Scottish Enterprise

Economic Impact Scenarios for Scotland's Energy Transition

September 2024

Executive Summary

The potential economic opportunities which could arise from Scotland's transition to Net Zero are presented in this report, to inform the development and delivery of Scottish Enterprise's mission to create an internationally competitive energy transition industry in Scotland. The relative capabilities of Scotland's company and research bases, alongside projections of the associated economic benefits, are analysed and compared in five-year increments out to 2050, across 18 low carbon sectors.

Projections are based on two scenarios, created from Scottish and Southern Energy Networks (SSEN) and Scottish Power Energy Networks (SPEN) input to the National Grid's "Future Energy Scenarios"[1], together with complementary scenarios for industrial decarbonisation from the Scottish Net Zero Roadmap (SNZR)[2]. These scenarios are:

- **Strong Ambition (SA)**

  High levels of renewable deployment are driven by both societal change (e.g., homeowners installing heat pumps or switching to electric vehicles) and strong policy support to enable the rollout of renewables. It outlines one of the fastest possible routes to Net Zero, therefore meeting the Scottish Government's target of Net Zero emissions by 2045. This scenario has been built from "Leading the Way" in the Future Energy Scenarios and "Regional H_2" in the SNZR.

- **Business as Usual (BaU)**

  The rate of change is slower with less appetite for change at a consumer level, and the Net Zero target is missed. This leads to greater deployment of negative emissions technologies (and relevant policy support to enable this) to counter some of the effects of the delayed transition. This scenario has been built from "Falling Short" in the Future Energy Scenarios and "Soft Start" from the SNZR.

As the potential future capacities presented here are sourced from a combination of existing scenarios regarding energy networks and industrial decarbonisation, they may not have included all projects currently in the pipeline in Scotland, particularly in the case of hydrogen where projects may not necessarily be grid-connected or associated with Scotland's industrial sites.

Key findings from this study:

1. **Scotland's company and research capabilities are well positioned to address emerging energy transition economic opportunities:**

   Company capabilities, based on a qualitative assessment of the current and potential supply chain and export capabilities of Scotland's company base provided by sector specialists in Scottish Enterprise, found a broad match between the strongest assessed

[1] Future Energy Scenarios (FES) | ESO (nationalgrideso.com)
[2] https://snzr.co.uk/

sector company capabilities and the largest projected market opportunities (particularly offshore wind, onshore wind, heat pumps and heat networks).

Emerging sectors such as Carbon Capture, Utilisation, and Storage (CCUS), Sustainable Aviation Fuels (SAF), hydrogen, and wave and tidal (marine) have also been assessed qualitatively as having strong company capabilities. These emerging sectors were also highly ranked in terms of the Research & Development (R&D) base in Scotland, which was scored based on the level of Research Council funding and number of research team leaders active in each area.

2. Projected scale of capacity increases significantly towards 2050:

As expected, for both scenarios the level of deployed low carbon capacity substantially increases from 2020 levels for both emerging and established technologies, with significant variation between the 18 sectors studied. For example, by 2050:

- **Onshore wind** capacity increases by **3-4 times** 2020 levels, from 8.4 GW to 26 GW in BaU or to 33.5 GW in SA.
- **Heat pump** installations increase **100-fold**, from 20,670 installations in 2020 to 1.5m-2.4m, alongside other clean heat sectors such as heat networks.

For some developing technologies, such as hydrogen production, there was negligible capacity in 2020. The 2050 projections for hydrogen deployment vary widely, from 0.3 GW by 2050 (BaU) to 6.9 GW (SA), however it should be noted that both of these scenarios include only a limited selection of hydrogen projects – specifically grid-connected and industrial hydrogen. There is scope that the future capacity of hydrogen production could be much higher, indeed, the Scottish Government has set an ambition for 25GW of hydrogen production by 2045.[3]

These examples provide some indication of the scale of transformation needed to enable the transition to Net Zero, with a variety of technologies required to become far more ubiquitous than they are today, even in BaU. These capacity examples provide context to the scale of investment, levels of employment required across construction and operations, and the turnover and GVA that could be generated.

3. **Attracting external investment** is a critical enabler of success:

Between £122bn and £198bn of investment would be required to deliver the BaU and SA scenarios respectively, over the period 2020-2050, with annual investment peaking in the mid-2030s in SA and slightly later in BaU. This overall investment figure broadly aligns with the £145bn estimated to be invested in Scotland under the Climate Change Committee's Balanced Pathway over the same time period.[4]

This is the estimated cost of developing this capacity, but not all of this investment will necessarily be spent in the Scottish economy. Scottish Enterprise and the Scottish Government are actively seeking to attract private sector investment to Scotland to help

[3] Hydrogen Action Plan (www.gov.scot)
[4] Fiscal Sustainability Perspectives: Climate Change | Scottish Fiscal Commission

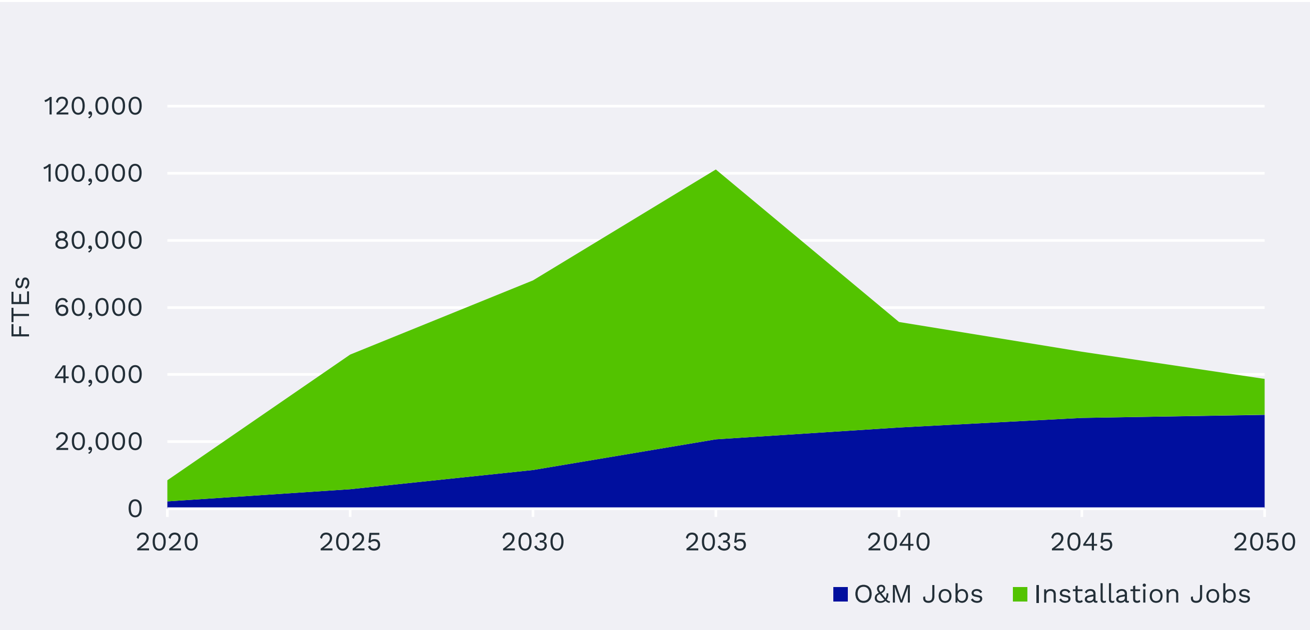
ensure projects can be delivered and maximise the proportion of goods and services which can be provided by Scottish companies.

4. Employment in low carbon technologies is projected to grow significantly and to exceed current employment in the oil and gas industry:

The size of the opportunity in low carbon sectors as we transition to Net Zero is large. We have estimated future employment in our SA and BaU scenarios using cost and economic data (see Appendix A: Methodology). Employment in SA is projected to peak at over 100,000 FTEs in the mid-2030s, then reduce to 39,000 by 2050 as construction work is completed. In BaU, employment figures are about two-thirds of that in SA and are projected to be 27,000 in 2050, following a slightly later peak in 2040.

By 2050, projected direct employment in both scenarios could grow to be 3-4 times larger than the 8,500 FTEs across the 18 low carbon sectors considered here in 2020. In SA, by the late 2030s projected operations and maintenance employment exceeds 2021 direct oil and gas jobs (23,800 FTEs).

Figure 1: Strong Ambition Scenario Direct Employment



Note: 2020 O&M employment has been calculated by the same methodology as for future years and does not reflect the actual split of O&M/Installation jobs in this year.

5. **Capturing supply chain opportunities** is key to anchoring increased investment and employment across Scotland:

The scale and nature of the economic benefits arising from the energy transition, are strongly related to both the scale of deployment and the extent to which that deployment can be delivered by Scottish companies, and enabling this is a key focus for Scottish Enterprise.

Opportunities for Scottish companies exporting overseas represents an additional unquantified upside to these projections. Export growth, which has not been included in this study, provides a means of sustaining economic benefits once construction and manufacturing activity reduces after peaking in the mid-2030s.

6. A 'portfolio' of opportunities across the energy transition sectors will help to support a just transition to Net Zero and build a more resilient Scottish economy:

   Offshore wind is the largest sector across all economic impact metrics in these scenarios over the next 10-15 years, accounting for one third of overall investment. Its relative importance grows up to 2035 when construction peaks, after which it becomes one of several leading sectors.

   Growth by sectors is staggered, with some expected to expand and peak earlier (such as onshore and offshore wind) while others (including clean heat) experience gradual or later growth to 2050. Hydrogen shows a relative increase in importance over time, growing from around 1% of jobs across these sectors to around 18% by 2050, making it one of the larger sectors in SA by 2050.

Contents

Front cover images from left to right:

- Beatrice Offshore Wind Farm, Moray Firth
- The hydrogen boiler system at Arbikie Distillery, Montrose

Introduction

Scottish Enterprise's new strategic ambition[5] sets out a focus of resources to support Scotland's economic transformation over the long-term. This will include taking a mission-led approach to deliver a sustained focus on opportunities that will drive up levels of innovation, internationalisation, and investment performance across Scotland's economy. The three missions focus on the most transformative economic opportunities, where Scottish Enterprise can make the biggest difference.

