Hydrogen:
A Business Opportunity for Scotland

Chairman: William Hazell, ERM

Session 1:
The Hydrogen Opportunity

The Role of Hydrogen to Decarbonise the UK - Matt Hitchens, BEIS UK Government

Hydrogen Potential for Scotland- David Butler, Scottish Enterprise

Hydrogen Leadership in Aberdeen - Councillor Philip Bell, Aberdeen City Council

The Regional Hydrogen Supply Chain Potential - Sam Gomersall, Pale Blue Dot

The Business Case for Hydrogen - Tara Schmidt, ERM

The Role of Hydrogen to Decarbonise the UK

Speaker: Matt Hitchens, BEIS UK Government

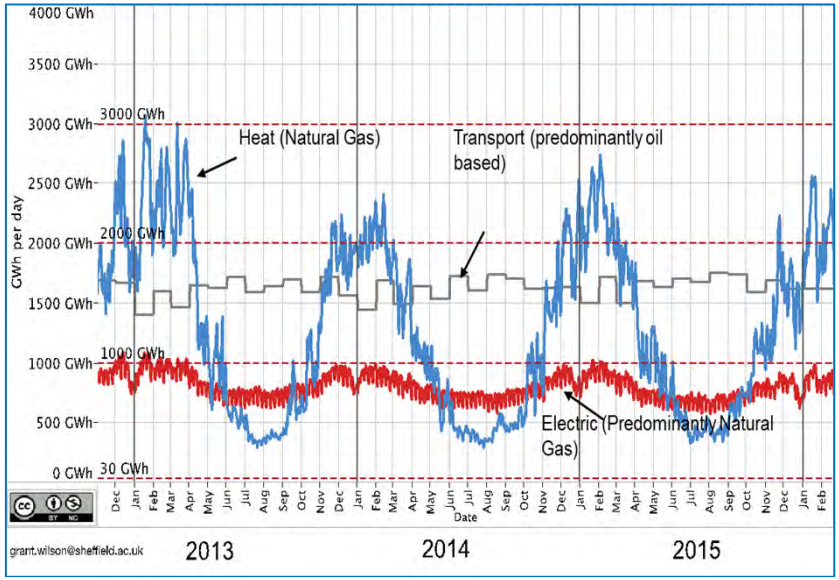
The role of hydrogen in decarbonising the UK's energy system

Matt Hitchens - BEIS
9th October 2018

Department for Business, Energy & Industrial Strategy

The challenge: clean growth

We will maximise the advantages for UK industry from the global shift to clean growth – through leading the world in the development, manufacture and use of low carbon technologies, systems and services that cost less than high carbon alternatives.



- Decarbonise **across the energy system** in line with carbon reduction legislation
- Continue positon as global climate leader
- Embed Clean Growth across all policies
- Build on UK strengths
- Inspire companies and people to maximise economic opportunities

Hydrogen's potential in meeting the challenge

- Interest in hydrogen on upswing in UK and internationally:
  - some technology barriers are diminishing (increased fuel cell life, distribution across gas network 'feasible', H2 vehicles on the road)
  - greater understanding of decarbonisation challenges in the UK context (including in other pathways)
- Decarbonising across the UK energy system with its seasonal demand swings a significant challenge. Solutions and technology that deliver flexibility and optionality will be highly valuable to the low-carbon transition
- As an energy vector hydrogen can play a complementary and enabling role - alongside electricity - in a deeply renewable, deeply decarbonised future energy system
- There is a significant UK hydrogen economy today, largely based around the petrochemicals industry; UK engineering strengths an opportunity - *More to do to understand how far the UK hydrogen economy could expand, decarbonise and enter other sectors – opportunities, costs, challenges*

Hydrogen context

GLOBAL PRODUCTION

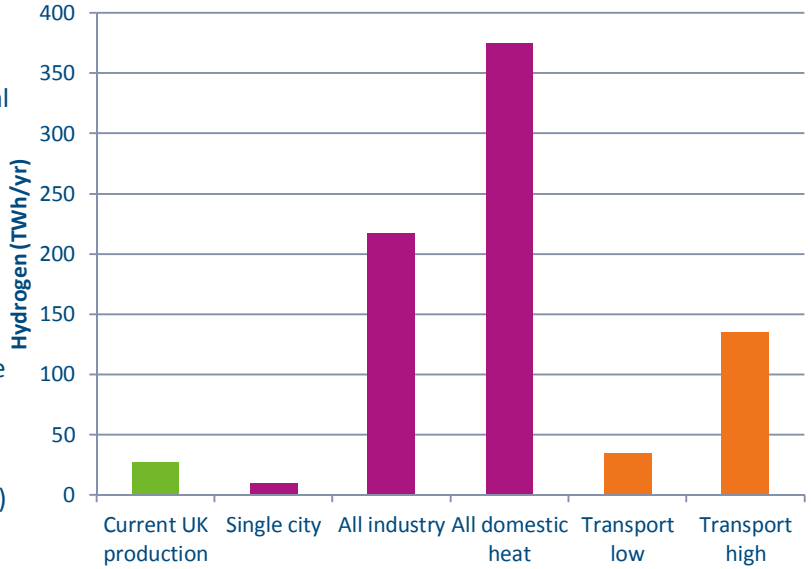
- 1,700 TWh/yr of hydrogen globally (this just over twice UK's annual demand for natural gas – 897 TWh/yr[1])
- 96% from fossil fuels (48% natural gas, 30% oil/naptha, 18% coal)
- 4% from electrolysis[2]

GLOBAL USE

- Main use as a feedstock for ammonia production - 50%
- 40% for oil refining and in chemical industries
- Around 95% of global hydrogen is produced and consumed at same location, as part of a larger industrial process [3]

UK PRODUCTION:

- Around 27 TWh/yr from about 15 sites [4] (1.6% of global production)
- Roughly half a by-product from chemical industry - used on site, sold as chemical feedstock, small percentage vented



- Towns gas was widely used in Britain until phased out in 1988, was around 50% hydrogen, 35% methane, 10% carbon monoxide and 5% ethylene. This was produced from coal and oil. Consumption peaked at 133.8 TWh/yr in 1969, of which about 30 TWh/yr was hydrogen.

WHAT WOULD SCALE UP LOOK LIKE? Using a range of sources we can estimate that:

- a single city (Leeds) would demand around 10 TWh/yr of hydrogen for heat[5]
- all industry would demand around 200 TWh/yr[6] (hydrogen may not be suitable for all industrial uses)
- all current domestic heat delivered through the gas grid would demand around 400 TWh/yr[7]
- a low ambition transport scenario would demand around 34 TWh/yr (10% of total vehicles FCEVs by 2050)[8]
- a high ambition transport scenario would demand around 135 TWh/yr (derived from the CCC's 'Critical Path' scenario)[9]

SOURCES: 1.DUKES (BEIS, 2017) 2.Hydrogen as Future Energy Carrier (Corbo et. al, 2011); 3.Scenarios for deployment of hydrogen in meeting carbon budgets (CCC, 2015); 4.Potential Role of Hydrogen in the UK Energy System (2016, ERP); 5.H21 Leeds City Gate (NGN, 2016); 6.ECUK (BEIS, 2016); 7.ECUK (BEIS, 2016); 8.Transport Energy Infrastructure Roadmap to 2050: Hydrogen Roadmap (LowCVP, 2015); 9.Scenarios for deployment of hydrogen in meeting carbon budgets (CCC, 2015)

Hydrogen challenges

- **Strategic case** for major UK scale up still developing
- **Cost –** particularly production, but across value chain
- **Availability** of low carbon hydrogen
- **Coordination** of wide ranging activity
- **Path through clean to green** (beyond 2050)
- **Safety**
- **Understanding and awareness** of hydrogen low
- International activity accelerating – need to **keep pace**

