Green Recovery
Investment Prospectus

June 2020

This document sets out proposals that are intended to help inform the decisions we must make as a country to deliver a green economic recovery. We will engage with our stakeholders to discuss these proposals, explaining how we think the projects can support the UK economy and deliver on our net-zero ambition. We welcome comments and feedback.

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SGN's medium to long term net-zero strategy is to replace natural gas with hydrogen and other green gases, enabling the decarbonisation of heat by 2045.

There is no realistic scenario whereby the UK can achieve net-zero carbon emissions by 2050 without hydrogen playing a key role in the decarbonisation of large emitting sectors such as domestic heat, industry and heavy transport. The need for a clean and storable alternative to electricity is the basis of calls for urgent investment in the development, demonstration and scale up of hydrogen solutions.

Peak demand for heat is more than four times that on the electricity network and 83% of the UK's 29 million homes are heated by boilers that burn natural gas. 20,000 homes a week or 1 million homes a year will need to switch to low-carbon heat between 2025 and 2050.

Although other technologies will have a role to play, hydrogen can deliver decarbonisation of heat at the scale required to meet the Government's net-zero targets in a way that is most cost-effective and least disruptive for customers. And as the UK seeks to reinvigorate its domestic economy and set out the path to deliver net-zero, we must seize the potential to become a global leader in renewable and low-carbon hydrogen technology. We must move quickly to realise this opportunity and achieve the maximum economic benefit.

We recommend unlocking regulatory investment in research, development and demonstration and expediting industrial decarbonisation through key project investment.

Our key, shovel-ready demonstration project, H100 Fife, is essential for the creation of the hydrogen economy. It will create a complete hydrogen to homes network that will test every aspect of green hydrogen production, storage, network delivery, home application and social acceptability.

Beyond delivery of regulatory investment, we have prepared a list of investable projects that can be expedited now. Additional investment in the other projects identified in this paper would result in the creation and support of around 1,500 engineering, construction and business support function jobs in 2020/21.

Further investment in all future phases of every project detailed in this paper has the potential to create and support in excess of 100,000 direct and indirect jobs across the UK economy up to and beyond 2050 and secure the long-term future of the UK oil and gas and manufacturing industries.

We are not proposing to deliver this alone.

The decarbonisation of our economy and heating infrastructure requires significant coordination across the supply chain. Unlocking the regulatory investment by incorporating this programme in our next price control period, GD2, will complement the industrial strategy and aid the UK's green recovery.

ORE Catapult's 7MW Levenmouth Demonstration Turbine will provide renewable power for the world-first H100 Fife project

Credit: ORE Catapult

Executive summary
Continued

Project title	Phase	Location	Investment	Carbon benefit	Jobs estimate	Earliest commencement date
H100 Fife	Phase 1	Levenmouth	£27.2m	662 t CO_2	100	Now
	Phase 2		£15m (estimate)	1,550 t CO_2	60	2022
	Phase 3		£75m (estimate)	18,000 t CO_2	300	2022
	Phase 4		£25m (estimate)	4,000 t CO_2	100	2024
	Phase 5		£1bn (estimate)	1.5 Mt CO_2e	6,000	2026
Acorn CCS (Linked to Aberdeen Vision and Acorn Hydrogen)	Development of remaining 7 sites	St Fergus/ Offshore North Sea/Southern North Sea/ North Welsh Waters	£400m (estimate) £10bn (estimate)	3 Mt CO_2 per annum 44 (47 total) Mt CO_2 per annum	1,600 42,400 (sum is 44,000)	2021 2022
Acorn Hydrogen (Linked to Aberdeen Vision and Acorn CCS)	1 reformation module and storage (supply 20% H_2 blend to Aberdeen Vision)	St Fergus/ Aberdeen	£214m	0.4 Mt CO_2	800	Now
	Additional 3 reformation modules and storage (supply 100% H_2 to Aberdeen Vision)		£631m	1.2 Mt CO_2	2,500	2024
Aberdeen Vision (Linked to Acorn CCS and Acorn Hydrogen)	20% hydrogen blend into Aberdeen	St Fergus/ Aberdeen	£100m (estimate)	0.4 Mt CO_2	400	Now
	100% hydrogen into Aberdeen		£150m (estimate)	1.2 Mt CO_2	600	2024
ERM Dolphyn project	10 MW demonstration	North/West Scottish Coast	£56m	4,000 t CO_2	50	Now
	100 MW demonstration		£300m	40,000 t CO_2	120	2025
	4 GW array		£10bn	1.5 Mt CO_2	5,000	2028
	Additional 36 GW capacity		£90bn	13.5 Mt CO_2	45,000	2032

Project title	Phase	Location	Investment	Carbon benefit	Jobs estimate	Earliest commencement date
Machrihanish	300 customer demonstration	West Scotland	£15m	662 t CO_2 in phase 2	100	2022
	1,000 customer demonstration		£15m	1,550 t CO_2	60	
Energy system transition	Over 60 named projects	SGN, other gas networks and the wider gas industry	Around £300m	Enables the decarbonisation of UK heat and industry	1,200	2021
Energy efficiency		Scotland, South London and South East England	c.£6.6bn – £30bn (Upgrading 1.1m homes at £6k per job – £26k per home)	0.4 Mt CO_2	1,891 15-year rollout 2,837 10-year rollout 4,052 7-year rollout	Q3/Q4 2020

Executive summary
Continued

Table justifications and assumptions

H100 Fife

The town of Methil, on the Fife coast, has a rare confluence of factors that make it a unique location for demonstrating hydrogen as an energy carrier.

With easy access to the Offshore Renewable Energy Catapult's 7 MW Levenmouth Demonstration Turbine (the world's largest offshore wind turbine dedicated to research and development) and a vacant 9ha Scottish Enterprise plot earmarked for energy development activity, the site boasts a clean energy source, space for a new hydrogen production and storage facility, and a community of potential domestic end users within a small geographical area.

Phase 1
has been fully priced at £27.2 million and will decarbonise the gas demand of 300 homes (an average UK domestic property uses 12,000 kWh of natural gas per year, at 0.184 kg CO_2/kwh), saving 662 t CO_2/year.

Our Gas to the West project (new network construction in Northern Ireland) created around 400 jobs for a £150 million investment (around three jobs per £1 million investment), it will be assumed that for hydrogen projects, four jobs per £1 million of investment will be required to account for the innovative nature of the technologies involved. Phase 1 of the H100 Fife will create approximately 100 jobs using this ratio. This project is ready for immediate commencement following investment.