One of these missions is to create an internationally competitive energy transition industry in Scotland. To support the development and delivery of this mission, research has been undertaken to understand the potential nature and scale of the economic opportunities relating to low carbon sectors, by:

- Developing a deeper understanding of Scotland's current and emerging capabilities across its company base. This will provide the basis for future growth in these sectors.
- Analysing the pattern of recent Research & Development (R&D) expenditure to understand Scotland's research strengths and how innovation across different technologies will help to overcome challenges.
- Producing scenarios for investment, employment, turnover, and GVA across 18 low carbon sectors from 2020-2050.

The 18 low carbon subsectors covered in this study are:					
Offshore Wind	Hydropower	Biogas	Heat Pumps	H_2 Buses/HGVs	Hydrogen Production
Onshore Wind	Solar	Biofuels	Heat Networks	EV Charging Infrastructure	SAF
Marine	Biomass	Energy from Waste	EV Buses/HGVs	Hydrogen Refuelling	CCUS
Details on how these sectors were identified can be found in Appendix A					

The 'Strong Ambition' (SA) and 'Business as Usual' (BaU) scenarios outline two potential pathways Scotland could take on its just transition to Net Zero. The scenarios show both where and when opportunities may arise. This will be used to inform Scottish Enterprise's support for innovation, supply chain capability, manufacturing, and infrastructure development to help deliver these projects. This support is intended to establish Scotland as a world leader in low carbon technologies and to sustain the economic benefits of the energy transition across Scotland by gearing up to serve an international market.

This research addresses a gap in knowledge as it provides projections which are consistent and comparable across a range of technologies, based on the best available, robust sources.

[5] Our focus on economic transformation (scottish-enterprise.com)

Alongside the future scenarios it also provides qualitative insights into the competitive strengths and capabilities of Scotland's company and research base. It is a reference for Economic Opportunities in Scotland's Net Zero and Climate Adaptation Economy.[6]

[6] Economic opportunities in Scotland's Net Zero and climate adaptation economy (climatexchange.org.uk)

Scottish Capability

Company Base Capability

The relative strengths of Scotland's low carbon company base have been assessed to identify current and potential capabilities to meet both domestic deployment and export market opportunities.

Each sector was given a qualitative score from 0-10 for both supply chain capability and export capability. These scores are based on the opinions of Scottish Enterprise and Scottish Development International specialists, held at a point in time (reviewed June 2024). They cover a range of activities including design and consultancy, manufacturing, installation, and operations and maintenance and are based on both proven and potential capability (i.e., potential to utilise existing skills and infrastructure in offshore oil and gas, or other existing carbon-intensive sectors that will transition to low carbon activities). A guide to these scores is given below:

Supply Chain Capability	Export Capability
0 – Scotland has no capabilities.	0 – No export activity likely
1-2 – Scotland hosts consultancy and design capabilities only.	1-2 – A small number of companies exporting services only
3-4 – Scotland does some installation and pre-project work.	3-4 – A small number of companies exporting goods
5-6 – Scotland does installation and pre-project work, supplies some equipment, or local operations and maintenance.	5-6 – A cluster of companies exporting goods and services
7-8 – As above, but significant Scottish equipment or other added value.	7-8 – A growing number of companies exporting goods and services
9-10 – Scotland hosts a range of world-leading companies that supply right along the value chain.	9-10 – A rapidly growing number of companies already actively exporting goods and services.

Selected results are presented in the table below alongside a comparison to the potential investment (see: Investment) that could be required domestically in these sectors. The results have been colour-coded to distinguish the top, middle, and bottom third ranking in terms of the average score across supply chain and export capability, and separately the level of investment required to deliver the growth projected in these scenarios. The full results of this assessment, including comments on how each score was determined, can be found in Annex A. The investment figures shown below are the average of the SA and BaU scenarios.

The three highest-scoring sectors in terms of both supply chain and export capability are marine, SAF, and biofuels, however all three have relatively small domestic markets based on both current size and potential for growth in our scenarios. With such strong Scottish capability in these areas (in part because of their expected ability to leverage the Scottish up and downstream offshore oil and gas/petrochemical sectors), it is hoped that Scotland can take advantage of much larger international markets to boost the economic benefits associated with these activities.

Table 1: Scottish company capability scores and scale of investment by sector

Sectors	Supply Chain Capability	Export Capability	Potential Investment 2020-2050 (£m)*
Marine	10	8	946
SAF and Biofuels	9	9	600 (SAF)/116 (Biofuels)
Offshore Wind	7	9	62,444
Heat Pumps	8	8	24,524
EV Buses & HGVs	7	8	10,900
Onshore Wind	6	8	27,878
Heat Networks	8	5	9,997
CCUS	7	7	4,503
Hydrogen	6	7	2,221
Hydropower	6	6	5,095
Hydrogen Refuelling	6	6	764
Solar PV	6	3	4,794
H2 Buses & HGVs	6	4	1,197
Biomass	8	1	599
Energy from Waste	6	1	2,473
EV Chargers	5	3	1,128
Biogas	6	1	29

*Investment figure used is average of total across both deployment scenarios outlined in this report

Top third ranking   Mid third ranking   Developing third

Sectors with a very large potential domestic market include offshore wind, heat pumps, heavy duty electric vehicles and onshore wind. Although current capacity is still set to double if the Scottish Government target of 20GW onshore wind by 2030[7] is reached, in comparison to other technologies it is a relatively mature market. The remainder are at an earlier stage and there should be more opportunities for proactively maximising levels of Scottish economic benefit from them. Internationalisation of these sectors beyond the peak of domestic deployment, would mean economic benefits are sustained.

There is one outlier in biomass – despite having a very strong supply chain, owing mostly to the fact that the wood is locally grown, turned to pellets, and distributed, there is a natural limit to the volume of biomass pellets that can be produced commercially from Scottish forestry. This leaves export markets out of reach and further deployment of biomass as a low carbon solution is less attractive than other forms of renewable heat domestically as it would be reliant on importing fuel to meet increased demand.

[7] Onshore Wind Policy Statement 2022 (www.gov.scot)

Hydrogen and CCUS are two areas which score in the middle third but are significant due to the level of policy focus they both receive. Although not captured in the scenarios described here, the Scottish Government has ambitions for Scotland to export green hydrogen, produced by electrolysis from the abundance of renewables projected to be installed in Scotland. CCUS is viewed as a priority due to its potential to facilitate a route to Net Zero for harder to decarbonise areas such as Scotland's industrial clusters. It could also provide an opportunity to utilise skills and infrastructure associated with offshore oil and gas for carbon dioxide sequestration in depleted oil fields in the North Sea basin.

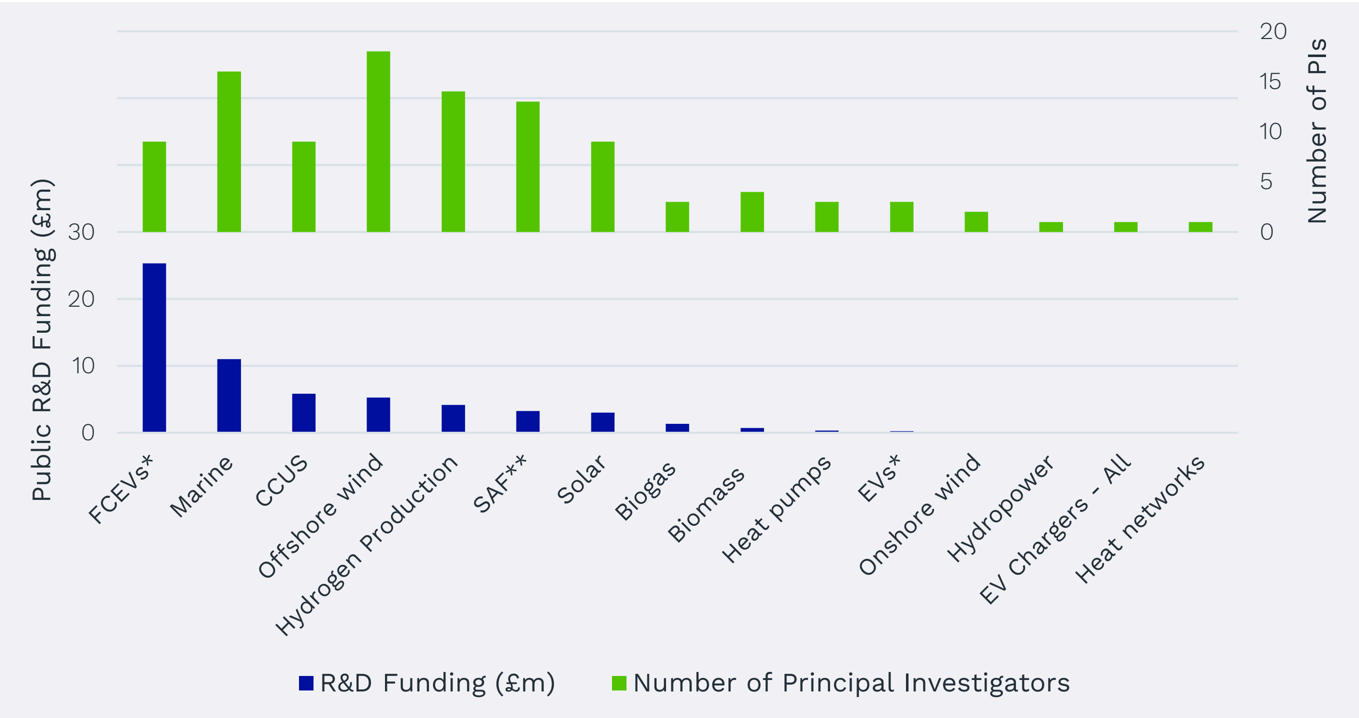
The technologies with relatively low Scottish capability, but larger potential market sizes – hydrogen vehicles and infrastructure, solar power, energy from waste, and electric vehicle chargers – are areas where Scotland could seek to strengthen and grow its company base to address these opportunities and maximise the economic benefits of the energy transition.

Research and Development Capability

Owing to the high number of novel and developing low carbon technologies likely to be used for the energy transition, Scottish Enterprise wanted to develop a deeper understanding of Research & Development (R&D) activity in Scotland.

To provide insight on the relative strength of local R&D activity, we commissioned independent research to collate data on awarded funds from research bodies for R&D and numbers of Principal Investigators (research team leaders) carrying out research in universities from January 2020 to August 2023. Selected results are given below, and a full breakdown can be found in Annex B.

Figure 2: Public Research Funding and Number of Principal Investigators in Low Carbon Subsectors, August 2020 – July 2023



*Includes data related to light vehicles **Includes biofuels

Figure 2 shows sectors allocated funding by public funding bodies (the UK Research Councils, EPSRC, BBSRC NERC and STFC). This does not necessarily mean research is not underway in areas with no data, just that no funding body support was identified in the period assessed.