UK Government – key policy activity

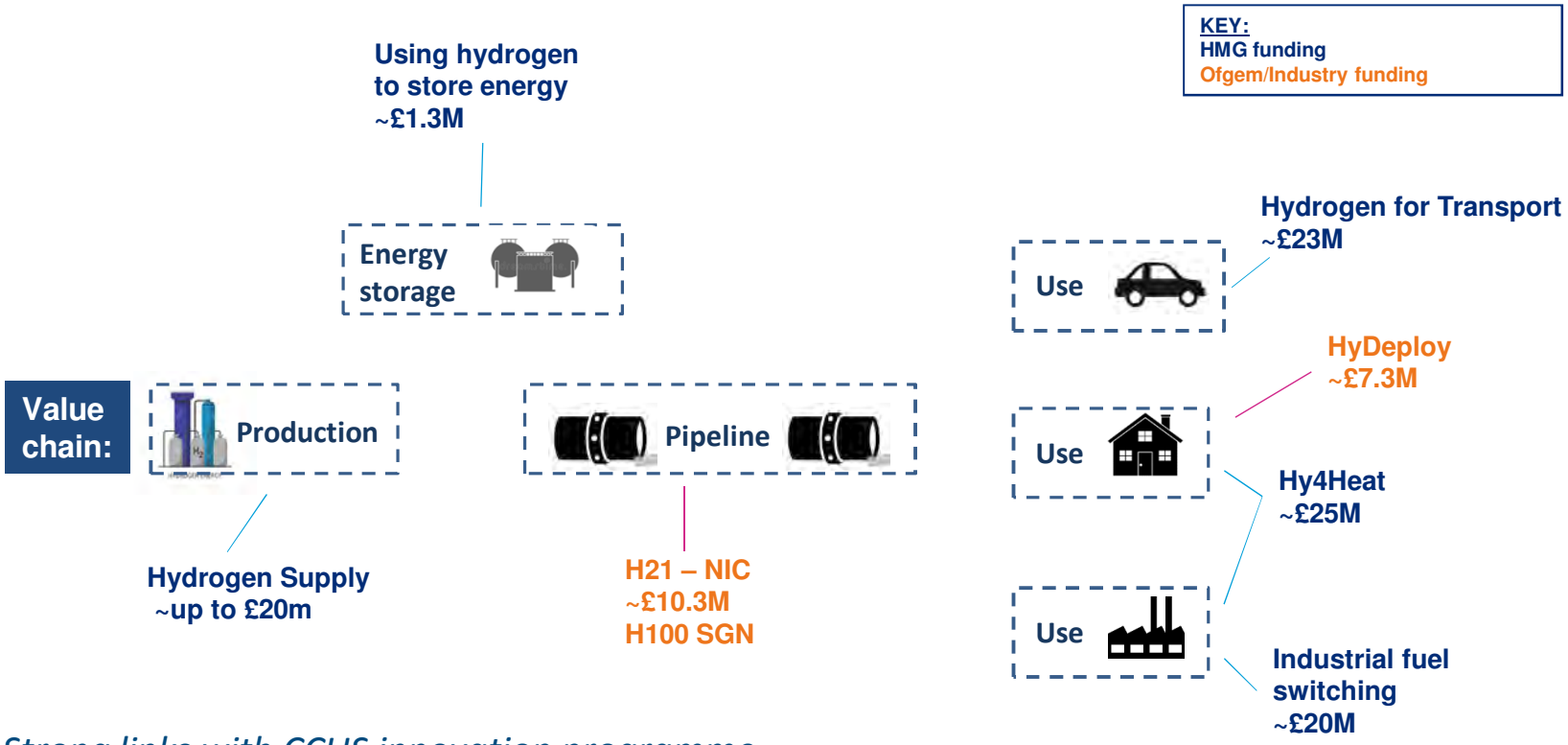
- **Heat Strategic Options Programme – assessing heat decarbonisation pathways to meet 2050 targets**
  - Electrification (heat pumps, hybrid heat pumps with gas boilers); or
  - Decarbonisation of gas grid (hydrogen, biomethane, heat networks)

  Not clear which approach(es) will work best at scale and offer the most cost effective long term answers

- **CCUS – exploring pathways to deploy CCUS at scale in 2030s**
  - Government wants the UK to become a global technology leader in CCUS and work internationally with industry and governments to bring about global cost reductions
  - Ambition is to have "the option of deploying CCUS at scale during the 2030s, subject to costs coming down sufficiently"
  - Interest broad role for CCUS including low carbon hydrogen production at scale

- **Hydrogen Economy Team – developing a strategic approach to UK Hydrogen Economy**
  - Improved understanding of potential to meet Clean Growth goals, with appropriate time horizons
  - Whole system perspective – starting with detailed understanding of potential in each sector
  - Building relationships – hydrogen industry, lead projects, key regions/clusters, international
  - Identifying opportunities to unlock deployment of low carbon hydrogen in UK context

Hydrogen Energy Innovation activity



Strong links with CCUS innovation programme

Case study: hydrogen in industry

- **Decarbonising industrial feedstock**
  - Importance of CCUS
  - Potential for electrolysis (Rhineland project)
  - Curtailed renewables?
- **By-product hydrogen**: produced in a number of places across the country, could be put to better, higher value uses – transport?
- **Industrial fuel-switching**
  - Good potential, particularly for high grade heat
  - Technological development and demonstration needed

Next steps …

Ongoing innovation, policy and strategic engagement activity as strategic approach develops. This will include Scottish focus.

Some forthcoming milestones:

- Visit to Grangemouth tomorrow
- Mission Innovation Hydrogen Challenge kick off workshop, Berlin
- CCUS International Conference, Edinburgh
- Publication – CCUS Deployment Pathway
- Publication – Heat Strategic Options Review of Evidence
- Hydrogen Supply Competition
  - Registration of interest deadline 21 November 2018
  - Submission of proposals deadline 5 December 2018

Hydrogen Potential for Scotland

Speaker: David Butler, Scottish Enterprise

Hydrogen production and applications

Hydrogen potential for Scotland

October 9th 2018

David Butler
SE Energy & Low Carbon Technology
Foresighting & Operations support

SCOTTISH DEVELOPMENT INTERNATIONAL

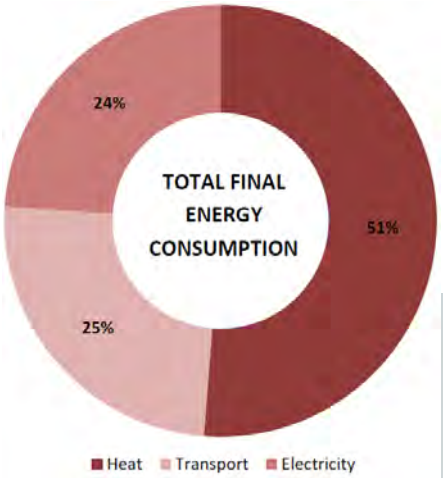
ONE OPPORTUNITY NORTH EAST Oil, Gas & Energy

Scottish Enterprise

Hydrogen potential for Scotland

- What could the applications be ?
- What could hinder this ?
- What timeframe are we thinking about ?
- From whose perspective are we looking ?

Scotland 2017

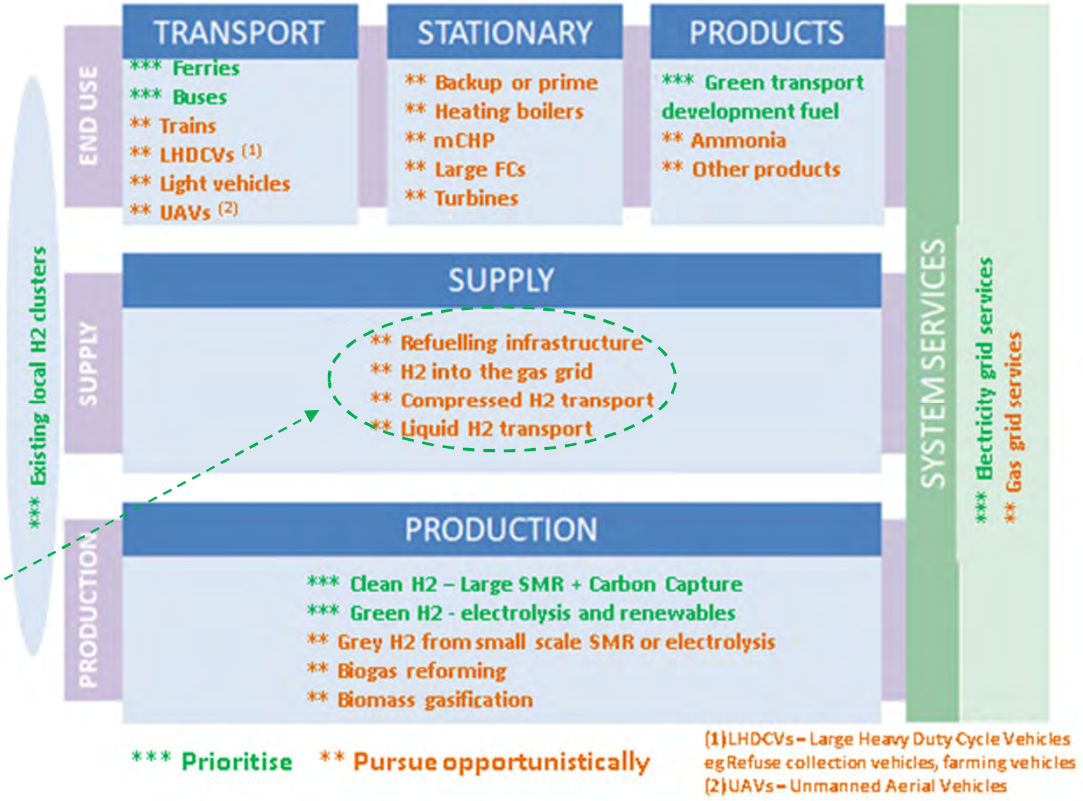


SE Hydrogen & Fuel Cells Foresighting

10 year evidence-based look ahead at a sub sector -

- Markets
- Technologies
- Scottish fit

Recommendations



Appendix A of 'An Analysis of the Aberdeen Hydrogen Supply Chain' by Pale Blue Dot highlights existing or potential local strengths in 'move/supply hydrogen' which could change these areas to '**prioritise**' for the North East