Phase 2
which will expand phase 1 to 1,000 properties, is estimated to cost £15 million and will involve the conversion of the existing network and expansion of the production facility. The above ratio estimates this phase will create an additional 60 jobs. The conversion of an additional 700 customers to 100% green hydrogen will provide annual emissions savings of 1,550 t CO_2. The earliest commencement of this phase is 2021.

Phase 3
will expand H100 Fife to decarbonise non-domestic customers in and around Levenmouth. There are 122 commercial and industrial properties demanding 97 GWh of natural gas per annum. This will require a ramp up in hydrogen production of at least ten times (either blue or green hydrogen) and new areas of network to be constructed, often to meet specific industrial loads. The decarbonisation of this gas demand will yield annual emissions savings of around 18,000 t CO_2. This phase is likely to require investment of around £75 million and will create 300 jobs. This phase will require the build-out of production and geological storage.

Phase 4
will develop hydrogen transport infrastructure, which will require additional processing to ensure hydrogen is of sufficient quality and pressure for use in road, rail and marine transport. The development of this phase is estimated to cost £25 million. Aberdeen Vision aims to create a transport hub for road transport, mainly for the city's bus fleet – this hub is estimated to deliver annual emissions savings of 1,300 t CO_2. This phase of H100 Fife will encapsulate road, rail and marine transport over a larger area. Therefore, this phase of H100 Fife is estimated to save around 4,000 t CO_2 per annum on completion. The investment of £25 million is estimated to create 100 jobs.

H100 Fife will be the world's first hydrogen heat network, testing every aspect of green hydrogen production

Phase 5
represents the significant development of the hydrogen economy in Fife. This includes integration with large industrial users (Mossmorran), the build-out of blue hydrogen production and integration with the electricity networks and large offshore wind generation assets, the rollout of significant hydrogen transport infrastructure and the full rollout of hydrogen to meet all heat and industrial demands in Fife. This phase will develop a significant hydrogen economy which will integrate with the "hydrogen coast" and is estimated to require at least £1.5 billion of investment. We deliver around 5 TWh of natural gas to Fife per annum – conversion of this demand to 100% hydrogen will reduce emissions by 860,000 t CO_2/annum. Further emissions reductions from the decarbonisation of electricity and transport yields the phase 5 estimate of emissions savings to be at least in the order of 1.5 Mt CO_2. This investment and rollout of phase 5 is estimated to create around 6,000 additional jobs.

Acorn CCS

Pale Blue Dot Energy's Acorn CCS facility is expected, subject to funding, to be operational by 2024. The 'Progressing Development of the UK's Strategic CO_2 Storage Resource Report' (April 2016) by Pale Blue Dot, Costain, the Energy Technologies Institute and Axis Well Technology assessed the UK's CCS potential.

The eight high potential sites assessed and priced in the report have a total capacity of 1,645 Mt CO_2, with a maximum injection rate of 47 Mt CO_2/year (for reference the total throughput of natural gas at St Fergus gas terminal, which accounts for 35% of total UK gas supply, emits around 55 Mt CO_2 per year at point of final use). The development of all eight sites to deliver the above stated capacity would require a capital investment of £4.4 billion and an OPEX of £6.0 billion, totalling £10.4 billion[1]. It should be noted that the costings in the referenced paper do not include the investment required for the capture capability at individual emitters.

The Energy Policy unit at Strathclyde University, led by Professor Karen Turner, has reported the potential for CCS to play an important role in helping to sustain around 44,000 direct and indirect Scottish jobs currently linked to oil and gas and other related industrial sectors. This investment will therefore be assumed to create and sustain an estimated 44,000 jobs in the UK oil and gas sector across the operational lifetime of the assets (out to around 2070).

Goldeneye has been identified as the first site for development in 2021, requiring an approximate investment of £400 million (CAPEX and OPEX of build), if it is assumed that every £1 million invested creates four jobs – this investment would create 1,600 jobs across its lifetime.

The table has been presented as a split in the repurposing of the Goldeneye field and the remaining seven sites identified in storage resource assessment report.

Acorn CCS is closely linked with our Aberdeen Vision project.

Phase 5 of H100 Fife will save 1.5 Mt of CO_2 and create 6,000 additional jobs

Executive summary
Continued

Acorn Hydrogen

Our Aberdeen Vision project (in partnership with Pale Blue Dot Energy) aims to develop and roll out a hydrogen economy in Aberdeen and the surrounding area. The feasibility study and required investment in this project will deliver a gas network infrastructure (transmissions and distribution) capable of delivering 100% hydrogen to the city of Aberdeen and the surrounding area. The projected costs do not account for the construction of the blue hydrogen production assets at St Fergus and the required hydrogen storage.

Aberdeen Vision will enable hydrogen demand and therefore stimulate hydrogen production. This new demand for hydrogen will be supplied from blue hydrogen production through Pale Blue Dot's Acorn Hydrogen. Acorn Hydrogen will reform natural gas at St Fergus to produce hydrogen for transport through the gas network infrastructure to customers.

One 200 MW reformer module at St Fergus will produce sufficient hydrogen for a 2% injection to the National Transmission System (NTS) and supply up to 20% of Aberdeen's demand (by volume) through a dedicated hydrogen transmission pipeline from St Fergus to Aberdeen. The cost of this module was estimated in the Aberdeen Vision Phase 1 Final Report to be £145 million. To ensure security of supply, 229 GWh of hydrogen is required in this Phase, at an estimated cost of £69 million. The total cost of this phase is therefore £214 million. If it is assumed that for every £1 million invested, four jobs are created, this phase will create around 850 jobs. This is linked with the jobs created in the Acorn CCS investment.

An additional three 200 MW reformer modules would provide sufficient supply for Aberdeen to convert to 100% hydrogen, this would require a further investment of £435 million. Additional hydrogen storage requirements of 650 GWh would require an additional investment of £196 million. The total cost of this phase is therefore £631 million. This investment is estimated to create around 2,500 jobs. These jobs are closely linked with the macroeconomic benefits and jobs created by investment in Acorn CCS.

The Aberdeen Vision Phase 1 Final Report estimated that a 2% by volume injection into the NTS at St Fergus will reduce emissions by around 320,000 t CO_2/year, with a 20% by volume blend of hydrogen and natural gas into the Aberdeen distribution network coupled with increased transport utilisation reducing emissions by around 80,000 t CO_2/year. The first phase therefore will reduce emissions by an estimated 0.4 Mt CO_2/year.