We found that a total of £96 million in R&D funding was awarded to Scottish universities from funding bodies across a broader range of low carbon technologies. Scottish Enterprise grant funding added another £36 million (+27%) to this over the same time period.

The amount of funding and number of principal investigators for each sector was combined to give each sector a relative R&D capability score, presented in table 2 below.

The sectors that had the highest funding and/or the highest number of Principal Investigators generally appeared aligned with the earlier stage of commercial readiness (broadly based on the Commercial Readiness Index developed by the Australian Renewable Energy Agency[8]) of key technologies of the sectors (with offshore wind and PV having both a strong local research base and more established markets).

Table 2: Scottish R&D capability ranking and commercial readiness of sector

Sectors	R&D Capability	Commercial Readiness Index rating
Offshore Wind	9	Widespread Development/Bankable Asset Class
H_2 Vehicles*	9	Hypothetical Commercial Proposition/Small-scale trials
Solar PV	8	Widespread Development/Bankable Asset Class
Hydrogen	8	Hypothetical Commercial Proposition/Small-scale trials
SAF**	8	Hypothetical Commercial Proposition/Small-scale trials
CCUS	8	Hypothetical Commercial Proposition/Small-scale trials
Marine	8	Hypothetical Commercial Proposition/Small-scale trials
Biogas	6	Commercial scale up/Multiple applications
Biomass	5	Widespread Development/Bankable Asset Class
Heat Pumps	4	Commercial scale up/Multiple applications
Electric Vehicles*	4	Commercial scale up/Multiple applications
Onshore Wind	3	Widespread Development/Bankable Asset Class
Hydropower	2	Widespread Development/Bankable Asset Class
Heat Networks	2	Commercial scale up/Multiple applications
EV Chargers – All	2	Commercial scale up/Multiple applications
Energy from Waste	no data	Commercial scale up/Multiple applications
Hydrogen Refuelling	no data	Hypothetical Commercial Proposition/Small-scale trials

*Includes data related to light vehicles **Includes biofuels

Top ranking | Mid ranking | Developing

[8] Commercial-Readiness-Index.pdf (arena.gov.au)

This analysis of R&D capability was broadened further to include the allocation of innovation funding from Scottish Enterprise R&D grant support and private investment in innovation. This analysis found that:

- Private funding accounts for around 64% of the funding provided for innovation (£232M of £365M invested in innovation between 2020 and 2023[9]) with the caveat that there may be additional funding, particularly for power networks and from very large companies using their own balance sheet for R&D funding, which will not have been identified in this analysis.
- There is significant variation in the balance of public and private funding between sectors. For example, public funding accounts for 27% and 99% of innovation funding in electric vehicles and fuel cell electric vehicles, respectively. This suggests nearer-to-market innovation is able to attract proportionally more private funding.
- Therefore, it appears that the public sector plays an important role providing early-stage feasibility support for emerging sectors such as CCS, hydrogen, and FCEV R&D.
- However, this could also reflect the nature of the research (e.g., theoretical vs near-to-market) being undertaken in Scotland. Public funding for Photovoltaics (PV) for example, makes up 94% of the total, but PV is a relatively mature technology with a well-developed global market.

[9] ECCI Climate Tech Mapping Report & Dataset 2024 & Scottish Enterprise grant funding data 2023 (both unpublished)

Scenario-based Projections

Two scenarios were explored – Strong Ambition (SA) and Business as Usual (BaU) which outline two potential growth pathways for the 18 low carbon technologies analysed. The SA scenario aligns with "Leading the Way", in the National Grid's Future Energy Scenarios (FES)[10] while BaU aligns with "Falling Short". Data primarily comes from Scottish Power and Scottish and Southern Energy Networks' Distribution and Transmission FES which feed into the National Grid publication. The FES is widely used by stakeholders across the energy industry, for example to underpin energy network investment, inform national and regional policy, and to provide focus for academic research and innovation. By using data from the energy networks serving Scotland, Scottish and Southern Energy and Scottish Power, this means that the outputs have undergone further analysis at a local level and are more geographically granular. Other aspects of the energy transition were captured in the study using the Scottish Net Zero Roadmap (SNZR).[11] scenarios, which outlines various routes for decarbonisation of Scotland's large industrial sites. The SA scenario aligns with SNZR's "Regional H_2", and BaU aligns with "Soft Start".

Many other deployment scenarios exist for the energy transition. Within the FES there are two more – "Consumer Transformation" and "System Transformation". There are a further four scenarios within the SNZR, and other pathways including ClimateXChange's Scottish Whole Energy System Scenarios.[12]. Targets set by both the UK and Scottish Government must also be considered, with the main driver of the energy transition being the UK Government's commitment to reach Net Zero emissions by 2050, and the more ambitious Scottish Government target of 2045. Specific technologies have target or ambition levels of deployment set by the Scottish Government including 8-11 GW of offshore wind in Scottish waters and 20 GW of onshore wind by 2030[13], 5GW of Hydrogen production capacity by the same year and 25GW by 2045[14], and for 7TWh of thermal energy to be supplied by heat networks by 2035,[15] amongst others.

About Our Scenarios

In Strong Ambition, the high levels of deployment are driven by both societal change (e.g., homeowners choosing to install heat pumps or switch to an electric vehicle) and strong policy support to enable the rollout of renewables. It outlines one of the fastest possible routes to Net Zero, therefore meeting the Scottish Government's target of Net Zero emissions by 2045.

In BaU, change is slower and there is less appetite for change at a consumer level, and the Net Zero target is missed. This leads to greater deployment of negative emissions technologies (and relevant policy support to enable this) to counter some of the effects of the delayed transition.

These contrasting scenarios allow for a range of potential impacts associated with the energy transition to be presented.

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10 Future Energy Scenarios (FES) | ESO (nationalgrideso.com)
11 SNZR_final.pdf (tmdassets.co.uk)
12 Scottish whole energy system scenarios (ed.ac.uk)
13 Draft Energy Strategy and Just Transition Plan (www.gov.scot)
14 Hydrogen Action Plan (www.gov.scot)
15 Heat networks - Renewable and low carbon energy - gov.scot (www.gov.scot)

Each scenario and policy target has been created based on a set of assumptions regarding a unique timeline of investment or policy decisions for that specific sector. Therefore none of these scenarios, including those presented in this report, are any more or less likely to occur than the others and they simply model a number of alternative pathways towards the ultimate goal of Net Zero emissions, and what the consequences of decisions made in that pathway could be. As the potential future capacities and associated economic benefit presented here are sourced from a combination of existing scenarios regarding energy networks and industrial decarbonisation, they may not have included all projects currently in the pipeline in Scotland, particularly in the case of hydrogen where projects may not necessarily be grid-connected or associated with Scotland's industrial sites.

Further detail on these scenario assumptions, and the investment, employment, turnover, and GVA projections, can be found in Appendix A – Methodology.

Capacity

The scenarios are based on domestic deployment of 18 low carbon technologies. An overview of the overall change in capacity for each scenario is given below with a full breakdown in five-year increments in Appendix D. These numbers primarily come from Scottish Power Energy Networks and Scottish and Southern Energy Networks. 2020 is used as the baseline year with capacity data sourced from the Scottish Energy Statistics Hub, DESNZ Energy Trends, Energy Saving Trust Renewable Heat in Scotland, and DfT Vehicle Licensing Statistics.

Table 3: Illustrative capacity scenarios for assessed sectors

Technology	Unit	2020	Strong Ambition 2050	Business as Usual 2050
Offshore Wind	MW	898	41,073	29,305
Onshore Wind	MW	8,356	33,485	25,968
Marine	MW	22	272	187
Hydropower	MW	2,402	6,163	3,699
Solar	MW	392	8,001	2,825
Biomass	MW	2,001	193	2,179
Biogas	MW	355	299	122
Biofuels	TWh	1	3	2
Energy from Waste	MW	80	31	464
Heat Pumps	Number	20,670	2,413,249	1,545,130
Heat Networks	Number	3,887	572,132	62,223
EV Buses/HGVs	Number	40	53,304	49,045
H_2 Buses/HGVs	Number	12	7,432	1,251
EV Chargers – All	Number	6,546	614,246	598,423
Hydrogen Refuelers	Number	2	777	114
Hydrogen Production	MW	0	6,858	311
SAF	MW	0	1,235	0
CCUS	$MtCO_2e$/year	0	7	8

Notes on Table 3: Demand used in place of capacity for Biofuels. Capacity for hydropower includes generation and storage. Capacity for biomass, biogas, and energy from waste includes electricity and heat. Capacity for heat networks is number of customers connected to a heat network with a renewable energy centre.

The increase in capacity across renewables could be substantial. Under these scenarios, offshore wind increases to 32-45 times its 2020 capacity, and even technologies with smaller market sizes see a significant increase with projected growth in marine energy of 8-12 times the 2020 capacity, and 7-20 times greater deployment of solar. Technologies that have long been utilised at scale in Scotland such as hydropower could see an increase in capacity of 54-157%

Clean heat is an area projected to see a massive uptake of low carbon solutions – the number of heat pumps installed could grow to be 75-115 times the 2020 capacity alongside an increase of 58,000-570,000 customers connected to a heat network with a renewable energy source (a combination of new connections and existing heat networks transitioning to a renewable energy centre). The transition to low/zero carbon heating is likely to be accompanied by a surge in the energy efficiency market.

There are also a number of emerging technologies with no or negligible capacity in 2020 – namely Hydrogen production, SAF, and CCUS. The projections for these technologies vary widely and it is likely that future deployment will depend heavily on the level of policy support offered to assist in providing a route to market for these nascent technologies.

The above examples indicate the scale of transformation required to enable these scenarios, with large increases in levels of deployment across a variety of technologies – even in BaU. This provides some context to the levels of investment, employment across construction and operations, and the turnover and GVA that could be generated from the energy transition.

