






E4tech

Tees Valley and North East Hydrogen Economic Study

Final Report

16th October 2014

GATESHEAD COLLEGE

Tees Valley Unlimited

North East Local Enterprise Partnership

HyTrEc Hydrogen Transport Economy for the North Sea Region

The Interreg IVB North Sea Region Programme

Investing in the future by working together for a sustainable and competitive region

elementenergy

Acknowledgements

Hydrogen Partnership	The Hydrogen Partnership was set up in 2014 to promote the development of the hydrogen economy in the region. The group, made up of Tees Valley Unlimited, North East LEP, Gateshead College, CPI, NEPIC and Sunderland University, has an ambition to support the development of the sector through the delivery of jobs, economic growth and by attracting inward investment.
GATESHEAD COLLEGE	Gateshead College is a European leader in the development of training and skills in the low carbon vehicle sector. The College's background in skills development in the electric vehicle sector led to the involvement in the European HyTrEc project with responsibility for the formation of an education forum for hydrogen and the development of a hydrogen safety training module. Their involvement in HyTrEc enabled the formation of the Hydrogen Partnership where they will continue to play a role to ensure that the region's workforce are well placed to take advantage and secure employment within this emerging sector.
HyTrEc Hydrogen Transport Economy for the North Sea Region	The Hydrogen Transport Economy (HyTrEc) project aims to improve access to and advance the adoption of hydrogen as an alternative energy vector across the North Sea Region. The European project will identify and address structural impediments constraining development of, access to and adoption of this alternative fuel in urban and rural settings. The project brings together eight partners from across Europe and is part of the Interreg IVB North Sea Region Programme and is partly funded by the European Regional Development Fund.
Tees Valley Unlimited	Tees Valley Unlimited is the Local Enterprise Partnership for Tees Valley, an area dominated by high value exporting industries. Tees Valley is home to major international businesses including BOC Linde, Air Products, Sabic, Sembcorp, SSI, and Growhow. And supplies over 50% of the UK's hydrogen, processes 20% of the UK's gas, 35% of the UK's fertilisers, and enough plastic for 8 billion bottles per year. It is home to Europe's second largest blast furnace and one of the UK's largest biofuel plants, it is the location for the first two Air Products novel waste gasification plants. In short it is the most integrated industrial complex in the UK, contributes £10bn to the UK economy, and exports £4bn worth of products every year. Tees Valley Unlimited's focus is on developing this world class industrial asset so it can continue to make a valuable contribution to the UK economy.
North East Local Enterprise Partnership	The North East Local Enterprise Partnership is a public private partnership set up to drive forward economic growth in the North East across Durham, Gateshead, Newcastle, North Tyneside, Northumberland, South Tyneside and Sunderland. We work with partners to deliver more and better jobs for the area by providing leadership and investment across six key themes: innovation, skills, business support and access to finance, employability and inclusion and transport and digital connectivity.

Contributing authors

Ben Madden (ben.madden@element-energy.co.uk)

Nick Asselin-Miller (nick.asselin-miller@element-energy.co.uk)

Alastair Hope-Morley (alastair.hope-morley@element-energy.co.uk)

Adam Chase (adam.chase@e4tech.com)

Geneviève Alberts (genevieve.alberts@e4tech.com)

Glossary of terms

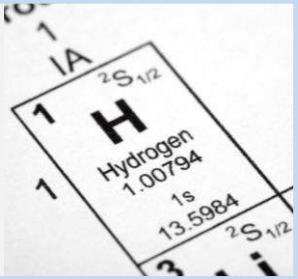
AP – Air Products
APUB - Alternative Powertrain for European Buses
CCS – carbon capture and storage
CHP – combined heat and power
EU – European Union
EV – electric vehicle
FC – fuel cell
FCEB – fuel cell electric bus
FCEV – fuel cell electric vehicle
FCH JU – Fuel Cells and Hydrogen Joint Undertaking
FIT – feed-in-tariff
H_2 – hydrogen
HGV – heavy goods vehicle
HRS – hydrogen refuelling station
ICE – internal combustion engine
IGCC – integrated gasification combined cycle
ISO – International Standards Organisation
ktpa – kilo tonnes per day
kWh – kilowatt hour (unit of energy)
MHE – material handling equipment
MSW – municipal solid waste
OEM – original equipment manufacturer
OLEV – Office for Low Emission Vehicles
RE – renewable energy
ROC – renewable obligation certificate
SAE – Society of Automotive Engineers
SMR – steam methane reforming
TCO – total cost of ownership
tpd – tonnes per day
TSB – Technology Strategy Board
TV&NE – Tees Valley and North East
UCG – underground coal gasification
ULEV – ultra low emission vehicle
WE – water electrolysis

Agenda

- **Executive summary**
- Final report

The growing use of H_2 as a new energy vector can potentially unlock many economic, social and environmental advantages

- **The global market for H_2 is well developed** (e.g. for ammonia and methanol production, refining crude oil, unsaturated fat hydrogenation) with **annual H_2 production equating to 1.5% of global primary energy use***
- Recently, use of H_2 as an **energy vector** has become a growth area, across a range of applications, including **transportation, energy storage, electricity generation and heat generation**



Policy drivers for hydrogen energy

✓ **Energy security**	▪ The wide variety of H_2 production pathways can contribute towards **de-risking future energy-supply** ▪ Greater national content provides large balance of payment benefits
✓ **Economic growth**	▪ Developing early supply chains/skills in the H_2 sector can **prepare region for export** as the technology becomes widespread
✓ **Climate change**	▪ H_2 can be produced directly from low carbon sources, thereby contributing **significantly to reducing CO_2 emissions** in the transport and chemical manufacturing sectors
✓ **Air quality**	▪ The only emissions from H_2 vehicles is water vapour, offering **improved air quality,** for polluted urban centres
✓ **System optimisation**	▪ H_2 can be stored in bulk, thus permitting large scale storage of power to the benefit of energy systems and energy intensive manufacturing ▪ Enables **increased penetration of intermittent renewable generation**

*Global annual energy consumption = 104 PWh (IEA, 2011), global annual H_2 production = 50 million tonnes (NREL, 2013), H_2 LHV = 33 kWh/kg

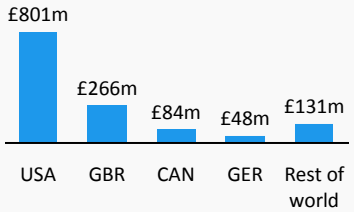
Globally, several emerging H_2 technologies are receiving increased attention as alternative energy solutions

FC = Fuel Cell

Significant investment is being directed towards the H_2 sector:

- OEMs (Toyota, Hyundai, Honda and Daimler) have spent £bn's developing fuel cell (FC) vehicles
- UK FC developer Intelligent Energy was valued at $1.1bn during its IPO in 2014

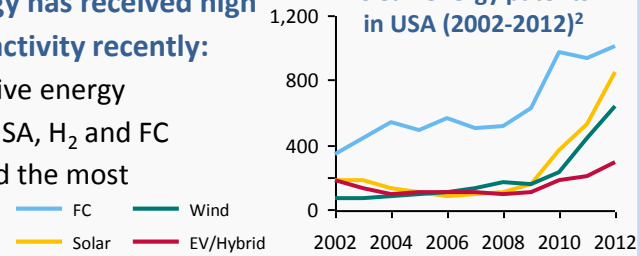
Cumulative VC & PE FC and H_2 investment (2000-2012)[1]



H_2 and FC technology has received high patent application activity recently:

- Comparing alternative energy technologies in the USA, H_2 and FC technologies received the most applications in 2012

Clean energy patents in USA (2002-2012)[2]



Most prominent early sectors for H_2 as an energy vector

1 Transportation

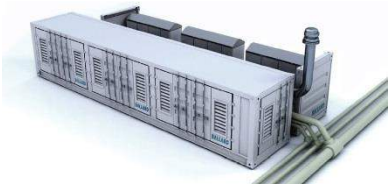
- Eliminate CO_2 and air quality impacts associated with fossil fuel vehicle emissions – EU proposes a 40% CO_2 emission reduction by 2030[2]
- Increase vehicle fuel consumption efficiency – Internal combustion engines have efficiencies of 20-35% compared to up to 60% for fuel cells[3]

Drivers
Relevance

1st gen fuel cell electric vehicle, achieves equivalent mileage to diesel car but with zero tailpipe emission

2 Distributed generation

- Increase power supply reliability, flexibility and upgradability
- Highly efficient FC power generation – c.60% FC efficiency vs 40% for centralised generation[4] (further 6% lost from transmission and distribution[5])



Large stationary fuel cell unit for off-grid electricity generation using H_2 feedstock

3 Power-to-gas

- Help integrate intermittent renewables into the grid by producing H_2 at times of high generation but low demand – 1.4% of total wind generation in Scotland was curtailed between 2012-13[6]
- Create seasonal energy storage reserves – existing electrochemical technologies are suited to minutes/days of storage duration[7]

Water electrolyser units to generate H_2 for injection into existing regional natural gas transmission system

Key players are planning where to focus early investment and deployments, whilst a number of regions (Germany, Netherlands, USA) are responding to this by putting themselves on the map as attractive locations for early deployments

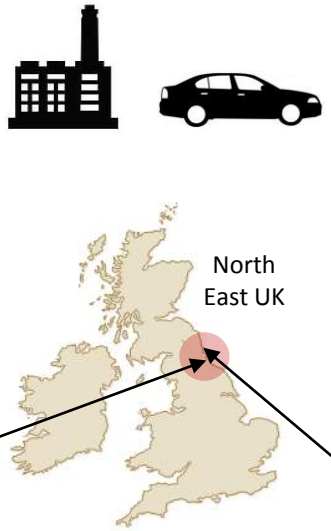
Left: Hyundai's ix35 FCEV, initial deployments from 2015, **Centre**: Ballard Power Systems' 1MW CLEARgen fuel cell at Toyota's USA HQ in California, **Right**: E-ON's 2 MW power-2-gas facility in Falkenhagen, Germany

The TV & NE region is in a strong position to engage with emerging H_2 technologies by taking advantage of its leading H_2 production capabilities

Existing industrial hydrogen assets

- The region holds a leading position in the UK **chemicals processing value chain**
- Defining aspects: UK's largest SMR plant, >50% of total UK H_2 production for the chemicals industry, a unique set of H_2 distribution pipelines and salt caverns for storing large volumes of H_2
- Existing asset base will allow large H_2 projects to be accommodated more rapidly and at lower cost than other regions

BOC SMR facility, North Tees

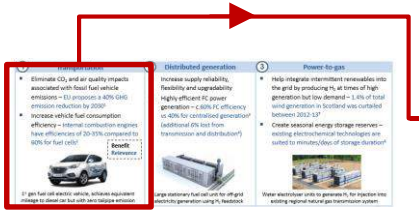


Low carbon vehicle production

- The region is a UK leader in the **automotive sector**
- Defining aspects: a well established, strong supply chain, particularly in the field of low carbon vehicles (e.g. In 2011 the Sunderland Nissan vehicle plant was the first UK based car manufacturing plant to produce >400k vehicles)
- Supply chain, skills, training infrastructure and reputation can make the region attractive for future manufacturing plants

Nissan manufacturing plant, Sunderland

Of the available options for engaging with hydrogen energy, the transport sector is likely to provide the largest opportunities for the region



Potential scale of UK H_2 fuel demand: 260 ktpa by 2030 (161 ktpa currently produced in Tees Valley for industry)

High value of H_2 as a transportation fuel: Pump sale price of up to £7/kg vs £1.50/kg for chemical industry*

+

Extensive low carbon automotive regional supply chain

Transport applications provide the most relevant opportunities for leveraging existing TV&NE capabilities in the H_2 and low carbon automotive sectors

Industrial opportunities including large scale energy storage, construction of a local high purity H_2 grid and 'green' H_2 production for industry could become increasingly relevant in the long-term

Opportunities for the Tees Valley and North East region

Near-medium

- Generate demand to justify using existing spare H_2 production capacity – this is a high value revenue stream for H_2 producers, relative to selling to industrial users
- Opportunities to expand TV&NE low carbon vehicle supply chain through attracting niche manufacturers
- Research into novel, high capacity H_2 carriers consistent with existing chemicals skill base

Medium-long term

- Widespread deployment of vehicles nationally provides significant, high-value export market for regionally produced fuel cell-grade H_2
- Opportunities for attracting major OEM investment to leverage existing supply chain
- Potential synergies through providing 'green' H_2 to regional industry users, helping to reduce climate impacts (and potentially costs) of industrial activities

*Supply to transport market requires additional steps for purification, distribution and retail – but a £7/kg sale price, still gives high profit when the associated costs are included (see analysis in main report)

An integrated programme of five detailed activity streams has been defined, facilitating access to the long-term benefits outlined above

	Activity	2015–2029
1 Production	- Leverage and upgrade existing production assets to supply the transport sector (improved purity)	Demand: regional transport-related H_2
	- Develop H_2 production from existing, large-scale 'green' sources, e.g. the planned AP plant(s)	Demand: 1MW FC, regional/extended transport H_2
	- Implement longer-term, large-scale 'green' H_2 production solutions – CCS, biomass, RES + storage	Demand: UK transport / regional industrial
2 Distribution	- Use and upgrade existing tube trailer distribution facilities for transport fuelling	Existing 200 bar capacity → Add 500bar tube trailer capacity if local demand justifies it
	- Research and develop novel high-capacity distribution mechanism for export to other regions	R&D with commercial partners → Deploy new system commercially, on a large (multi-MW) scale, in order to export large quantities of regional H_2 to other UK regions
3 Vehicles	- Attract one or more niche vehicle supply chain player to invest in the region through a major deployment	Funding + engagement → Deploy and build supply chain
	- Long-term, sustained OEMs engagement to secure region as major deployment center for OEMs, linked to targeting a major OEM inward investment	Promote region, small OEM deployment → Large OEM trial deployment → Full-scale rollout + production facilities
4 Refuelling	- Build locally sourced HRS and supply chain	Design/deploy HRS
	- Build HRS network into viable refueling network	Support vehicle deployments with new HRS as and when required → Build full regional coverage
5 x-cutting	- Support development of local supply chains, training	Ensure strong training, skills and support infrastructure are developed
	- Effective comms. with both public and industry	Sustained dissemination and direct engagement with key stakeholders

AP = Air Products, HRS = hydrogen refuelling station, CCS = carbon capture and storage, RES = renewable energy source

Near-term 2015-20 | Medium-term 2020-25 | Longer-term 2025+

Recommendation | *Contingent on success of previous activity*

Early recommended production and distribution activities will help unlock significant long-term H_2 export and industrial diversification opportunities

Specific activities are recommended… …to access local and national opportunities, and attain long-term benefits

1 Production 2 Distribution

- **Leverage and upgrade existing production assets** to meet high fuel cell purity standards
- **Develop new pure H_2 production** from existing, large-scale 'green' sources, (e.g. AP TV1 & TV2)
- **Use and upgrade existing tube trailer distribution facilities** for transport fuelling
- **Research and develop novel high-capacity distribution mechanism** for export to other regions
- **Plan for long-term, large-scale 'green' H_2 production** (CCS, biomass, intermittent renewables + energy storage)

H_2 transport use opportunities

- **Supply regional and national H_2 vehicle rollouts**, as a high-value revenue stream for H_2 producers
- **Produce 'green' H_2** as the market for 'green' H_2 grows
- **Drive development of solutions to the purification + distribution challenges** facing the sector

2030 prize

- Supplying H_2 to c. **25% of the expected 1.5m H_2 vehicles** in UK
- 65ktpa total H_2 production and distribution, bringing **cumulative revenues of c. £850m (2020-2030) and 450+ jobs by 2030**
- Additional TV&NE H_2 retailing revenue, plus regional air quality and CO_2 benefits

Industrial use opportunities

- **Diversify supply options for industrial H_2 using novel production techniques** to help de-risk the cost-effective supply of H_2 to the region's industry
- Help **'green' the H_2 produced in the region**

2030 prize

- **Potential to supply significant portion of existing 160ktpa demand**
- Benefits of 'green' H_2 could reach **£95m/year by offsetting CO_2 emissions**
- Additional value from de-risking supply of H_2

Early action on H_2 vehicles and refuelling infrastructure will help to unlock significant long-term transport inward investment opportunities

Specific activities are recommended… …to access local and national opportunities, and attain long-term benefits

3 Vehicles 4 Refuelling 5 Cross-cutting

- Start vehicle deployment projects linked to inward investment
- **Attract one or more niche vehicle supply chain player** to invest in the region through a major deployment
- **Long-term, sustained OEM engagement** to secure region as deployment centre for OEMs and target a major OEM for inward investment
- **Build locally sourced HRS** and **supply chain**
- **Build HRS network** into viable refuelling network
- **Develop local supply chains and training** from academic institutions
- **Adopt clear and targeted dissemination strategy**

Local vehicle and infrastructure opportunities

- Economic, supply chain and environmental benefits associated with local vehicle / infrastructure deployments are **limited due to small vehicle numbers**

Supply chain opportunities for UK and global export

- Increase regional **attractiveness towards inwards investment**
- **Supply UK with locally manufactured HRS**
- Attract supply chain players to **locate maintenance, training, or manufacturing facilities in the region**
- Solidify **reputation** as a low carbon transport cluster
- Ensure the right **skills, knowledge, infrastructure and supportive policies** are pervasive in the region
- **Raise profile of the region** to major industry players as they begin to make investment decisions for new European plants in the longer-term (post-2020)
- Use existing local skills in the industrial gas production / distribution sector to **support the growing need for distribution and dispensing of high pressure H_2 for transport purposes** – (direct provision of services, or through offering training in the sector)

2030 prize

- Limited direct economic benefit, likely **c.100 support jobs**

2030 prize

- Benefits of attracting an SME assembly plant to the region: c. **£10m capital investment**, **£8m/year revenue** by 2030 **and c. 40 additional jobs**
- Long-term benefit from a new Nissan-style OEM assembly plant, **£400m capital investment** in 2020's, **£60m per year in revenue** by 2030 and **1,500 direct jobs**
- Supply 25% of HRS to UK by 2030 (c. 300 units), creating **£300m cumulative by 2030**
- Benefits from **transferring skills and training across UK**, particularly if novel H_2 carriers are commercialised in TV&NE

HRS = hydrogen refuelling station

Circa £46m of investment is required to unlock the significant long-term opportunities, much of this could be obtained from external funding sources

