Aberdeen Hydrogen Hub

Hydrogen: A Business Opportunity for Scotland workshop

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A range of new fuel cell vehicle types and brands are expected to be available in the next five years

2019	2020	2021	2022	2023	2024	2025

c.100 FCEV cars in the UK, mostly Toyota Mirai and Hyundai ix35

2nd gen Toyota Mirai begins production of ~30,000 stacks per year

Cars

Hyundai Nexo starts UK deployment with 15 vehicles

A range of other cars are being deployed worldwide, likely to come to the UK with the right support regime. Audi, BMW, Honda Daimler, PSA and many Chinese brands all have hydrogen plans in the early 2020s

c.55 buses deployed across London, B'ham & Aberdeen as part of the JIVE project

UK bus builders Wrightbus and Alexander Dennis actively developing FC buses for UK and export markets

>200 additional buses deployed in the UK due to H2Bus Europe and other initiatives

Buses

20 single deck buses (Wrightbus and Van Hool) are running in London and Aberdeen

JIVE 2 will deploy 32 buses in Brighton & Dundee. Additional projects under development in Liverpool and Scotland.

Demo projects / development

Early commercial

Mass market introduction

Source: Element Energy

These new models and brands will increase the choice for hydrogen vehicle customers, but will only enter supportive markets

2019	2020	2021	2022	2023	2024	2025

Small fleets of ULEMCO dual fuel hydrogen trucks in operation

HV Systems H2Van due for UK deployment

Numerous Chinese initiatives to develop FC vans (e.g. SAIC), potentially available in the UK in the 2020s

Vans

125 Symbio/Renault Kangoo vans operating in the UK and France

787 Symbio/Renault Kangoo vans planned for EU deployment

StreetScooter to produce over 400 Work L vans for DHL and Innogy in Germany

Alstom & Eversholt develop FC-powered "Breeze" trains based on Class 321 EMUs

Vivarail develops Class 230 hydrogen train

Hydrogen fuel cell trains deployed in the UK

Freight and other train types to be prototyped

Trains

2 Coradia iLint trains started carrying passengers in Germany in Sept. 2018

Siemen's Mireo Plus H prototype to be completed

Demo projects / development

Early commercial

Mass market introduction

Source: Element Energy

The HGV sector is a key target market for hydrogen technologies, but the availability / choice of vehicles is currently limited

2019	2020	2021	2022	2023	2024	2025

Scania deploys 4 fuel cell trucks for ASKO in Norway. FCH JU project for 15 trucks (with European OEMs) begins

ULEMCO dual fuel street sweepers and vans deployed in Aberdeen

1,000 FC trucks project deployed in Switzerland (2023), aim for 1,600 by 2025

Trucks

Switzerland's "1,000 trucks" project begins (Hyundai Hydrogen Mobility)

Nikola Tre enters European production

Scania refuse truck deployed in Sweden

FC truck development and demonstration project with IVECO and VDL launched

Demo projects / development

Early commercial

Mass market introduction

Source: Element Energy

Various other potential sources of demand for hydrogen exist and could grow in Aberdeen over the coming years

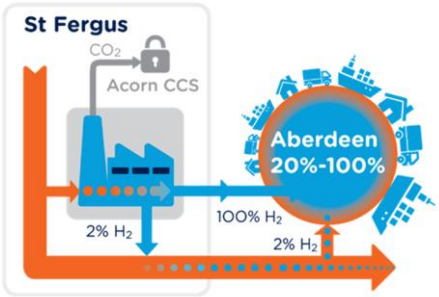
Materials handling vehicles
(available today)

Source: HyLIFT EUROPE

Marine
(prototypes from early 2020s, larger roll-out from mid-2020s)

Source: Windcat Workboats

Hydrogen for heat
(from mid-2020s)



Source: SGN

We have identified a wide range of potential demands for hydrogen via the extensive stakeholder consultation exercise conducted in this study

- Council fleet (>400 vehicles)

Source: ULEMCo

- Buses and coaches (c.200 urban buses and 30+ coaches)

Source: First Bus

- Trucks (hundreds based locally)