Investment

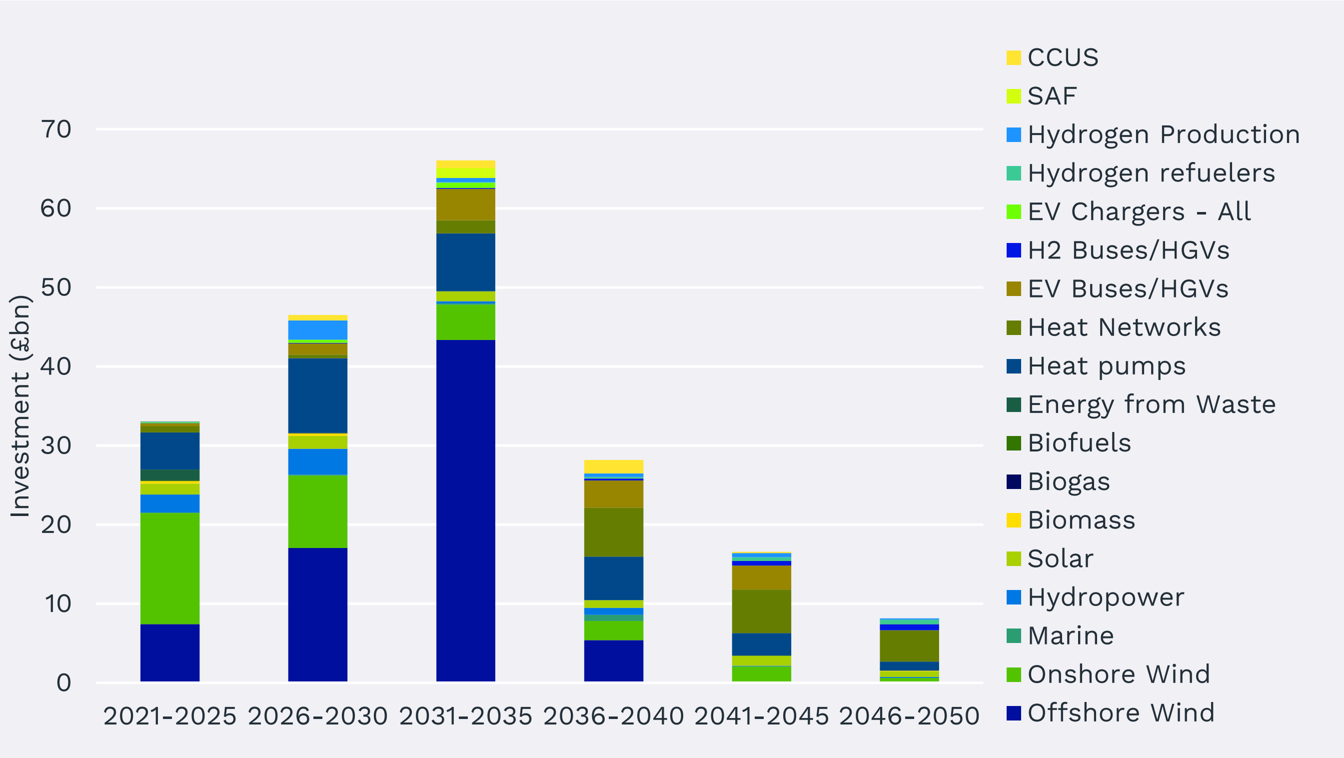
Combining the projected deployment with projected capital expenditure (CapEx) for each technology allowed an estimation of the scale of investment needed to deliver each scenario. The cost projections account for a decline in cost due to improved efficiency, and economies of scale. A total of £122-198bn is estimated to be required across 2020-2050 to enable the scenarios outlined above. The investment required to enable these scenarios broadly aligns with the £145bn estimated to be invested in Scotland under the Climate Change Committee's Balanced Pathway over the same time period.[16]

The finance required to deliver the energy transition is at a scale well in excess of traditional public sources of funding. The First Minister's Investor Panel recognised the need for Scotland to compete internationally to attract the private capital required and recommended, inter alia, a more co-ordinated and professional approach to investor relations. Scottish Enterprise has a key role to play through Scottish Development

[16] Fiscal Sustainability Perspectives: Climate Change | Scottish Fiscal Commission

International's Capital Investment function and continues to expand its network of international investors and promoting key investment-ready opportunities.

Figure 2: Investment required by technology per 5-year period in the Strong Ambition scenario[17]



The investment figures show a clear peak over the period 2031-2035 which is dominated by the offshore wind sector. These figures align with the nearly 30GW of offshore wind projects successful in applying for seabed rights in Scottish waters through the ScotWind leasing process which are expected to be built over the course of the next decade once consented.[18]

The proportion of this investment that could go to Scottish companies is dependent on the extent to which development expenditure (DevEx) and capital expenditure (CapEx) is secured locally, which can be described as Scottish content. We can refer to the Supply Chain Development Statements (SCDS) for the ScotWind offshore wind projects to understand what levels of Scottish content may be achievable. As part of the SCDS each developer has to outline both a commitment and ambition level of spending and whether this will be in Scotland, the rest of the UK, Europe, or the rest of the world. Scottish Enterprise analysis of the SCDS shows that on average, when excluding operations, developers commit to 33% of spending in Scotland, with the ambition level increasing to 47%. If we assume the same Scottish content levels are achieved in all offshore wind projects, then over the peak years of 2031-2035 an increase from £14.3bn to 20.4bn out of a total £43.3bn investment could be secured by Scottish companies.

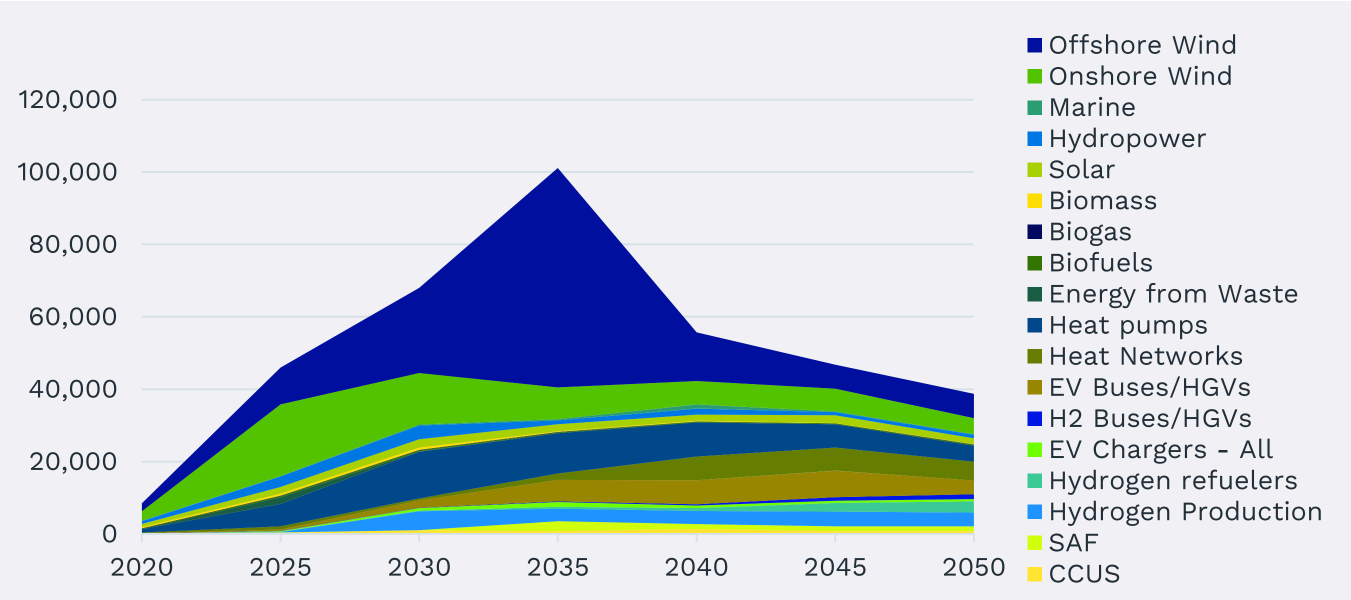
[17] No CCUS-related investment has been included as the data source used only included scenarios out to 2045.
[18] [ScotWind leasing round | Crown Estate Scotland]

There is a lack of existing data on Scottish content for many other technologies being considered here and further research is required to quantify this and articulate the realistic target areas for expanding the Scottish supply chain. This is important when considering where public sector resources are best allocated as some economic benefits may be secured in Scotland simply by building out projects where there is existing supply chain capability, or aspects of the work that must be delivered locally. Other areas will need to be targeted by creation or expansion/diversification of indigenous companies or attracting inward investors to Scotland to supply the necessary products and services.

Employment

Direct employment in the 18 low carbon technologies analysed could grow from 8,500 FTEs in 2020 to 27,000 in BaU and to 38,500 in SA in 2050. However like investment, peak employment is around 2035, with over 100,000 potential jobs in SA.

Figure 3: Potential Jobs by technology and year in the Strong Ambition scenario.



These are the number of jobs which could theoretically be supported by the investment associated with the development and operation of Scottish projects based on assumptions on the turnover per employee calculated from the Scottish Annual Business Statistics.[19] Further detail on how these job projections have been calculated can be found in Appendix A - Methodology.

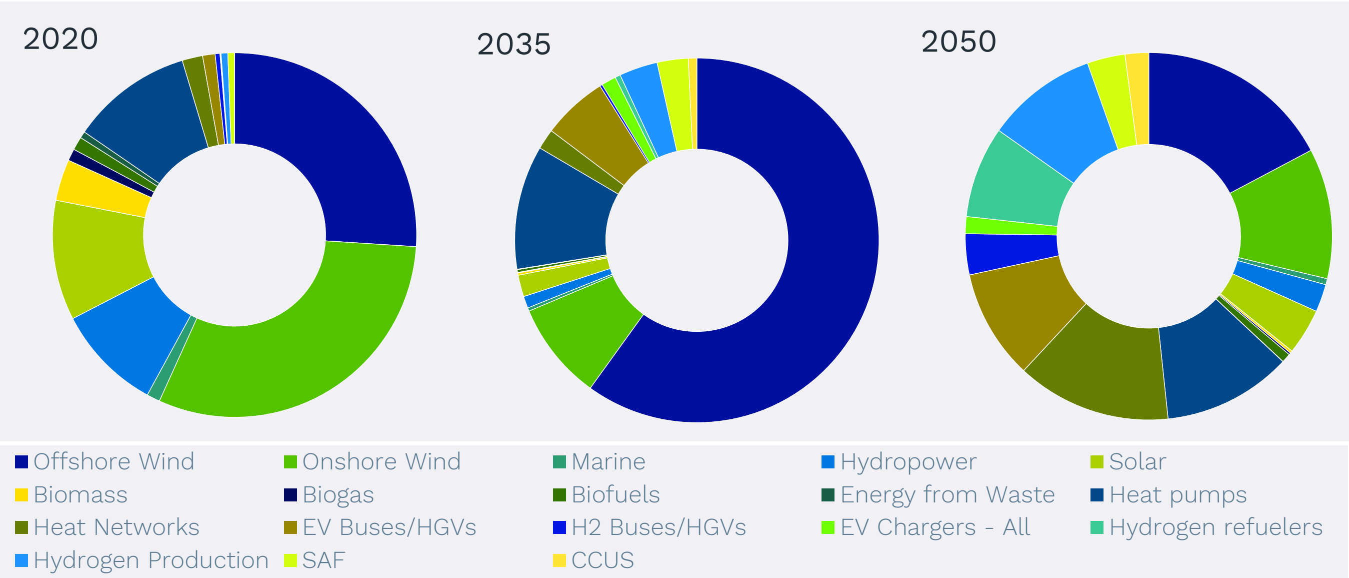
At peak direct employment in 2035, almost 80% of jobs are associated with capital expenditure (i.e. shorter-term jobs in the construction and installation of projects) which creates a decline as more projects move to an operational phase. As this research only considers domestic deployment, there is scope that more prolonged economic benefits could be realised by obtaining a foothold in the international market.