Projects identified by Steering Panel

Production

- SMR purification kit: £200k-400k (400-1,000kg/day flow rate)
- Tube trailer filling upgrade: £2.5-3m (additional 3,000kg/day)
- Waste syngas purification kit: £3-5m (400kg/day flow rate)
- Large stationary fuel cell: £2-3m for 1 MWe stationary fuel cell

Distribution

- New 230 bar tube trailer capex: £300k
- New 500 bar tube trailer capex: £1m
- High-capacity H_2 carriers initial research (£50-500k), demonstration and dedicated research program: (£1m+)

Vehicles

- Vehicle capex: 1st Gen OEM FCEV (£120k), 2nd Gen (£50k), Transit van with ICE conversion (£55k), Kangoo with FC-RE (£40k), FC bus (£550k) – **deployment contingent on end-users**
- Suggested hydrogen sale price: £7/kg

Infrastructure

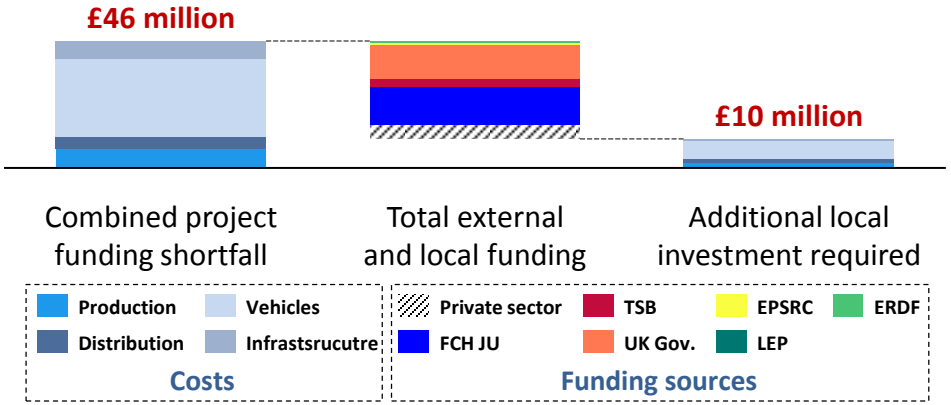
- Up-front development cost of a locally sourced HRS: £0.5-1m
- HRS capex: £0.8m (80kg/day), £1.4m (500kg/day), £2.2m (1,000kg/day)

Cost

- **Total combined project cost = £46 million**
- Note this is an average of the upper and lower bound costs for each individual activity suggested

Project funding opportunities

- **FCH JU** – Europe's major hydrogen and fuel cell funding agency, with a total funding budget of €1.4bn available
- **TSB** – the UK's Technology Strategy Board, responsible for innovation funding in the UK and with a remit to support hydrogen and fuel cells (recent funding rounds of £5-£10m have supported activities including manufacturing scale up and technology demonstration)
- **UK Government** - Ultra-Low Emissions Strategy launched in 2013 - £11m initial funding to support H_2 infrastructure rollout in the UK
- **LEP and local funding** – will be required to make up the difference in funds not available from local partners
- **Private sector** funding likely to be available where new revenue streams are unlocked (e.g. sale of existing SMR gas)



FCH JU = Fuel Cells and Hydrogen Joint Undertaking, TSB = Technology Strategy Board, ERDF = European Regional Development Fund, ESPRC = Engineering and Physical Science Research Council

An implementation plan has been recommended to work towards achieving the long-term goals identified, driven by a clear mandate and focused budget

Campaigning to establish a strong end-user base, securing local and European funding whilst ensuring efficient organisation and good communication are key to overall success of the projects identified

Phase 1 (May-Dec 2014)

- The existing partnership (Zero Carbon Futures, Gateshead College, TVU, North East LEP, CPI, Sunderland University) has successfully initiated activities to identify opportunities for the region
- Partners now must agree that they support the initiative and findings from the "Hydrogen Economic Study" and agree to back an overall strategy for the region
- Enacting this strategy will require coordination and allocation of sufficient resource to do this
- Based on previous successful regional hydrogen projects, we suggest a secretariat (housed within one of the main advocates) and suitable budget made available for skilled support (e.g. bid writing and feasibility work) as and when needed
- A budget for this needs to be established - based on the London Hydrogen Partnership activities, an indicative budget of c.£100k p.a. is required

Phase 2 (Jan-Dec 2015)

- Once the strategy is agreed and the resource is identified, there are a number of tasks to be undertaken in 2015:

a) Start to attract private sector industrial partners into the partnership

b) Make contact with local end users to encourage the adoption of hydrogen vehicles (for large fleet deployments of e.g. buses, vans, forklifts)

c) Make contact with suppliers to develop project concepts developed in the study and to discuss the criteria under which niche manufacturers could invest in the region

d) Begin discussions with funding bodies to prepare for formal funding applications

e) General outreach and promotional activities around the region's strategic direction in relation to hydrogen

f) Market TV&NE's production capabilities to other regions interested in deploying hydrogen technologies as potential customers for TV&NE hydrogen

g) Engagement with the major OEMs deploying hydrogen vehicles to promote the region as an attractive deployment centre

Late-2014 → **Early/mid-2015** → **Late-2015**

A relatively small short-term public investment could unlock opportunities for the region to gain orders of magnitude more economic benefit by 2030

Short-term investment from 2015

- Local public sector investment circa £10m (for a total after external funding of £46m)
- Risk of H_2 transport market failure

Long-term benefits by 2030

- ~£850m from H_2 production and dist. revenues
- ~£180m from H_2 vehicle manufacturing revenues
- ~£300m from H_2 refuelling station manufacturing revenues
- >1,500 new jobs across H_2 supply chain

- The North East region is already a world leader in large scale H_2 production and distribution for the chemical industry and the opportunity now exists to leverage regional experience, expertise and assets to become **a major H_2 producer for the transportation sector** and **an emerging European fuel cell vehicle cluster**
- **Action is required now** to position the region as an **attractive location for manufacturers to deploy 1st generation H_2 transport technologies**, and thereby build the supply chain, skills and infrastructure required to **attract long-term investments in H_2 production, as well as vehicle assembly and manufacturing plants**
- Whilst the short-term investment required is not insignificant, **the potential revenues that could be unlocked are orders of magnitude higher**

HRS = hydrogen refuelling station

References

[1]**Bloomberg New Energy Finance**

[2]**Clean Energy Patent Growth Index** "2013 Year in Review"

[3]**European Commission** press release (Jan 2014) [http://europa.eu/rapid/press-release_IP-14-54_en.htm]

[4]**DoE** "Comparison of fuel cell technologies" (2014)

[5]**DUKES** "5.9 Plant loads, demand and efficiency" (2013), Combined thermal efficiency for all UK centralised power generation units (including combined cycle gas turbine stations, coal fired stations and nuclear stations)

[6]**National Grid** "Electricity Transmission Losses Report" (2013), **OFGEM** "Electricity distribution System Losses – Non-Technical Overview" (2009)

[7]**National Grid** "Winter Outlook Report" (2013)

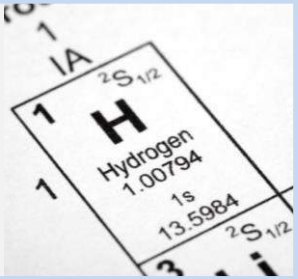
[8]**NREL** "The Value of Energy Storage for Grid Applications" (2013), **Carbon Trust** "Strategic Assessment of the Role and Value of Energy Storage Systems in the UK Low Carbon Energy Future" (2013)

Agenda

- Executive summary
- **Final report**
  - **Introduction to the hydrogen economic study**
  - The long-term opportunity and timeline to implementation
  - Near-term activities to access the long-term opportunity
  - Economics and funding opportunities
  - Next steps to implementing strategic recommendations

The growing use of H_2 as a new energy vector can potentially unlock many economic, social and environmental advantages

- **The global market for H_2 is well developed** (e.g. for ammonia and methanol production, refining crude oil, unsaturated fat hydrogenation) with **annual H_2 production equating to 1.5% of global primary energy use***
- Recently, use of H_2 as an **energy vector** has become a growth area, across a range of applications, including **transportation, energy storage, electricity generation and heat generation**



Policy drivers for hydrogen energy

✓ **Energy security**	▪ The wide variety of H_2 production pathways can contribute towards **de-risking future energy-supply** ▪ Greater national content provides large balance of payment benefits
✓ **Economic growth**	▪ Developing early supply chains/skills in the H_2 sector can **prepare region for export** as the technology becomes widespread
✓ **Climate change**	▪ H_2 can be produced directly from low carbon sources, thereby contributing **significantly to reducing CO_2 emissions** in the transport and chemical manufacturing sectors
✓ **Air quality**	▪ The only emissions from H_2 vehicles is water vapour, offering **improved air quality,** for polluted urban centres
✓ **System optimisation**	▪ H_2 can be stored in bulk, thus permitting large scale storage of power to the benefit of energy systems and energy intensive manufacturing ▪ Enables **increased penetration of intermittent renewable generation**

*Global annual energy consumption = 104 PWh (IEA, 2011), global annual H_2 production = 50 million tonnes (NREL, 2013), H_2 LHV = 33 kWh/kg

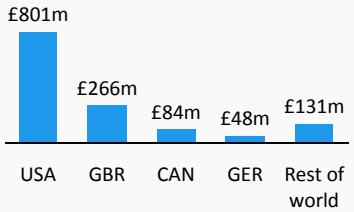
Globally, several emerging H_2 technologies are receiving increased attention as alternative energy solutions

FC = Fuel Cell

Significant investment is being directed towards the H_2 sector:

- OEMs (Toyota, Hyundai, Honda and Daimler) have spent £bn's developing fuel cell (FC) vehicles
- UK FC developer Intelligent Energy was valued at $1.1bn during its IPO in 2014

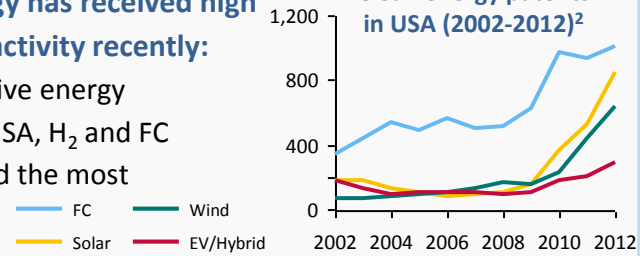
Cumulative VC & PE FC and H_2 investment (2000-2012)[1]



H_2 and FC technology has received high patent application activity recently:

- Comparing alternative energy technologies in the USA, H_2 and FC technologies received the most applications in 2012

Clean energy patents in USA (2002-2012)[2]



Most prominent early sectors for H_2 as an energy vector

1 Transportation

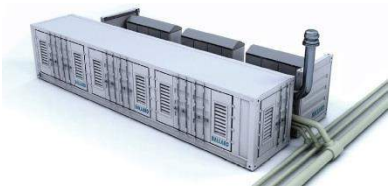
- Eliminate CO_2 and air quality impacts associated with fossil fuel vehicle emissions – EU proposes a 40% CO_2 emission reduction by 2030[2]
- Increase vehicle fuel consumption efficiency – Internal combustion engines have efficiencies of 20-35% compared to up to 60% for fuel cells[3]

Drivers
Relevance

1st gen fuel cell electric vehicle, achieves equivalent mileage to diesel car but with zero tailpipe emission

2 Distributed generation

- Increase power supply reliability, flexibility and upgradability
- Highly efficient FC power generation – c.60% FC efficiency vs 40% for centralised generation[4] (further 6% lost from transmission and distribution[5])



Large stationary fuel cell unit for off-grid electricity generation using H_2 feedstock

3 Power-to-gas

- Help integrate intermittent renewables into the grid by producing H_2 at times of high generation but low demand – 1.4% of total wind generation in Scotland was curtailed between 2012-13[6]
- Create seasonal energy storage reserves – existing electrochemical technologies are suited to minutes/days of storage duration[7]

Water electrolyser units to generate H_2 for injection into existing regional natural gas transmission system

Key players are planning where to focus early investment and deployments, whilst a number of regions (Germany, Netherlands, USA) are responding to this by putting themselves on the map as attractive locations for early deployments

Left: Hyundai's ix35 FCEV, initial deployments from 2015, **Centre**: Ballard Power Systems' 1MW CLEARgen fuel cell at Toyota's USA HQ in California, **Right**: E-ON's 2 MW power-2-gas facility in Falkenhagen, Germany

References

[1]**Bloomberg New Energy Finance**

[2]**Clean Energy Patent Growth Index** "2013 Year in Review"

[3]**European Commission** press release (Jan 2014) [http://europa.eu/rapid/press-release_IP-14-54_en.htm]

[4]**DoE** "Comparison of fuel cell technologies" (2014)

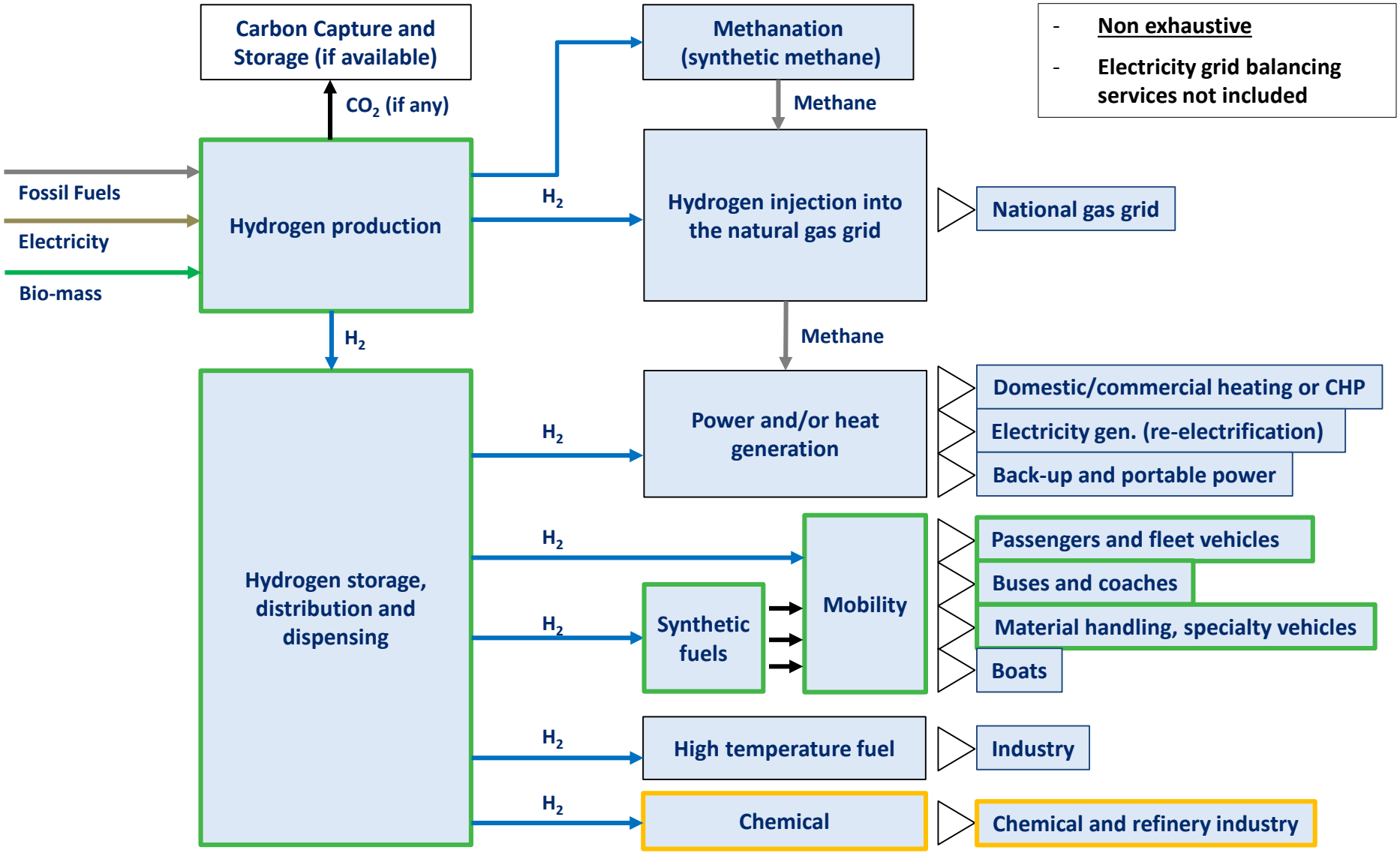
[5]**DUKES** "5.9 Plant loads, demand and efficiency" (2013), Combined thermal efficiency for all UK centralised power generation units (including combined cycle gas turbine stations, coal fired stations and nuclear stations)

[6]**National Grid** "Electricity Transmission Losses Report" (2013), **OFGEM** "Electricity distribution System Losses – Non-Technical Overview" (2009)

[7]**National Grid** "Winter Outlook Report" (2013)

[8]**NREL** "The Value of Energy Storage for Grid Applications" (2013), **Carbon Trust** "Strategic Assessment of the Role and Value of Energy Storage Systems in the UK Low Carbon Energy Future" (2013)

The transport and industrial sectors are the main focus of this strategy, due to their increased relevance to the TV&NE region



Primary focus of study

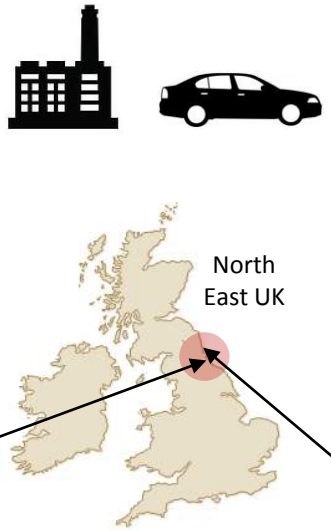
Secondary focus of study

The TV & NE region is in a strong position to engage with emerging H_2 technologies by taking advantage of its leading H_2 production capabilities

Existing industrial hydrogen assets

- The region holds a leading position in the UK **chemicals processing value chain**
- Defining aspects: UK's largest SMR plant, >50% of total UK H_2 production for the chemicals industry, a unique set of H_2 distribution pipelines and salt caverns for storing large volumes of H_2
- Existing asset base will allow large H_2 projects to be accommodated more rapidly and at lower cost than other regions