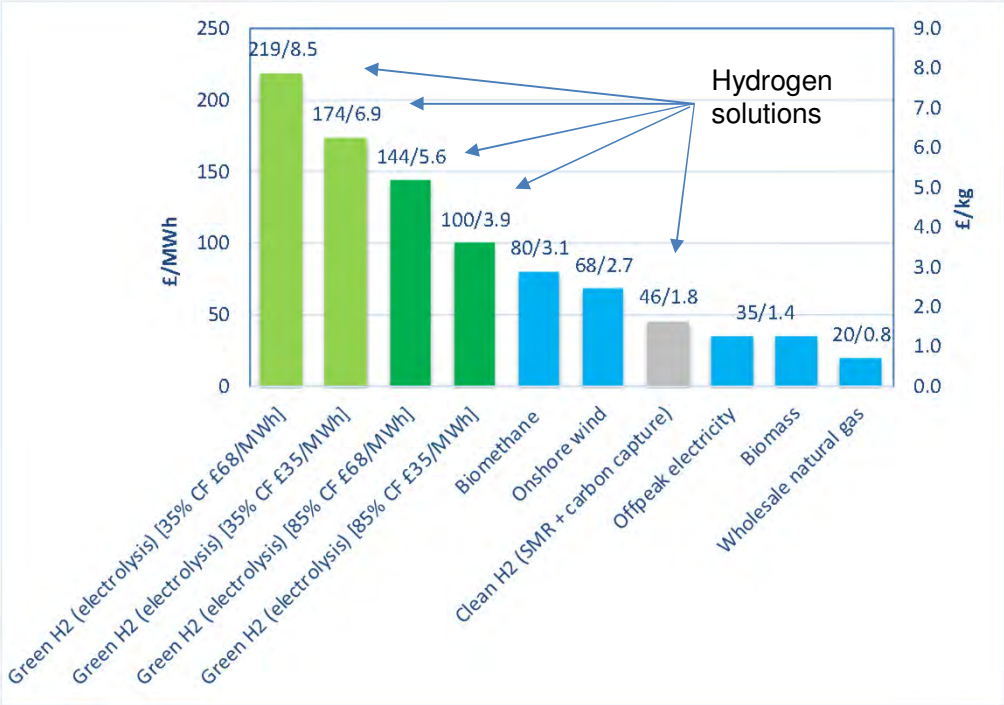
Input from E4tech, TNEI, Scottish Government, ETP, Scottish Cities Alliance

Insights from H&FC Work - Production

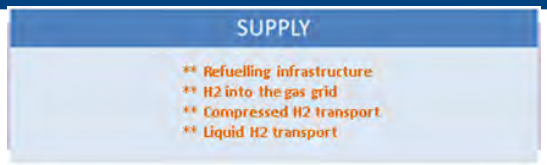
PRODUCTION

*** Clean H2 – Large SMR + Carbon Capture
*** Green H2 - electrolysis and renewables
** Grey H2 from small scale SMR or electrolysis
** Biogas reforming
** Biomass gasification

- Hydrogen production requires extra conversion and processing steps relative to the direct use of the energy used to make it
- Steam Methane Reforming + Carbon Capture & Storage (SMR + CCS) is the lowest cost route for hydrogen production (at large scale ~75kt H2 pa) and is a route for decarbonising Scotland's O&G and petrochemical industries
- Electrolysis should be a revenue route for constrained renewables
- Biogas or biomass into hydrogen – better ways to use this limited resource (directly)



Insights from H&FC work – Supply

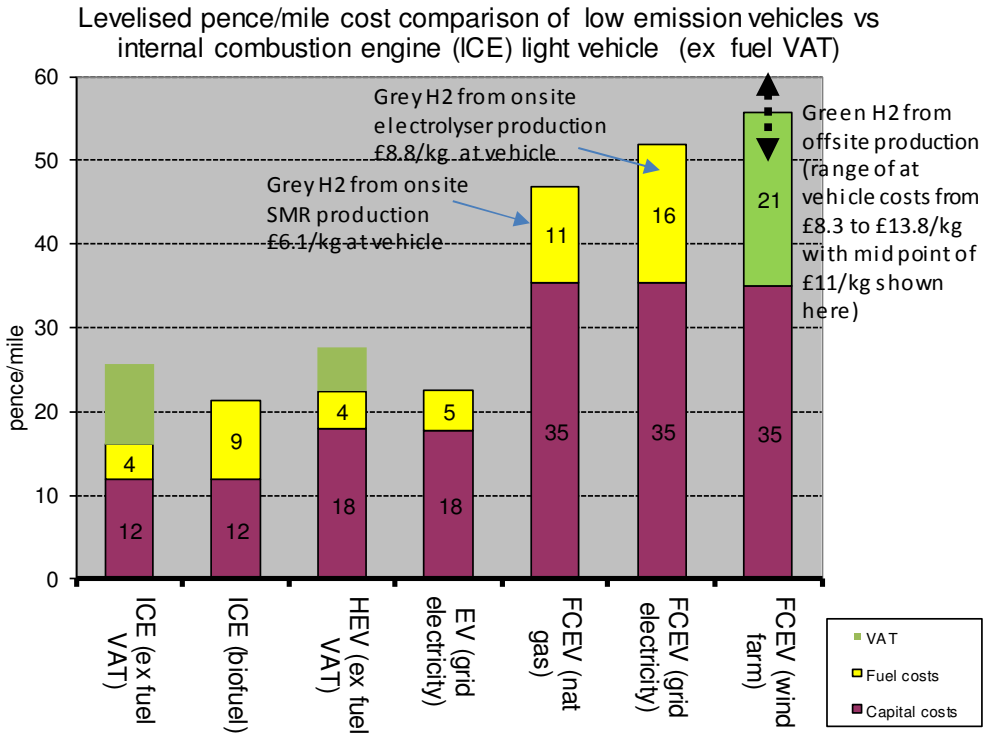


- Production is the start of the hydrogen supply chain.
- Large scale clean hydrogen production via SMR would be shipped by gas networks. Cheap but costs would also have to cover management of CO2 as well.
- Small onsite SMR or electrolysers would save on logistics costs
- Green hydrogen would likely have to be shipped to demand by road.
- Type of end use can create significant costs on top of delivered costs eg hydrogen refuelling stations add £2.10/kg onto these costs at the vehicle presently.

£/kg H2	Production costs	Compression / Handling costs	Distribution costs	Delivered price of hydrogen
Clean hydrogen -Large scale offsite SMR with CCS	1.80	no compression needed for shipping via gas pipeline	0.40 [+0.40 for CO2]	2.60
Grey hydrogen –Forecourt SMR on natural gas	3.30	0.70	n/a (onsite)	4.00
Grey hydrogen -Forecourt electrolyser on grid electricity	5.60	1.10	n/a (onsite)	6.70
Green hydrogen - Offsite windfarm electrolyser (35% CF £68/MWh PPP)	8.50	1.70	1.50	11.70
Green hydrogen - Offsite windfarm electrolyser (35% CF £35/MWh PPP)	6.80	1.40	1.50	9.70
Green hydrogen - Offsite windfarm electrolyser (85% CF £68/MWh PPP)	5.60	1.10	1.50	8.20
Green hydrogen - Offsite windfarm electrolyser (85% CF £35/MWh PPP)	3.90	0.80	1.50	6.20

Insights from H&FC work - End use - Transport

- On a like for like basis Fuel Cell vehicles will always be more expensive and less efficient than electric vehicles.
- It seems likely that the opportunities for FCEVs will be in market niches where EV (or hybrid EVs) struggle. However, biofuels or natural gas could also eat into these niche markets.
- The Renewable Transport Obligation) will not enable the market break out of FCEVs. But it will reduce the running costs of existing hydrogen vehicle fleets and for new pilot projects (by about 4.5p/mile for light FCEVs).



