






E4tech

Tees Valley and North East Hydrogen Economic Study

Executive Summary

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

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

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

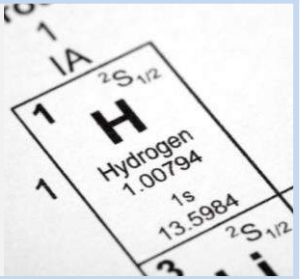
Ben Madden (ben.madden@element-energy.co.uk)

Adam Chase (adam.chase@e4tech.com)

Geneviève Alberts (genevieve.alberts@e4tech.com)

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

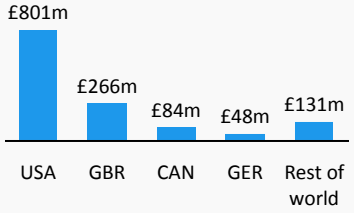
Globally, several emerging H_2 technologies are receiving increased attention as alternative energy solutions

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

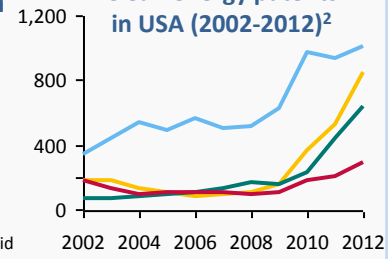
Cumulative VC & PE FC and H_2 investment (2000-2012)[1]



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

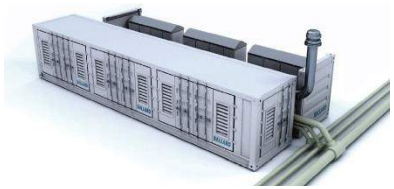
- Eliminate CO_2 and air quality impacts associated with fossil fuel vehicle emissions – EU proposes a 40% CO_2 emission reduction by 2030[2]
- Increase vehicle fuel consumption efficiency – Internal combustion engines have efficiencies of 20-35% compared to up to 60% for fuel cells[3]