BOC SMR facility, North Tees



Low carbon vehicle production

- The region is a UK leader in the **automotive sector**
- Defining aspects: a well established, strong supply chain, particularly in the field of low carbon vehicles (e.g. In 2011 the Sunderland Nissan vehicle plant was the first UK based car manufacturing plant to produce >400k vehicles)
- Supply chain, skills, training infrastructure and reputation can make the region attractive for future manufacturing plants

Nissan manufacturing plant, Sunderland

This strategy assesses how the TV&NE region can become a leader in the automotive and industrial applications relevant to hydrogen energy

A number of regions are emerging as leaders in the deployment of H_2 technologies

- Globally, **several major vehicle OEMs are planning to bring hydrogen fuel cell vehicles to market in the 2015-2020 period** – they are currently evaluating the most viable regions for early deployment, based on a range of factors including population density/wealth, supportive local/national policies, presence of a H_2/fuel cell supply chain, etc.
- A number of regions (including: California, Germany, Scandinavia, Japan and Korea, as well as London and Aberdeen in the UK) are currently investing in order to position themselves as attractive early deployment regions for fuel cell vehicle deployments
- An **opportunity exists for other regions to join these early adopter regions and secure the longer-term benefits that may come from early engagement with H_2 technologies** – including leveraging existing regional skills and assets and building a supply chain to eventually supply other regions

This H_2 strategy aims to establish TV&NE region as a key deployment area for new H_2 technologies

- Local TV&NE stakeholders now wish to **leverage the significant existing TV&NE capabilities in H_2 production and low carbon transport to establish the region as a major UK player in the emergence of H_2** as a new energy vector
- This TV&NE hydrogen strategy document represents the outputs of the analysis carried out by Element Energy and E4tech and aims to:
  - **Understand the rationale behind investing in the H_2 sector**, through evaluating the size of and likely timing for the long-term opportunities associated with engaging with H_2 as a new energy vector
  - **Define a set of targeted near-term activities** that will help to ensure the region can secure the long-term aspirations and benefits identified
  - Assess at a high-level the total investment required and likely funding sources available

The TV&NE H_2 strategy has identified a series of near-term activities which have the potential to maximise the long-term benefits achievable

Planning for long-term benefits, through short-term activities

The TV&NE hydrogen strategy project has assessed existing regional capabilities and assets in the industrial production/distribution of hydrogen, as well as in the low carbon automotive sector. Coupled with a range of consultations with potential end-users of hydrogen vehicles, supply chain partners and manufacturers, the project has:

- **Identified and evaluated the most viable long-term opportunities for the region to benefit** from the rollout of H_2:
  - Given the pre-commercial nature of most H_2 technologies, the **major economic and environmental benefits only become significant in the period from 2025**
  - Whilst it is impossible to predict the exact size of these benefits, it has been possible to estimate an overall size of the opportunity, by detailing a number of specific and achievable targets for the region (e.g. attracting a OEM H_2 vehicle assembly plant)
- **Identified a series of near-term targeted activities** with the potential to maximise the likelihood of achieving the long term opportunities and associated regional benefit:
  - To achieve these long term benefits, there is a case **to act early to invest** in the infrastructure, supply chain and skills relating to hydrogen energy, in order to secure the region as a leading player in the sector
  - A plan of action has been designed, which begins with a relatively measured level of engagement (to avoid over-committing to a technology whose benefits are only felt in the medium term) and is deliberately flexible and responsive to the uncertainties in the rate of development of H_2 technologies (which the TV&NE region cannot control)
- The next slides assess the long-term opportunities, followed by the near-term activities recommended

Agenda

- Executive summary
- **Final report**
  - Introduction to the hydrogen economic study
  - **The long-term opportunity and timeline to implementation**
  - Near-term activities to access the long-term opportunity
  - Economics and funding opportunities
  - Next steps to implementing strategic recommendations

Long-term opportunities in 2030

This section identifies the long-term opportunities in 2030, associated with engaging with H_2 as a new energy vector

A substantial opportunity exists for supplying the emerging H_2 transport market from regionally produced H_2, with knock-on benefits for industry

Hydrogen production for transport applications

- The emerging use of H_2 in transport applications presents an **opportunity for existing spare production capacity in the region to be used in both regional and national H_2 vehicle rollouts, as a high-value revenue stream for H_2 producers**, although existing H_2 sources produce 'brown' H_2, making up a decreasing fraction of consumption
- As demand increases, an opportunity is also created to deploy new 'green' H_2 production (e.g. H_2 from waste, SMR + CCS, water electrolysis), as the market for 'green' H_2 grows
- However, **a number challenges are presented** in supplying H_2 to the transport sector, in particular **purification** and **distribution to the point of use** – both of these would benefit from further technology development (which could be driven by the region)

2030 opportunity

- Supplying H_2 to c. **25% of the expected 1.5m H_2 vehicles** in UK
- 65ktpa total H_2 production and distribution, bringing **cumulative revenues of c. £850m (2020-2030) and 450+ jobs by 2030**
- Additional TV&NE H_2 retailing revenue, plus regional air quality and CO_2 benefits

Hydrogen production for industrial purposes

- The portfolio of H_2 supply options for industrial H_2 users are all subject to **production cost risks and opportunities** associated with external factors outside of the control of the region (e.g. carbon price, gas prices, electricity prices, availability of subsidies, equipment cost reductions, etc.)
- As a result, a **long-term strategy aimed at diversifying supply options for industrial H_2 using novel production techniques** could help to de-risk the long-term cost-effective supply of H_2 to the region's industry, and help to 'green' the H_2 produced

2030 opportunity

- **Potential to supply significant portion of existing 160ktpa demand**
- Benefits of 'green' H_2 could reach **£95m/year by offsetting CO_2 emissions**
- Additional value from de-risking supply of H_2

Supplying H_2 to 25% of the UK passenger vehicle market in 2030 could earn the region £230m in revenues and create 450+ new jobs

Benefit to region	Total in 2030	Notes
Volume of H_2 sales	65 ktpa	25% of national market (260ktpa)
H_2 sales revenue to fuel retailer	£230m	Based on a selling price of £7.00 /kg-H_2
H_2 distribution revenue to fuel distributor	£30m	Based on a distribution cost of £0.42 /kg-H_2
H_2 production & purification revenue to fuel producer	£200m	Based on weighted average production costs of £ 3.01/kg-H_2
Jobs in H_2 distribution	420	Over 100 trailers based on novel hydrogen storage material (~1.7 tonne capacity) in operation nationally supplying to over 350 HRSs
Jobs in H_2 production & purification	30+	Based on large SMR production with 3 shifts per day

Production type	Available capacity	2030 % share	Cost
Existing SMR spare capacity	2 ktpa	3%	£2.50/kg[1]
Waste gasification plant (TV1)	20 ktpa	31%	£3.41/kg[1]
Waste gasification plant (TV2)	20 ktpa	31%	£3.41/kg[1]
New SMR + CCS plant	23 ktpa	35%	£2.36/kg[2]

Average 2030 production cost = **£3.01/kg**

[1]Element Energy analysis (see H_2 production section), [2]A portfolio of power-trains for Europe (McKinsey, 2011)

Significant long-term benefits are available from attracting H_2 transport supply-chain players to the region, but early investment is required

Vehicle and infrastructure-related opportunities

- The **direct economic, supply chain and environmental benefits associated with any vehicle/infrastructure deployments in the region are likely to be limited**, particularly in the near-term pre-2020, when vehicle numbers will be small

2030 opportunity

- Limited direct economic benefit, likely **c.100 support jobs**

Supply chain and training opportunities

- **Vehicle/infrastructure deployments provide an opportunity for TV&NE to increase its profile and attractiveness towards inwards investment:**
  - **A large deployment project has the potential to attract niche supply chain players** (e.g. fuel cell manufacturers, integrators) to locate maintenance, training, or manufacturing facilities in the region, in the 2015-2020 period
  - This would help to solidify TV&NE's reputation as a low carbon transportation cluster, as well as ensuring the right skills, knowledge, infrastructure and supportive policies are pervasive in the region
  - This in turn **raises the profile of the region as and when major industry players (e.g. OEMs) begin to make investment decisions** for new European plants in the longer-term (post-2020)
- In addition to inward investment opportunities, there is a **clear opportunity presented by using existing local skills and assets in the industrial gas production / distribution sector to support the growing national and global need for distribution and dispensing of high pressure H_2** for transport purposes – either throw direct provision of services, or through offering training in the sector

2030 opportunity

- Benefits of attracting an SME assembly plant to the region: c. **£10m capital investment**, **£8m/year revenue** by 2030 **and c. 40 additional jobs**
- Long-term benefit from a new Nissan-style OEM assembly plant, **£400m capital investment** in 2020's, **£60m per year in revenue** by 2030 and **1,500 direct jobs**
- Supply 25% of HRS to UK by 2030 (c. 300 units), creating **£300m cumulative by 2030**
- Benefits from **transferring skills and training across UK**, particularly if novel H_2 carriers are commercialised in TV&NE

Automotive - Short term prize: Attracting a niche H_2 vehicle supply chain company

Required preconditions

- Location must be able to physically serve a regional, UK and EU market
- Regional market conditions and standards should be very similar to those found in wider markets
- Long term commitment to growth of sector at national and regional level
- Appropriate skills & training available from day 1
- Regional supply base desirable
- Financial support for plant investment desirable

+

Possible outcomes

- First-plant-in-Europe for a manufacturer in the H_2 vehicle supply chain
- Examples of products include fuel cell system, hydrogen tank, integrated forklifts or niche road vehicles
- This example assumes an FC bus engine manufacturing plant to serve the EU market, starting 2018
- All high value components imported, regional sourcing of minor components, increasing local content over time
- FC bus engines sold to bus manufacturers across EU

→

Benefits for region

- **Capital investment of up to £10 million in 2018**
- Supply of c. **900 FC bus engines across Europe in 2030**
- As FC bus volumes ramp up direct **employment increases to c. 40 in 2030**
- Local supply chain sourcing of 10% of content in 2030 results in **annual purchases in the region of £8 million**

Automotive - Long term prize: Attracting a major H_2 vehicle manufacturing company

Required preconditions

- Location must be able to physically serve a UK, EU and potentially wider market
- UK market conditions and standards should be very similar to those found in other markets
- Regional market initiatives help to attract management interest
- Long term commitment to growth of sector at national level
- Regional commitment to growth of skills and supply base
- Financial support for plant investment may help

+

Possible outcomes

- First-plant-in-Europe for a major FCEV manufacturer
- Products could include FC engines, whole powertrains or integrated vehicles
- This example is based on an FCEV integration plant to serve the EU market, starting 2023
- All high value components imported, regional sourcing of minor components, increasing local content over time
- Integrated FCEVs sold across EU, exported via Sunderland port

→

Benefits for region

- **Capital investment of £400 million** in 2023
- Supply of 250,000 FCEVs in 2030
- Increasing FCEV volumes result in c. **1,500 direct jobs by 2030**
- Local supply chain sourcing of 5% content in 2030 results in **annual purchases in the region of £61 million**

A number of activities are recommended for accessing the long-term opportunities identified, split into five separate activity streams (1 of 2)

Activity stream	Summary
1 Production	▪ Here, activities are centred around using existing spare SMR-based production capacity to supply the transport sector in the near-term (whilst ensuring sufficiently pure H_2 is available for this purpose), followed by the production of 'green' H_2 from waste gasification in the medium-term ▪ This is followed by assessing a diversification to one of a number of potential sources of 'green' H_2 in the long-term, which are consistent with the TV&NE skills/asset base (including CCS + SMR, additional waste gasification, renewables-based electrolysis with salt cavern storage, etc.)
2 Distribution	▪ Near-term activities involve ensuring the availability of existing 230 bar tube-trailer distribution assets for the distribution of high-purity H_2 for transport purposes, with a potential upgrade in the medium-term to 500 bar tube-trailers, depending on the scale of regional transport demand growth ▪ In parallel, it is recommended that the region works closely with developers of novel, high-capacity, low-cost distribution mechanisms (liquid hydrogen, organic/inorganic hydrides, etc.), to allow export of large volumes of regionally produced H_2 to other regions
3 Vehicles	▪ The short-term goal here is to spearhead a large (> 100) deployment of vehicles in non-passenger car automotive sectors (buses, vans, fork lifts, etc.), in order to a) create hydrogen demand in the region and b) attract an inward investment from the chosen manufacturer to the region – ideally an assembly plant, thereby helping to grow the regional H_2 transport supply chain ▪ With regards to OEMs, a long-term engagement strategy is recommended with the aim of attracting an OEM assembly plant to the region in the longer-term, when the OEMs consider expanding production into Europe (earliest realistic date 2023) ▪ This dialogue would be supported by a very small (low cost) near-term deployment of OEM H_2 vehicles, leading to a larger deployment in the medium-term

A number of activities are recommended for accessing the long-term opportunities identified, split into five separate activity streams (2 of 2)

Activity stream	Summary
4 Refuelling infrastructure	▪ The activities for infrastructure centre around supporting vehicle deployments with sufficient refuelling capacity to support them, with the aim of building out a publically accessible regional network beyond 2025 ▪ In parallel, it is recommended that regional skills and assets are leveraged, in order ensure that one of the early hydrogen refuelling stations (HRS) maximises the use of locally-sourced components, with a view to boosting the local skills in the HRS supply chain
5 Cross-cutting activities	▪ This includes long-term engagement with the local supply chain and academic institutions to support the development of new skills and training in the region ▪ A diversification of the existing training activities for electric vehicles to become a leading centre for the training of technicians and operatives throughout the hydrogen mobility value chain (from H_2 distribution, dispensing and in particular in automotive manufacture/assembly and maintenance) ▪ A clear and targeted dissemination strategy, targeting industrial stakeholders and the public, ensuring they are informed of developments and have the resources required to support their engagement with the H_2 sector

A range of activities are required in order to maximise the chances of accessing the long-term benefits outlined above

	Activity	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
1 Production	Leverage and upgrade existing production assets to supply the transport sector (improved purity)	Demand: regional transport-related H_2														
	Develop H_2 production from existing, large-scale 'green' sources, e.g. the planned AP plant(s)					Demand: ~1MW FC, regional/extended transport H_2										
	Implement longer-term, large-scale 'green' H_2 production solutions – CCS, biomass, RES + storage										Demand - UK transport / regional industrial					
2 Distribution	Use and upgrade existing tube trailer distribution facilities for transport fuelling	Existing 200 bar capacity				Add 500 bar tube trailer capacity if regional demand justifies it										
	Research and develop novel high-capacity distribution mechanism for export to other regions	R&D with commercial partners				Deploy new system commercially, on a large (multi-MW) scale, in order to export large quantities of regional H_2 to other UK regions										
3 Vehicles	Attract one or more niche vehicle supply chain player to invest in the region through a major deployment	Funding + engagement				Deploy and build supply chain										
	Long-term, sustained OEMs engagement to secure region as major deployment center for OEMs, as well as targeting a major OEM inward investment	Promote region, small OEM deployment					Large OEM trial deployment					Full-scale rollout				
4 Refuelling	Build locally sourced HRS and supply chain	Design/deploy HRS														
	Build HRS network into viable refueling network	Support vehicle deployments with new HRS as and when required										Build full regional coverage				
5 xcutting	Support development of local supply chains, training	Ensure strong training, skills and support infrastructure are developed														
	Effective comms. with both public and industry	Sustained dissemination and direct engagement with key stakeholders														

Near-term 2015-2020 | Medium-term 2020-2025 | Longer-term 2025+

Period of uncertainty | *Reduced uncertainty*

Agenda

- Executive summary
- **Final report**
  - Introduction to the hydrogen economic study
  - The long-term opportunity and timeline to implementation
  - **Near-term activities to access the long-term opportunity**
  - Economics and funding opportunities
  - Next steps to implementing strategic recommendations

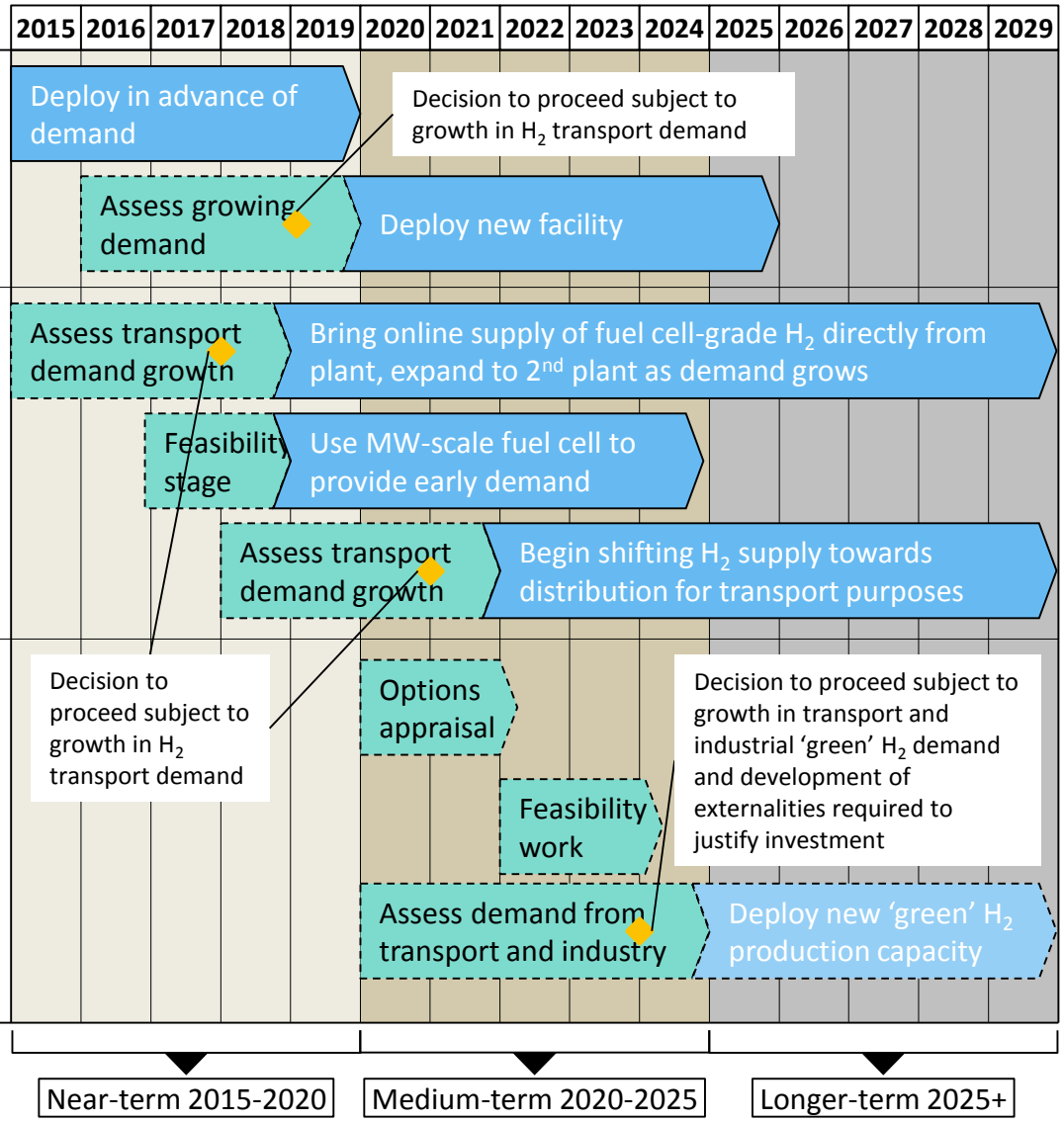
Near-medium-term activities 2015-2020

This section identifies the near-term activities in 2015-2020, that are recommended in order to help secure the aim of accessing the benefits identified for 2030 and beyond, and activities are split across five activity themes, as described above