- Element energy saying FCEV capital costs could fall by half in ten years
- E4Tech saying cost of production could fall by 25% in ten years
- ..but these are predicated on economies of scale…
- H2 RTFO change should knock £2+/kg or 4.5p/mile off green hydrogen fuel costs

Insights from H&FC work - End Use - Electricity

Electricity storage and other solutions - Distribution networks

Technology	Cost of capacity (£/kW)	Overall conversion efficiency	Operating life (years)	Cost of Energy (£/MWh)
Hydrogen Fuel Cell, storage & electrolyser	5423	31%	15	817
Hydrogen electrolyser & storage (as DSR)	1932	65%	15	388
Flywheel	1510	85%	15	198
Sodium Sulphur battery	1961	80%	10	181
Vanadium Redox Flow battery	1317	70%	10	143
Lithium Ion battery	556	90%	15	127
Part-loaded wind turbine (Supply response)	3000	59%	20	68
Distribution Reinforcement (UK average)	875	93%	40	35
Demand Side Response (DSR)	225	<90%	25	24
Active Network Management	33	<90%	25	5

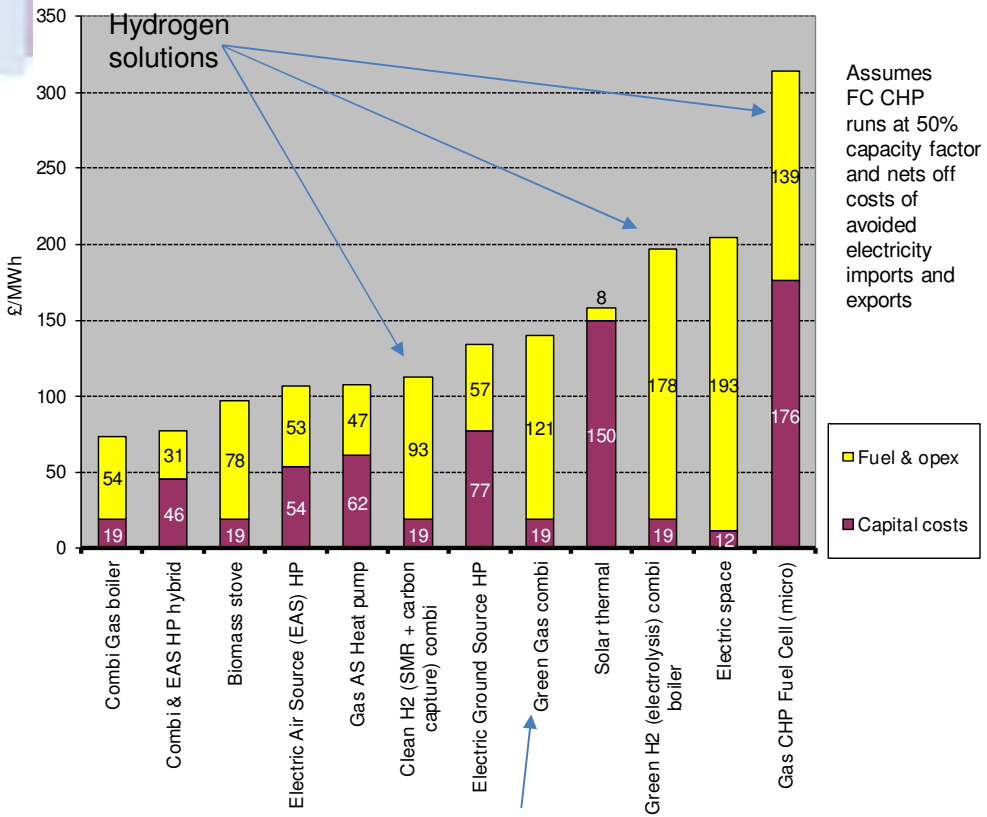
Distribution networks technology	Cost of capacity (£/kW)	Overall conversion efficiency (%)
Electrolyser	700	74%
Hydrogen compression & storage	529	88%
Site ancillaries	703	na
Hydrogen Fuel Cell	3491	47%
Combined Hydrogen System	5423	31%

Insights from H&FC work - End Use - Heat

STATIONARY

- ** Backup or prime
- ** Heating boilers
- ** mCHP
- ** Large FCs
- ** Turbines

Lifetime Cost of energy (LCOE) cost comparison of low emission heating systems vs gas fired combi boiler (new systems)



Assumes FC CHP runs at 50% capacity factor and nets off costs of avoided electricity imports and exports

Using biogas should not require new equipment (Capex) as it could utilise existing gas pipes and boilers

New domestic heating system	Capex £/kW
Combi Gas boiler	83
Combi & EAS HP hybrid	200
Biomass stove	83
Electric Air Source (EAS) HP	233
Gas AS Heat pump	267
Clean H2 combi boiler	83*
Electric Ground Source HP	333
Green Gas combi boiler	83
Solar thermal heating	650
Green H2 combi boiler	83*
Electric space	50
Gas CHP Fuel Cell	7620

* Probably costs more – higher operating temp, higher gas seal specs needed

Scottish Enterprise

Current Position- conclusions

- Range of potential strategic benefits from hydrogen
- Increasing focus by Scottish and UK Government
- Academic capabilities
- Company capability: niche transport, fuel cells and potentially bulk production and handling by O&G, petrochemical industries
- Number of hydrogen projects providing base for development clusters
- Scottish involvement in EU projects
- Relatively high profile internationally
- But alternatives will impact market opportunities

SME Diversification Programme

- Match **industry needs** with **solution providers**
- Three-year, **co-funded partnership** between Opportunity North East and Scottish Enterprise
- Provide supply chain SMEs with understanding of **industry challenges** and **commercial opportunities** in diversification markets
- Facilitate SME **access to customers** in these markets
- Provide one-to-one support to SMEs to **build capacity** and enable them to pursue/secure new business
- Provide customers in diversification markets with access to **motivated, informed and capable supply chain SMEs**
- **Anchor** oil, gas and energy supply chain companies for the long term