The second phase, where 100% of demand in Aberdeen is met by hydrogen, is estimated to reduce emissions by an additional 1.1 Mt CO_2/year. It is assumed that an additional saving of 0.1 Mt CO_2 will be realised from a further uptake of hydrogen fuelled transport. This second phase will therefore reduce emissions by a further 1.2 Mt CO_2/year (Total of 1.6 Mt CO_2/year).

The construction of the first reformation module and supporting storage is assumed to be ready for investment now, with the second phase ready in 2024.

Aberdeen Vision

The success of Acorn Hydrogen and all other blue hydrogen production is dependent on the successful development of Carbon Capture and Storage (CCS) infrastructure (Acorn CCS). The success of blue hydrogen production is dependent on the extent of a demand, which is realised by the transition of current natural gas demand to hydrogen demand. This requires the repurposing and transition of gas distribution infrastructure to deliver up to 100% hydrogen.

Aberdeen Vision will repurpose gas distribution infrastructure in Aberdeen and construct a hydrogen transmission pipeline from St Fergus to Aberdeen. The emissions savings from Aberdeen Vision are directly linked to the emissions savings described in Acorn Hydrogen and are not in addition to these savings.

The design, permitting and construction of the 100% hydrogen pipeline to Aberdeen is estimated to require an investment of around £80 million. Modifications to the distribution infrastructure in order to enable 20% hydrogen by volume blending in Aberdeen is estimated to cost around £20 million. This overall investment in phase 1 of around £100 million is assumed to create and support approximately 400 jobs in Aberdeen. To enable the phase 2 conversion to 100% hydrogen is estimated to require a further investment of £150 million, creating and supporting an additional 600 jobs.

Dolphyn

ERM's Dolphyn project aims to establish industrial scale green hydrogen production through the design, construction and demonstration of floating offshore wind turbines with integrated electrolyser green hydrogen production. This project will commence initially with a smaller scale 2 MW turbine demonstration as a proof of concept, followed by a larger 10 MW turbine demonstration. The initial stages of this project have secured funding through the BEIS hydrogen supply competition.

The 2 MW demonstration followed by the 10 MW demonstration will require an investment of £56 million and will deliver around 4,000 t CO_2/year (total 12 MW capacity). This phase has now commenced and is suitable for immediate investment concluding in 2026.

The Dolphyn project will then look to develop a 100 MW demonstration (array of 10x10 MW turbines). This will require an investment of around £300 million and reduce emissions by a further 40,000 t CO_2. This phase is expected to be ready for investment and commencement by 2025 and completed by 2030.

ERM will then look to progress to full scale industrial green hydrogen production through the construction of a 400 turbine array at 4 GW. This array is estimated to require a £10 billion investment and will deliver emissions reductions of around 1.5 Mt CO_2/year. This is expected to commence construction in 2028 and will be completed by 2034.

3,000 jobs

could be created through phase 1 and 2 of Acorn Hydrogen.

£80 million

The design, permitting and construction of the 100% hydrogen pipeline to Aberdeen is estimated to require an investment of around £80 million.

Executive summary
Continued

The final phase of this rollout will construct a further nine 4 GW arrays (total 40 GW), which will represent a significant volume of green hydrogen capable of supplying a large proportion of GB heat and industrial demand. The development of nine further arrays will require an investment of up to £90 billion (this is likely to be lower due to economy of scale and efficiency savings of industrial scale manufacturing). The construction of these further arrays could commence in 2032 and, upon completion, reduce emissions by a further 13.5 Mt CO_2/year.

A study conducted by Energy and Utility Skills[2] estimated that growth in the UK offshore wind sector (to an overall capacity of 35 GW) by 2032 will directly support 36,000 jobs – this equates to around 1,000 jobs per GW of capacity.

For green hydrogen production, due to the added element and complexity of electrolysis and the more remote locations, it will be assumed that 1,250 jobs will be created and supported per GW of offshore green hydrogen production at the industrial scale. For the 10 MW demonstration, due to the smaller scale, it is estimated up to 50 jobs will be created and supported. For the 100 MW demonstration, it is estimated that 120 jobs will be created and supported (based on the above ratio). Investment in each array is estimated to create and maintain 5,000 jobs.

Machrihanish & Campbeltown

A FEED study was conducted to consider the site at Machrihanish as a possible location for the H100 demonstration. Despite not being chosen, we seek to develop this site as a route into West Scotland for hydrogen. Required investment in this site to enable the first phase build-out is estimated to be £15 million. This phase can be started now and will supply 300 homes with green hydrogen and enable the installation and testing of alternative downstream renewable technologies. This phase will reduce emissions by 662 t CO_2/year and create and support 100 jobs in the region.

Phase 2 of this project will expand the network to 1,000 customers and require a further £15 million investment, saving an additional 1,550 t CO_2 and creating and supporting a further 60 jobs in the area. This phase will likely be ready in 2022.

The project has significant growth potential similar to H100 Fife, which will be quantified following investment in phase 1. This includes the development of a hydrogen economy in West Scotland.

The Macrihanish project will reduce CO_2 emissions by 662 tonnes, creating and supporting 100 jobs in rural Argyll

Energy system transition

The investment of around £300 million in the RIIO-GD2 programme will conduct the necessary work to enable the decarbonisation of the energy delivered through the network. This investment is estimated to create and support 1,200 jobs, both in SGN and wider project partners in the gas industry.

This work can commence in 2021.

1,500 jobs

could be created in 2020/21 through investment in key projects.

1,000 homes

The Machrihanish & Campbeltown site could supply green energy to 1,000 homes.

H100 Fife

Levenmouth in Fife, home to the town of Methil, offers a location that is unique for demonstrating hydrogen as an energy carrier. It provides access to an existing 7 MW wind turbine (owned by ORE Catapult), and a vacant 9ha plot owned by Scottish Enterprise that is development land for energy activities. This site, identified for the hydrogen production and storage facility, as well as the hydrogen demonstration facility, is located adjacent to the potential domestic end users.

This is an area of high deprivation, and is recognised to be within the 5% of most deprived areas according to the Scottish Index of Multiple Deprivation (SIMD). The waterfront at Levenmouth has been an area steeped in the energy industry for decades, with Methil being appointed as a new coal exportation dock in the 1870s. With this came a wave of jobs and employment opportunities linked to the export of coal from Fife, creating a mining town and coal port with a wagon line built to bring coal to the dock from the collieries. At one point, Methil was Scotland's main coal export dock.