Production activities make use of existing assets as demand grows, whilst preparing for long-term investments in new 'green' capacity

1

	Activity	
Existing facilities	Adapt existing BOC SMR tube trailer facility for fuel cell-grade H_2 distribution	1a
	Increase spare capacity for tube trailer facility to supply growing regional H_2 market	1b
AP waste gasification*	Partner with AP to develop pure hydrogen off-take at the Tess waste plant	
	Early 'green' H_2 production to supply MW-scale stationary fuel cell	1c
	Install high-capacity distribution mechanism to supply growing H_2 transport market	
Future facilities	Study to identify preferred long-term 'green' H_2 production plant – SMR+CCS, H_2 from waste, electrolysis from local renewables, etc.	
	Feasibility/engineering work on preferred plant	
	Implement longer-term, large-scale 'green' H_2 production solutions for transport and industry	



◆ Indicates major decision, essential to unlocking initiating stage of particular project

Near-term 2015-2020 | Medium-term 2020-2025 | Longer-term 2025+

Activity 1a: Project to use existing SMR-capacity to produce affordable H_2 for the transport sector in the region

Rationale

- There are currently no regional facilities available for producing/distributing high purity fuel cell-grade H_2 for transport use
- However, the BOC Middlesbrough plant has a tube trailer filling facility:
  - Fleet of 230 bar tube trailers
  - Purity is currently 99.98%, but no QA facilities to guarantee ISO 14687 (or alternatively > 99.999%) purity for transport applications
  - Total capacity of facility c. 2,000kg/day
  - Currently significant spare capacity

Suggested activities

- Engage directly with BOC to discuss pricing and logistics for 230 bar tube trailer distribution to new H_2 transport project(s)
- Evaluate costs of PSAs and QA equipment from suppliers, needed to **guarantee fuel cell-grade H_2 purity** levels
- **Use existing tube-trailer facility**, with at least 2 trailers to provide an initial distribution capability
- Sufficient scale already exists to supply H_2 for all expected pre-2020 H_2 transport projects, i.e. **maximum of c. 1000 kg/day capacity (bus and forklift projects)**

Key project facts/assumptions

- Maximum capacity unchanged at 2,000kg/day
- H_2 purity improved from 99.98% to >99.999%

1a Project economics

- Purification equipment capital costs are estimated to be £200-400k[1] for a system with a maximum flow rate of 400-1000 kg/day system
- Additional costs for civils and electrical infrastructure are not included

Impact on priority drivers: Direct economic, Inward investment, Environmental, Branding

[1]Costs are indicative

Activity 1b: Project to upgrade existing SMR-capacity to produce increased volumes of H_2 for the transport sector in the region

Rationale

- As demand grows in the region from additional H_2 vehicle deployments, the relatively limited capacity of the existing tube trailer facility (c. 0.7ktpa) will be exceeded
- In order to continue to supply to the region, the capacity of the tube-trailer filling facility could be upgraded to cover the full BOC plant spare capacity – i.e. c. 2ktpa of fuel cell-grade H_2

Suggested activities

- Work with BOC to understand the maximum capacity that can be deployed at the tube trailer site and the costs/implications of upgrading capacity **Upgrade capacity of facility to maximise use of plant spare capacity** (subject to sufficient demand from the transport sector), through adding additional tube trailer bays and compression equipment at the trailer facility
- This is likely to go hand-in-hand with an upgrade to a 500 bar, tube-trailer facility, with c. 5-10 trailer to cope with the installed capacity (see activity 2b)

Key project facts/assumptions

- Tube trailer dispensing capacity upgraded by 3 -5 tonnes/day, giving a total installed dispensing capacity of c. 5-7 tonnes/day
- Compression equipment upgraded to allow 500 bar filling

Impact on priority drivers: Direct economic, Inward investment, Environmental, Branding

1b Project economics

- Tube trailer filling equipment capital costs are estimated to be £5-6 million[1] for an additional 3 tonnes/day
- Additional costs for civils and electrical infrastructure are not included

[1]Costs are indicative

Activity 1c: Project to develop large-scale 'green' H_2 production capacity based around the planned AP waste gasification plant(s)

Rationale

- Air Products is developing a waste gasification plant, to process 1,000 tpd of sorted MSW, from late 2014
- This is currently planned to generate electricity from c. 1.5m Nm^3/day of syngas
- Once demand for H_2 for transport grows to a sufficient scale (to justify investment) in the region, this high value revenue stream could be tapped through purifying transport-grade 'green' H_2 from syngas
- This could also provide a bulk source of affordable 'green' H_2 to industry

Suggested activities

- Engage closely with Air Products to understand the likely H_2 price, funding required for conversion – work towards installing **a MW-scale syngas purification system to produce c. 1,000kg/day of fuel cell-grade H_2** at the AP facility, demonstrating the principle of purifying waste-based syngas
- Given the likely oversupply of H_2 for the limited early rollout of H_2 vehicles, it will be necessary to install a stationary H_2 fuel cell at the site, to generate electricity at high efficiency and provide a load for H_2 – work with a range of large low temperature stationary fuel cell suppliers (e.g. AFC, Ballard) to **understand the costs and funding requirements for a 1MW fuel cell**

Key project facts/assumptions

- Plant modified to allow 400 kg/day (c. 1MW) of syngas derived H_2 to be exported
- Purification equipment installed to clean-up H_2 from <95% purity to >99.999%
- 1MW low-temperature stationary fuel cell deployed

Impact on priority drivers: Direct economic, Inward investment, Environmental, Branding

1c Project economics

- Purification equipment could be procured for c. £3-5m[1] per purification unit with maximum flow rate of 500kg/day
- Capital costs for large 1 MW_e stationary fuel cells range between £2-2.5 million
- Additional costs for civils and electrical infrastructure are not included

[1]Costs are indicative

The long-term aim in H_2 production is to ensure a diverse mix of large-scale, low-cost, 'green' H_2 sources, for both transport and industry uses

1

Rationale

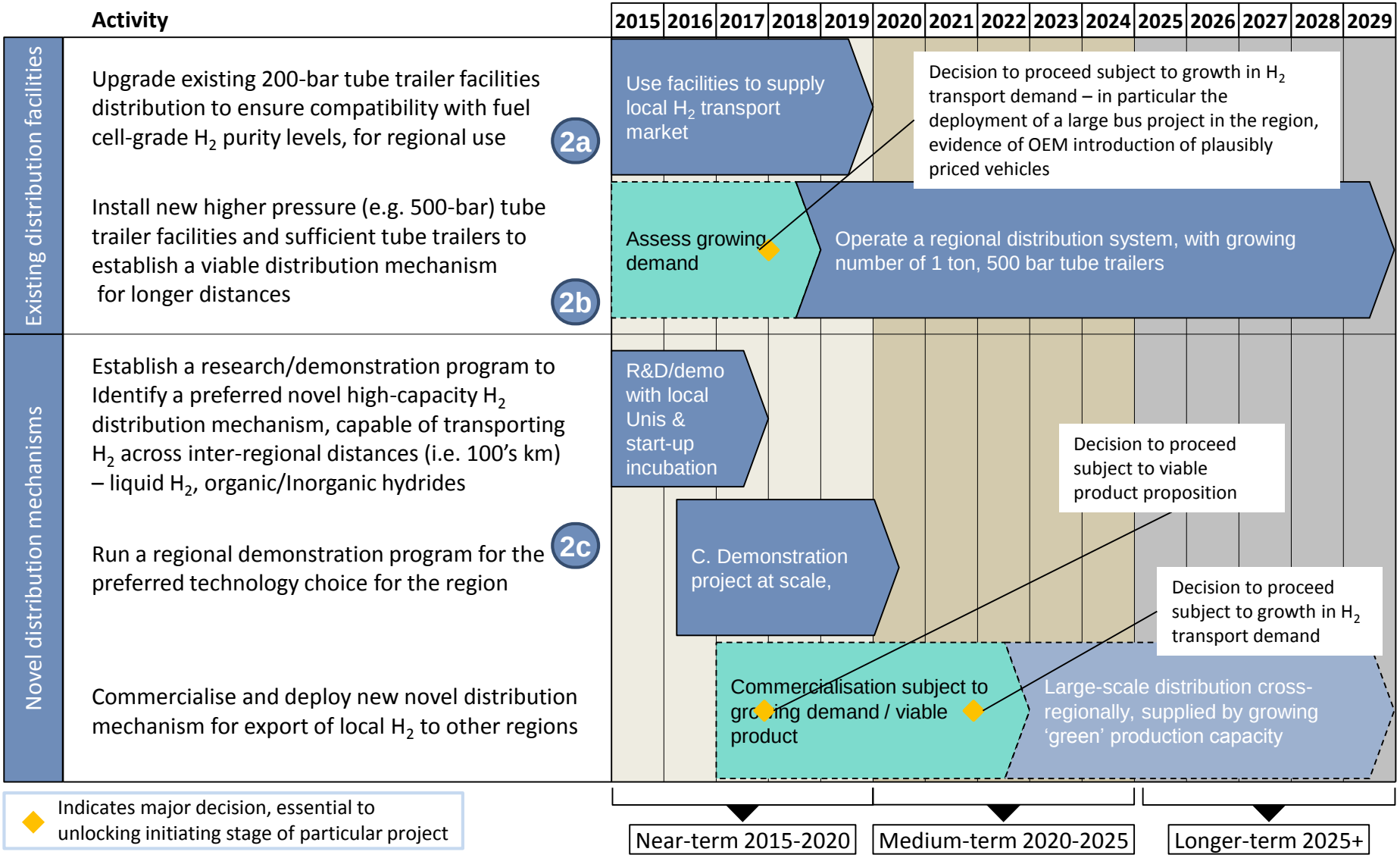
- The TV&NE region has extensive existing large-scale, 'brown' H_2 production facilities, with spare capacity in the 1,000's tpa
- The study has identified a range of 'green' H_2 production sources which are consistent with the existing chemical skills base. These will become relevant as H_2 demand from the transport sector grows and the cost of natural gas based generation increases
- By leveraging existing regional skills and capabilities in the region, **a significant opportunity exists for deploying these new 'green' H_2 production assets, to become a major exporting region** for transport-related 'green' H_2 (when deployed in conjunction with suitable distribution mechanisms)
- These new, more diverse 'green' production sources, will have the added benefit of providing alternative sources of H_2 for regional industrial applications – contributing to **decarbonising the regional industrial sector and de-risking future production costs**

Suggested activities

- **Identify a preferred solution for large-scale 'green' H_2 production**. Options appraisal in c. 2020 could assess:
  - Purifying waste-derived syngas, e.g. at the planned Air Products waste gasification plants
  - Connecting existing/new SMR production capacity to a regional CO_2 pipeline associated with regional CCS projects
  - Water electrolysis from regional renewables, e.g. the planned Dogger Banks wind farm
  - Other sources, e.g. SMR on anaerobically digested biogas
- Work closely with production, distribution and industrial use stakeholders to **ensure that the eventual production mix closely matches the requirements of both transportation and industrial applications**, thereby maximising the size of the addressable market
- Carry out **engineering/feasibility studies from c. 2022**, with the aim of **deploying the plant from c. 2025**

Distribution activities make use of existing/upgraded capacity to serve regional demand, whilst developing novel methods for export

2



Activity 2a: Develop a fuel cell-grade H_2 distribution capability based around existing production capacity

Rationale

- No regional distribution mechanisms currently exist for delivering H_2 to the transport sector in the region
- BOC operates a 230 bar tube trailer facility in North Tees industry cluster
- This fleet usually carries H_2 at lower purity than required for fuel cells and hence either new QA systems are needed or dedicated fuel cell grade logistics are required
- Its capacity is c. 2,000kg/day, based on decanting to 230 bar tube trailers (total UK fleet is 65 trailers, from 5 sites)
- There is sufficient existing to supply any vehicles considered here before 2020 (except potentially buses)

Suggested activities

- Work with BOC to ensure that there is **sufficient existing tube trailer capacity to supply fuel cell-grade purity H_2** to planned transport applications, that tube trailers can carry high purity H_2 (purified using PSA from project 1A)
- **Negotiate an acceptable price** (ideally <£3/kg) for H_2 delivered to regional HRS
- Deploy **sufficient tube trailer capacity to cover deliveries to the HRS deployed / planned** to support known H_2 vehicle projects, plus any redundancy required to ensure sufficient reliability for fuel delivery

Key project facts/assumptions

- Existing tube trailers (post-refurbishment and clean-up) used to deliver H_2 HRS
- Unlikely that any new procurement required due to size of existing fleet (65 trailers)

Impact on priority drivers: Direct economic, Inward investment, Environmental, Branding

2a Project economics

- New 230 bar tube trailers can be purchased for c. £300k per vehicle, if required

Activity 2b: Upgrade the existing tube trailer facility to accommodate higher-capacity tube trailers, to cope with increasing demand

Rationale

- The 230 bar BOC tube trailer facility has limited capacity, partly due to its scale, but also due to the costs of using relatively low-pressure compression for large volumes of H_2 and longer distances
- In the absence of novel distribution methods in the near-medium term, the easiest way to ensure more cost effective higher capacity distribution from a centralised source, is to switch to higher pressure compression and use higher capacity trailers

Suggested activities

- Work with FCEV/bus users to evaluate how much capacity will be required and delivery schedules, etc.
- Engage with BOC to understand the costs of upgrading the tube trailer facility, funding sources available, resulting price for H_2, etc.
- Subject to growth in demand (e.g. if a major H_2 bus project is secured), **upgrade the existing facility to accommodate the largest tube trailer technology available (currently a capacity of 1.1 tonnes H_2 at 500 bar)**
- Support any necessary funding applications
- Deploy sufficient tube trailer capacity to cover deliveries to all the HRS deployed/planned, plus any redundancy required to ensure sufficient availability of all HRS

Key project facts/assumptions

- 3 x new 500 bar tube trailers with 1.1 tonne capacity each could support a maximum of 50 buses
- Fleet configuration will allow for one vehicle to be filling, one to be delivering and one spare as redundancy

Impact on priority drivers: Direct economic, Inward investment, Environmental, Branding

2b Project economics

- New 500 bar tube trailers can be purchased for c. £900k per vehicle

Activity 2c: Work closely with local academic institutions and industrial partners to commercialise novel, high-capacity H_2 storage mechanism

Rationale

- The only existing H_2 distribution capabilities in the region are from the BOC tube trailer facility in the North Tees industry cluster
- A number of new technologies are in development across the globe, which aim to commercialise bulk H_2 storage and distribution – including liquid organic carriers, inorganic hydrides and more efficient H_2 liquefaction
- Accessing low-cost bulk distribution mechanisms could be valuable to TV&NE, as this would enable the establishment of H_2 export capacity beyond regional borders

Suggested activities

- **Develop a regional research project based at local Universities and research centres to assess the most appropriate novel high-capacity H_2 carriers for the region**, including e.g.: Liquid organic H_2 carriers, solid hydride storage, new cryogenic (e.g. liquid) solutions, etc.
- Engage with preferred system developers e.g. Hydrogenious, Chiyoda (organic hydrides), Hydrexia, McPhy (inorganic hydrides) and liquefaction companies to **develop a medium-scale (e.g. 500kW) demonstration project in the region**
- This would involve **working closely with local academic institutions**, as well as **attracting other global experts to partner** in the region, potentially through providing incubation support/investment to encourage them to establish a base in the TV&NE region

Key project facts/assumptions

- Initial feasibility research project will be undertaken
- Findings from initial research will scope the deployment of a demonstration facility and dedicated research program

2c Project economics

- Feasibility/initial research project cost estimate: £50-500k
- Demonstration facility and dedicated research program cost estimate: £1m+

Impact on priority drivers:

- Direct economic
- Inward investment
- Environmental
- Branding

The long-term aim in the distribution sector is to build sufficient capacity to enable widespread distribution and export to other regions

2

Rationale

- The TV&NE region has extensive existing large-scale H_2 production facilities, with spare capacity in the 1,000's tpa
- In addition to this, a range of potential future sources have been identified for the large-scale production of 'green' H_2, supported by the extensive regional skills and facilities already in place
- The scale of available production far outweighs the likely future size of transport-related demand from the region
- Therefore, in order to access the high value revenue stream of selling H_2 to the transport sector, there is a **clear requirement for a cost-effective, bulk H_2 distribution mechanism , capable of transporting 1,000's tpa across relatively large distances**, in order to supply transport demand in other UK regions

Suggested activities

- Following successful demonstration of the preferred novel distribution mechanism **from c. 2018** onwards, work with the selected supply chain partner to **take the demonstration activities towards a full commercial-scale deployment** in the TV&NE region
- This should only be **done in parallel with enabling the export of 'green' H_2 from new production capacity coming online** and a clear signal of demand from the auto (or other sectors) e.g. the AP waste gasification plant **from c. 2022** onwards – in order to support large-scale export of 'green' H_2 for the transport sector in other UK regions
- Work closely with the selected supply chain partner, to build local skills and expertise – with the aim of establishing a strong expertise and technical capacity to allow export of the technology elsewhere throughout Europe and globally

Vehicle activities centre around securing a near-term investment from a niche player, whilst laying the ground for a major OEM to invest