ONE OPPORTUNITY NORTH EAST Oil, Gas & Energy

Scottish Enterprise

Market Opportunities and Further Information

Previous market opportunities

- Wave and tidal power
- Water industry/pipelines
- Floating offshore wind

Next market opportunity

- UK Nuclear (decommissioning and new projects)
- **8 November 2018**, Aberdeen


colin.mchardy@opportunitynortheast.com


@OpportunityNE_1


Opportunity North East Limited

ONE Oil, Gas & Energy

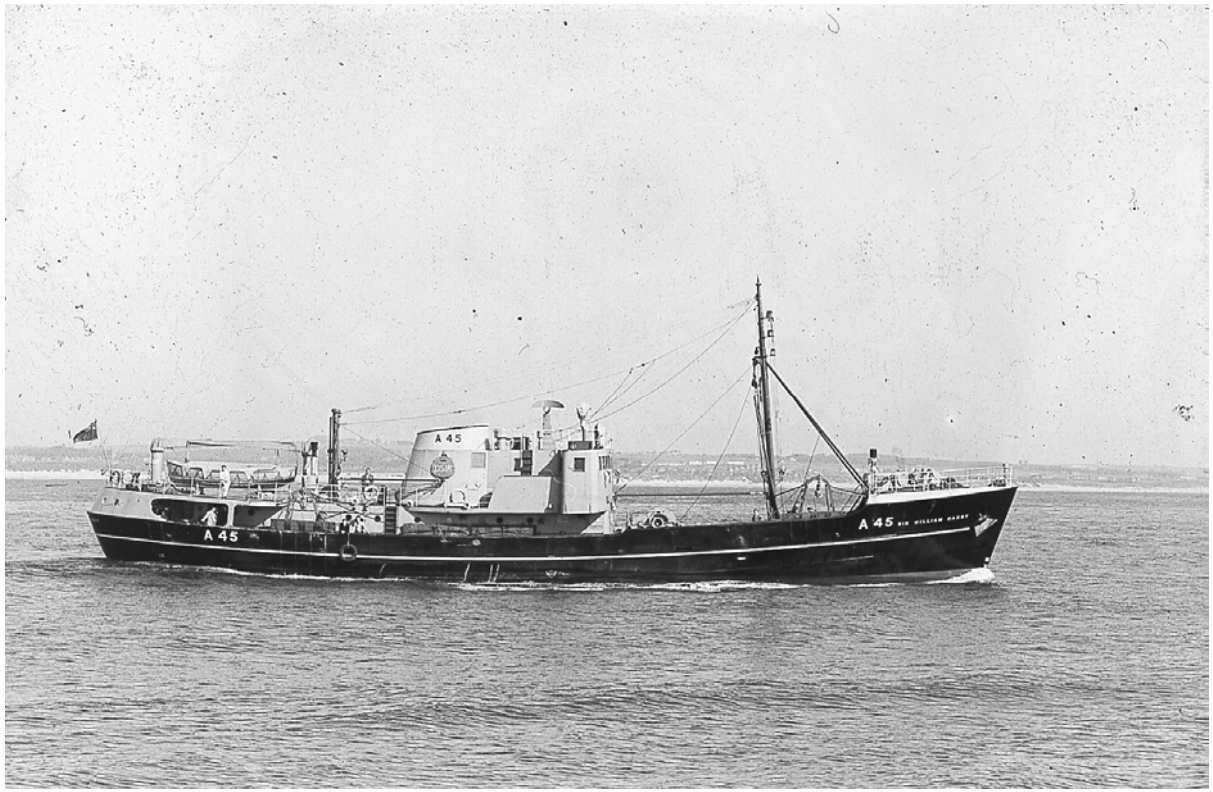
Hydrogen Leadership in Aberdeen

Speaker: Councillor Philip Bell, Aberdeen City Council

Councillor Philip Bell
Aberdeen City Council
Hydrogen Leadership in Aberdeen

ITN Video

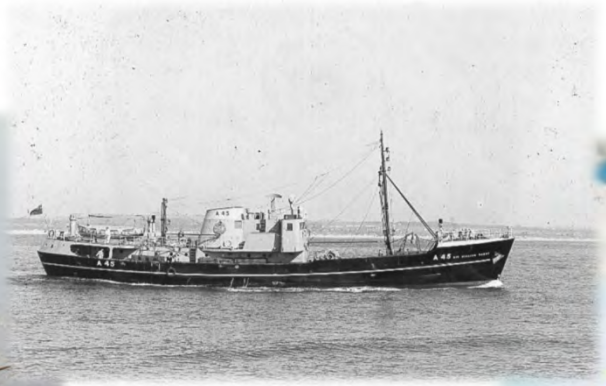
CLIPPER SHIP "**THERMOPYLAE**" LEFT ABERDEEN
FOR **GRAVESEND** ON HER **MAIDEN VOYAGE 1868**.



SIR WILLIAM HARDY RESEARCH TRAWLER

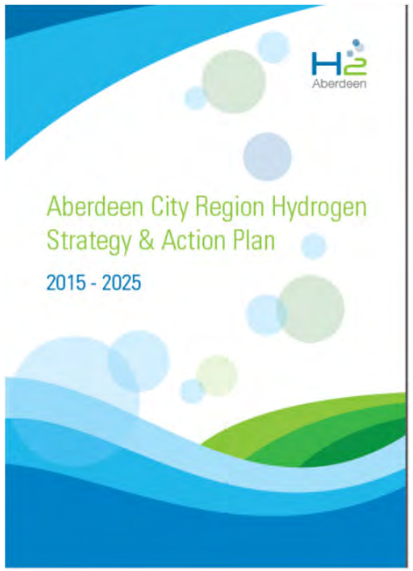
H2 Aberdeen

Aberdeen in Transition



H2 Aberdeen

- **Ensure the city as a leader in the emerging hydrogen and fuel cells sector**
- **Outlines actions required over the next 10 years**
  a. Opportunities to diversify activities
  b. Develop the supply chain
  c. Develop supporting infrastructure
  d. Deploy first generation vehicles
  e. Support Aberdeen City as early adopter after London



H2 Aberdeen

H2 Aberdeen

ABERDEEN CITY COUNCIL

Interreg North Sea Region HyTrEc2 European Regional Development Fund

EUROPEAN UNION

HyTrEc2 Hydrogen Transport Economy for the North Sea Region

Thank you

Councillor Philip Bell, Aberdeen City Council
h2aberdeen@aberdeencity.gov.uk

Interreg North Sea Region HyTrEc2 European Regional Development Fund
EUROPEAN UNION

The Regional Hydrogen Supply Chain Potential

Speaker: Sam Gomersall, Pale Blue Dot

Pale Blue Dot.

Hydrogen supply chain
Regional potential

Oct 2018

Sam Gomersall

Vision for the hydrogen supply chain

Scotland to be a world leader in the hydrogen supply chain

We have world leading projects (Aberdeen/shire, Orkney, Fife)
We have an existing O&G and renewables supply chain capability
We have a broad technical capability and international repute
Promote the vision

Pale Blue Dot.

Hydrogen supply chain: ACC scope

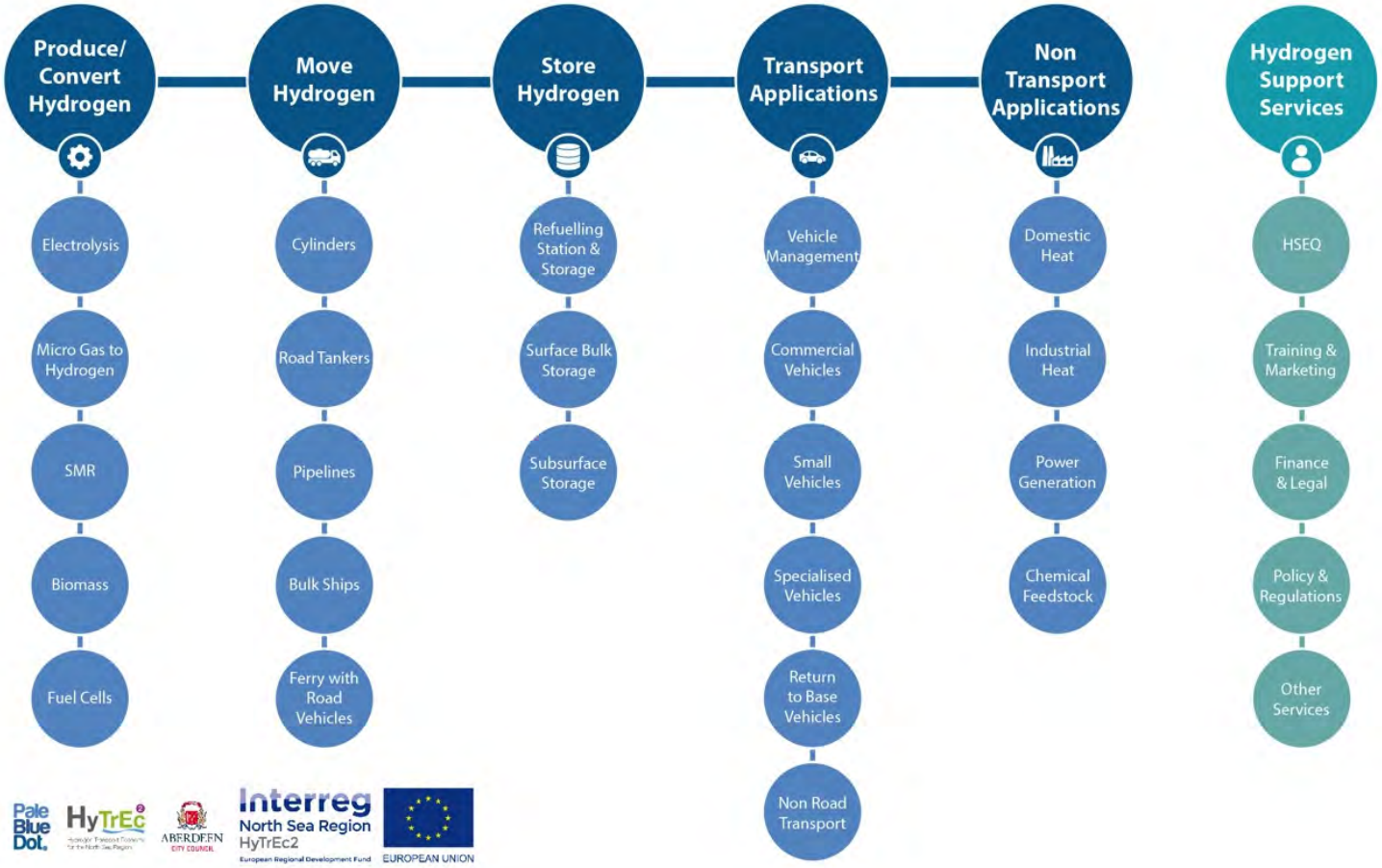
- Develop a hydrogen supply chain map
- Identify means to grow the hydrogen supply chain
- Assess Aberdeen region supply chain *position* & *potential*

ACC hydrogen vision

"To be a world-class energy hub leading a low carbon economy and at the forefront of hydrogen technology in Europe"