[19] Scottish Annual Business Statistics 2021 - gov.scot (www.gov.scot)

Comparison to LCREE total employment: The Low Carbon and Renewable Energy Economy (LCREE) survey produced each year by ONS has a broader scope than this report. In 2020, the LCREE survey reports a total of 20,700 FTEs (individual sectors do not sum due to rounding) employed in LCREE sectors in Scotland. Sectors not included in this report are: Nuclear power (2,200 FTEs); Energy efficient lighting (700 FTEs); Energy efficient products (6,500 FTEs), Energy monitoring, saving or control systems (1,400 FTEs); Low carbon consultancy, advisory and offsetting services (900 FTEs); and Fuel cells and energy storage systems (200 FTEs). In future iterations of this work, we hope to expand the scope of our analysis with energy efficiency being a priority area for further research owing to the high baseline of employment in this area and its importance in enabling deployment of clean heat technologies.

While peak employment is heavily influenced by the construction of offshore wind projects due to be deployed around that time, a number of other technologies see steady growth or deployment in later years. Over time, as a portfolio of renewables projects become operational, employment diversifies across many technologies, as illustrated in Figure 4 below. This will help to develop a more resilient Scottish economy as well as supporting a just transition in which employment benefits are distributed across Scotland's regions.

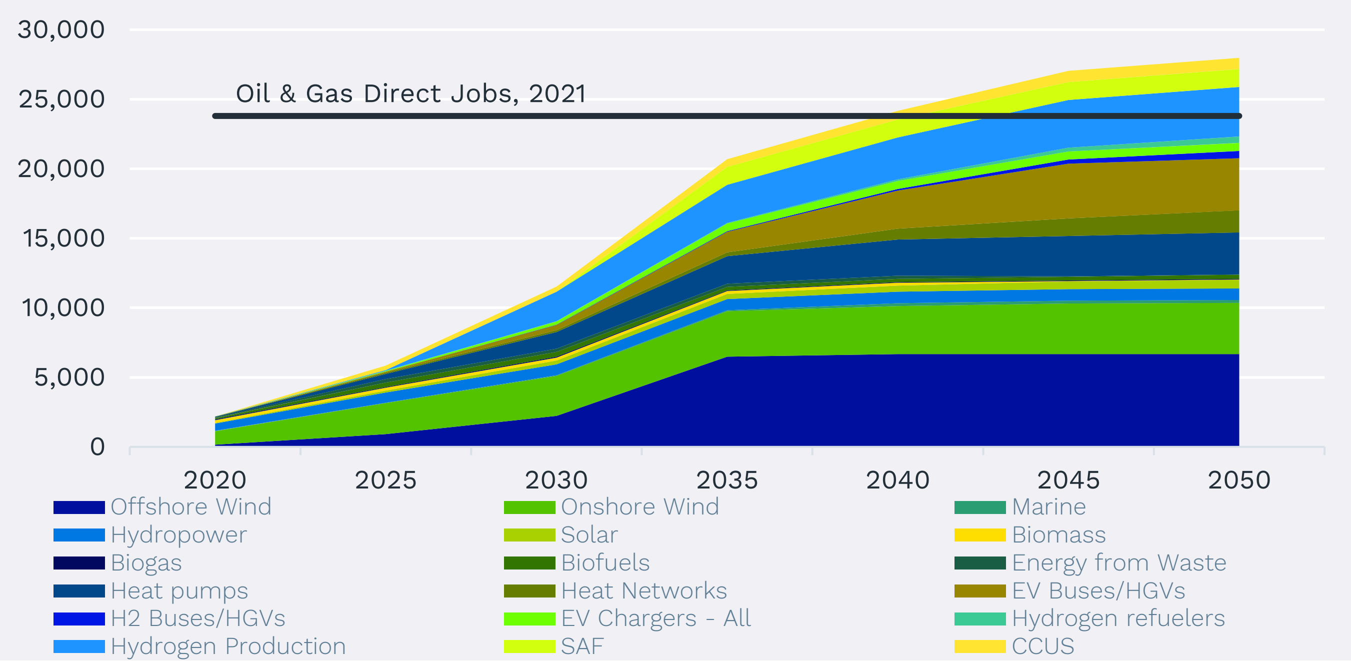
Figure 4: Share of employment by technology in selected years – Strong Ambition scenario



While the effects of construction and installation jobs create rapid growth followed by a decline in low carbon employment, in operations and maintenance, a steady increase in employment out to 2050 is projected. Importantly, projections suggest that this growth in direct employment from low carbon technologies can exceed the 2021 level of oil and gas employment[20] by the late 2030s in SA.

[20] Workforce Insight 2022 (oeuk.org.uk)

Figure 5: Operations and maintenance jobs by technology and year in the Strong Ambition scenario



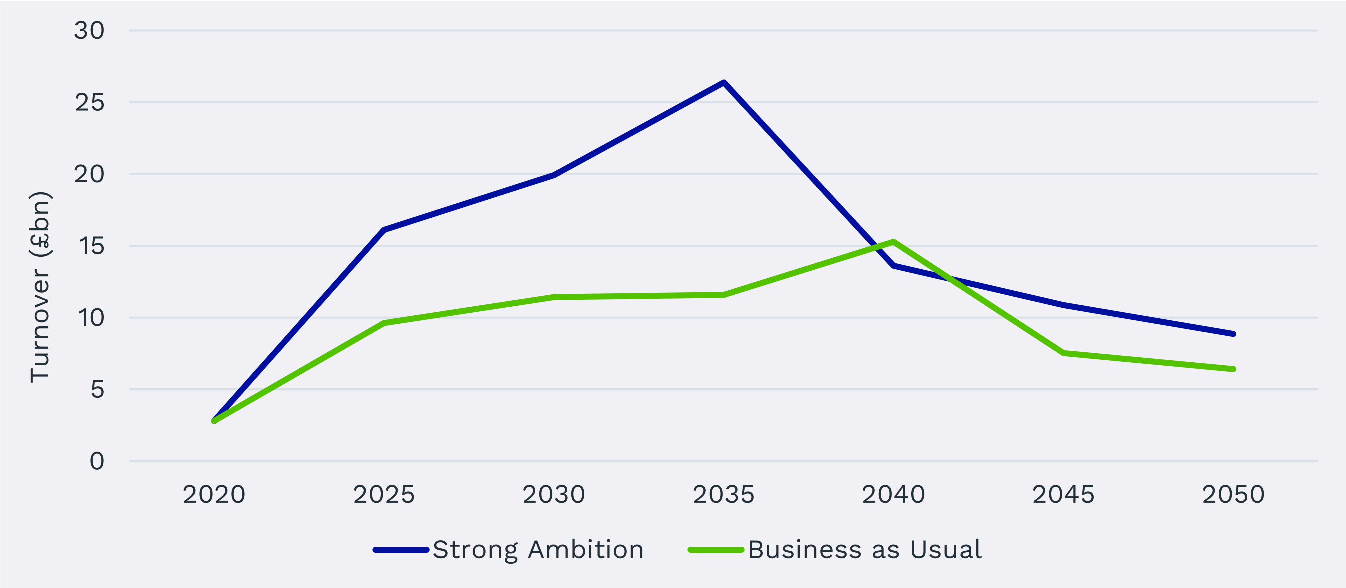
Turnover and GVA

Potential low carbon related turnover in Scotland has been calculated using an estimate of turnover per employee for each subsector. This is derived from available baseline data on employment and turnover levels (for example, from the LCREE survey) and scaled based on the projected future job levels highlighted above. A challenge with this method is that the turnover estimated this way is based on current market conditions and then assumed constant throughout the scenarios. In reality, a change would be expected, particularly for emerging technologies which will shift from being dominated by research, to development, to construction and manufacturing, to operations and maintenance.

Similarly to employment, what has been modelled here is the potential turnover if turnover per employee remained constant. GVA is estimated as a fixed proportion of turnover based on a range of industry datasets.

Potential turnover in low carbon technologies is projected to grow from £2.8bn in 2020 to £6.4bn in 2050 in BaU, and £8.9bn in SA, peaking at £26.4bn in 2035. GVA follows a similar trend growing from £1.2bn in 2020 to £2.8bn in 2050 in BaU and £3.8bn in SA.

Figure 6: Turnover by scenario and year.



As well as turnover generally being lower throughout the period 2020-2050 for the BaU scenario compared to SA, it also peaks later, reflecting the slower deployment in this scenario. The benefits that construction and installation of these low carbon technologies could bring to the economy are also evidenced here, as is the importance of maximising the benefits we can draw from this to maintain a share of this market beyond domestic deployment.

Conclusions

Scotland has committed to reaching Net Zero emissions by 2045 and is making positive progress in its energy transition. Alongside Scotland's strong track record in adopting renewables technologies, its existing strengths in oil and gas also provide a comparative advantage that should be harnessed. Scotland's offshore energy skills and infrastructure can be used to support the growth of many low carbon technologies, particularly offshore wind, marine energy, hydrogen production and CCUS.

This work provides a baseline assessment of sectors that will contribute to delivering the energy transition in Scotland. With reference to the 'Strong Ambition' and 'Business as Usual' scenarios we provide employment, investment, turnover and GVA projections for 18 low carbon sectors. It has not been possible to produce equivalent numbers for exports at present. However, opportunities from internationalisation will play an important role in creating further economic and employment benefits across Scotland over time as the 18 sectors grow and mature. This will help to sustain the economic benefits once projected construction and manufacturing activity peaks in the mid-2030s.