Source: www.commercialmotor.com

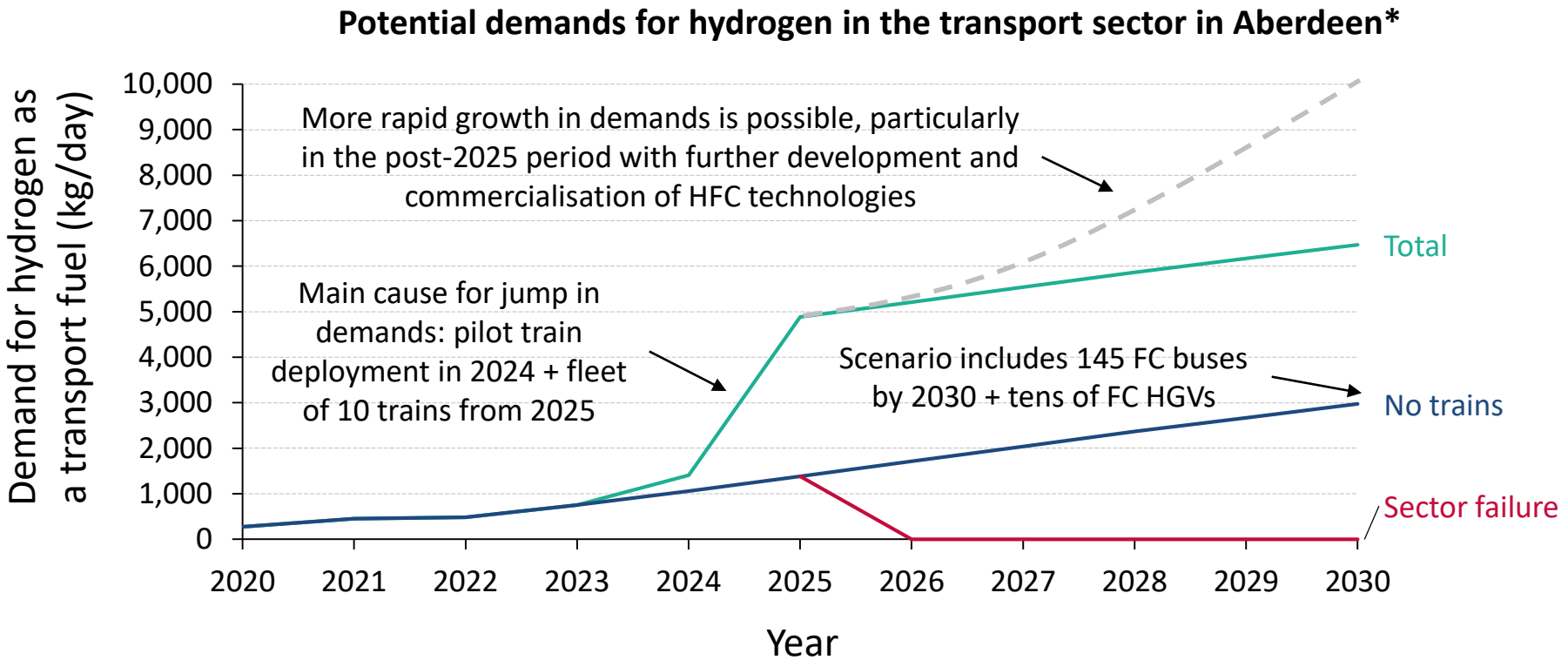
- Rail (tens of diesel trains could be replaced with FC trains)

Source: Alstom

- Marine (first deployment of hydrogen-fuelled boats planned)

Source: Vivarail

There is potential to create hydrogen demands of many tonnes per day in Aberdeen in the transport sector alone



- Expansion in Aberdeen's FC bus fleet under the JIVE project (+ other existing hydrogen-fuelled vehicles in the city) will lead to a sustained demand for hydrogen of hundreds of kg/day in the early 2020s.
- Further growth is possible, but the eventual levels of demand are subject to uncertainty.

* Range of outcomes using assumptions of modest growth in the hydrogen transport market and based on discussions with a wide range of stakeholders undertaken for this study in August / September 2019.

There are several potential hydrogen supply routes relevant to Aberdeen

Option		Pros*	Cons
1	**Natural gas reformation at / near point of demand**	• Scalable • Cost-effective	• Not “green”
2	**On-site electrolysis (grid-connected)**	• No need for logistics • Proven model in Aberdeen	• Limited scope for accessing low cost energy • Space constraints at depots
3	**Off-site electrolysis, potentially directly coupled to renewables**	• Potential to access low cost renewable energy (+ RTFCs**) • Scalable	• Logistics required
4	**Natural gas reformation with carbon capture (Acorn project)**	• Low cost and low carbon fuel	• Not available until mid-2020s
5	**Offshore hydrogen production (Dolphyn project)**	• Potential for low cost renewable hydrogen generation at scale	• Concept not yet demonstrated • Not available until mid-2020s or beyond