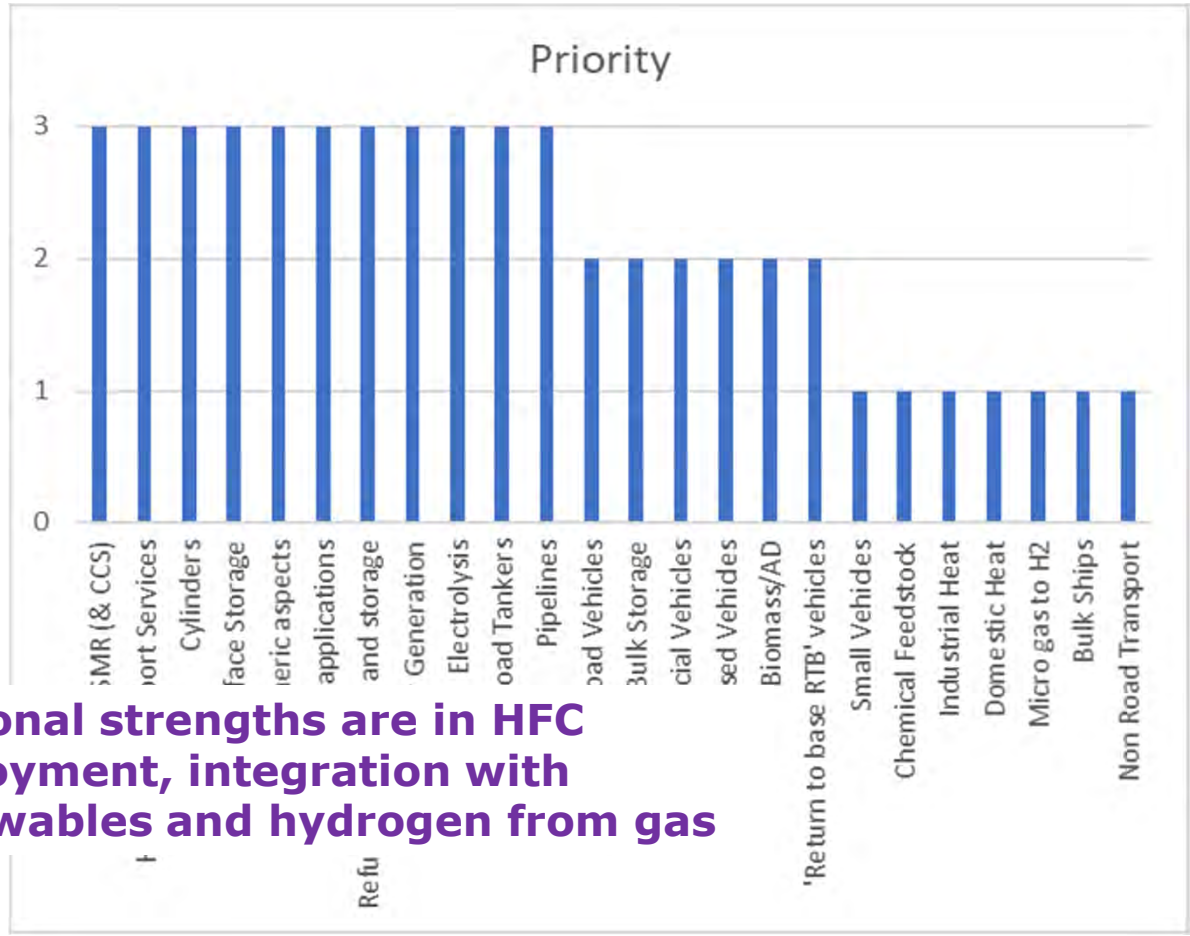
Pale Blue Dot.

Hydrogen supply chain: top level



Pale Blue Dot.

Supply chain priority



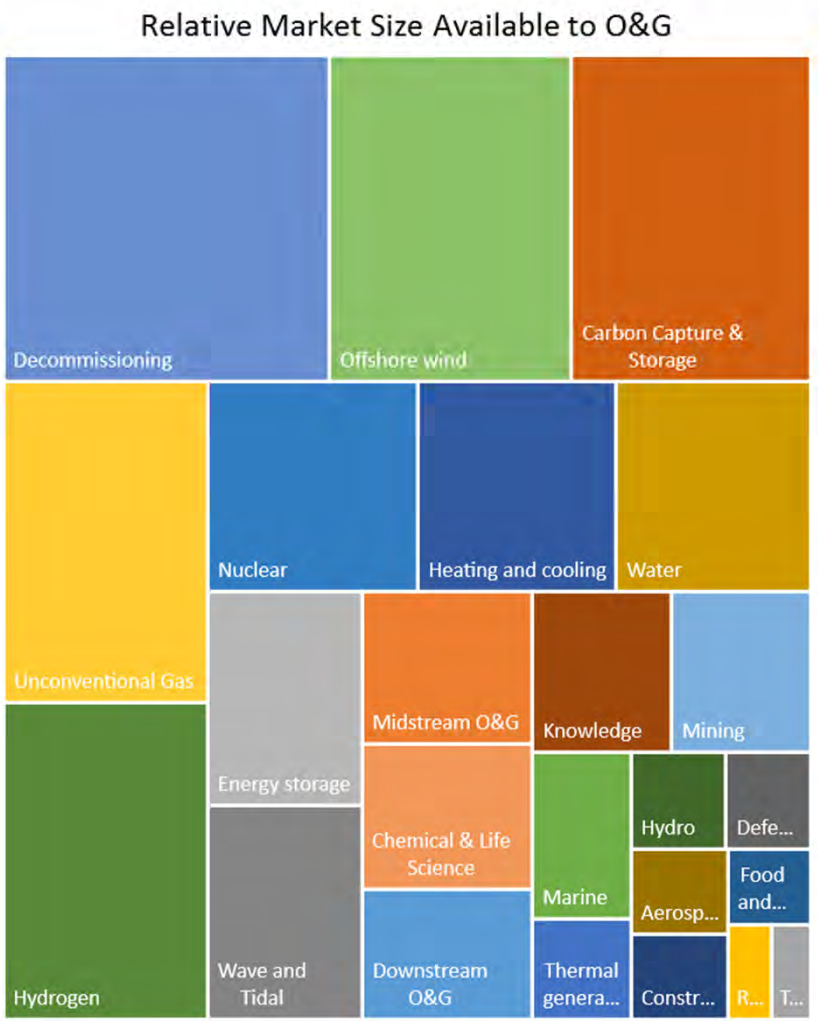
Regional strengths are in HFC deployment, integration with renewables and hydrogen from gas

Pale Blue Dot.

Regional supply chain examples

Emil Rangelov's H2Vans

O&G diversification



Pale Blue Dot
Oil and Gas Diversification Study
Scottish Enterprise 2016

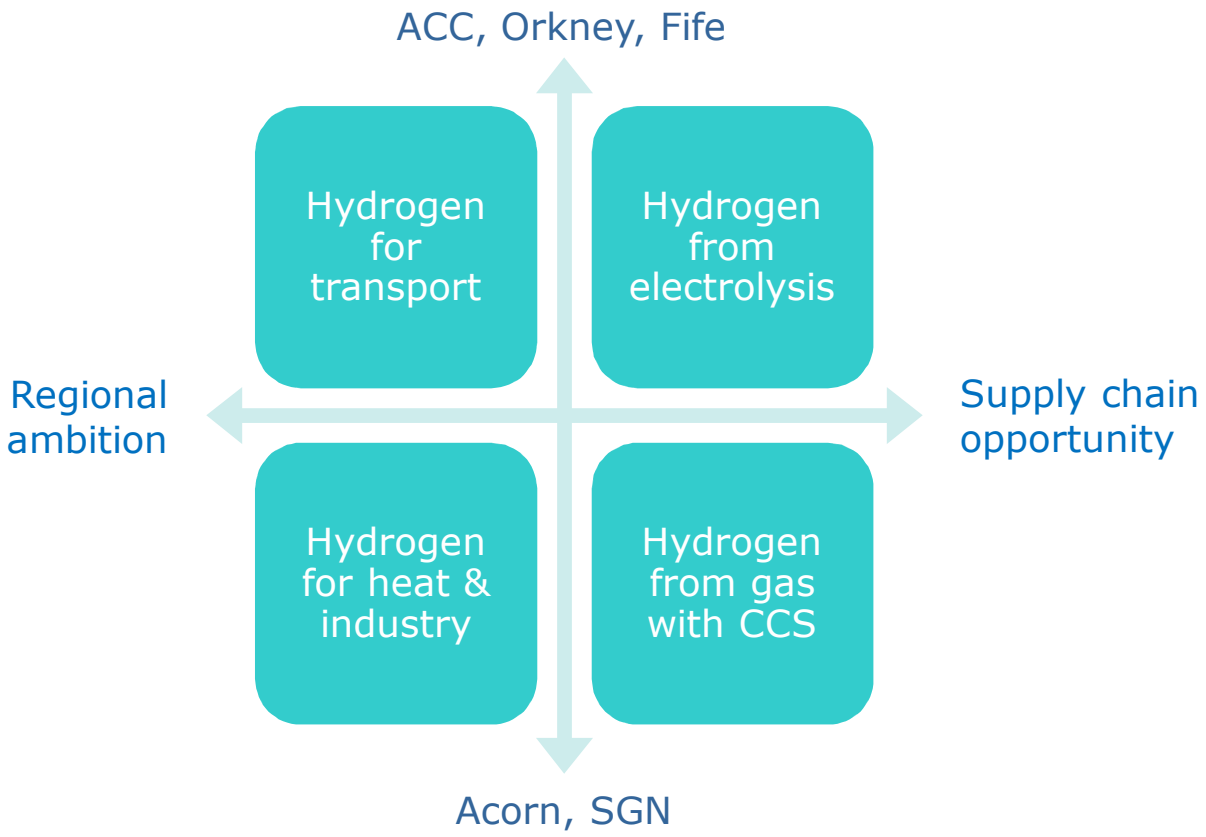
Pale Blue Dot.