This study has highlighted a number of important findings for understanding and managing Scotland's energy transition:

1. **Scotland's R&D and commercial capabilities are well positioned to address emerging energy transition economic opportunities**

   There appears to be a broad association between the company base and the more established market opportunities and between Scotland's R&D base and emerging opportunities for the 18 sectors analysed in this study.

   Offshore wind was ranked high both in terms of company and R&D capability which should support growth of the sector as it delivers projects and innovates to provide solutions to key challenges. Similarly, Scotland has relative commercial and R&D strengths in biofuels and SAF, but the economic opportunities are modest in these scenarios. While offshore wind was identified as presenting the largest market opportunity, heat pumps and heat networks were also assessed as having a strong company base that should be able to exploit the significant heat market opportunities.

   Initiatives such as the EU's Regional Innovation Scoreboard emphasise the importance of strong end-to-end support for innovation (from research through to companies investing and selling innovative products and services) to become world class[21].

2. **Attracting external investment is a critical enabler of success**

   Between £122bn and £198bn of investment is required to deliver the BaU and SA scenarios respectively over the period 2020-2050, with annual investment peaking in the mid-2030s in SA, and slightly later in BaU. Scottish Enterprise and the Scottish

[21] Regional Innovation Scoreboard 5357c81b-9222-464b-8468-38ccd83b5624_en (europa.eu)

Government are actively seeking to attract private sector investment to Scotland to help deliver these opportunities.

Turnover in the assessed sectors increases by 2-3 times in each scenario, rising from £2.8bn to between £6.4bn – 8.9bn, in BaU and SA respectively. GVA rises similarly from £1.2bn to between £2.8bn and £3.8bn.

3. **Total employment is projected to grow significantly and could exceed current employment in the oil and gas industry**

Total direct FTEs are projected to peak at over 100,000 in the mid-2030s in SA, then reduce to 40,000 by 2050 as local construction work drops away. Peak employment figures are about two-thirds of this in BaU and are projected to be 25,000 in 2050. These job estimates relate to the number of direct jobs required to deliver Scottish projects, including jobs which could be out with Scotland should activities not include the Scottish supply chain.

Direct jobs in both scenarios grow to be 3-4 times larger than the 8,500 direct FTEs in these low carbon sectors now. This will include a combination of new jobs as well as existing jobs that will transition from carbon-intensive activities. Oil and gas direct jobs in Scotland numbered 23,800 in 2021. By the late 2030s, the projected total of potential energy transition-related jobs in both scenarios exceeds this. The analysis does not currently indicate how likely these are to comprise of new jobs, or jobs that have transitioned from sectors like oil and gas.

As this report focused on domestic deployment of low carbon technologies there is a clear peak in the 2030s followed by a decline in the associated economic benefit which is driven by temporary construction and installation related spending. Higher Scottish content will help to maximise the number of related jobs secured in Scotland. It will also strengthen company capabilities, allowing them to export to international markets and sustaining economic benefits as each technology moves beyond a construction to an operations and maintenance phase.

4. **Capturing supply chain opportunities is key to anchoring increased investment and employment across Scotland**

Capital Investment is associated with approximately 75% of projected employment, which in turn is dependent on the share of investment secured by Scottish employers. The future jobs figures give an indication of the total 'size of the prize' if all of this investment goes to Scottish companies.

Supply Chain Development Statements submitted by developers as part of the ScotWind offshore wind leasing round outline both "Commitment" and "Ambition" levels of spending in Scotland, the rest of the UK, Europe, and the rest of the world. Scottish Enterprise analysis of these statements shows an average commitment level of 33% and an ambition level of 47% Scottish content when excluding operations. To illustrate the potential impact that increased Scottish content could have, this would equate to an increase from £14.3bn to £20.4bn out of a total £43.3bn investment being secured by Scottish companies in the peak years of 2031-2035 under the SA scenario.

The projected peak and subsequent reduction in employment seen in these scenarios is driven by capital spending delivering Scottish projects. Many of these jobs will be short-term and project based. Maximising economic benefit from these may depend on a transition to serial work, with employers servicing a range of projects in Scottish, UK and export markets. Jobs, local content, and exports are likely to be highly linked and to maximise the economic benefits we need to grow energy transition opportunities that can service export markets as well as sustain employment in Scotland.

5. **A 'portfolio' of opportunities across energy transition sectors will help to support a just transition to Net Zero and build a more resilient Scottish economy**

The relative scale of opportunities is likely to differ across the 18 sectors analysed and other low carbon technologies. Offshore wind is the largest sector in these scenarios across all the metrics over the next 10-15 years, accounting for a third of overall investment. Its relative importance grows up to 2035, then after construction peaks in the mid-2030s it becomes one of several leading sectors.

Growth across the various sectors is staggered. Some sectors expand and also peak earlier (notably onshore and offshore wind) while others, such as clean heat, experience gradual growth over the course of the next 30 years. Hydrogen (including infrastructure) shows a relative increase in importance over time (for example, from around 1% of jobs in 2020 to around 18% by 2050) making it one of the larger sectors in the Strong Ambition scenario by 2045.

Emerging sectors such as CCS, hydrogen, SAF and marine are small in size (as measured by employment and turnover) but have qualitative strengths in their supply chain. This means they should be able to leverage upstream and downstream links to Scotland's oil and gas/petrochemical sectors as they develop. Appropriately, Scottish R&D activity in these areas is shown as very strong.

To varying degrees, established sector strengths are matched with market opportunities. The company base in offshore wind and heat pumps, for example, are ranked as very strong and these are significant market opportunities. While onshore wind (and to a lesser extent hydropower) are expected to be significant opportunities in the next decade, current strengths in Scotland's company base are not as strong.

In the short term, onshore and offshore wind are the largest opportunities. However, support will also be required for sectors projected to experience gradual or later growth. This includes heat pumps as well as developing technologies such as hydrogen and CCUS, which require support just now to innovate and scale so they are ready to play a bigger role later in the transition. Technologies which have been traditionally viewed as having a smaller impact, including marine and solar, have unique benefits which lead to them growing to several times their current size and taking a large share of future employment.

6. **Further research will help to strengthen our evidence base relating to anticipated energy transition economic opportunities**

While this report outlines two scenarios for future deployment of several low carbon technologies and the associated economic benefits, there are some limitations to this, and further research is required to paint a more thorough, accurate picture. Some areas to be considered for future work are:

- Expanding the scope to include more low carbon technologies and key enablers like energy efficiency, and the power and gas networks.
- Develop similar data as in this report to capture potential export opportunities.
- Research on current and potential Scottish content levels for individual technologies.
- Detailed subsector analyses to identify exploitable gaps in export markets.
- Cross-comparison with other energy transition scenarios.
- Opportunities from manufacturing.
- Research on the policy landscape and where decisions could influence these scenarios.
- Progress tracking against the scenarios as more recent data is published.

Appendices

Appendix A – Methodology

Base year (2020) economic data was sourced from the Office for National Statistics (ONS) Low Carbon and Renewable Energy Economy (LCREE) survey as per Table 4 below.[22] GVA was calculated from turnover as a fixed percentage for each technology based on either analysis by the Fraser of Allander Insitute[23] or assumptions around assigning Standard Industrial Classification (SIC) codes to each technology and comparing this to data from the Supply, Use, and Input-Output tables[24] to determine GVA as a percentage of turnover.

Table 4: Alignment of LCREE Sectors to Scenario Sectors

LCREE Sector	Scenarios Sector	Explanation
Offshore Wind	Offshore Wind	
Onshore Wind	Onshore Wind	
Solar	Solar	
Hydropower	Hydropower	
Other Renewable Electricity	Marine	The LCREE sector "Other Renewable Electricity" includes marine and geothermal, however there is no geothermal capacity in Scotland, so it has been attributed entirely to marine.
Carbon Capture and Storage	CCUS	
Renewable Heat	Heat pumps, Heat networks	Divided across heat pumps, heat networks with a renewable energy centre, and solar thermal based on the relative heat output for each technology in 2020. Solar thermal was not included in this report.
Renewable Combined Heat and Power	Energy from Waste	All other forms of CHP with capacity in Scotland would be classed under Bioenergy or non-renewable.
Bioenergy	Biomass, Biogas, Biofuels	Divided across biomass, biogas, and biofuels based on the relative heat and electricity output/demand for transport for each technology in 2020.
Alternative Fuels	Hydrogen, SAF	The alternative fuels sector is small (<100 employees identified in the LCREE survey) so employment has been estimated as 50 FTEs each for hydrogen and SAF with the turnover divided equally across both technologies.
Low emission vehicles and infrastructure	EV Buses and HGVs, H_2 Buses and HGVs, EV Chargers, Hydrogen Refuelers	The LCREE sector was divided across the sectors listed as well as light zero emission vehicles based on the relative turnover and FTEs of Scottish companies active in these areas. Light vehicles were not included in this analysis.

22 Low carbon and renewable energy economy, UK - Office for National Statistics (ons.gov.uk)
23 The-Economic-Impact-of-Scotlands-Renewable-Energy-Sector1-1.pdf (fraserofallander.org)
24 Supply, Use and Input-Output Tables - gov.scot (www.gov.scot)

2020 was used as the base year in our analysis to allow us to consider potential changes in 5-year increments out to the Scottish and UK Government net zero target years of 2045 and 2050 respectively.

The Strong Ambition and Business as Usual scenarios created for our projections were formed using existing Future Energy Scenarios from Scottish and Southern Energy (SSE) and Scottish Power (SP) distribution and transmission[25] networks alongside scenarios for the decarbonisation of Scotland's large industrial sites from the Scottish Net Zero Roadmap (SNZR) developed by NECCUS. The Strong Ambition scenario aligns with the "Leading the Way" scenario from SSE and SP and the Business as Usual Scenario aligns with "Falling Short". The respective SNZR scenarios used are "Regional H_2" and "Soft Start". Additionally, SAF projections were based on assumptions around Petroineos Grangemouth's current volume of jet fuel production transitioning to sustainable fuel in Strong Ambition, with no SAF production in the Business as Usual scenario.

This study aims to provide data which is consistent and comparable across a range of technologies by using the best available, robust sources so the decision on which subsectors to include was data driven. Starting from the longlist of 45 subsectors which feature in the Annexes, this was reduced to 18 based on the availability of scenario-based projections from the above sources.

A Cluster Level Techno-Economic Analysis of the SNZR scenarios was commissioned by NECCUS and produced by Element Energy and Cambridge Econometrics. This gave projected investment, employment, turnover, and GVA for CCUS, but for the other technologies this had to be inferred from the capacities. The process used was broadly the same with some minor differences between technologies.