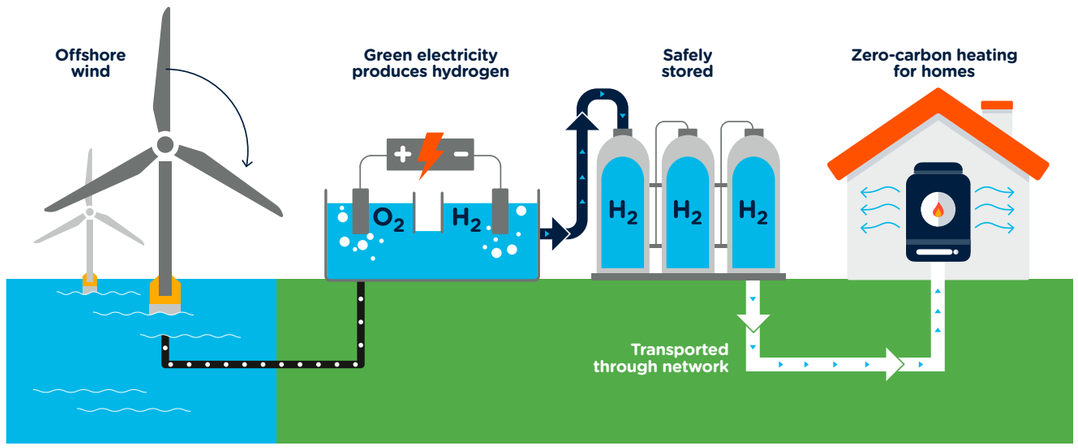
Moving into the 1970s, oil field exploitation in the North Sea brought a new form of employment to the area and a major facility for the construction of platforms was established. Energy Park Fife, as it is know today, still hosts contributors to the offshore market with links to fossil fuels but also renewables, including Biba. This site has seen the transformation of old energy to new, starting with coal mining and exporting, through to oil platform fabrications and more recently offshore wind turbine jacket structures.

The presence of the 7 MW wind turbine on site demonstrates the inclusion of clean energy into the function of the park and sets the context for the delivery of the next innovative advancement in the energy sector – hydrogen delivered from offshore wind to customers through our H100 Fife project.

By securing and constructing a hydrogen demonstration in Levenmouth, a location has been selected that is ideal for evidencing the replacement of natural gas with hydrogen and the wider rollout of hydrogen in the energy system. In addition to the phases discussed in this paper, the location of the H100 Fife project lends itself to a range of opportunities, including:

- A central Scottish location, close to motorway connections and only 40 minutes from Edinburgh airport.
- The presence of Fife College, which demonstrates an excellence in energy courses and has a campus located in Levenmouth.
- A platform of renewables and hydrogen education delivered by Bright Green Hydrogen that can be built upon in higher education.
- Aligning with Fife Council's targeting of mid-Fife as a priority area for investment and economic rejuvenation, with 2019 statistics reporting Fife's unemployment rate to be 4.1%, compared to 3.5% for Scotland and 4.0% for the UK (Defined as: % of working age (16–64) residents who are out of work). In April 2020 the claimant rate in Levenmouth rose by 8.6%, the highest increase in Fife.

H100 Fife phase 1



The location of the H100 Fife project lends itself to a range of opportunities

H100 Fife

H100 Fife is seeking to deliver a first-of-a-kind 100% hydrogen network, supplying around 300 domestic properties in phase 1. This will be a new purpose-built generation and storage solution, supplying a pipeline network, comprising of fully tested common natural gas components and fittings, laid in parallel to the existing gas network delivering an end-to-end hydrogen system. Phase 1 will be delivered through an investment of £27.2 million.

The growth potential of the H100 Fife site is significant, and can be summarised in four expansion phases:

Phase 2
(estimate £15 million)

1,000 properties:

(a) Expanding the initial 300 connections to 1,000 customer connections in phase 2. This could include a conversion of existing natural gas assets, forming one of the regional conversion demonstrations.

Phase 3
(estimate £75 million)

Industrial and commercial:

(a) Exploring integrating a hydrogen supply solution for industry through collaboration with Diageo, one of the world's largest distillers, who have their main packaging site and a distillery in Levenmouth. These are located 2–3km from the hydrogen production site.

(b) 52 manufacturing businesses operate in the Levenmouth area.

(c) Within Energy Park Fife is the offshore jacket manufacturers, BiFab, who have fabricated infrastructure for the offshore oil and gas industry as well as offshore wind turbines.

(d) Close to Levenmouth is the Coaltown of Balgonie anticline, that has the storage capacity for hydrogen to serve 250,000 homes.

(e) Levenmouth Water Treatment Works is nearby; there is future opportunity to generate hydrogen from waste water.

(f) Options for utilising the oxygen for both fisheries and medical applications are also being explored.

Phase 4
(estimate £25 million)

Transport:

(a) Levenmouth was originally served by a rail link that was decommissioned decades ago. Funding has now been announced by Transport Scotland for reinstating the Levenmouth rail link. A hydrogen alternative to diesel or electric will be explored. This infrastructure upgrade will further improve the connectivity of Levenmouth with key routes and cities, as well as locally.

(b) Hydrogen powered haulage logistics also offers a possible transport opportunity, in addition to new or existing hydrogen fleet vehicles.

(c) As the site is located next to a marine port, there is the prospect for marine hydrogen transport or hydrogen powered vessels.

Phase 5
(estimate £1 billion)

Whole systems and Hydrogen coast:

(a) Hydrogen could integrate with the power network, providing storage and supporting transport. There is an opportunity to expand on the 'East Neuk' project undertaken with Scottish Power Energy Networks to roll out whole system solutions.

(b) The rollout of property connections could expand to supply an extended decarbonised east coast network.

(c) Mossmorran's Natural Liquid Gas and Ethylene Plant is located 25km from Levenmouth and produces industrial hydrogen as a by-product of ethylene production. In addition, there is an existing liquid natural gas pipeline between St Fergus and Mossmorran.

(d) H100 Fife is proposing a fully green solution to hydrogen networks through electrolysis. However, in the future of heat, the gas networks must adopt a technology agnostic view to the production of hydrogen. The inclusion of Grangemouth into the wider rollout of hydrogen represents large scale decarbonisation through the reformation of natural gas to produce hydrogen with carbon capture.