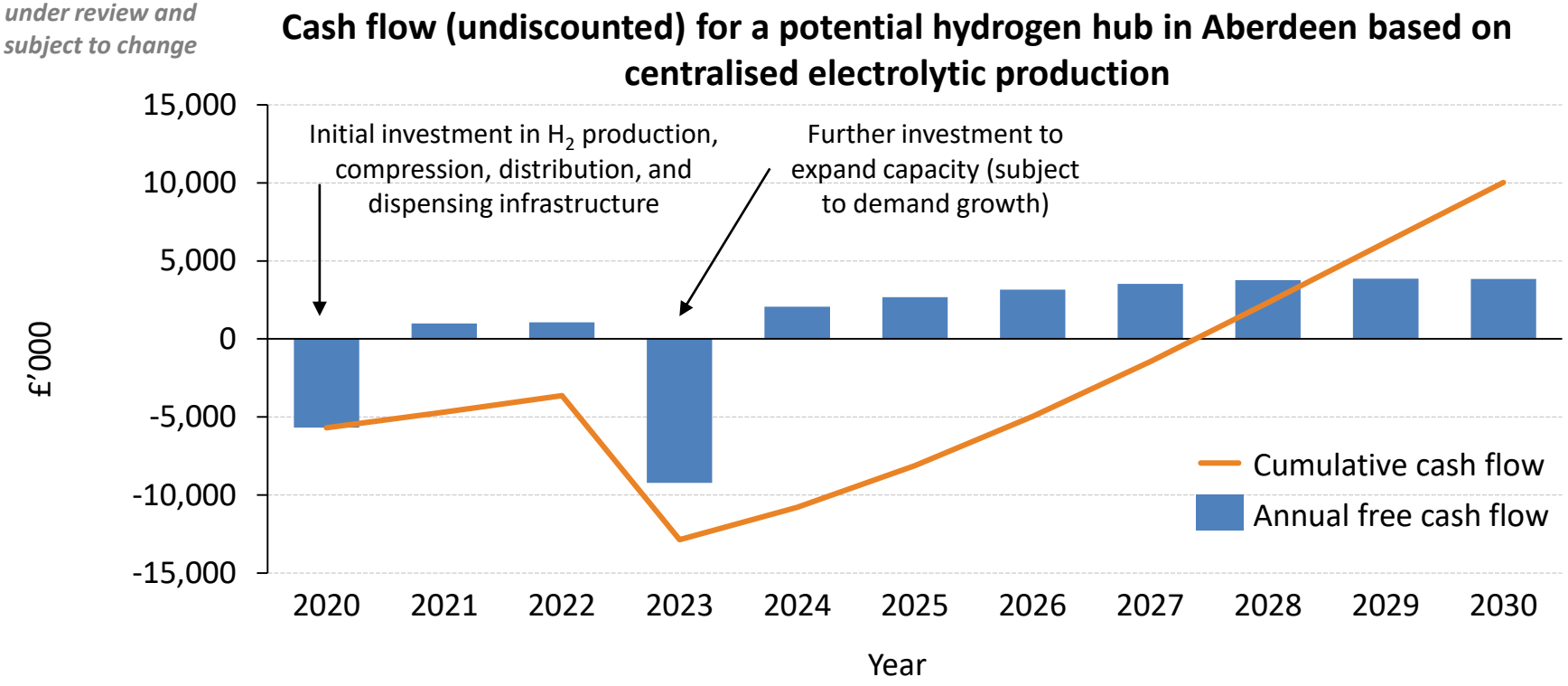
* Non-exhaustive list of pros and cons.

** Renewable Transport Fuel Certificates.

Renewable hydrogen supply hub cash flow

NPV over 10 years (8% discount rate)	£0.15m
IRR over 10 years	8%

Illustrative – figures under review and subject to change



Key assumptions

- Demand growth as per the "no trains" scenario above.
- Revenues based on sales of hydrogen @ £6/kg (buses / municipal HGVs), £8/kg (cars), £5/kg (HGVs).
- Additional revenue from RTFCs* (based on £5/kg to 2022, reducing to £1/kg by 2030).

* Renewable Transport Fuel Certificates.

This initiative offers opportunities for a wide range of organisations

Realising the vision of delivering a new hydrogen hub in Aberdeen offers **opportunities** to:

- Suppliers of (renewable) energy for hydrogen generation
- Equipment suppliers (hydrogen generation, compression, storage, dispensing)
- Infrastructure operators (service and maintenance)
- Suppliers of hydrogen-consuming technologies
- Hydrogen end users

However, several **barriers to implementing the hub** remain, including:

- Challenging case for capital investment while demands for hydrogen (and demand growth) remain uncertain
- Covering fixed and variable opex while offering attractively priced fuel
- Further experience needed before fleet operators could consider committing to long-term fuel supply contracts
- Timescales – delivering the new infrastructure within the required timescales and aligning infrastructure roll-out with growth in demands

The current phase of work is due to be followed by a procurement exercise for the supply of hydrogen to Aberdeen's growing vehicle fleet

Timeline for developing and delivering the Aberdeen hydrogen hub (draft, subject to change)