3

	Activity		2015–2016	2017–2018	2019–2020	2021–2022	2023–2024	2025–2026	2027–2029
Choice of niche vehicles	Support a major (10's units) H_2 bus deployment, subject to inward investment decision from manufacturer/supply chain partner	3a*	Users + funding	Staggered deployment of 10's of fuel cell buses with various regional/external operators*					
	Support a major (~100 units) H_2 materials handling vehicle deployment, subject to inward investment from manufacturer/supply chain partner	3a*	Users + funding	Staggered deployment of >100 H_2 forklifts with regional operators (e.g. ports etc)*					
	Support a major (10's units) H_2 vans deployment, subject to inward investment decision or link to Nissan aspirations	3a* 3a*	Users + funding	Staggered deployment of 10's of H_2 vans with regional operators (e.g. logistics, etc)*					
OEM vehicles	Deploy a small number (<10) of OEM vehicles to raise profile of the region in the eyes of OEMs and other supply chain stakeholders (e.g. Hyundai)	3b	Funding	Deployment to high-profile end-users					
	Work to develop an H_2 REEV vehicle, working with OEM base vehicle + niche supply chain players willing to invest in the region	3c	Develop vehicle, centered around env200 platform	Deploy vehicle					
	Deploy a larger number of OEM vehicles, as more models become available			Funding	Deployment to high-profile end-users				
	Engage OEMs to secure position of TV&NE as a major deployment region and long-term OEM Investment into the region		Long-term engagement, with the aim of attracting inward investment to the region from a major OEM (target would be assembly plant c. 2025)						

*Unlikely that more than one of these projects would be deployed due to investment required

Decision to proceed subject to secured inward investment by manufacturer, funding availability and identification of end-users

Decision to proceed subject to availability of funding

◆ Indicates major decision, essential to unlocking initiating stage of particular project

Near-term 2015-2020 | Medium-term 2020-2025 | Longer-term 2025+

*one or more of these projects should be targeted

Period of uncertainty | Near-term activity

A number of manufacturers have indicated a potential willingness to set up assembly facilities in the region if sufficient local demand exists

3a

Strategic vehicle demonstration deployment could assist in attracting inward investment

- A handful of vehicle manufacturer/integrator SME's (e.g. ULEMCo, Symbio, HyPulsion, Ballard) and larger OEM's (e.g. Van Hool) have developed a series of H_2 transportation technologies
- These manufacturers are expecting to **ramp-up their production in line with forecasted demand increases** for H_2 vehicles across Europe and will look to deploy new assembly facilities in the short-medium term
- A number of these organisations, in particular ULEMCo, Symbio, HyPulsion, Ballard and Van Hool have indicated that **with sufficient regional demand they would consider setting up assembly facilities in the TV&NE region**
- Note, a deployment of **unprecedented scale** is a requirement needed to attract manufacturers – the order of magnitude is likely for 10's-100's of vehicles, although not all these would need to be deployed regionally

VANHOOL BALLARD

Product: 13m Fuel Cell bus, all-inclusive OEM package

Currently location: Belgium

3a

HYPulsion

Product: H_2 fuel cell-powered fork lifts

Currently location: France

3a

Symbio FCell ULEMCo

Product: Fuel Cell range extenders for EVs / ICE Transit conversions to H_2 fuel

Currently location: France/Liverpool

3a

A bus demo project to attract Van Hool/Ballard would be the **most costly** but would provide the largest demand for H_2 of any of the projects and **could result in a OEM investing in the region**

A demo project to attract Symbio, HyPulsion or ULEMCo would come at a **lower overall project cost by an order of magnitude** and **could result in a SME investing in the region**

NOTE: it is unlikely that all three of these projects would be deployed simultaneously and we have assessed them separately

Activity 3a: Work towards a major bus deployment project, with the aim of attracting inward investment to the region

Rationale

- No significant H_2 vehicle deployments in the region
- However, the region has a number of bus operators serving the major urban areas in the region
- A number of fuel cell bus supply chain players (e.g. Van Hool, Ballard, etc.) have stated a willingness to set up a vehicle support base or an assembly plant in the region if a suitably large order for H_2 buses were led by the region
- These bus manufacturers suggest that for a large volume order major cost reductions (to c. £500k per bus) are feasible, which brings a project within the range of fundability using national funds.
- Buses provide the most cost-effective way of creating demand for locally sourced H_2, thereby helping to enable the projects in activity streams 1, 2 and 4

Suggested activities

- **Engage with fuel cell bus supply chain players** (Van Hool, Ballard, etc.) to understand their willingness to deploy manufacturing capacity to the region, based on a bulk order spearheaded by the region – including the minimum requirements for making this commitment
- **Work closely with bus operators to develop an appetite** for operating fuel cell buses (c.20-50) from regional bus depots
- Work with other UK regions to establish a sufficiently large demonstration project to drive prices to an affordable level
- **Work with EU / national funding agencies**, to ensure support for the majority of the cost of an FC bus project
- **Prepare a large-scale procurement for >100 buses** (with c. 50 for the region) and work closely with the identified supply chain player(s) to **help them establish regional operations**

Key project facts/assumptions

- Deploy 20-50 fuel cell buses to at least two operators, from 2018, operation for 10 years

Impact on priority drivers: Direct economic; Inward investment; Environmental; Branding

3a Project economics

Net present value (2018-2028)

# buses \ H_2 price	£3.50	£7.00
20	-£7.9m	-£10m
50	-£20m	-£26m

Maximum funding shortfall

# buses \ H_2 price	£3.50	£7.00
20	-£9.1m	-£13m
50	-£23m	-£32m

Delta capex = £550k, delta fixed opex = £9.4k/year, FC bus fuel consumption = 8kgH_2/100km, incumbent bus fuel consumption = 36l/100km, mileage = 220km/day, availability = 85%, hydrogen cost = £7/kg, bus diesel cost = £1.1/l

Activity 3a: Work towards a major materials handling deployment project, with the aim of attracting inward investment to the region

Rationale

- No significant H_2 vehicle deployments in the region
- However, the region boasts a number of major ports and associated logistical operations, with large fleets of materials handling vehicles in operation
- A number of these captive fleets are likely to exhibit favourable economics for deploying fuel cell fork lifts (in the US over 5,000 have been deployed commercially)
- Fork lifts in multi-shift operations (where economics are favourable) will consume substantial quantities of H_2, helping to create demand for locally sourced H_2
- Some fuel cell fork lift suppliers have indicated a willingness to invest in regional assembly if a large demand can be generated (100's of vehicles)

Suggested activities

- Work **closely with end-users** identified as part of this study (Asda, Tesco, etc.) **to understand their appetite for engaging** with this technology and deploying vehicles
- **Engage with H_2 fork lift manufacturers** (e.g. HyPulsion) to discuss their willingness to commit to deploying manufacturing capacity to the region, based on a bulk order from regional end-users – including the minimum requirements for making this commitment
- Consult with EU / national funding agencies to understand the availability of funding to support a project
- **Prepare a procurement exercise for >100 fork lifts**
- Work closely with the vehicle supplier to help them establish new operations in the region

Key project facts/assumptions

- Deploy 50 x fuel cell forklifts from 2015, to 3 customers
- Suppliers aim for capital costs to be at cost parity with battery incumbent

Impact on priority drivers: Direct economic; Inward investment; Environmental; Branding

3a Project economics

Project start	2015
Project lifetime	5 years
Net present value	-£0.4m (2015-2019)
Max. funding shortfall	-£0.6m (in 2019)
Annual environmental benefits[1]	£4,500/year

Delta capex = £0 delta fixed opex = £0/year, FC vehicle fuel consumption = 2.5kgH_2/100km, incumbent fuel consumption = 105kWh/100km, mileage = 80km/day, availability = 85%, hydrogen cost = £7/kg, electricity cost = £0.1/kWh, [1]See env benefit assumption page

Activity 3a: Work towards a major H_2-ICE van deployment project, with the aim of attracting inward investment to the region

Rationale

- No significant H_2 vehicle deployments in the region
- A number of major logistics operators and other users of Transit-sized vans are operating in the region
- These return-to-base fleets provide an ideal chance for deploying ULEMCo H_2-ICE vans in a controlled way
- Due to their lower efficiencies relative to fuel cell H_2 vehicles, H_2-ICE vans can provide a significant demand for H_2, thereby supporting demand creation for locally-sourced H_2. They are however not expected to offer a long term competitive proposition
- Their lower up-front cost to end-users also makes them an attractive proposition for the early years

Suggested activities

- Work **closely with end-users** identified as part of this study **to understand their appetite for engaging** with this technology and deploying vehicles
- **Engage with ULEMCo** to discuss their willingness to commit to deploying manufacturing capacity to the region, based on a bulk order from regional end-users – including the minimum requirements for making this commitment
- Consult with EU / national funding agencies to understand the availability of funding to support a project
- **Prepare a procurement exercise for 10's of H_2-ICE vans**
- Work closely with ULEMCo to help them establish new operations in the region

Key project facts/assumptions

- Deploy 50 x Ford Transit vans with ULEMCo ICE conversion equipment installed, to three separate regional fleets

Impact on priority drivers: Direct economic; Inward investment; Environmental; Branding

3a Project economics

Project start	2015
Project lifetime	5 years
Net present value	-£1.6m (2015-2019)
Max. funding shortfall	-£1.8m (in 2019)
Annual environmental benefits[1]	£1,000/year

Delta capex = £26k delta fixed opex = £550/year, FC vehicle fuel consumption = 2.5kgH_2/100km, incumbent van fuel consumption = 8.7l/100km, mileage = 57km/day, availability = 80%, hydrogen cost = £7/kg, electricity cost = £0.1/kWh, [1]See env. benefit assumption page

Activity 3a: Work towards a major H_2 REEV vans deployment project, with the aim of attracting inward investment to the region

Rationale

- No significant H_2 vehicle deployments in the region
- A number of major logistics operators and other users of light commercial vans (LCVs) are operating in the region
- These return-to-base fleets provide an ideal opportunity for deploying Symbio H_2 range-extended Renault Kangoo LCVs in a controlled way
- The lower up-front cost of these range-extended vehicles also makes them an attractive proposition to end-users

Suggested activities

- Work **closely with end-users** identified as part of this study **to understand their appetite for engaging** with this technology and deploying vehicles
- **Engage with Symbio Fuel Cell (and other potential suppliers)** to discuss their willingness to commit to deploying manufacturing capacity to the region, based on a bulk order from regional end-users – including the minimum requirements for making this commitment
- Consult with EU / national funding agencies to understand the availability of funding to support a project
- **Prepare a procurement exercise for 10's H_2 range-extended Renault Kangoos**
- Work closely with Symbio to help them establish new operations in the region

Key project facts/assumptions

- Deploy 50 x Renault Kangoo vans with Symbio fuel cell range extenders installed, to three separate regional fleets

Impact on priority drivers: Direct economic; Inward investment; Environmental; Branding

3a Project economics

Project start	2015
Project lifetime	5 years
Net present value	-£1.0m (2015-2019)
Max. funding shortfall	-£1.1m (in 2019)
Annual environmental benefits[1]	£1,500/year

Delta capex = £19k delta fixed opex = £390/year, FC vehicle fuel consumption = 0.7kgH_2/100km, 6.78kWh/100km, incumbent van fuel consumption = 4.6l/100km, mileage = 57km/day, availability = 80%, hydrogen cost = £7/kg, electricity cost = £0.1/kWh, [1]See env. benefit page

Activity 3b: Initiate a small OEM H_2 vehicle deployment in the region, to high profile end user(s)

Rationale

- One of the strategy's long-term aims is to attract inward investment from a OEM
- A high-profile way of ensuring early OEM engagement is to initiate a (deliberately) small-scale deployment of OEM vehicles to the region (Left Hand Drive Hyundais are the only vehicles realistically available to the region pre-2018)
- By selecting high-profile end-users for the vehicles (e.g. Councils, multinationals), the profile of H_2 transport in the region can be raised, both with the general public and key industrial stakeholders

Suggested activities

- **Engage with Hyundai to discuss a procurement of a small number (<5) fuel cell iX35's to the region** – with the aim of achieving a significantly reduced cost to their stated cost in 2014 (c. £120k)
- **Identify end-users for the vehicles, from a range of high-profile local industry/public sector actors**. These should ideally have a willingness to contribute significantly to the cost of the vehicles
- **Support end-users/the OEM in obtaining up to 50% funding** towards the vehicles from public sources, e.g. through accessing FCH JU Topic 1.7 or any future OLEV funding to reduce vehicles costs to the point of affordability
- Ensure high-profile, **active dissemination** of the project
- Note we deliberately recommend not looking for a major OEM deployment, due to the limited availability of vehicles and the fact that there will be cheaper more diverse supply from circa 2018

Key project facts/assumptions

- Deploy 5 x Hyundai ix35 FCEVs to very high profile public or corporate customers, from 2015

Impact on priority drivers: Direct economic; Inward investment; Environmental; Branding

3b Project economics

Project start	2015
Project lifetime	5 years
Net present value	-£0.4m (2015-2019)
Max. funding shortfall	-£0.5m (in 2019)
Annual environmental benefits[1]	£200/year

Delta capex = £93k delta fixed opex = £480/year, FC vehicle fuel consumption = 9kgH_2/100km, incumbent fuel consumption = 7l/100km, mileage = 57km/day, availability = 80%, hydrogen cost = £7/kg, diesel cost = £1.35/kg, [1]See env. benefit assumption page

Activity 3c: Work to develop a range-extended version of one of their electric vehicles

Rationale

- Nissan is the only global OEM with major operations in the region – with a strong presence in electric vehicles through its battery plant at Sunderland
- Whilst attracting a second global OEM to the region is a key aim of the strategy, Nissan may provide a nearer-term opportunity to build a OEM-led H_2 and fuel cell supply chain in the region
- A number of players (e.g. Symbio) are working with OEMs (including Renault, part of the Nissan-Renault alliance) to develop range-extended versions of their electric vehicles – this presents an opportunity, particularly around Nissan's electric env200 model

Suggested activities

- **Engage with Nissan to understand its willingness to develop a range-extended version of one of its electric vehicles** in the region (ideally the env200, due to its multi-platform uses), through partnering with supply chain players such as Symbio
- Establish the scale (demo, or series production) of their interest and **support e.g. Symbio and Nissan** in getting the project underway
- **Identify end-users** for the first trial vehicles to be deployed to the region and work towards larger procurements, with a view towards setting up a permanent Symbio/Nissan partnership, with a TV&NE component

Key project facts/assumptions

- Range extended env200 vehicle could be applied to a number of platforms, including Light Commercial Vans, taxis, passenger car, etc.

3c Project economics

- Indicative up-front development cost estimated at c. £1-2m

Impact on priority drivers: Direct economic; Inward investment; Environmental; Branding

The long-term aim in the transport sector is to establish the TV&NE region as an attractive deployment and investment centre for OEMs

3

Rationale

- One of the long-term aims of the strategy is to attract inward investment from a OEM to the TV&NE region:
  - A strong automotive supply chain is in place, with a low carbon focus since the Sunderland Nissan Leaf investment
  - By aiming to attract an additional niche vehicle supply chain partner/manufacturer to the region (linked to the large deployments described above), TV&NE will build the critical mass, skills and infrastructure required to make the region an attractive proposition to OEMs
  - If supported by long-term Government policies to make the UK an attractive region for OEM FCEV investment, this, and the access to other European markets afforded by local port infrastructure, could put TV&NE in a strong position for attracting OEM investments, as they look to deploy their first European FCEV facilities in the mid to late 2020's
- **Early and sustained engagement with OEMs, coupled with the activities recommended in this strategy will help to maximise the chances of investment from a major OEM** in the longer-term

Suggested activities

- **Ensure continued, long-term engagement with OEMs developing FCEVs**, i.e. Hyundai, Toyota, Honda, Daimler, Nissan, etc., ensuring that they are aware of the activities underway in the region and the strong supply chain and regional skills for production and distribution of H_2, as well as vehicle / component manufacture and support
- Engagement **could be supported through activities including large procurements of OEM vehicles** as they move closer to the point of affordability (from 2018)
- **Coordinate activities with BiS and the UK H_2Mobility** consortium, to ensure support from central Government, as ultimately central Government support will also be critical to ensuring OEMs arrive in the UK
- As investment decisions approach, engage with the Automotive Investment Organisation, to secure their support in attracting inward investment

Refuelling should support individual vehicle deployments, prior to establishing full regional coverage, ideally with locally sourced HRS

4

	Activity		2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
Local capabilities	Work with local academic/supply chain Partners, together with international HRS suppliers (e.g. industrial gas companies) to develop a locally sourced HRS, as part of the required HRS network	4a	Design new locally sourced HRS system → Deploy system to region → Engage supply chain partners in HRS roll-out nationally and internationally														
Refuelling infrastructure build-out	Support vehicle deployments with new HRS as and when demand requires it – using local technology where possible	4b	Build 2nd / 3rd HRS subject to large niche vehicle rollout; Build 3rd / 4th / 5th HRS subject to large OEM vehicle rollout; Deployments as and when required														
	Build out network into viable refueling network, as demand continues to grow, offering good coverage across the region		Build 1st HRS for small vehicle trials, etc.					Build full regional coverage, prioritizing early deployment sites based on local demand and ensuring that any deployments are backed by real prospects for increased future demand									

◆ Indicates major decision, essential to unlocking initiating stage of particular project

Near-term 2015-2020 | Medium-term 2020-2025 | Longer-term 2025+

Activity 4a: Develop a new, low-cost HRS solution using local supply chain players and locally sourced components/manufacturing

Rationale

- There is currently a limited HRS supply chain in the region, with Haskel as the only identified player
- However, the region boasts world-class assets and skills in the production, handling and distribution of industrial gases, including H_2
- As such a clear opportunity exists to leverage these capabilities in the development of a HRS maximising local supply chain content – helping to build the local H_2 supply chain and offering significant future export potential

Suggested activities

- **Work with existing HRS suppliers** (e.g. Haskel, BOC, H2Logic, ITM, etc.), to understand their willingness to source components for their systems from the TV&NE supply chain (potentially in return for procuring at least one HRS for the region)
- Work with the selected HRS supplier to **publish an call for local sub-component suppliers to provide equipment for an existing HRS design**
- Develop this into **a new, low-cost HRS solution, with major components and assembly being sourced from within the TV&NE region**
- **Deploy at least one of these HRS to the region**, in an easily accessible location, as part of the network required to meet regional H_2 demand