For renewable electricity generation, bioenergy, hydrogen, and SAF, once the projected capacities from each had been produced, we then used cost data[26] to calculate the required investment to deliver each scenario. The investment figures were then divided by a turnover per employee figure taken from the latest Scottish Annual Business Statistics (SABS),[27] which allowed a number of construction/installation jobs to be calculated. The turnover per employee figure was obtained from turnover and employment data for relevant SIC codes, such as Installation and Repair of Machinery. For operations and maintenance jobs, the projected generation/supply of fuel was multiplied by the cost per MWh, which was also then divided by a turnover per employee figure to calculate employment. The construction/installation and operations and maintenance jobs were then combined to get total jobs.

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[25] SSEN DFES 2022 North of Scotland report (regen.co.uk), North of Scotland Future Energy Scenarios (NoSFES) - SSEN Transmission (ssen-transmission.co.uk), DFES_SP_Distribution_December_2022.pdf (spenergynetworks.co.uk), SP Transmission Future Energy Scenarios not publicly available

[26] Electricity generation costs 2023 - GOV.UK (www.gov.uk), storage-costs-technical-assumptions-2018.pdf (publishing.service.gov.uk), Hydrogen production costs 2021 - GOV.UK (www.gov.uk), T41_CostReductionBiofuels-11_02_19-final.pdf (ieabioenergy.com), Synthetic/Sustainable Aviation Fuel Mapping (evaluationsonline.org.uk)

[27] Scottish Annual Business Statistics 2021 - gov.scot (www.gov.scot)

For heat pumps and heat networks, data on current cost.[28] was used alongside projected reduction in cost from the European Heat Pump Association..[29] The capital cost of each was used to calculate construction/installation jobs as for other technologies above. Operations and maintenance jobs were calculated using the levelised cost of heat for a heat network, and a flat maintenance cost of £200 per year for heat pumps.[30] then divided by turnover per employee as above.

Costs for electric vehicles (EVs) and hydrogen-fuelled vehicles were taken from previous Scottish Enterprise Electric Vehicle foresighting work and used to calculate jobs associated with the manufacture/assembly of vehicles. Employment relating to installation of EV/H_2 infrastructure was also calculated by the same method with costs sourced from reports commissioned by the Scottish Government or Scottish Enterprise..[31] Operations and maintenance jobs for vehicles were calculated by considering current employment in the same sector for internal combustion engine vehicles and scaling this to projected EV numbers. EV charger maintenance jobs were assumed to scale up by a fixed number of jobs per charger and hydrogen refuelling maintenance costs were also given in the report and used to infer employment numbers by dividing by a turnover per employee figure.

Projected employment figures for each sector were then used to calculate turnover by scaling up the 2020 turnover per employee. GVA was then be calculated from this by taking the appropriate percentage of turnover as described above for the base year calculation.

There are some limitations to this method of projecting economic impacts, including the assumptions made to obtain GVA as a percentage of turnover for new technologies which may not necessarily align well with existing SIC codes, and the relatively large margin of error associated with LCREE data. The use of a fixed turnover per employee figure is another potential limitation as this would also be expected to change over time and no assumptions have been made regarding either Scottish content or exports.

The LCREE survey is the primary source of official information on LCREE activity in the UK according to the Office of National Statistics. The LCREE data is based on annual survey results from approximately 25,000 UK businesses.[32] A drawback of surveys is that they rely on self-reported data, which can be affected by sources of bias such as response styles and low response rates which would reduce the reliability of samples.

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[28] A guide to air source heat pumps - Energy Saving Trust, heat_networks.pdf (publishing.service.gov.uk)
[29] Market conditions (ehpa.org)
[30] How Much Does A Heat Pump Cost in the UK? | A 2024 Guide (theecoexperts.co.uk)
[31] Scottish Bus Electrification (zemo.org.uk), Hydrogen and Fuel Cell Opportunities, E4tech, 2017
[32] Low Carbon and Renewable Energy Economy (LCREE) Survey QMI - Office for National Statistics (ons.gov.uk)

Appendix B – Capacity Projections

Strong Ambition

Technology	Unit	2020	2025	2030	2035	2040	2045	2050
Offshore Wind	MW	898	5,262	14,362	38,123	41,073	41,073	41,073
Onshore Wind	MW	8,356	19,136	26,152	29,559	31,432	33,024	33,485
Marine	MW	22	36	59	100	272	272	272
Hydropower	MW	2,402	3,019	5,311	5,483	6,107	6,130	6,163
Solar	MW	392	1,723	3,438	4,789	5,826	7,185	8,001
Biomass	MW	2,001	2,078	2,115	1,909	1,871	174	193
Biogas	MW	355	301	317	315	299	295	299
Biofuels	TWh	1	3	3	2	2	3	3
Energy from Waste	MW	80	247	252	243	235	58	31
Heat pumps	Number	20,670	296,628	956,555	1,592,349	2,070,079	2,316,996	2,413,249
Heat Networks	Number	3,887	27,483	44,354	99,327	287,255	455,632	572,132
EV Buses/HGVs	Number	40	949	5,370	20,761	38,824	56,051	53,304
H2 Buses/HGVs	Number	12	121	358	868	1,764	4,276	7,432
EV Chargers - All	Number	6,546	59,268	243,347	576,136	607,061	612,841	614,246
Hydrogen refuelers	Number	2	13	37	90	183	449	777
Hydrogen Production	MW	0	84	4,030	5,034	5,738	6,558	6,858
SAF	MW	0	0	0	1,235	1,235	1,235	1,235
CCUS	$MtCO_2e$/year	0	0	2	3	6	7	7

Business as Usual

Technology	Unit	2020	2025	2030	2035	2040	2045	2050
Offshore Wind	MW	898	3,272	7,152	15,110	27,797	29,305	29,305
Onshore Wind	MW	8,356	12,463	20,102	23,903	25,273	25,649	25,968
Marine	MW	22	41	54	59	59	59	187
Hydropower	MW	2,402	3,010	3,029	3,032	3,695	3,696	3,699
Solar	MW	392	960	1,610	2,021	2,221	2,526	2,825
Biomass	MW	2,001	2,173	2,179	2,179	2,179	2,179	2,179
Biogas	MW	355	261	225	172	134	124	122
Biofuels	TWh	1	3	4	4	3	3	2
Energy from Waste	MW	80	399	486	491	487	480	464

Technology	Unit	2020	2025	2030	2035	2040	2045	2050
Heat pumps	Number	20,670	64,462	229,962	471,608	874,399	1,211,203	1,545,130
Heat Networks	Number	3,887	24,807	31,456	39,228	46,068	53,832	62,223
EV Buses/HGVs	Number	40	384	1,236	4,152	13,946	35,455	49,045
H2 Buses/HGVs	Number	12	50	106	211	397	718	1,251
EV Chargers - All	Number	6,546	24,198	91,643	237,932	455,946	593,133	598,423
Hydrogen refuelers	Number	2	5	10	20	37	66	114
Hydrogen Production	MW	0	3	150	161	162	152	311
SAF	MW	0	0	0	0	0	0	0
CCUS	$MtCO_2e$/ year	0	0	1	3	6	8	8

Appendix C – Investment Projections

Refer to Appendix A for assumptions surrounding these projections.

Investment (£m) - Strong Ambition

Technology	2021-2025	2026-2030	2031-2035	2036-2040	2041-2045	2046-2050	Total
Offshore Wind	7,394	17,056	43,347	5,382	0	0	**73,179**
Onshore Wind	14,063	9,152	4,444	2,443	2,077	601	**32,781**
Marine	84	110	180	756	0	0	**1,130**
Hydropower	2,283	3,256	289	903	85	122	**6,937**
Solar	1,371	1,638	1,256	964	1,264	759	**7,252**
Biomass	304	325	0	0	0	52	**681**
Biogas	0	46	0	0	0	11	**57**
Biofuels	78	6	0	0	6	15	**105**
Energy from Waste	1,404	43	0	0	0	0	**1,447**
Heat pumps	4,684	9,394	7,310	5,493	2,839	1,107	**30,827**
Heat Networks	818	445	1,675	6,202	5,530	3,963	**18,632**
EV Buses/HGVs	315	1,441	3,933	3,447	3,039	0	**12,175**
H2 Buses/HGVs	36	75	144	241	569	776	**1,840**
EV Chargers - All	99	346	626	58	11	3	**1,142**
Hydrogen refuelers	19	41	91	160	458	565	**1,334**
Hydrogen Production	63	2,459	571	446	511	184	**4,235**
SAF	0	0	1,200	0	0	0	**1,200**
CCUS	4	675	982	1,672	173	0	**3,504**
Total	**33,017**	**46,508**	**66,050**	**28,166**	**16,562**	**8,157**	**198,459**

Investment (£m) - Business as Usual

Technology	2021-2025	2026-2030	2031-2035	2036-2040	2041-2045	2046-2050	Total
Offshore Wind	4,022	7,272	14,518	23,145	2,751	0	**51,708**
Onshore Wind	5,358	9,965	4,958	1,787	490	416	**22,975**
Marine	114	62	22	0	0	562	**761**
Hydropower	2,249	70	11	906	4	11	**3,252**
Solar	585	621	382	186	284	278	**2,336**
Biomass	500	16	0	0	0	0	**516**
Biogas	0	0	0	0	0	0	**0**
Biofuels	85	40	0	0	0	0	**126**
Energy from Waste	2,714	743	43	0	0	0	**3,499**
Heat pumps	743	2,356	2,778	4,631	3,873	3,839	**18,221**
Heat Networks	770	102	125	94	125	146	**1,362**

Technology	2021-2025	2026-2030	2031-2035	2036-2040	2041-2045	2046-2050	Total
EV Buses/HGVs	121	277	780	1,913	3,901	2,633	**9,625**
H2 Buses/HGVs	20	30	46	82	141	235	**553**
EV Chargers - All	33	127	275	410	258	10	**1,113**
Hydrogen refuelers	5	9	17	29	50	83	**193**
Hydrogen Production	2	99	7	1	0	98	**206**
SAF	0	0	0	0	0	0	**0**
CCUS	0	896	1,063	2,335	1,208	0	**5,502**
Total	**17,321**	**22,685**	**25,027**	**35,519**	**13,085**	**8,312**	**121,948**

Appendix D – Direct Employment Projections

Refer to Appendix A for assumptions surrounding these projections.