Oil and Gas supply chain: hydrogen potential

SEGMENTATION → COMPANY TYPE ↓	RESERVOIRS	DRILLING & WELLS	PLATFORMS & TOPSIDES	MARINE, SUBSEA & PIPELINES	INTEGRAL & SUPPORT SERVICES
• Main contractor • Integrated services • Project management / Consultancy In Scotland: • Manufacturing / Fabrication • Supplier / Distributer / Stockist • Services Provider • Technology Provider • Specialist • Consultant • Agent R&D identified separately	Reservoir engineering / Management Data acquisition / processing / interpretation	Drilling units Well engineering / Design Oilfield / Well services Drilling modules / Packages	Engineering, design & construction Installation / Removal Operations, maintenance, modifications and decommissioning	Engineering, design & construction Installation / Removal Operations, maintenance, modifications and decommissioning	HSSE Air / Sea transport Ports / Logistics / Freight / Warehouse Utilities / Catering / Facilities management Recruitment & training QA/QC Certification & Integrity IT / Communications Medical Meteorological Laboratory Finance, legal & insurance Risk, cost & planning Other consultancy
	Data acquisition / processing Data interpretation / evaluation Survey equipment Geoscience survey / studies Reservoir modelling / development Software, Storage and Management	Tubulars, Completions & Accessories Drilling machinery & equipment Drilling fluids & systems Downhole tools & investments Wells/Wellhead equipment Well testing, Control & Monitoring Well Enhancement Well Abandonment Waste treatment, management & disposal	Production / Process / Accommodation modules & equipment Rotating / Power equipment Piping components Instrumentation / Process control Production enhancement Inspection / Repair / Maintenance Steel, metal & non-metal materials Chemicals / Gases / Paints Lifting & Handling Safety / Fire Protection Electrical / Electronic engineering Mechanical / Hydraulic engineering Waste treatment, management, cleaning & disposal	Vessels / deck equipment Mooring & foundations Survey / positioning Structures / Christmas trees / Manifolds / Templates / Wellhead equipment Process, pumping & power systems Controls, sensing, monitoring & communication Pipe / Flexibles / risers / flowlines Umbilicals / cables Driving / ROV / AUV Subsea inspection / Repair / Maintenance Subsea Well Intervention Buoyancy / Protection Environmental / Site Studies / Monitoring	

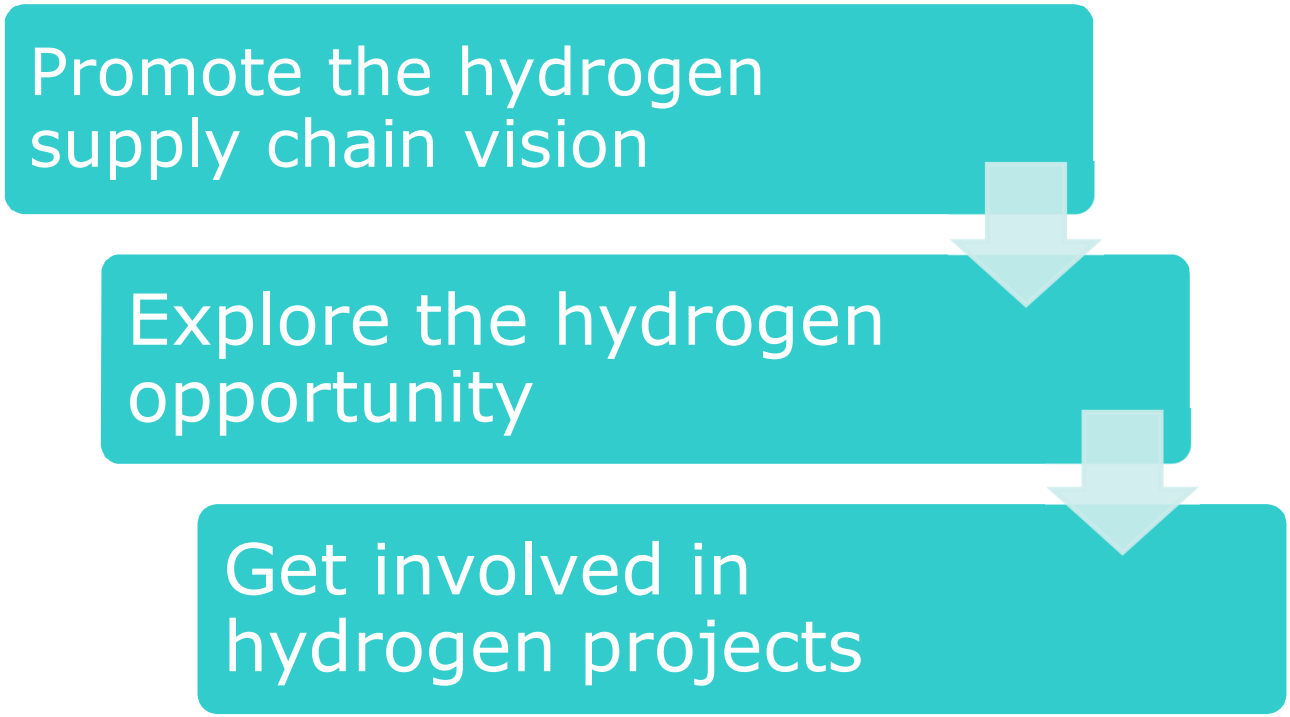
Pale Blue Dot.

Regional hydrogen potential



Pale Blue Dot.

Call to action



The Business Case for Hydrogen

Speaker: Tara Schmidt, ERM

The Financial Drivers Around Energy Transition and Hydrogen

Tara Schmidt, Principal Consultant, ERM

9 October 2018

The business of sustainability

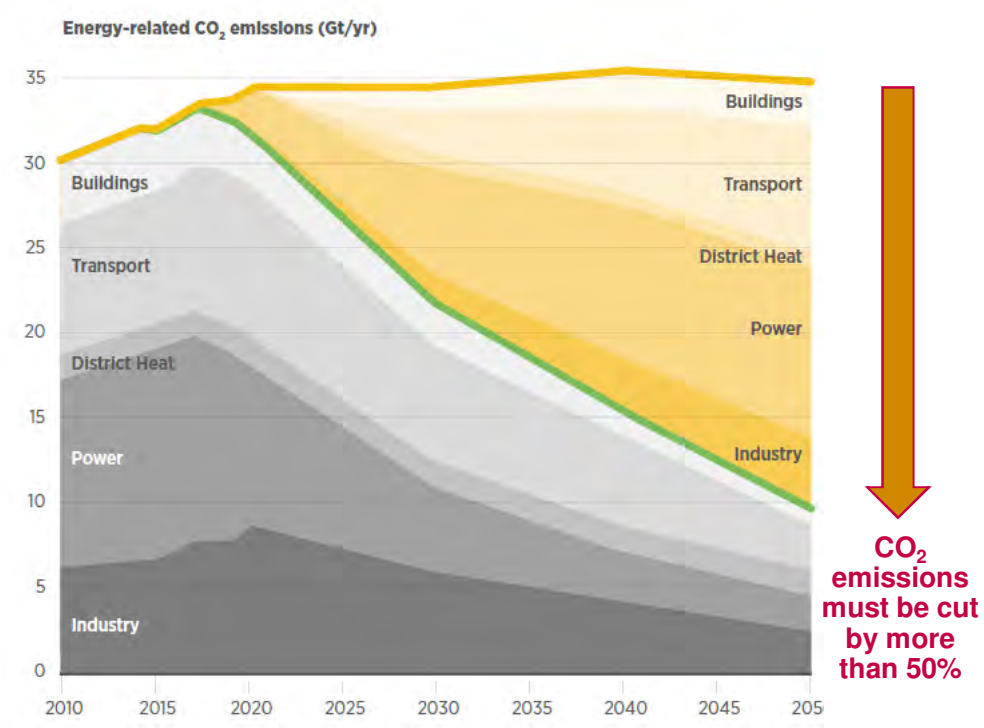
ERM

Introducing ERM

- A **leading global provider** of sustainability, risk, environmental, health, safety and social services
- Track record with more than **50% of the Global 500 companies** over the last four years, from asset to board level
- An **active thought leader**, supporting the G20's Task Force on Climate-related Financial Disclosures to assess the financial implications from the transition to a lower carbon economy and physical climate change
- A trusted adviser on sustainability issues to **a breadth of leading financial institutions** in their evolving response to climate change
- **Practical working experience** implementing projects on behalf of energy producers and infrastructure investors around the globe
- **Strategic support** to major corporations across wide variety of sectors, assessing transition impacts and delivering response strategies