Key project facts/assumptions

- Develop a HRS using local supply chain and expertise
- Higher than usual costs are expected due to inherent inefficiencies of developing new equipment and non-recurring engineering costs

Impact on priority drivers: Direct economic, Inward investment, Environmental, Branding

4a Project economics

- Total expected costs for novel 80kg/day HRS = £1.2m

Activity 4b: Deploy new HRS to expand the network as and when investment is secured for additional vehicle deployment projects

Rationale

- There are currently no HRS with a sufficient scale to support any of the recommended H_2 vehicle deployments in the region
- Depending on the number of vehicle projects deployed, there will be differing requirements for HRS, in various configurations and locations
- However, to avoid the 'chicken and egg' situation of vehicles not deploying due to lack of HRS and vice-versa, there is a good argument for deploying at least one, centrally-located and publically accessible HRS to support early vehicle deployments (and to link with projects 1a and 2a)

Suggested activities

- **Work with supply chain** (Air Products, Air Liquide, BOC, H2Logic, Haskel, ITM Power, etc.) **to procure at least one small (e.g. 80kg/day) dual pressure HRS (350 and 700 bar)**, which should be centrally-located and publically accessible – there should be visibility of at least one vehicle project prior to investing. Ideally this should be using locally-sourced content (see activity 4a)
- Station should be deployed consistent with UKH_2Mobility HRS configurations and roll-out plans, whilst potential EU / national funding sources should be identified to support HRS rollout
- **As subsequent vehicle deployments are funded** (e.g. buses, vans, forklifts, etc.), decisions should be made on **expanding the network to cater for their requirements**

Key project facts/assumptions

- Size of HRS scoped based on the size of demand and expecting loading required for break-even
- Three main sizes of HRS are likely to be available in the early years of rollout: 80, 500 and 1,000 kg/day

Impact on priority drivers: Direct economic, Inward investment, Environmental, Branding

4b Project economics

- Costs depend on number of HRS deployed and load factors experienced
- HRS capital costs: £0.8m (80kg/day), £1.4m (500kg/day), £2.2m (1000kg/day)
- See upcoming individual HRS analysis

In the near-term, HRS siting should prioritise early adopters, whilst also attempting to achieve a well distributed public network

4

HRS build-out is recommended to align with end-users deployments

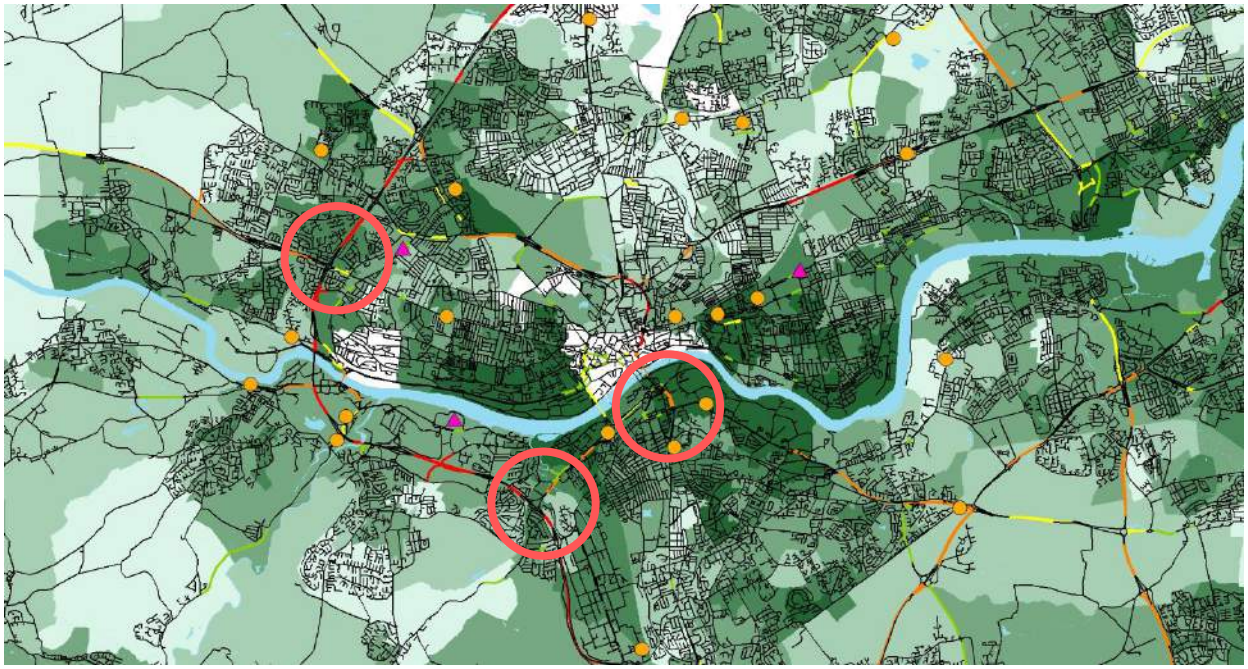
- In the short-term the end-user strategy is likely to primarily target "captive fleets" for the rollout of nucleated deployments
- Supporting infrastructure deployment should correspond with the geography of these early vehicle rollouts
- Early HRS sites should be selected based on end users identified, but should also target locations where significant throughput can be supported by demand from private sector vehicles

HRS site selection methodology

- **Consumer surveys conducted as part of UKH_2Mobility have shown the following factors are most relevant to HRS siting activities:** end-user location preference, hydrogen distribution logistics, consumer wealth distribution, vehicle daily traffic flow, inner-city congestion levels and poor air-quality zones
- Additional findings indicate end-users have a preference for at least **two HRS per urban cluster** in order to provide sufficient confidence in the availability of refuelling infrastructure
- A methodology for identifying suitable HRS sites based on **traffic flow** and **consumer wealth distribution** within a city has been developed for evaluating HRS sites in the North East region
- A three-stage process was used to establish an infrastructure rollout in the North East cities:
  1. Producing a Graphical Information System (GIS) map overlaying the two metrics described above
  2. Using a similar methodology to identify city-specific priority areas for each city
  3. Selecting suitable HRS priority siting areas – highlighted for further investigation of sites as part of a deployment strategy
- Individual city analysis applying this methodology has been conducted for **Newcastle, Middlesbrough and Sunderland** and the choice of best location will be dictated by the location of real vehicle demand

Newcastle and Gateshead: three priority areas have been highlighted for further analysis as potential HRS sites

Newcastle-upon-Tyne & Gateshead



- Newcastle-upon-Tyne is the **largest city in the region** (by population)
- HRS siting analysis for Newcastle and Gateshead indicates **three suitable areas** for deployment of an HRS:

1. A high-profile site South of the river between the two cities
2. By the A184 and A1 interchange to the West of Gateshead
3. By the A69 and A1 interchange to the West of Newcastle

Traffic intensity

- 440 – 8413
- 8413 – 16,611
- 16,611 – 28,776
- 28,776 – 49,478
- 49,478 – 85,566

Average car and taxi traffic daily flow rate

Index of Multiple Deprivation

- 1.73 – 10
- 10.001 – 20
- 20.001 – 40
- 30.001 – 60
- 60.001 – 80

Higher score indicates greater deprivation

Suggested HRS deployment area

Main road, major interchange or arterial route

Relevant existing infrastructure

- Petrol & diesel refuelling station (inc. energy company, supermarket, independent retailers
- Local bus operator depot (inc. Go North East, Stagecoach, Arriva)

[1]Office for National Statistics, [2]RAC Foundation (2011 Census)

Sunderland: two priority areas have been highlighted for further analysis as potential HRS sites

4

Sunderland

Traffic intensity

- 440 – 8413
- 8413 – 16,611
- 16,611 – 28,776
- 28,776 – 49,478
- 49,478 – 85,566

Average car and taxi traffic daily flow rate

Index of Multiple Deprivation

- 1.73 – 10
- 10.001 – 20
- 20.001 – 40
- 30.001 – 60
- 60.001 – 80

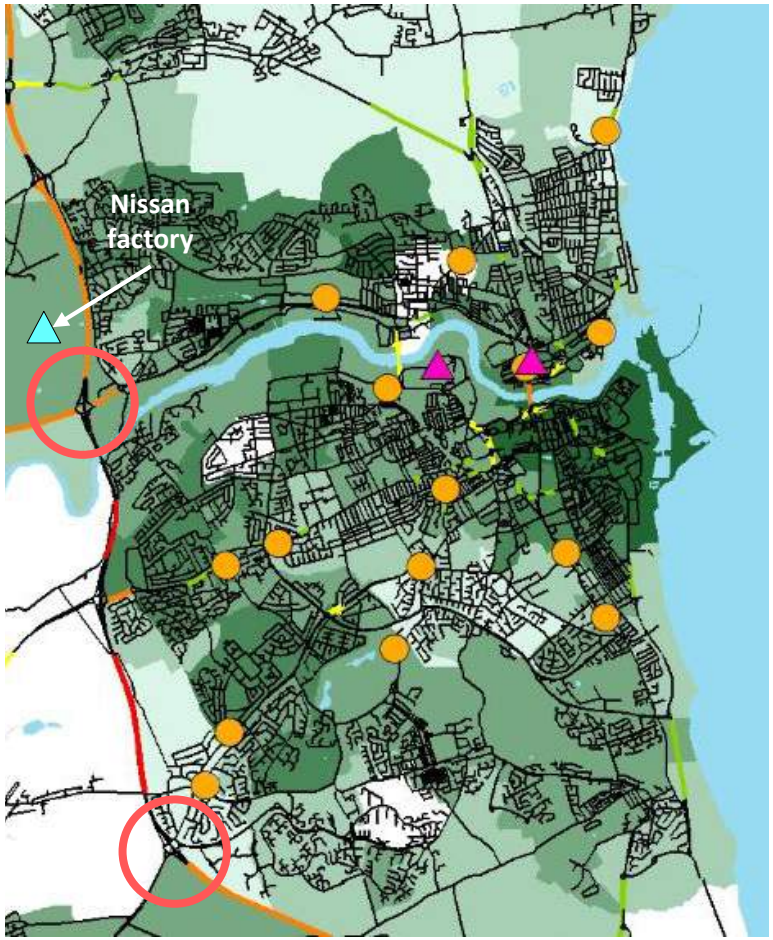
Higher score indicates greater deprivation

Suggested HRS site

Main road, major interchange or arterial route

Relevant existing infrastructure

- Petrol & diesel refuelling station (inc. energy company, supermarket, independent retailers
- Local bus operator depot (inc. Go North East, Stagecoach, Arriva)



- Analysis for Sunderland indicates two well connected road interchanges suitable for HRS deployment nearby:

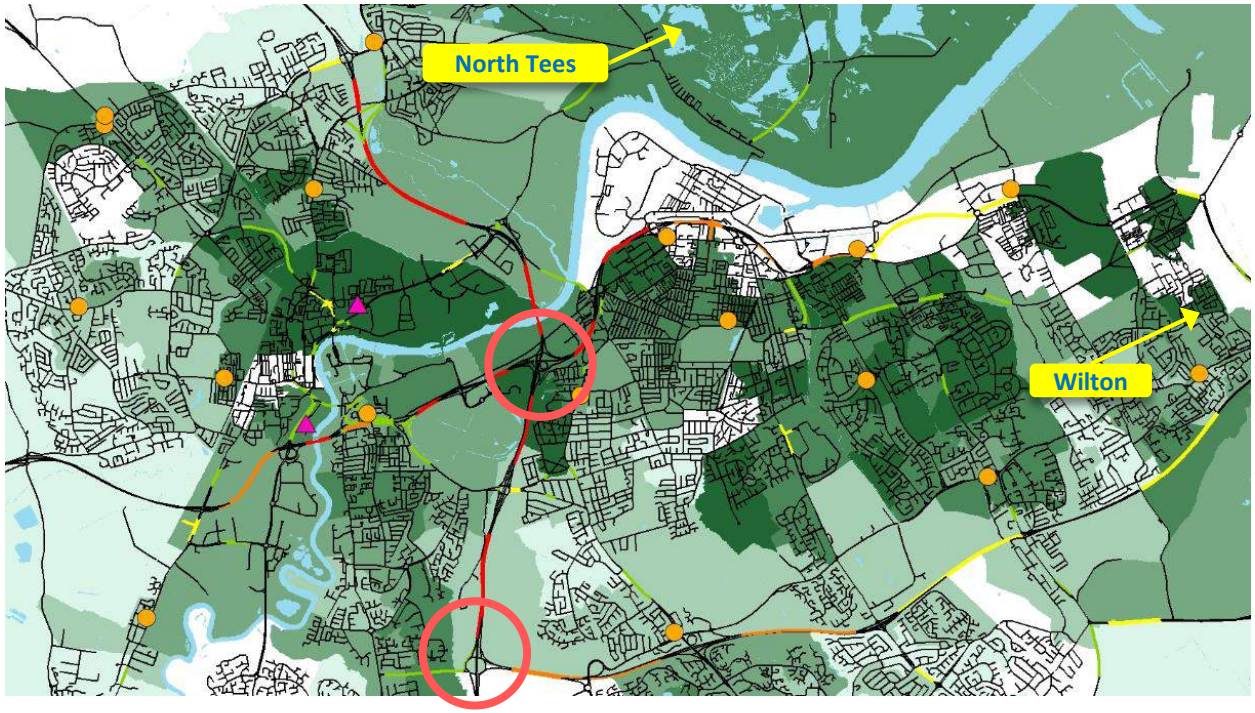
1. By the A1231 and A19 interchange in the North West region of the city, adjacent to the Nissan factory
2. By the A19 and A690 interchange in the wealthier, South West region of the city

[1]Office for National Statistics, [2]RAC Foundation (2011 Census)

Middlesbrough and Stockton-On-Tees: two priority areas have been highlighted for further analysis as potential HRS sites

4

Middlesbrough and Stockton-On-Tees



- Middlesbrough is the **nearest urban area to the main regional chemical industry operations**
- The city centre is **less than 8 miles from Billingham, Wilton and North Tees**
- Its proximity to the source of significant H_2 production suggests Middlesbrough as a potential early city for **HRS deployment**
- Two suitable site have been identified:

1. By the A66 and A19 interchange in the North West region of the city
2. By the A19 and A174 interchange adjacent to Stainsby Wood in the South West region of the city

Traffic intensity

- 440 – 8413
- 8413 – 16,611
- 16,611 – 28,776
- 28,776 – 49,478
- 49,478 – 85,566

Average car and taxi traffic daily flow rate

Index of Multiple Deprivation

- 1.73 – 10
- 10.001 – 20
- 20.001 – 40
- 30.001 – 60
- 60.001 – 80

Higher score indicates greater deprivation

Suggested HRS deployment area

Main road, major interchange or arterial route

Relevant existing infrastructure

- Petrol & diesel refuelling station (inc. energy company, supermarket, independent retailers
- Local bus operator depot (inc. Go North East, Stagecoach, Arriva)

[1]Office for National Statistics, [2]RAC Foundation (2011 Census)

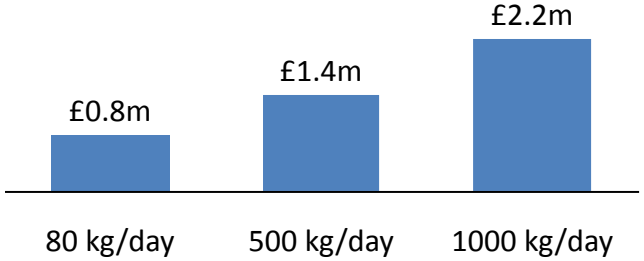
Strategic HRS size selection must balance scale of expected demand throughput over lifetime against capital available at start of project

Large upfront capital costs must be offset by maximising HRS utilisation

- HRS economics are governed by demand throughput
- Each HRS size has a minimum throughput in order to achieve a positive NPV (see below right matrix)
- Small 80 kg/day HRS are unlikely to breakeven even if maximum dispenser loading is reached
- 1000kg/day HRS can be opex positive from day 1 if load factors of >40% are achieved (>60% for 500kg/day)

2015 HRS capital costs (£ millions)

Costs include 700 bar dispenser and nozzle, compression and storage equipment are excluded



Maximum funding shortfall - £ millions

HRS load factor	HRS dispensing capacity: 80kg/day	500kg/day	1000kg/day
0%	-£1.4 (-)	-£2.5 (-)	-£3.9 (-)
20%	-£1.1 (-)	-£1.4 (-)	-£2.1 (-)
40%	-£0.9 (-)	-£1.2 (-)	-£1.9 (+)
60%	-£0.8 (-)	-£1.1 (+)	-£1.6 (+)
80%	-£0.8 (-)	-£1.0 (+)	-£1.4 (+)

(-) = HRS project is opex negative

(+) = HRS project opex positive

Note, HRS economics are particularly favourable due to low cost production and a £3.50/kg margin

Net present value - £ millions

HRS load factor	HRS dispensing capacity: 80kg/day	500kg/day	1000kg/day
0%	-£1.0	-£1.8	-£2.8
20%	-£0.9	-£0.9	-£1.1
40%	-£0.8	-£0.1	£0.6
60%	-£0.6	£0.8	£2.3
80%	-£0.5	£1.6	£4.0

