Written Evidence Submitted by the Centre for Energy Transition, University of Aberdeen

(HNZ0082)

About the Centre for Energy Transition

The Centre for Energy Transition looks to embrace the opportunities that lie ahead for north-east Scotland from a just energy transition and support the energy sector through research and skills development. The Centre will also nurture start-ups and spin-outs, building on the University's record of success in this area.

The Centre brings together experts from a wide range of disciplines to tackle themes associated with the transition to net-zero. We work in partnership with government, society and the energy industry to ensure our research has impact and contributes to a sustainable and just energy transition.

Our work extends across themes including the hydrogen economy, carbon capture and storage, renewable generation and the circular economy – all key components of the path to net-zero. Each of these themes bring together experts from law, natural science, engineering and social sciences to produce research that has a direct societal and economic impact.

Response

2. The progress of recent and ongoing trials of hydrogen in the UK and abroad, and the next steps to most effectively build on this progress.

There is a variety of ongoing or scheduled demonstrative projects covering different aspects of hydrogen production, transportation/storage, and consumption in industry, transport or heating applications.[1] These trials involve proofs of concept at local level, with the expectation to be extended to other regions. Funders include national Governments or EU, with participation of local authorities (and communities), companies and research/academia.

One important focus is to facilitate generation of hydrogen from renewable sources (green hydrogen), to fulfil with the targets towards decarbonisation of the Scottish and the UK Governments:

- Production of 5GW renewable and low-carbon hydrogen in Scotland by 2030.
- Capacity for 25GW of electrolysis by 2045, producing 126TWh per year of green hydrogen.
- 32TWh of green hydrogen to deliver Scotland's deep decarbonisation targets and 94TWh for export by 2045.

There are several projects on power-to-gas conversion using wind energy, either offshore or onshore. The development of electrolysers in the hundreds MW scale is a common target of several projects to achieve scalable operations and competitive prices between green hydrogen and gas (for example). Current projects on hydrogen production/storage include (some examples in Table 1):

- Large scale fuel cells installations, converting hydrogen and renewable methane into power in various applications (0.4 - 30 MW).
- Hydrogen storage and large scale storage.

[1] A. Demirbas Future hydrogen economy and policy Energy Sources, Part B, 12 (2) (2017), pp. 172-181

- Residential micro CHP for single family homes and small buildings (0.3 - 5 kW).
- Mid-sized installations for commercial and larger buildings (5 - 400 kW).

Table 1. Some examples of projects for green H2 Production

Project	Description
FCH JU OYSTER	EUR 5m to investigate the feasibility and potential of combining offshore wind turbine directly with an electrolyser and transporting renewable hydrogen to shore. MW scale.
SGN's H100 Fife project, by Ofgem	Aims to deliver a 100% green hydrogen gas network to 300 homes in Fife, using fixed and floating offshore wind in deeper waters, and build a world-first hydrogen heating network at Methil in Scotland.
Aberdeen Hydrogen Hub, Supported by the Scottish Government's Energy Transition Fund	Generation of hydrogen demand in transport, heat and industry applications. Initial estimated 500kg per day, with demand forecasted to increase to 3.5 tonnes per day of hydrogen by 2030 to meet potential transport demand for road, rail, and marine, as well as for heat and industry applications.
Pioneer Mobile Hydrogen Refuelling Station, NanoSUN	Grant of €2.5M by the European Innovation Council (EIC) under its pilot Accelerator Programme, to develop lowest cost path to delivery of transportation grade fuel to point of use.
Iberdrola – Scottish Power	Installation of 600MW by 2025, with the first green hydrogen projects expected to be announced in 2021 focussing on decarbonising large industry, food and drink and heavy transport.
BIG HIT project in Orkney	Supported by the FCH JU, to generate hydrogen from wind and tidal energy in the Orkney islands.