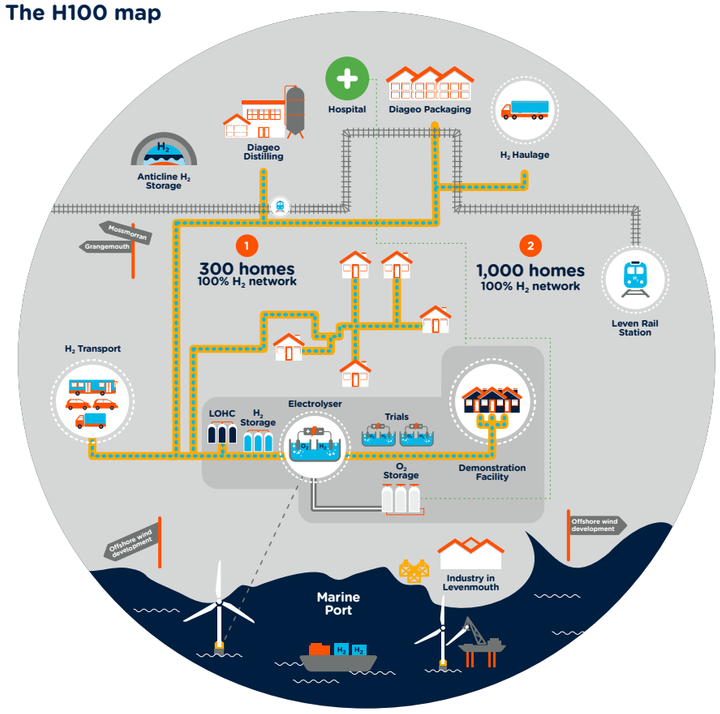
(e) With the production of hydrogen using electrolysis, derived from offshore wind, the hydrogen system at Levenmouth is demonstrating a world first power to gas zero-carbon solution for domestic heat.

(f) Hydrogen from offshore wind is a valuable process that is being demonstrated at Levenmouth, opening a market solution for hydrogen production at scale.

(g) Neighbouring offshore wind activity off the coast of Fife is accelerating with the Neart na Gaoithe (NnG) 450 MW wind farm and Cierco's 12 MW–53 MW development next to Energy Park Fife. Existing and future developments in the offshore wind market close to Energy Park Fife offer the opportunity for power integration for hydrogen production.

(h) Forth Ports are the main port owners in Fife, including those at Methil, Burntisland, Kirkcaldy, Rosyth and also neighbouring ports in Dundee and Leith (Edinburgh). Marine activity is still prominent in Fife and Forth Ports are key players in all tiers of the renewables sector. Marine applications are already being looked at by the hydrogen sector.

The H100 map



Carbon capture and storage – Acorn CCS

Carbon capture and storage (CCS) describes the process of capturing carbon dioxide emissions from processes which would otherwise have vented the waste gas to atmosphere. CCS enables the use of natural gas in a net-zero world by removing the CO_2 emissions from its use. The production of blue hydrogen requires CCS for the energy produced to be classified as low carbon.

Whilst green hydrogen (hydrogen from electrolysis) must provide the bulk of hydrogen supply in the long term as natural gas supplies diminish, blue hydrogen, and by default CCS, provides a step change to that end goal (green hydrogen generation capacity to satisfy all heat and industrial demand will require the build-out of significant offshore wind generation assets and other renewable generation assets, which will take decades).

Blue hydrogen production allows the continued use of natural gas in a net-zero world, securing the prosperity and future of the natural gas supply chain and those employed in it, whilst moving towards net-zero emissions with economically produced energy, allowing the large scale build-out of green hydrogen from offshore wind (and the subsequent cost competitiveness through its economy of scale) and stimulating the CCS industry.

CCS also enables BECCS (bio energy and CCS) which produces negative carbon emissions – emissions from biomethane are part of the natural carbon cycle, and therefore if captured, emissions are effectively removed from the atmosphere. BECCS will be critical in eliminating emissions from sectors of the economy which cannot be practically transitioned fully away from fossil fuels, such as aviation.

The UK's CCS potential is significant. Pale Blue Dot's Strategic UK CCS Storage Appraisal Project, funded by the Department of Energy and Climate Change, concluded that there are no major technical hurdles to storing industrial scale CO_2 offshore in UK sites[3]. The project identified 20 specific CO_2 storage sites (this only represents a small proportion of overall national potential with a combined capacity of 78 billion tonnes of CO_2). The top 15% of this potential capacity would capture all UK emissions for over 100 years. The UK undoubtably possesses a CCS capacity well in excess of its practical needs and a capacity marketable on a global scale.

Pale Blue Dot's (Aberdeen based) Acorn CCS facility is a carbon capture and storage project specifically designed to overcome one of the acknowledged blockers to CCS deployment in the UK – the high capital costs involved in getting started. Based at the St Fergus gas terminal in North East Scotland, Acorn CCS can repurpose existing gas pipelines to take CO_2 directly to the Acorn CO_2 Storage Site (the first CO_2 storage licence to be awarded by the Oil and Gas Authority).

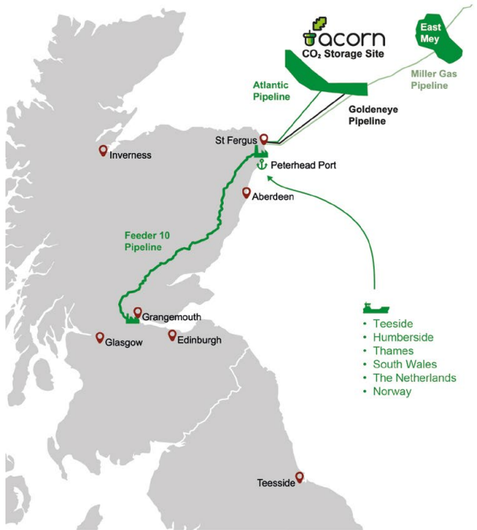
78 billion tonnes

Potential storage capacity for offshore CO_2 in the UK.

100 years

15% of this potential capacity would capture all UK emissions for over 100 years.

acorn: Overview



Pale Blue Dot Energy Limited ©

Phase 1: Establishing the CCS infrastructure

Low Capital Cost CO_2
Around 340,000 tonnes per year of existing CO_2 from the St Fergus gas terminal.

Pipeline reuse
More than £750 million cost savings from reuse of high capacity on and offshore pipelines.

World class CO_2 stores
Two large, well understood CO_2 stores with plenty room for growth.

Phase 2: A catalyst for clean growth

A major hydrogen production and CCS hub at St Fergus.

An economic opportunity for the deep-water port at Peterhead to include CO_2 import facilities.

A repurposed onshore pipeline to deal with Scotland's major industrial emissions.