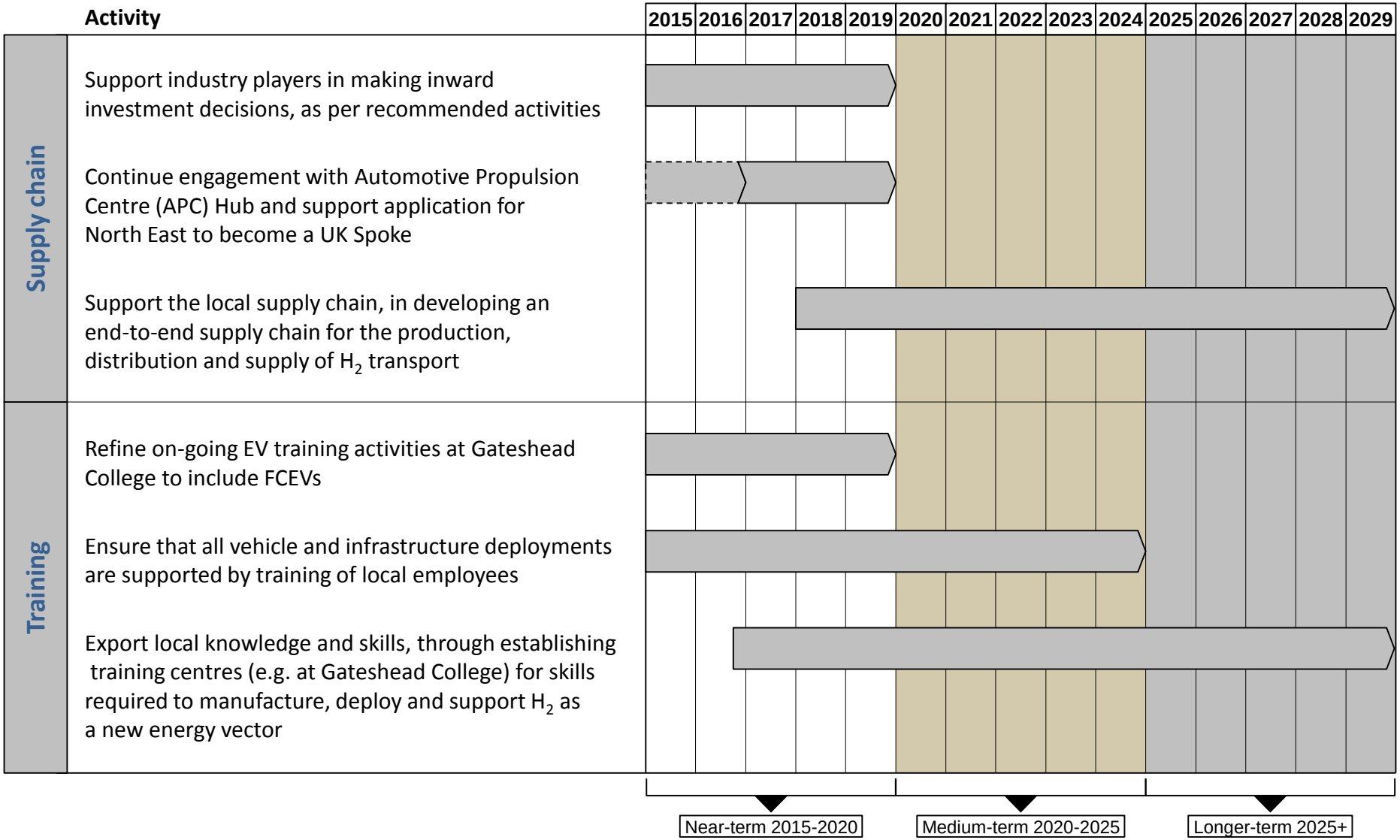
HRS throughput scale (kg/day)

0	100	200	300	400	500	600	700	800

Discount rate = 10%, delivered hydrogen cost = £3.50/kg, hydrogen pump price = £7/kg, Capex = £0.64m (80kg/day), £1.3m (500kg/day), £2.2m (1000kg/day), opex = 5% of capex, lifetime = 15 years

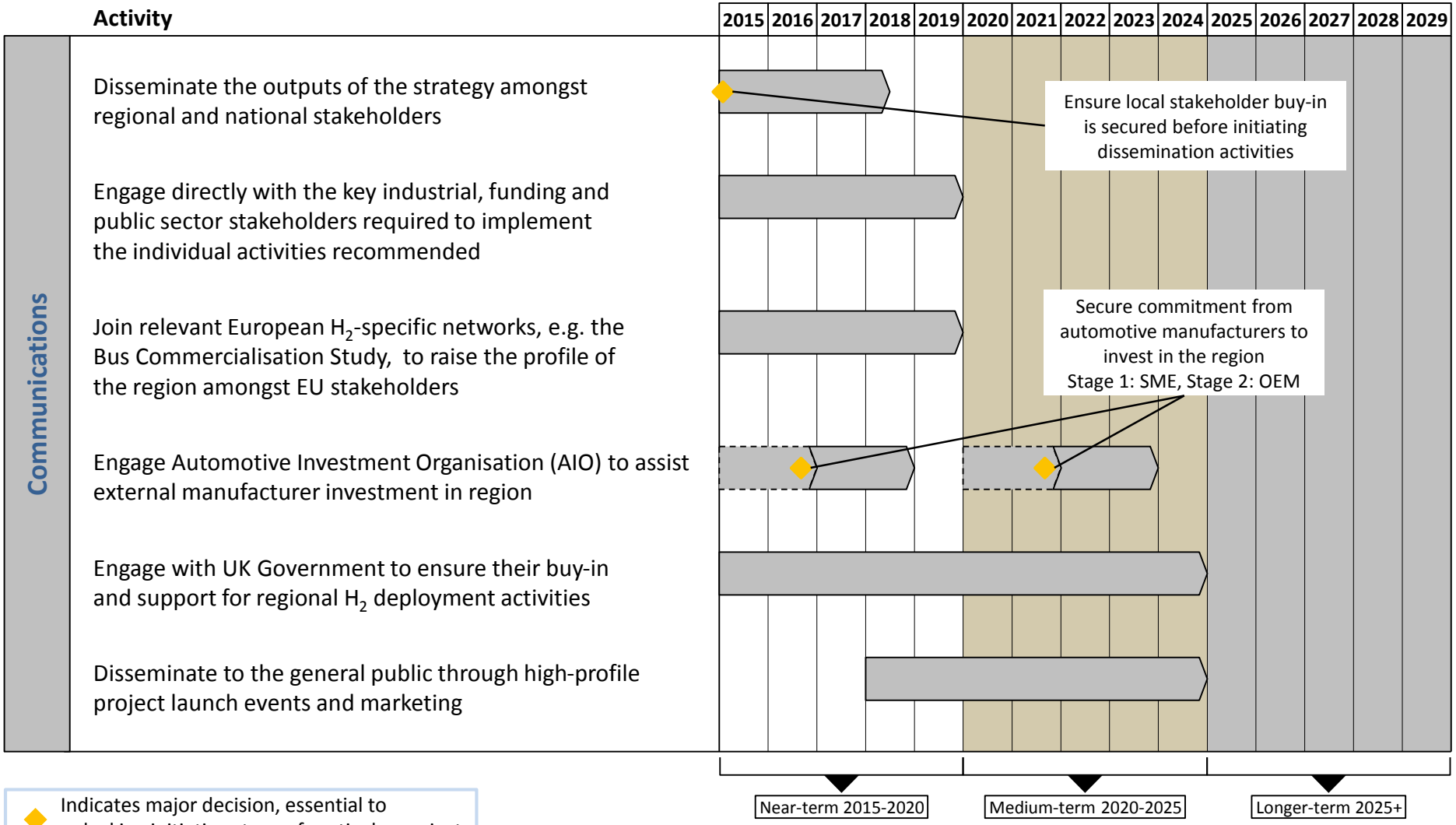
Strong support should be offered to new supply chain and training initiatives

5



Once local buy-in is secured a communication strategy should be implemented to engage with industry, government and the general public

5



Indicates major decision, essential to unlocking initiating stage of particular project

Agenda

- Executive summary
- **Final report**
  - Introduction to the hydrogen economic study
  - The long-term opportunity and timeline to implementation
  - Near-term activities to access the long-term opportunity
  - **Economics and funding opportunities**
  - Next steps to implementing strategic recommendations

A range of projects have been specified, each with varying funding requirements and associated risks

#	Project name	Start[1]	Lifetime	Economic summary
1a	Clean-up SMR existing spare capacity	2015	15 years	Purification equipment capex: **£200k-400k** (400-1,000kg/day flow rate)
1b	Upgrade SMR existing capacity	2020	10 years	Tube trailer filling upgrade: **£2.5-3m** (additional 3,000kg/day capacity)
1c	Clean-up portion of waste derived syngas	2019	15 years	Purification equipment capex: **£3-5m** for 400kg/day flow rate Large stationary fuel cell capex: **£2-3m** for 1 MWe stationary fuel cell
2a	Upgrade existing tube trailer facilities	2015	5 years	Existing tube trailer fleet could be used for small demand New 230 bar tube trailer capex: **£300k**
2b	Deploy new 500 bar tube trailer facilities	2019	10 years	New 500 bar tube trailer capex: **£1m** 3 trailers needed to support 50 buses (filling, delivering and redundancy)
2c	Trial high-capacity H_2 carriers	2015	5 years	Feasibility/initial research project: **£50-500k** Demonstration facility and dedicated research program: **£1m+**
3a	Deploy fleet of fuel cell buses	2017	10 years	Maximum funding shortfall: **-£13m** (20 buses), **-£32m** (50 buses) Net present value: **-£10m** (20 buses), **-£26m** (50 buses)
3a	Deploy fleet of fuel cell forklifts	2017	5 years	Supplier stated that target capex will be parity to incumbent
3a	Deploy fleet of H2 Transit vans	2017	5 years	50 vehicles, maximum funding shortfall: **-£1.6m** Net present value: **-£1.8m**
3a	Deploy fleet of small commercial vans	2017	5 years	50 vehicles, maximum funding shortfall: **-£1.0m** Net present value: **-£1.1m**
3a	Deploy fleet of 1st Gen OEM FCEVs	2017	5 years	5 vehicles, maximum funding shortfall: **-£0.4m** Net present value: **-£0.5m**
3b	Work with Nissan to develop H2 RE-EV	2015	15 years	Up front development cost circa **£1-2m**
3c	Engage with OEMs to entice local deployment	2015	8 years	No significant costs are incurred
4a	Develop a 'local content' HRS	2015	15 years	Up front development cost circa **£0.5-1m**
4b	Support local vehicle deployment	2015	15 years	HRS capex: **£0.8m** (80kg/day), **£1.4m** (500kg/day), **£2.2m** (1,000kg/day)

[1]Year in which costs are incurred for deployment, upgrade or research activities

Quantifying avoided carbon taxes and air quality damage costs gives the total environmental benefits of each demand scenario

Pollutant	Taxes or damage cost[1]	Description
CO_2	£19/tCO_2	▪ To address its Climate Change targets, the UK introduced a key climate taxation policy to industrial organisations, the **Carbon Price Floor** ▪ An analogous carbon taxation scheme has been assumed for the transport sector
NO_x	£955/tNO_x	▪ Damage cost includes the health impacts of secondary particulate matter (as the emission of NOx causes the formation of nitrates, which are classed as particulate matter) ▪ Damage cost does not include the health impacts of ozone formation as a result of NOx emissions
PM_{10}	£48,517/tPM_{10}	▪ Damage cost includes health impacts of particulate matter (both mortality and morbidity impacts) in addition to the impact of building soiling by PM emissions ▪ This does not include the secondary impacts of particulate matter

Incumbent vehicle tank-to-wheel (TTW) emission rates

Vehicle	CO_2 emissions[2]	NO_x emissions[3]	PM_{10} emissions[3]
1st Generation OEM FCEV	179 gCO_2/km	0.07 gNO_x/km	0.005 gPM_{10}/km
2nd Generation OEM FCEV	89 gCO_2/km	0.07 gNO_x/km	0.005 gPM_{10}/km
Renault Kangoo + Symbio FC	213 gCO_2/km	0.1035 gNO_x/km	0.005 gPM_{10}/km
Ford Transit + ULEMCo	119 gCO_2/km	0.09 gNO_x/km	0.005 gPM_{10}/km
Fuel cell bus	1222 gCO_2/km	0.072 gNO_x/km	0.036 gPM_{10}/km

Fuel well-to-tank (WTT) emissions

Fuel type	WTT CO_2 emissions[4]
Diesel	594 gCO_2/l-diesel
Petrol	437 gCO_2/l-petrol
SMR Hydrogen	7844* gCO_2/kg-H_2

**Assumes waste heat from BOC SMR process is captured and exported as steam, therefore excluding GHG associated to SMR efficiency losses*

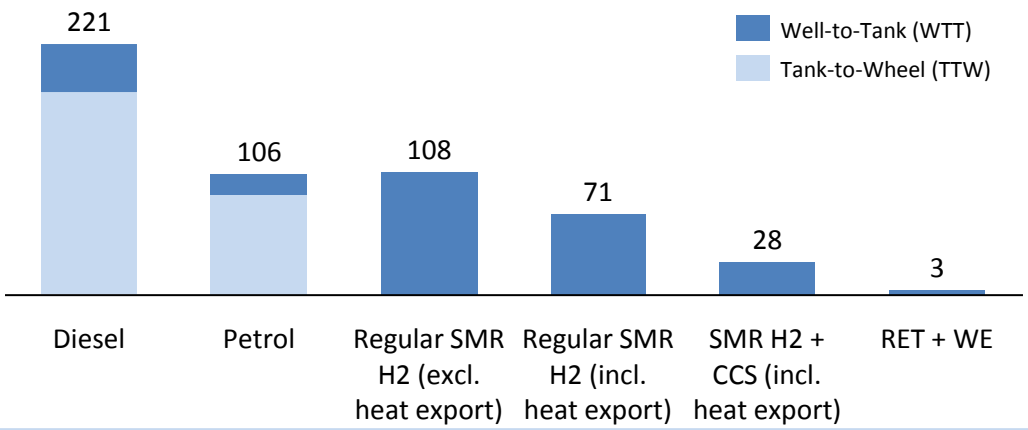
[1]CO_2 costs represent DECC projection for EAU price including CPS, NO_x and PM_{10} costs from 2010 DECC IGCB air quality damage assessment, [2]From manufacturer specifications, [3]Assumes incumbent is compliant with EURO VI requirements, [4]Assumes emissions associated with fuel production, purification and distribution pathways described in Concawe WtW analysis 2013

As demand for 'green' H_2 rises in the long-term, CCS technology could eliminate 75% of GHG emissions associated with regular SMR in Tees Valley

WTT analysis allows GHG emissions from different vehicle types to be compared

- GHG Well-to-Tank (WTT) analysis considers emissions associated with fuel production up to the point of use
- GHG Tank-to-Wheels (TTW) analysis considers emissions associated with drivetrain conversion of fuel to kinetic energy, WTT and TTW can be combined to give an overall Well-to-Wheel (WTW) figure
- WTT analysis for SMR derived H_2 includes all GHG emissions from natural gas production, conditioning and distribution and all associated emissions with the reformation process itself and subsequent delivery of H_2 to HRS
- SMR activities in Tees Valley have an advantage in terms of their CO_2 footprint due to their export of waste heat produced as a reformation by-product. As a result, some of the GHG emissions associated with heat production from the SMR plant can be offset to the steam customer, thereby reducing the total carbon dioxide assigned to hydrogen
- In the longer term, H_2 production pathways including SMR with CCS (84% CO_2 removal efficiency) and WE with RET will significantly lower the Tees Valley carbon emissions

Well-to-Wheel GHG emission rates – gCO_2/km



Vehicle fuel consumption figures

- Diesel incumbent (Hyundai ix35) = 7 l/100km
- Petrol incumbent (Toyota Prius) = 3.9 l/100km
- 1st Generation FCEV = 0.9 kg/100km

Source: Concawe WtW analysis 2013

RET = renewable energy technology, WE = water electrolysis, SMR = steam methane reforming, CCS = carbon capture and storage

The main reason for near-term activities is to facilitate accessing long-term benefits, but some limited direct benefits are achievable

#	Project name	Air quality impact £000/year	CO_2 impact £000/year	Other benefits
1a	Clean-up SMR existing spare capacity	n/a	n/a	See economics for 2030 prize; also creates 'first mover' visibility for region in UK at early stages of H_2 rollout; creates long term growth option for process industries
1b	Upgrade SMR existing capacity	n/a	n/a	
1c	Clean-up portion of waste derived syngas	n/a	n/a	See economics for 2030 prize; creates long term 'green' growth option for process industries
2a	Upgrade existing tube trailer facilities	n/a	n/a	See economics for 2030 prize
2b	Deploy new 500 bar tube trailer facilities	n/a	n/a	
2b	Trial high-capacity H_2 carriers	n/a	n/a	Improves linkages for region in R&D circles internationally; enables long-term goal of being a major 'green' H_2 exporting region
3a	Deploy fleet of fuel cell buses	19	25.7	Reductions in CO_2, air pollution, noise; innovative image for operators; operating cost savings; enables attracting a niche manufacturer to the region, building supply chain and skills/training required to attract major OEM
3a	Deploy fleet of fuel cell forklifts	4.5	0.0	
3a	Deploy fleet of H2 Transit vans	0.7	0.28	
3a	Deploy fleet of small commercial vans	1.3	0.27	
3b	Deploy fleet of 1st Gen OEM FCEVs	0.2	0.03	Reductions in CO_2, air pollution, noise; innovative image for operators; raises profile of region with OEMs
3c	Work with Nissan to develop H2 RE-EV	n/a	n/a	Potential to unlock significant long-term supply chain benefits
4a	Develop a 'local content' HRS	n/a	n/a	Jobs in installation, O&M; visibility and image for region
4b	Support local vehicle deployment	n/a	n/a	

Total project cost for the recommended combination is £45m (Option A with buses), or £6m for the fall-back combination (Option B with no buses)

Project combination A

Production

- Use existing spare production capacity from the BOC SMR plant from the BOC tube trailer facility, with additional purification equipment to improve 99.98% purity to 99.999% (**project 1a**)
- Invest in cleaning up syngas to H_2 at AP facility (**project 1c**)

Distribution

- Use existing 230 bar tube trailer facilities (**project 2a**), sufficient to supply the regional demand until 2020
- Deploy 500 bar tube trailer facilities **(project 2b)** in 2018 to supply the large FC bus fleet depot(s)
- Research novel high-capacity carriers (**project 2c**)

Vehicles

- Adopt one vehicle demonstration project in 2015 (e.g. 50 FC forklifts) and small OEM deployment (**projects 3a/b**)
- Deploy up to 50 buses in 2018 (**project 3a**)
- Annual hydrogen demand is 200 kg/day in 2015 and increases to 1 tonne/day in 2018

Infrastructure

- Develop low-cost, locally-sourced HRS (**project 4a**)
- Deploy three 80 kg/day HRS in 2015 to supply the fleet of FC forklifts, each at 70% load factor (**project 4b**)
- Deploy two 500 kg/day HRS in 2018 to supply the fleet of 50 FC buses, each at 55% load factor (**project 4b**)

Cost

- **Total combined project cost = £45 million**
- Note this is an average of the upper and lower bound costs for each individual activity suggested

Project combination B

Production

- Use existing spare production capacity from the BOC SMR plant from the BOC tube trailer facility
- Install purification equipment at the filling facility to improve 99.98% purity to 99.999% (**project 1a**)