Key parameters and targets for 2030 to produce hydrogen from renewable electricity for energy storage and grid balancing using electrolysers are summarised in Table 2.

Table 2. Some examples of projects for green H2 Production (https://www.fch.europa.eu/soa-and-targets)

Electrolyser Technology	Electricity consumption	Capital cost	Operation / maintenance cost	Degradation	Current density	Use of catalysts
	kWh/kg	EUR/kW	EUR/(kg/d)/yr	%/1000hrs	A / cm^2	mg / W
Alkaline	48	400	16	0.1	0.8	0.7
Proton exchange membrane	50	500	21	0.12	2.5	0.1-0.4

To bridge the transition towards green hydrogen, more investment in blue hydrogen technologies is advisable, combining steam methane reforming and carbon capture and storage in depleted wells through the Acorn CCS and Acorn Hydrogen projects (https://pale-blu.com/acorn/). At this respect, the reuse of decommissioned offshore O&G platforms has great potential to use already existing infrastructure and technical means available in the UK, including the National Decommissioning Centre.

Hydrogen production must be coupled to distribution networks and consumers, and must consider balancing with other energy vectors. Several trials in the UK demonstrate the feasibility at local level (see Aberdeen Hydrogen Hub or H100 Fife). This requires developing infrastructure for transportation in pipelines or refilling stations for discrete storage (in tanks), and contrasting with electrification. Several models account for the availability of wind/solar/tidal energy to produce hydrogen, and its potential transport and storage prior to consumption. Table 3 summarises some trials to reconvert existing gas networks into H2 or H2/CH4 pipelines, which requires repurposing up to a maximum % of hydrogen, followed by complete replacement (to avoid leaking and cracking).

Table 3. Some examples of projects for H2 Transportation: Green hydrogen blending in the natural gas for Household usage.

Project	**Description**
HyDeploy Project – UK 20% green H2 blend in NG	hydrogen trial underway at Keele University. £7 million project led by Cadent in partnership with Northern Gas Networks with various other key participants
Grhyd Project First 6% then, increase to 20% in later stage	ENGIE trial. Natural gas distribution network Le Petit village in France, and an NGV refuelling station for buses;
ARENA, funding to Australian Gas Network	feasibility of blending 10% hydrogen into natural gas networks for selected regional towns in South Australia and Victoria.
Snam, Italy	NG transmission network in Contursi Terme (Salerno) 7 billion cubic meters of green hydrogen/year
Planned	ATCO's initiation in Janadakot, Australia Turkey's plan to test green hydrogen injection from 2021 Westküste100 green hydrogen project HyPSA project, Australia

Table 4 illustrates some demonstrations on applications for H2. More effort should be driven to understand the implications of interconversion between energy vectors and the costs (economic and energetic) of converting and storing hydrogen. In such scenario, final user applications should be encouraged by engaging with companies in industry power, transport and heat sectors, to make that technology visible, available and flexible to citizens.

Table 4. Some examples of projects to promote H2 demand, focused on the user end/application.

Project	**Description**
UK Chancellor	£10 million fund to help UK's world-famous distilleries go green by switching to low carbon fuels such as hydrogen, biofuel boilers and geothermal energy in their production processes. Using hydrogen to heat thermal oil to replace steam in the distillation process, or direct fuel switching from fossil fuels to hydrogen.
Scotland's first hydrogen	Scottish Enterprise, Transport Scotland, the Hydrogen

powered train.	Accelerator, Arcola Energy and a consortium of industry-leaders in hydrogen fuel cell integration, rail engineering and functional safety to deliver.
Study on Fuel Cells Hydrogen Trucks, Roland Berger	Commissioned by Fuel Cells and Hydrogen Joint Undertaking, aims to unlock the full commercial potential of hydrogen truck's potential, with an estimated total budget of EUR 470 million.
HyFlyer2 project, EMEC	Supply green hydrogen from Orkney for hydrogen-electric aircraft development programme, £12.3 million funded project. The aim is to build hydrogen fuelling systems required to power the aircraft for flight tests, including its mobile fuelling platform designed to suit an airport environment.
GenComm, Logan Energy	€9.4 Million project funded by the Interreg program VB North West Europe (NWE344), that will address the energy sustainability challenges of communities in North West Europe through the implementation of smart, hydrogen-based energy solutions. First hydrogen refuelling station in Europe to adopt the MC Filling Method, currently under consideration as a future standard hydrogen fuelling protocol for passenger vehicles.