An international CO_2 storage hub in the Central North Sea.

"CCS is a necessity, not an option."
Committee on Climate Change, May 2019

With this important pipeline infrastructure already in place, Acorn CCS can be started with just a modest amount of existing CO_2 emissions – captured directly from the gas processing units at the St Fergus gas terminal. The first phase of Acorn CCS offers a low capital cost start, with an investment decision planned in early 2021, that can be delivered by 2024 – establishing the critical CO_2 transport and storage infrastructure required for the wider Acorn build-out, including Acorn Hydrogen and the import of CO_2 to St Fergus from ships at Peterhead Port and from Scotland's industrial Central Belt.

Designated a European Project of Common Interest (PCI), Acorn is an important catalyst for clean growth opportunities in Scotland and in regions where CO_2 transport and storage is limited. Acorn can help transform the UK's carbon intensive industries into low-carbon industries and sustain jobs.

The project is led by Pale Blue Dot Energy, with funding and support from industry partners (Chrysaor, Shell and Total), the UK and Scottish Governments, and the European Union[4]. Acorn CCS and Acorn Hydrogen are closely linked with our Aberdeen Vision project and together will spearhead the development of the hydrogen economy in the north east of Scotland.

The full industrial development of CSS is critical to the decarbonisation of the UK economy and will require a multi-billion-pound investment over decades.

The initial phase of the development of Acorn CCS will see the repurposing of the Goldeneye pipeline in the North Sea for carbon dioxide transportation, with future phases developing a further seven high potential sites.

Green hydrogen – ERM Dolphyn

Whilst blue hydrogen must, and will, play a significant role in the decarbonisation of heat and industry, the reformation of natural gas does still require natural gas, which is a finite resource. The end state of the UK gas industry must be one supplied by as close to 100% green hydrogen as is practically possible.

Green hydrogen is produced by the electrolysis of water into oxygen and hydrogen and is powered by renewably generated electricity. Renewable energy is practically infinite and reliance on it in a fully scaled solution (with sufficient generation capacity and storage capacity) will provide a secure supply of zero carbon energy. Whilst 2050 targets can be achieved through the use of blue and green hydrogen, green hydrogen is the only form of hydrogen generation which can reach a point of no security of supply issues (blue hydrogen is reliant on natural gas supply) and should be fully depended on beyond 2040.

The UK is a world leader in offshore wind energy which is currently dedicated to electricity generation. To optimise costs and minimise transmission losses, wind farms generating electricity are optimally located nearer demand (this is due to the fact electricity is kinetic energy, as opposed to chemical energy, which is more practical to transport long distances) – this is not always in locations where the greatest wind resource is. The greatest and most consistent wind speeds in the UK are typically found in deep water locations around the Atlantic Coast and the North Coast. Building out wind generation for electricity at these locations is unlikely to be practical or economical due to power transmission requirements.

Producing hydrogen with renewable energy in remote locations allows instant energy storage to chemical energy, which can then be delivered long distances through gas pipes (which equivalently deliver significantly greater quantities of energy than electrical cables at a fraction of the cost).

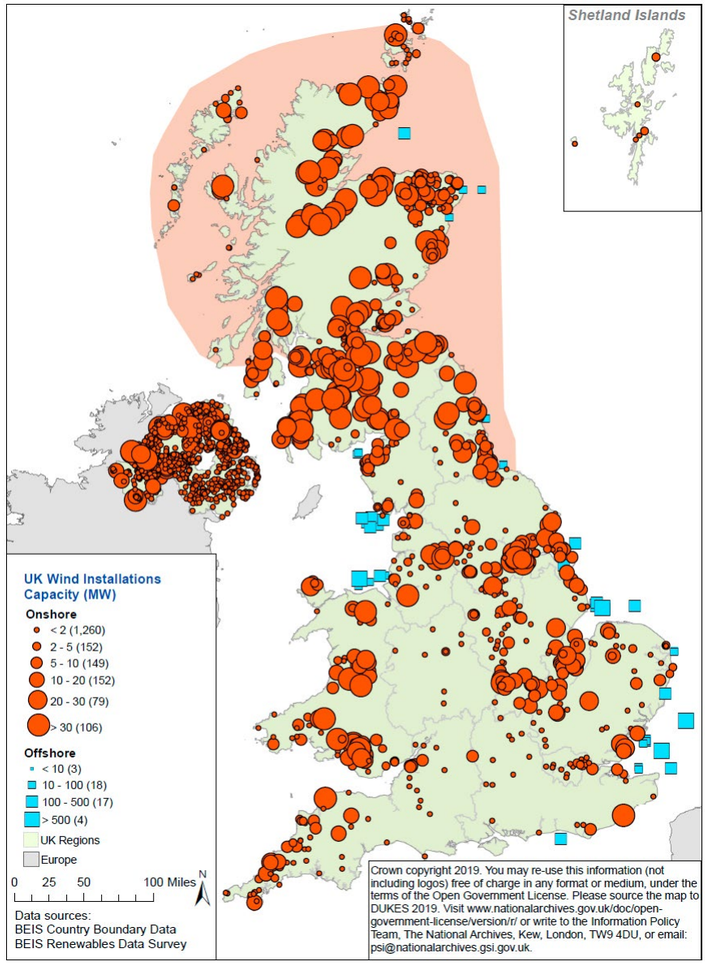
Green hydrogen enables the oil and gas model of transporting stored energy ashore (rather than generating energy where it is needed as is the case with electricity generation) to be applied to the offshore wind energy sector.

ERM was awarded UK Government funding to further develop their Dolphyn Project[5]. The first of a kind Dolphyn project is an innovative integrated system combining all of the technologies required to bring together the latest floating wind turbine and electrolyser technologies. The project aims to create a 2 MW prototype by March 2021, providing a proof of concept. If successful, ERM aim to significantly scale up the production of green hydrogen to arrays of 10 MW floating electrolyser wind turbines (arrays of 400 – 20 by 20). Each array, with a generation capacity of 4 GW, capable of supplying heat to 1.5 million homes. The potential of this project is tremendous, and its success has the potential to unlock green hydrogen production in remote locations, potentially utilising offshore oil and gas platforms (enabling their repurposing) and stimulating the offshore wind industry to a significant hydrogen market.

This project at scale could transform the UK energy industry and become the primary source of energy for the UK economy. Green hydrogen production at scale will drive down the price of energy. This technology is critical in the future success and longevity of the hydrogen economy and provides a route to a self-sufficient, zero-carbon energy supply from a secure and infinite resource. This will bring significant macroeconomic benefits, export potential, IP for British industry and manufacturing and enduring job security.