Direct Jobs (FTE) - Strong Ambition

Technology	2020	2025	2030	2035	2040	2045	2050
Offshore Wind	2,200	10,150	23,518	60,625	13,394	6,673	6,673
Onshore Wind	2,600	19,783	14,307	8,803	6,510	6,228	4,436
Marine	100	143	187	301	1,150	206	206
Hydropower	800	2,839	3,807	1,064	1,654	902	945
Solar	900	1,859	2,318	1,945	1,655	2,135	1,567
Biomass	310	579	627	200	196	18	85
Biogas	90	52	112	55	52	51	66
Biofuels	100	421	347	244	233	259	312
Energy from Waste	50	1,795	94	38	37	9	5
Heat pumps	913	6,219	12,925	11,117	9,444	6,438	4,395
Heat Networks	154	849	536	1,831	6,555	6,399	5,269
EV Buses/HGVs	94	421	1,995	5,873	6,596	7,349	3,744
H2 Buses/HGVs	36	49	109	223	394	940	1,393
EV Chargers - All	6	179	660	1,321	641	588	579
Hydrogen refuelers	2	97	216	482	861	2,419	3,116
Hydrogen Production	50	119	5,191	3,447	3,585	4,072	3,793
SAF	50	50	50	2,791	1,292	1,292	1,292
CCUS	0.0	337	1,016	760	1,436	804	804
Total	**8,455**	**45,940**	**68,015**	**101,120**	**55,685**	**46,781**	**38,679**

Direct Jobs (FTE) - Business as Usual

Technology	2020	2025	2030	2035	2040	2045	2050
Offshore Wind	2,200	5,593	10,186	20,703	33,418	8,197	4,761
Onshore Wind	2,600	8,138	14,656	8,822	5,013	3,435	3,377
Marine	100	186	123	72	45	45	844
Hydropower	800	2,806	788	734	1,581	744	751
Solar	900	813	903	636	404	550	566
Biomass	310	846	248	228	228	228	228
Biogas	90	45	39	30	23	22	21
Biofuels	100	448	501	395	348	271	195
Energy from Waste	50	3,456	1,006	130	76	75	72
Heat pumps	913	1,009	3,229	4,058	6,875	6,348	6,724
Heat Networks	154	796	182	225	215	266	309
EV Buses/HGVs	94	162	398	1167	3127	6870	6401

Technology	2020	2025	2030	2035	2040	2045	2050
H2 Buses/HGVs	36	26	41	67	120	209	351
EV Chargers - All	6	64	244	566	939	878	573
Hydrogen refuelers	2	27	46	93	160	274	456
Hydrogen Production	50	50	190	80	71	67	258
SAF	50	50	50	50	50	50	50
CCUS	0	514	1,425	934	2,499	1,274	1,274
Total	**8,455**	**25,002**	**34,230**	**38,967**	**55,171**	**29,781**	**27,191**

Direct Operations and Maintenance Employment Projections

Direct O&M Jobs (FTE) – Strong Ambition

Technology	2025	2030	2035	2040	2045	2050
Offshore Wind	918	2,220	6,496	6,673	6,673	6,673
Onshore Wind	2,223	2,878	3,253	3,459	3,634	3,685
Marine	39	50	76	206	206	206
Hydropower	721	785	796	816	823	832
Solar	147	273	376	451	556	620
Biomass	200	221	200	196	18	20
Biogas	52	55	55	52	51	52
Biofuels	323	340	244	233	251	293
Energy from Waste	42	40	38	37	9	5
Heat pumps	370	1,194	1,988	2,585	2,893	3,013
Heat Networks	90	123	276	799	1,267	1,591
EV Buses/HGVs	67	377	1,458	2,727	3,937	3,744
H2 Buses/HGVs	9	25	61	124	300	522
EV Chargers - All	56	228	540	569	574	575
Hydrogen refuelers	8	22	54	109	268	464
Hydrogen Production	41	2,120	2,734	3,029	3,433	3,563
SAF	0	0	1,292	1,292	1,292	1,292
CCUS	328	367	558	619	804	804
Total	**5,839**	**11,530**	**20,700**	**24,174**	**27,038**	**27,980**

Direct O&M Jobs (FTE) – Business as Usual

Technology	2025	2030	2035	2040	2045	2050
Offshore Wind	571	1,105	2,575	4,516	4,761	4,761
Onshore Wind	1,448	2,212	2,631	2,781	2,823	2,858

Technology	2025	2030	2035	2040	2045	2050
Marine	44	45	45	45	45	142
Hydropower	718	723	724	740	740	741
Solar	82	128	159	172	196	219
Biomass	222	228	228	228	228	228
Biogas	45	39	30	23	22	21
Biofuels	342	450	395	348	271	195
Energy from Waste	68	78	77	76	75	72
Heat pumps	80	287	589	1,092	1,512	1,929
Heat Networks	82	87	109	128	150	173
EV Buses/HGVs	27	87	292	980	2,490	3,445
H2 Buses/HGVs	3	7	15	28	50	88
EV Chargers - All	23	86	223	427	555	560
Hydrogen refuelers	3	6	12	22	39	68
Hydrogen Production	1	67	71	70	67	136
SAF	0	0	0	0	0	0
CCUS	514	637	651	922	1,264	1,264
Total	**4,273**	**6,272**	**8,826**	**12,598**	**15,288**	**16,900**

Appendix E – Turnover Projections

Refer to Appendix A for assumptions surrounding these projections.

Turnover (£m) - Strong Ambition

Technology	2020	2025	2030	2035	2040	2045	2050
Offshore Wind	601	2,771	6,419	16,548	3,656	1,822	1,822
Onshore Wind	1,099	8,358	6,045	3,719	2,751	2,631	1,874
Marine	7	9	12	20	75	13	13
Hydropower	581	2,062	2,765	773	1,201	655	687
Solar	71	147	183	153	131	168	124
Biomass	110	205	222	71	69	6	30
Biogas	32	18	40	19	18	18	23
Biofuels	35	149	123	86	83	92	110
Energy from Waste	23	826	43	17	17	4	2
Heat pumps	174	1,187	2,468	2,122	1,803	1,229	839
Heat Networks	29	162	102	350	1,251	1,222	1,006
EV Buses/HGVs	18	81	382	1,126	1,264	1,409	718
H2 Buses/HGVs	7	9	21	43	77	183	271
EV Chargers - All	1	29	107	215	104	95	94
Hydrogen refuelers	0	16	35	78	140	393	506
Hydrogen Production	7	17	753	500	520	590	550
SAF	7	7	7	405	187	187	187
CCUS	0	58	190	137	267	149	149*
Total	**2,802**	**16,112**	**19,918**	**26,382**	**13,614**	**10,867**	**9,006**

Turnover (£m) - Business as Usual

Technology	2020	2025	2030	2035	2040	2045	2050
Offshore Wind	601	1,527	2,780	5,651	9,122	2,237	1,300
Onshore Wind	1,099	3,438	6,192	3,727	2,118	1,451	1,427
Marine	7	12	8	5	3	3	55
Hydropower	581	2,038	572	533	1,148	540	545
Solar	71	64	71	50	32	43	45
Biomass	110	294	82	75	75	75	75
Biogas	32	12	10	8	6	6	6
Biofuels	35	159	177	140	123	96	69
Energy from Waste	23	1,590	463	60	35	34	33
Heat pumps	174	193	616	775	1,313	1,212	1,284
Heat Networks	29	152	35	43	41	51	59
EV Buses/HGVs	18	31	76	224	599	1,317	1,227

Technology	2020	2025	2030	2035	2040	2045	2050
H2 Buses/HGVs	7	5	8	13	23	41	68
EV Chargers - All	1	10	40	92	153	143	93
Hydrogen refuelers	0	4	8	15	26	45	74
Hydrogen Production	7	7	28	12	10	10	37
SAF	7	7	7	7	7	7	7
CCUS	0	84	245	160	447	214	214*
Total	**2,802**	**9,627**	**11,419**	**11,590**	**15,281**	**7,524**	**6,619**

Appendix F – GVA Projections

Refer to Appendix A for assumptions surrounding these projections.

GVA (£m) - Strong Ambition

Technology	2020	2025	2030	2035	2040	2045	2050
Offshore Wind	288	1,330	3,081	7,943	1,755	874	874
Onshore Wind	417	3,176	2,297	1,413	1,045	1,000	712
Marine	3	5	6	10	38	7	7
Hydropower	227	804	1,078	301	468	255	268
Solar	34	70	88	74	63	81	59
Biomass	50	94	102	32	32	3	14
Biogas	13	8	17	8	8	8	10
Biofuels	15	63	52	36	35	38	46
Energy from Waste	11	380	20	8	8	2	1
Heat pumps	73	499	1,036	891	757	516	352
Heat Networks	12	68	43	147	526	513	422
EV Buses/HGVs	9	39	184	540	607	676	344
H2 Buses/HGVs	3	5	10	21	37	88	130
EV Chargers - All	0	14	51	103	50	46	45
Hydrogen refuelers	0	7	15	33	59	165	213
Hydrogen Production	3	7	286	190	198	224	209
SAF	4	4	4	202	94	94	94
CCUS	0	27	81	62	116	69	0
Total	**1,164**	**6,597**	**8,451**	**12,016**	**5,894**	**4,660**	**3,801**

GVA (£m) - Business as Usual

Technology	2020	2025	2030	2035	2040	2045	2050
Offshore Wind	288	733	1,335	2,713	4,378	1,074	624
Onshore Wind	417	1,307	2,353	1,416	805	552	542
Marine	3	6	4	2	1	1	28
Hydropower	227	795	223	208	448	211	213
Solar	34	31	34	24	15	21	21
Biomass	50	135	38	34	34	34	34
Biogas	13	5	4	3	3	2	2
Biofuels	15	67	74	59	52	40	29
Energy from Waste	11	731	213	28	16	16	15
Heat pumps	73	81	259	325	551	509	539
Heat Networks	12	64	15	18	17	21	25
EV Buses/HGVs	9	15	37	107	288	632	589

Technology	2020	2025	2030	2035	2040	2045	2050
H2 Buses/HGVs	3	2	4	6	11	20	33
EV Chargers - All	0	5	19	44	73	68	45
Hydrogen refuelers	0	2	3	6	11	19	31
Hydrogen Production	3	3	12	5	5	4	17
SAF	4	4	4	4	4	4	4
CCUS	0	41	113	76	198	105	0
Total	**1,164**	**4,026**	**4,744**	**5,079**	**6,910**	**3,333**	**2,791**

Annexes

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