At a global level, the 18 richest countries in the world have implemented programs to apply hydrogen energy solutions. China, Japan, USA and South Korea have agreed to produce 10 million fuel cell cars and realize 10,000 refuelling stations by 2030[2]. Research on hydrogen by the EU is instrumented through the Fuel Cells and Hydrogen Joint Undertaking, which funds a series of state-of-the-art and future targets projects on hydrogen generation, and fuel cells application in transport and energy (https://www.fch.europa.eu)/. Other recent international plans include Spain's green H2 Roadmap with 2030 milestones, Chile's National Green H2 Strategy, and Europe's aims for 300GW of offshore wind by 2050.

4. The infrastructure that hydrogen as a Net Zero fuel will require in the short- and longer-term, and any associated risks and opportunities;

Transport has been identified as a promising application area for Net Zero fuels, in particular hydrogen[3]. Successful trials of hydrogen vehicles in Aberdeen (including buses and fleet vehicles[4]) and elsewhere have demonstrated the viability of use of hydrogen technology for road vehicles; however, they have also increased recognition of the investments necessary for developing this to its greatest potential. Hydrogen technologies in the transport sector have been vaunted as particularly germane for fleet vehicles, due to shorter refuelling times and more extensive ranges than battery electric vehicles[5], in combination with their obvious emissions benefits. These benefits are perhaps of particular advantage in the commercial sector (such as heavy goods vehicles). However, such advantages are currently difficult to

[2] Hydrogen Council Path to Hydrogen Competitiveness A Cost Perspective, Hydrogen Council Report, January 2020 (2020)
[3] Low Carbon Innovation Coordination Group (2014). Technology Innovation Needs Assessment (TINA): Hydrogen for Transport Summary Report. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/593457/H2_for_Transport_summary_report.pdf
[4] http://hyer.eu/best-practices/h2-aberdeen/
[5] https://www.euronews.com/living/2020/02/13/hydrogen-fuel-cell-vs-electric-cars-what-you-need-to-know-but-couldn-t-ask

fully realise given the lack of a network of refuelling infrastructure that would allow for long-distance travel. As not all trips are local, transport applications of hydrogen require geographically dispersed supporting infrastructure (including fuelling, maintenance and repair) to make it a viable option. It is estimated that the infrastructure investment for fuelling stations could reach 60% of the total capital costs. Delivery by cryogenic liquid hydrogen tanks is the most economic pathway for medium market penetration. Pipelines are the most effective for handling large flows. Operating costs for pipelines are relatively low.

With respect to the latter point, it is pertinent to note that the maintenance and repair of hydrogen vehicles require specialist training, equipment and parts. For hydrogen to see wide uptake as a fuelling mechanism in the transport sector, it will be necessary to ensure that there is sufficient expertise available to ensure access to reliable support in the event of a breakdown or other maintenance need. This assurance will require access to training and support for investment in necessary equipment on the part of maintenance and repair providers.

To fully exploit the benefits of hydrogen in the transport sector will require, first, engagement efforts between government, industry, researchers and the public to assess high-level barriers, challenges, opportunities, and perceptions. Comprehensive analysis of the requirements for large-scale hydrogen adoption in the transport sector (including safety requirements, fuel availability, infrastructure requirements, training and investment needs in supporting operations and maintenance, etc.) should also be undertaken, including attention to requirements for geographic coverage.

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