Full rollout of this technology and the development of green hydrogen production is highly desirable and essential to hydrogen security of supply in the long term. This represents a multi-billion-pound investment requirement in the very best interests of the UK economy, job market and environment.

UK wind installations capacity (MW)



Aberdeen Vision and Acorn Hydrogen

Aberdeen is Europe's leading oil and gas centre, with over half a century of heritage in delivering energy to the UK economy. In its 50 years as the UK's energy capital, it has developed capabilities and IP that have generated trillions in exports and inward investment into the UK. The nearby port at St Fergus is where 35% of the UK's natural gas is brought to shore. As we strive towards our net-zero emissions target, the development of a hydrogen economy and supply chain in Aberdeen and the north east of Scotland presents a tremendous opportunity to put the region at the leading edge of the zero-carbon supply chain, maintaining its status as a world-leading energy centre in a net-zero world.

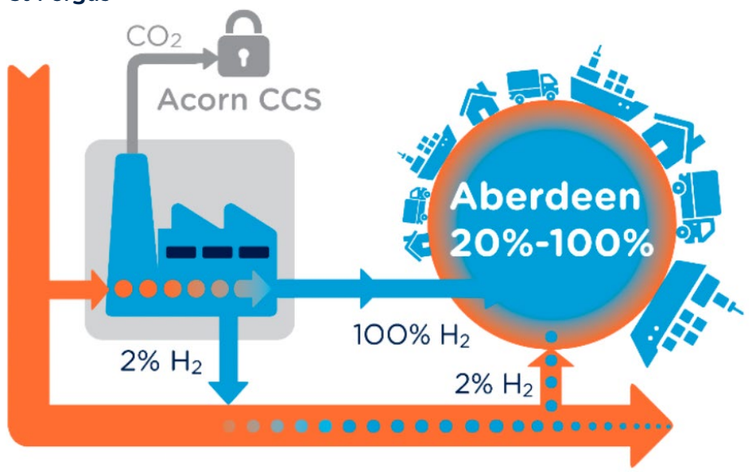
The opportunity to develop a hydrogen economy along the east coast of Scotland will require significant infrastructure repurposing and build-out in and around key locations for hydrogen production to deliver deep decarbonisation, which includes Aberdeen as a strategic location. Through a range of initiatives including Aberdeen Vision, H100 Aberdeen feasibility, Acorn CCS, Acorn Hydrogen and ERM's Dolphyn project, Aberdeen continues to be a hub of activity for hydrogen deployment.

The uses of hydrogen in transport have also been pursued in Aberdeen, which is now home to one of the largest and most varied hydrogen road transport fleets in the UK including buses, hydrogen refuelling stations and hydrogen fleet vehicles available to businesses as part of a car club. Furthermore, The Event Complex Aberdeen (TECA) is a world-class, £330 million facility and is recognised as the UK's most sustainable venue, all powered by an onsite energy centre and anaerobic digestion plant using renewable energy sources and features the largest hydrogen fuel cell installation in the UK.

The strategic location of Aberdeen (close proximity to oil and gas infrastructure, natural gas supply chains, high potential CCS sites, high potential offshore wind locations and a highly skilled workforce across engineering and construction) and its strong links to critical hydrogen projects makes it an essential area for investment as part of the Green Recovery in the coming years. The consequences of not investing in this area, and industry, would result in the missed opportunity to develop a world-leading hydrogen economy in the UK, which would be highly detrimental to not only the economy of the north east of Scotland, but the UK's ability to achieve net-zero targets.

A hydrogen economy in Aberdeen would maintain its status as a world-leading energy centre in a net-zero world

St Fergus



Our Aberdeen Vision project aims to unlock the hydrogen economy in Aberdeen and the surrounding area. Acorn Hydrogen will supply the hydrogen for this project with Aberdeen Vision enabling the demand through the construction and repurposing of the infrastructure required to transport it. Phase 1 of this project has concluded and assessed the feasibility of constructing a 200 MW Steam Methane Reformer (SMR) at St Fergus (as part of Acorn Hydrogen), constructing a 100% hydrogen pipeline to Aberdeen and developing Aberdeen's gas network infrastructure to enable up to 20% by volume into the energy blend.

SMR blue hydrogen production, which will be built out as part of Pale Blue Dot's Acorn Hydrogen project, will separate natural gas from St Fergus gas terminal into hydrogen and carbon dioxide using steam, with the CO_2 by-product captured and stored permanently at Pale Blue Dot's Acorn CCS facility in the North Sea. Hydrogen both from reformed natural gas and electrolysed offshore wind (Dolphyn project) would be injected into a dedicated 100% hydrogen pipeline, laid to Aberdeen, allowing an initial 20% blend by volume to the network increasing to 100%. The pipeline would supply the existing and proposed refuelling solutions in Aberdeen. There is also future opportunity to blend into the National Transmission System.

The full build-out of this project will require an investment of around £100 million to achieve enough capacity for a 20% blend in Aberdeen City with further investment required to achieve a 100% hydrogen distribution.

This project provides a route for the decarbonisation of heat, industry and transport in the north east of Scotland. The creation of hydrogen demand (enabled by a repurposed gas infrastructure) will enable the repurposing of the North Sea oil and gas industry to produce blue and green hydrogen.

This project has the potential to deliver at least 1.5 million tonnes of CO_2e emissions reduction per annum (with a 100% hydrogen Aberdeen Local Distribution Zone (LDZ)), and in the process provide a significant boost and growth stimulus to the north east of Scotland and the city of Aberdeen; an area and city heavily reliant on the oil and gas industry. Early investment in this project, which is planned to roll out to 100% hydrogen by around 2028, will provide welcome economic and decarbonisation benefits to the area and industry, and will afford this critical project the maximum chance of success.

Machrihanish hydrogen demonstration

Machrihanish Airbase Community Council (MACC) is the proposed area for a secondary H100 demonstration site, following on from the progression of H100 Fife. The site is the former RAF Machrihanish which was operated as a military airbase between 1918 and the 1990s, located around five miles to the north west of Campbeltown.

Campbeltown is one of five Statutory Independent Undertakings (SIUs) operated by SGN and is supplied by liquefied natural gas (LNG), which is shipped in via road tanker. The site operates as a business park and community facility, comprising of 137 households and 21 commercial premises. These are connected to a private wire network supplied by National Grid through MACC as the landlord. There is no existing gas infrastructure at this site. There is also 250kW of solar PV developed on site which supplies the private wire, with a further 1 MW consented. Beyond a hydrogen network, features of this site offer the option to explore hydrogen solutions for aquaculture, industrial demand, decarbonising haulage routes and marine applications.