Distribution

- Use existing 230 bar tube trailer facilities (**project 2a**), sufficient to supply the regional demand only until 2018
- Research and develop high-capacity H_2 carriers (**project 2c**) with long-term commercialisation goals

Vehicles

- Adopt one vehicle demonstration project in 2015 (e.g. 50 FC forklifts) and small OEM deployment (**projects 3a/b**)
- Annual hydrogen demand is 200 kg/day in 2015 and remains constant for the duration of the project lifetime, no further deployments occur

Infrastructure

- Develop low-cost, locally-sourced HRS (**project 4a**)
- Deploy three 80 kg/day HRS in 2015 to supply the fleet of FC forklifts (**project 4b**)
- No further HRS are deployed

Cost

- **Total combined project cost = £6 million**
- Note this is an average of the upper and lower bound costs for each individual activity suggested

A range of funding sources could support the suggested near-term activities and their funding shortfalls

Source	Description	Likely size of funding	Timescales
FCH JU (FCH 2 JU)	Public-private partnership between EC and industry, to advance the commercialisation of hydrogen and fuel cells	Up to 70% under Horizon 2020	Annual calls for proposals 2014-20
TSB	UK Government-run body to help fund innovation in a range of technology areas	Up to 60% for SMEs (50% otherwise)	Regular calls for proposals
Structural Funds	EU funds for encouraging development across a range of thematic objectives	Up to 60% of project value	Annual calls for proposals 2014-20
UK Government	UK Government Ultra-Low Emissions Strategy – Initial funding to support H_2 infrastructure in the UK announced October 2014	£11m (incl. new HRS (£7m), upgrades (£2m) and vehicles (£2m))	2015-2020
Local Enterprise Partnerships (Tees Valley Unlimited and North East LEP)	LEPs are voluntary partnerships between local authorities and businesses, with the aim of helping to determine local economic priorities and leading economic growth and job creation within local areas – they have access to a share of the £1.4bn Local Growth Fund, as well as setting priorities for EU Structural Funds allocation	Range of services available, from incubation support, to support in securing private sector investment, as well as direct support through a range of schemes	Various

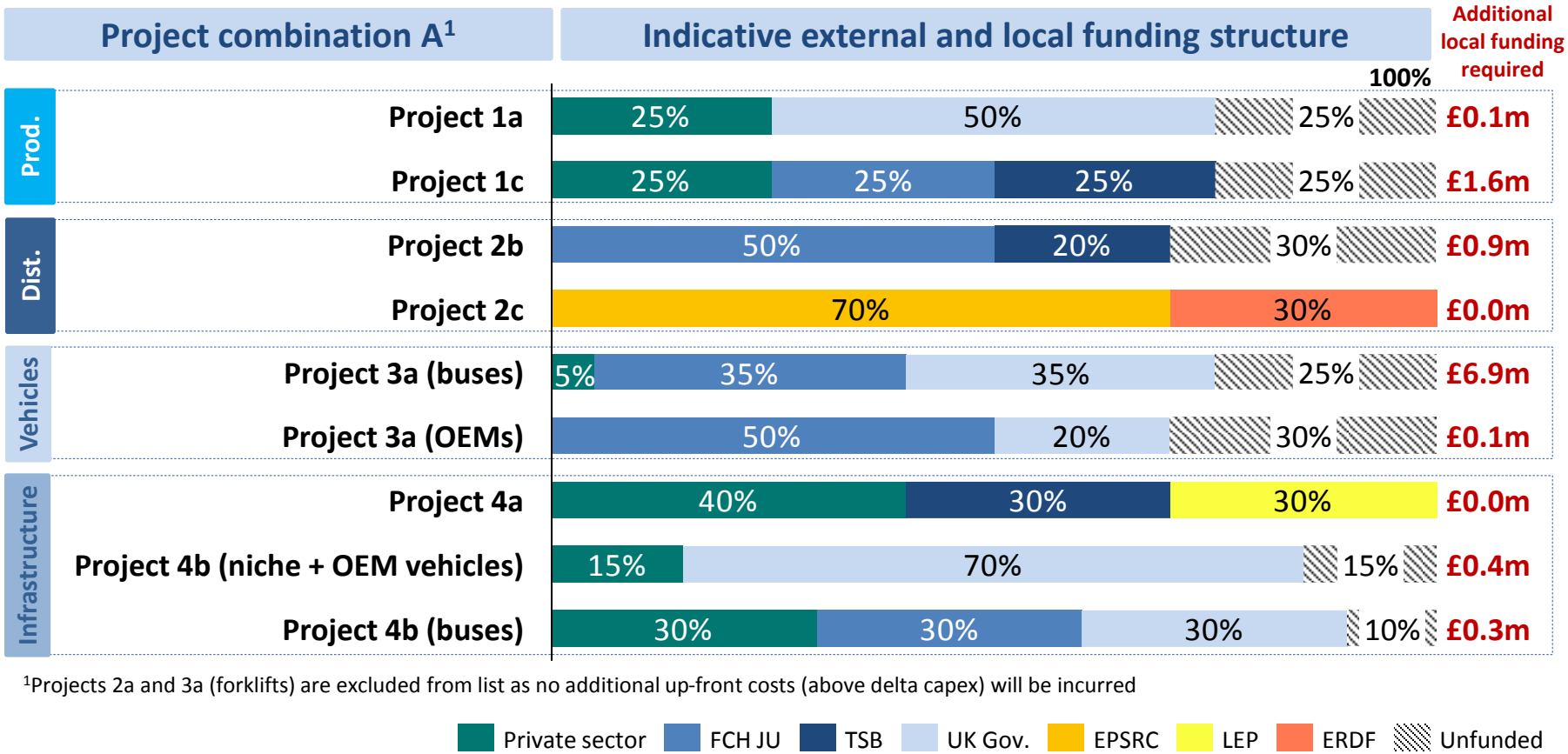
A mixed funding strategy is likely

- Clearly the mix of funding sources described is varied and different sources will be relevant to different projects –decisions will need to be made to determine which sources are most relevant to different activities, and whether to combine applications for several activities into an overall project envelope
- There may be opportunities to link certain funding applications (e.g. to support buses, OEM vehicles, infrastructure, etc.) to large deployment projects already planned by others, and these should be pursued where possible

Considerable national/EU funding likely to be available, when combined with private sector contributions could reduce overall costs by >50%

	Project combination A	Funding
Production	▪ Existing BOC capacity + purification (**project 1a/1b**) ▪ Invest in cleaning up syngas to H_2 at AP facility (**project 1c**)	▪ Purity improvements allow BOC to access new transportation markets, so some private sector investment can be expected ▪ However, given the risks some (e.g. 50%) public sector contribution will be needed ▪ The Air Products facility has sufficient innovation to justify TSB or FCH JU funding (c. 50-70%), with the remainder coming from project partners
Distribution	▪ Use existing 230 bar tube trailer facilities (**project 2a**) ▪ Deploy 500 bar tube trailer facilities **(project 2b)** ▪ R&D high-capacity H_2 carriers (**project 2c**)	▪ Any upgrades to the existing BOC facility will open access to new transportation markets, so some private sector investment can be expected ▪ A 500 bar facility may have sufficient innovation to justify TSB or FCH JU funding (c. 50-70%), with the remainder coming from project partners ▪ Novel H_2 carriers would require 100% funding from e.g.: EPSRC or ERDF, but LEP support could help secure this funding
Vehicles	▪ Deploy e.g. 50 FC forklifts in 2015 (**project 3a**) ▪ Deploy up to 50 buses in 2018 (**project 3a**) ▪ Deploy 5 OEM fuel cell vehicles (**project 3b**)	▪ Fork lifts: expected to be TCO breakeven but may require small locally-sourced incentives or private sector investment to accelerate change ▪ Buses: requires large national or international project intervention (up to 50%), remainder required from local parties (not bus operators, who will only pay cost of incumbent) ▪ Other niche vehicles: £1-10k additional cost could be met by vehicle users, remainder would be sourced from national or FCH JU funds (up to 50-100%) ▪ OEM vehicles: high-profile public sector and corporate end-users should be sought to contribute significantly to the capital cost of the vehicles, remainder from local funds
Infrastructure	▪ Develop a locally-sourced 80kg/day HRS (**project 4a**) ▪ Deploy three 80 kg/day HRS in 2015 and two 500kg/day HRS in 2018 (**project 4b**)	▪ For an increased local content HRS, LEP, TSB or other innovation funding may be required ▪ Generally HRS infrastructure is being installed at a 50-70% funding ▪ Some local public money may be required to support e.g. land rent, civil works, etc.

We have devised an indicative funding structure which could reduce the overall total funding shortfall of option A to £10 million



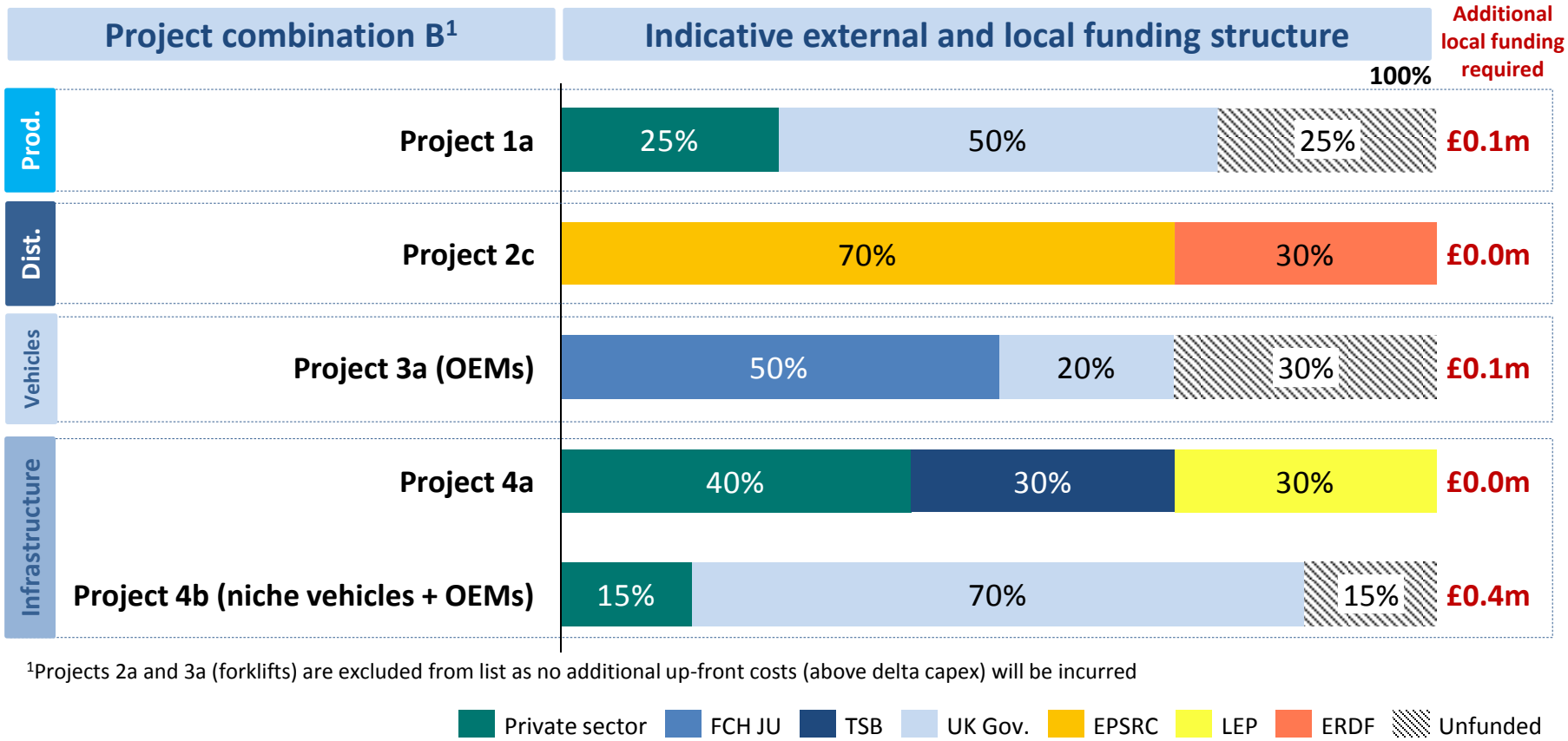
[1]Projects 2a and 3a (forklifts) are excluded from list as no additional up-front costs (above delta capex) will be incurred

- The above illustrates a suggested funding breakdown for each project based on available funding sources thereby allocating a cumulative **total external funding contribution of £35 million**
- The total funding shortfall after including external funding is c. **£10 million over 5 years**
- To maximise total external funding, **the region must initiate activities to secure funds before the start of 2015**

Considerable national/EU funding likely to be available, when combined with private sector contributions could reduce overall costs by >50%

Project combination B		Funding	
Production	▪ Existing BOC capacity + purification (**project 1a**)	Production	▪ Purity improvements allow BOC to access new transportation markets, so some private sector investment can be expected ▪ However, given the risks some (e.g. 50%) public sector contribution will be needed
Distribution	▪ Use existing 230 bar tube trailer facilities (**project 2a**) ▪ Research and develop high-capacity H_2 carriers (**project 2c**)	Distribution	▪ Any upgrades to the existing BOC facility will open access to new transportation markets, so some private sector investment can be expected ▪ Novel H_2 carriers would require 100% funding from e.g.: EPSRC and ERDF
Vehicles	▪ Deploy e.g. 50 FC forklifts in 2015 (**project 3a**) ▪ Deploy 5 OEM fuel cell vehicles (**project 3b**)	Vehicles	▪ Fork lifts: expected to be TCO breakeven but may require small locally-sourced incentives or private sector investment to accelerate change ▪ Alternative niche vehicles: £1-10k additional cost could be met by vehicle users, remainder would be sourced from national or FCH JU funds (up to 50-100%) ▪ OEM vehicles: high-profile public sector and corporate end-users should be sought to contribute significantly to the capital cost of the vehicles, remainder from local funds
Infrastructure	▪ Develop a locally-sourced 80kg/day HRS (**project 4a**) ▪ Deploy three 80 kg/day HRS in 2015 (**project 4b**)	Infrastructure	▪ For an increased local content HRS, LEP, TSB or other innovation funding may be required ▪ Generally HRS infrastructure is being installed at a 50-70% funding ▪ Some local public money may be required to support e.g. land rent, civil works, etc.

An analogous indicative funding structure is presented which could reduce the overall total funding shortfall of option B to £0.6 million



[1]Projects 2a and 3a (forklifts) are excluded from list as no additional up-front costs (above delta capex) will be incurred

- The above illustrates a suggested funding breakdown for each project based on available funding sources thereby allocating a cumulative **total external funding contribution of £5.2 million**
- The total funding shortfall after including external funding is **£0.6 million over 5 years**
- To maximise total external funding, **the region must initiate activities to secure funds before the start of 2015**

Agenda

- Executive summary
- **Final report**
  - Introduction to the hydrogen economic study
  - The long-term opportunity and timeline to implementation
  - Near-term activities to access the long-term opportunity
  - Economics and funding opportunities
  - **Next steps to implementing strategic recommendations**

A strong commitment will be required to take the recommendations of the strategy forward, this could take a number of forms

Putting the TV&NE H_2 strategy recommendations into action

- A **strong partnership has been created around the Steering Committee for this study**, with a strong public sector backing for taking the region's H_2-related activities forward by leveraging its existing capabilities, in order to access the long-term benefits available from the development of hydrogen as a new energy vector
- However, in order to implement the recommendations of the strategy, a **strong, mandate and focused, cohesive approach will be required to drive forward the various suggested activity streams**, secure the funding and private sector investment required, ensure that inward investments are secured as desired and ensure strong local buy-in to the strategy
- A number of approaches can be envisaged, based on observing those deployed in different regions active in the sector, as follows:
  - **Use existing resources from the Steering Committee members**, e.g. within Gateshead College, TVU, etc. to drive the strategy forward, in conjunction with private sector partners
  - **Partnership approach whereby a permanent grouping is formed**, comprising both industry and public sector stakeholders, to meet regularly to discuss the latest H_2-related developments, as well as initiating and supporting regional activities in the sector. This would be a similar approach to that adopted in London with the 'Hydrogen London' network
  - Recruitment of **a single person with responsibility for driving the strategy forward** and engaging with the relevant regional and national stakeholders to ensure the long-term aims are achieved. This would be a similar approach to that being employed by the Scottish Cities Alliance
  - **Assigning a consultancy** to spearhead the strategy's activities and to have overall responsibility for achieving the long-term aims of the strategy
- The consensus of the steering committee is to continue the partnership, grow private sector membership and appoint a secretariat (either from within the grouping or as an external consultant)

An implementation plan has been recommended to work towards achieving the long-term goals identified, driven by a clear mandate and focused budget

Campaigning to establish a strong end-user base, securing local and European funding whilst ensuring efficient organisation and good communication are key to overall success of the projects identified

Phase 1 (May-Dec 2014)

- The existing partnership (Zero Carbon Futures, Gateshead College, TVU, North East LEP, CPI, Sunderland University) has successfully initiated activities to identify opportunities for the region
- Partners now must agree that they support the initiative and findings from the "Hydrogen Economic Study" and agree to back an overall strategy for the region
- Enacting this strategy will require coordination and allocation of sufficient resource to do this
- Based on previous successful regional hydrogen projects, we suggest a secretariat (housed within one of the main advocates) and suitable budget made available for skilled support (e.g. bid writing and feasibility work) as and when needed
- A budget for this needs to be established - based on the London Hydrogen Partnership activities, an indicative budget of c.£100k p.a. is required

Phase 2 (Jan-Dec 2015)

- Once the strategy is agreed and the resource is identified, there are a number of tasks to be undertaken in 2015:

a) Start to attract private sector industrial partners into the partnership

b) Make contact with local end users to encourage the adoption of hydrogen vehicles (for large fleet deployments of e.g. buses, vans, forklifts)

c) Make contact with suppliers to develop project concepts developed in the study and to discuss the criteria under which niche manufacturers could invest in the region

d) Begin discussions with funding bodies to prepare for formal funding applications

e) General outreach and promotional activities around the region's strategic direction in relation to hydrogen

f) Market TV&NE's production capabilities to other regions interested in deploying hydrogen technologies as potential customers for TV&NE hydrogen

g) Engagement with the major OEMs deploying hydrogen vehicles to promote the region as an attractive deployment centre

Late-2014 → **Early/mid-2015** → **Late-2015**