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

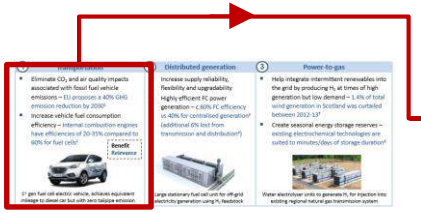
BOC SMR facility, North Tees

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

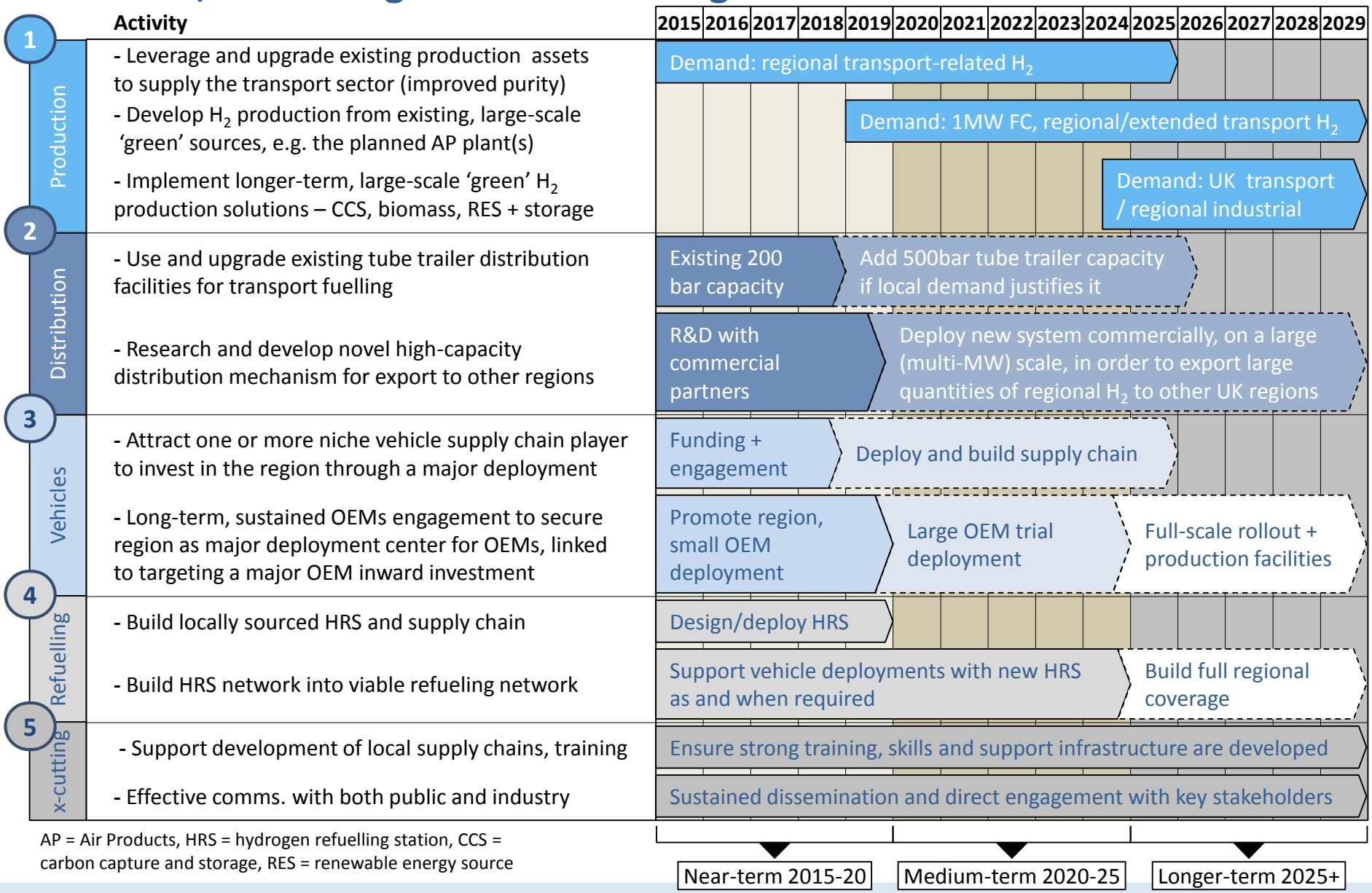
- Generate demand to justify using existing spare H_2 production capacity – this is a high value revenue stream for H_2 producers, relative to selling to industrial users
- Opportunities to expand TV&NE low carbon vehicle supply chain through attracting niche manufacturers
- Research into novel, high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



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

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

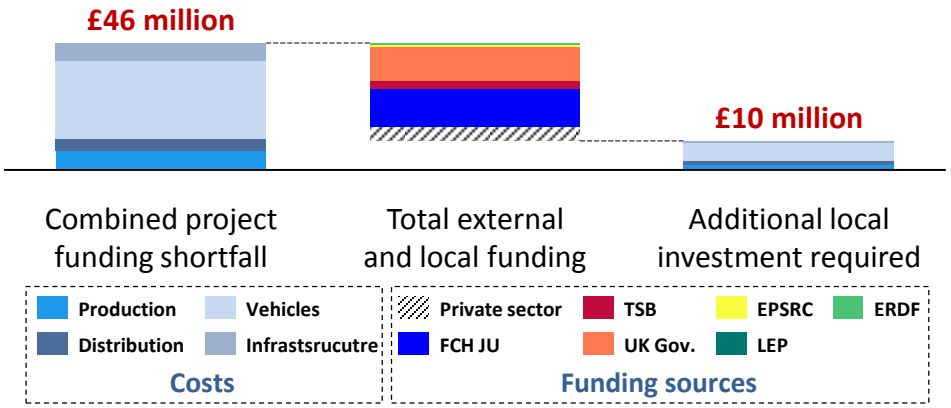
- Up-front development cost of a locally sourced HRS: £0.5-1m
- HRS capex: £0.8m (80kg/day), £1.4m (500kg/day), £2.2m (1,000kg/day)

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

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**

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)