H100 Fife will be the world's first 100% hydrogen heat network. This site was chosen following a comprehensive and competitive process between different bidders and locations. Feasibility studies were conducted for sites in Aberdeen, Machrihanish and at Levenmouth. Machrihanish and Levenmouth were progressed to FEED and Levenmouth was ultimately selected for the H100 demonstration.

We have ambitions to build out all three sites in time. The site at Machrihanish is of particular interest (the site at Aberdeen has been incorporated into the Aberdeen Vision project) due to its remoteness and variation in renewable supply (wind and solar). The build-out of this site, which will likely require an investment in excess of £15 million, aims to produce hydrogen from the electrolysis of renewable energy sources to supply a 100% hydrogen network to around 300 customers in Machrihanish. A further £15 million would lead to an expansion to 1,000 customers in Campbeltown.

In parallel, the project would seek to install a range of downstream renewable technologies, such as air source heat pumps, to compare the operation of heat pumps and hydrogen boilers at the same location. This would represent an ideal test bed to determine the suitability of various heating technologies to feed into a coordinated whole system approach to the decarbonisation of heat with electricity networks. The remote west coast location of this site does not tie into the proposed east coast of Scotland hydrogen coast concept; however, it does present itself as a useful test bed for low-carbon heat technologies.

Investment in this project would stimulate the local economy and provide an invaluable opportunity to develop a hydrogen economy in the west of Scotland, providing a route to the decarbonisation of the wider area, including the city of Glasgow. This project is likely to have the same growth potential as H100 Fife, with similar access to offshore wind potential. The economic growth and development of the area, if this project is progressed to full completion, is tremendous.

Energy system transition

In RIIO-GD2, we aim to prove and demonstrate the safe and efficient transportation of up to 100% hydrogen through our network, enabling the rollout of 100% hydrogen networks in 2026 at strategic locations. We proposed a highly ambitious and far reaching programme of work to Ofgem in GD2, the detail of which can be found in the RIIO-GD2 business plan and supporting appendices.

This programme of work, which contains over 60 named projects, intends to tackle the technical and safety knowledge gaps and subsequently remove all barriers preventing the large-scale rollout of hydrogen networks in GB. The programme will also consider regional strategy in order to ready and identify frontier towns suitable for the first rollout of 100% hydrogen networks.

The execution of this programme of work as part of the whole suite of R&D is essential in enabling the repurposing of the GB gas network infrastructure to enable the hydrogen economy.

100%

In RIIO-GD2, we aim to prove and demonstrate the safe and efficient transportation of up to 100% hydrogen.

60

Number of projects needed to tackle technical and safety knowledge gaps to pave the way for a large-scale rollout of hydrogen networks.

[1] Progressing Development of the UK's Strategic Carbon Dioxide Storage Resource – a summary of results from the Strategic UK CO_2 Appraisal Project – April 2016, Costain, Energy technologies Institute, Pale Blue Dot and Axis Well Technologies.

[2] https://renewablesnow.com/news/study-sees-260-growth-in-uk-offshore-wind-jobs-by-2032-severe-competition-for-talent-632330/

[3] Energy Technologies Institute, Strategic UK CCS Storage Appraisal – https://www.eti.co.uk/programmes/carbon-capture-storage/strategic-uk-ccs-storage-appraisal

[4] https://theacornproject.uk/

[5] https://www.erm.com/news/erm-gets-go-ahead-to-develop-green-hydrogen-at-scale-from-offshore-wind/

https://www.modernpowersystems.com/features/featuregetting-green-hydrogen-production-into-deep-water-the-dolphyn-project-7780776/featuregetting-green-hydrogen-production-into-deep-water-the-dolphyn-project-7780776-503836.html

Energy efficiency programme

The delivery of a national energy efficiency programme for UK households would create jobs; substantially reduce carbon emissions and support net-zero targets, reducing the impact of climate change; and help customers with rising energy bills and affordability challenges in the wake of the COVID-19 pandemic.

Energy use in homes accounts for approximately 14% of UK greenhouse gas emissions. These emissions need to fall by 24% by 2030 to meet decarbonisation targets, suggesting a major improvement in housing energy efficiency is required. Whilst energy efficient white goods, lighting and consumption monitoring/ metering (e.g. smart meters) are becoming increasingly commonplace, improvements in housing infrastructure and insulation are less advanced and could provide significant improvements in energy efficiency with respect to household heating.

A major driver for energy efficiency is the associated carbon savings and reductions in consumer bills. The The Committee on Climate Change (CCC) estimate that the annual direct emission savings from all residential energy efficiency could be 6 $MtCO_2$ by 2030. It is also believed that total energy use could be reduced by approximately 25% by 2035 through cost-effective investments in energy efficiency, with related consumer savings on annual domestic heating energy bills through energy efficient insulation.

Previous energy efficiency schemes have seen challenging levels of customer take-up even when it has been offered for free due to the perceived hassle factor (i.e. clearing lofts). However, this was before net-zero and increased evidence and acceptance of climate change impacts and affordability pressures due to rising customer bills. A programme now accompanied with a targeted communications plan could drive a significant improvement in consumer take-up.

A national, network-led programme could be an effective way to establish a least cost solution which could be quickly established using existing infrastructure. Local networks could utilise existing supply chains creating a significant number of local jobs and providing benefits to the wider economy.

In the short term, estimates suggest 66,000–86,000 new jobs could be sustained annually across the UK. While some resources could quickly start and carry out activities such as survey work, there is a requirement to either up-skill our existing resources or recruit additional resources in order to undertake all of the activities requried for a full energy efficiency upgrade.

Deployment of energy efficiency in households is likely to be more efficient if a ‘street by street’ approach is adopted where scope and scale efficiencies can be realised, enabling very targeted customer communications to help win customer support. Local networks have significant experience of through managing the Iron Mains Replacement Programme which was mandated by the Health and Safety Executive in 2002, their established processes and approach currently sees replacement at 70–75% based on 2002 levels and will complete in 2032.

Local authorities, charities and energy suppliers could be required to provide additional customer information and work with networks to support customer engagement and communication. This could help target and prioritise local areas to drive maximum benefits and protect vulnerable customers whilst helping to engage customers and drive higher take-up.

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