Reaching a 2°C scenario is a cross-sector challenge – and will require radical solutions

Sectoral contribution to CO_2 cuts, 2010 – 2050



Source: IRENA Hydrogen Report, 2018

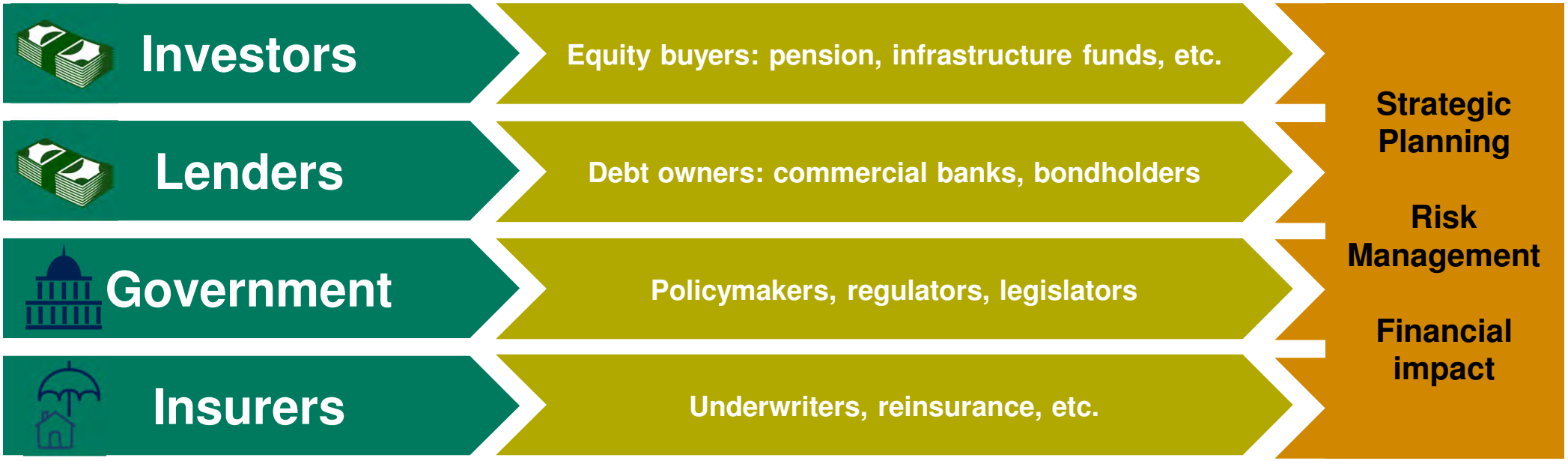
Decarbonising implies thinking differently about how energy is supplied and consumed

- ⇩ Coal
- ⇩ Oil
- ⇩ Gas
- ⇧ Energy efficiency
- ⇧ Renewable energy
- ⇧ Carbon capture & storage / use
- ⇧ **HYDROGEN**

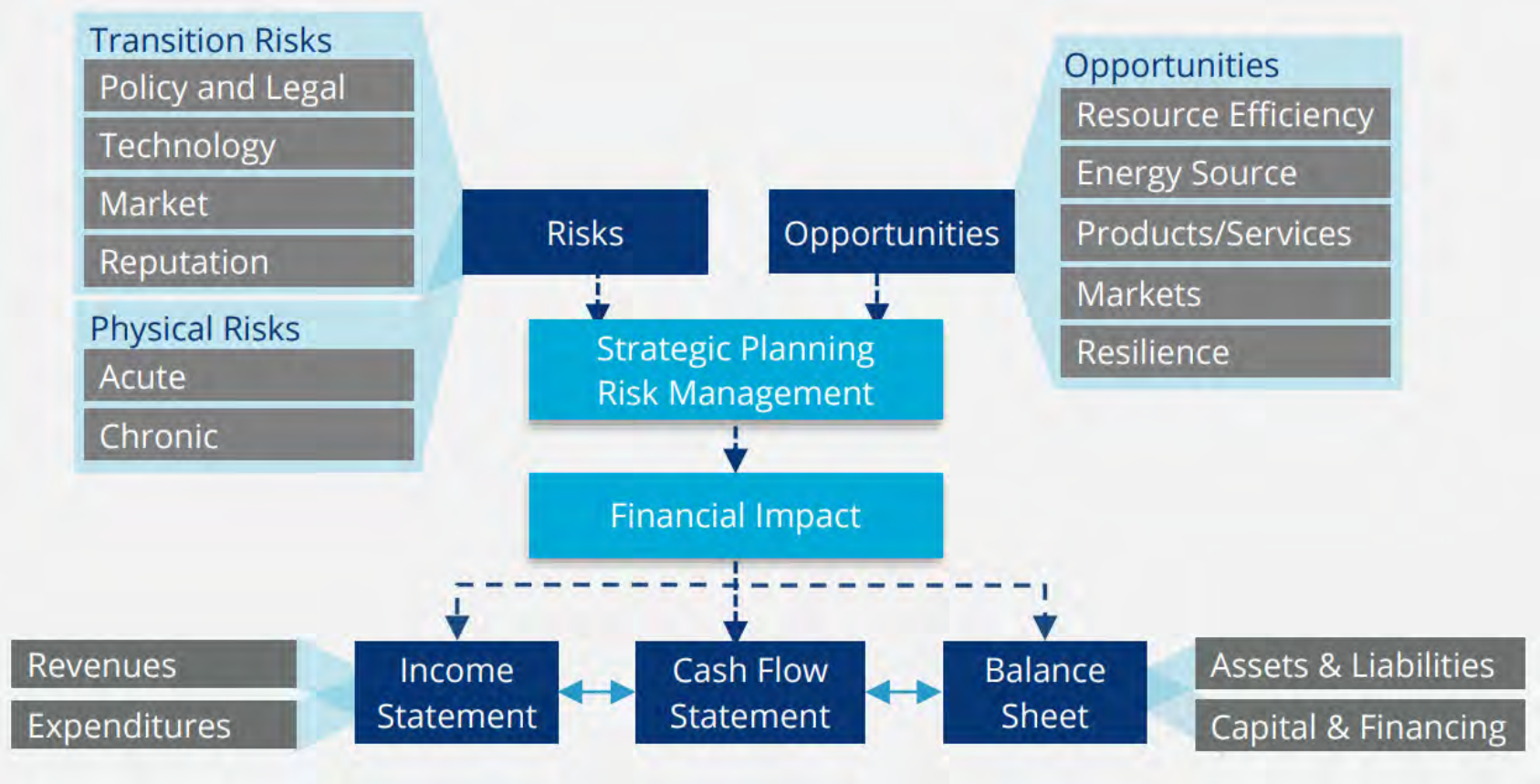
Financial drivers for sectoral investments in hydrogen

	Technology & market	Policy & regulation	Reputation
Buildings Decarbonise heat	Zero emission, efficient homes	Buildings to accelerate decarbonisation	Consumer preference for low cost / impact heating
Transport Zero-emission transport	Growth in non-ICE fleets / transport	Leading policymakers minimise 'shock' costs	Avoid 'dieselgate' scenarios
Industry Minimise fossil fuel consumption	Reduces virgin feedstock and energy costs	Decarbonising the 'difficult' industries	Perception as dirty / out of date
Power Long-term energy storage	Facilitates accelerated renewables growth	Reduces curtailment, boosts grid flexibility	Tech export powerhouse
Supply revolution Zero-emission hydrogen supply	Breakthrough tech generates vast upside	Leading policymakers minimises 'shock' costs	Global leadership in clean technology

The pressure from financial institutions is rising



Climate-Related Risks & Opportunities… and Financial Impact



Source: TCFD Recommendations

Thank you

Tara Schmidt
Principal Consultant
ERM
Tara.schmidt@erm.com
+44 131 221 6777
Edinburgh, UK

Molly Iliffe
Senior Consultant
ERM
molly.iliffe@erm.com
+44 131 221 6761
Edinburgh, UK

The business of sustainability

ERM