen vehicles and infrastructure technology, to be implemented as the infrastructure expands.

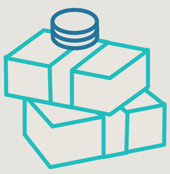
Jobs:

3,900

net direct jobs

5,000

net additional jobs



GVA:

£370m

Present Value:

£3.0bn

Source: Mott MacDonald Limited

Risks

There are numerous risks associated with the development of the masterplan and the below is not exhaustive but picks out several of the key points:

- **Operational trials** - Vehicle supply and availability, lack of refuelling infrastructure to support some journeys, supply of hydrogen prior to the electrolyser being operational, stakeholder support and buy in
- **Hydrogen supply chain risks** – Sizing (demand calculations), component and installation cost, delivery, electricity price, performance and interface risks in the delivery supply chain
- **Campus risks** – demand, skills/experience in local labour market, inadequate space, access constraints
- **Other risks** – planning constraints, Health and Safety requirements, competition, investment and stakeholder buy-in, unknown risks that will become clear as the concept is explored further.

Potential mitigation for these risks includes (but is not limited to):

- Early engagement with Stakeholders
- Utilising a UK based supply chain as much as possible for the manufacture of the infrastructure
- Considering partnering with regional Higher Education / Academic Institutions to ensure skill availability and early training momentum
- Review the potential for ‘pop up’ trials prior to 2025 to reduce risk around demand and inform the development of the Hub.

Implementation and Delivery

The hydrogen infrastructure is more likely to be developed as a privately financed independent hydrogen producer/supplier which will be procured under a competitive contracting arrangement. A public-private partnership is a potential way to take the Campus forward. Further assessment work required to develop the Hub concept will need to take into account the management and implementation models to take it forwards.

Work to develop the Hub for it to be fully operational for 2025 should commence in 2021, and in parallel to this, opportunities for implementing smaller-scale or ‘pop-up’ trials should be explored prior to 2025 to inform the development of the Hub, test demand and confirm technology requirements.

Summary

The driving motivation for the Hub is to provide R&D Research & Development facilities and opportunities to enable an early understanding of what the challenges of hydrogen for multi-modal transport may be. The Hub facility and its living lab operations will provide the primary evidence to inform the DfT’s strategies and policy on hydrogen moving forwards and confirm its role in supporting the decarbonisation of the transport sector.

The commencement of early trials as soon as possible will support the design and development of the hub prior to 2025 and inform the scale and nature of the primary operational trials proposed from 2025. It will also provide support for existing commitments in the FY21/22 such as the development and delivery of ZERT and UK Shore Trials.

Disclaimer

This document provides a high-level summary of work undertaken to determine the size, scale and suitability of a Hub in Tees Valley. The outcome was expected to be, and constitutes, an outline design for such a Hub. It allows its configuration, costs, outcomes and practical challenges and uncertainties to be better understood as a basis for more detailed subsequent work.

This study has drawn upon insights and advice from stakeholders which has been considered in good faith alongside cross-checking, where possible and appropriate, with other sources. The content remains the responsibility of Mott MacDonald, as do any errors, omissions or misrepresentations.

Endnotes

1 https://www.gov.uk/government/news/uk-embraces-hydrogen-fuelled-future-as-transport-hub-and-train-announced

2 https://www.southteesdc.com/wp-content/uploads/2020/01/South-Tees-Master-Plan-Nov-19.2.pdf

3 Most hydrogen in the UK and globally is currently produced using industrial processes that generate emissions (grey hydrogen). One alternative is to also capture and store those emissions (then known as blue hydrogen). Green hydrogen is produced using electrolysis that itself draws upon electricity from renewable energy. No CO2 is emitted at point of use or at point of production.

4 Hydrogen Tools. (2020). Available at: https://h2tools.org/hyarc/calculator-tools/energy-equivalency-fuels

5 Integrated Design for Efficient Advanced Liquefication of Hydrogen. (2020). Available at: https://www.idealhy.eu/index.php?page=lh2_outline

6 Which in the first instance is focused upon the transport sector but which could feasibly, given similarities in enabling technologies, evolve to become part of a cross-sector ecosystem of science and innovation supporting the energy transition.

Produced with inputs from:

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