Just Transition Review of the Energy Sector

Chapter 3 – Just Transition Scenarios Analysis

Reliance Restricted

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Contents

Abbreviations

Abbreviation	Description	Abbreviation	Description
BECCS	Bioenergy with Carbon Capture and Storage	LCREE	Low Carbon and Renewable Energy Economy
BEIS	The Department for Business, Energy and Industrial Strategy	m	Million
bn	Billion	$MtCO_2e$	Million tonnes of carbon dioxide equivalent
BOP	Balanced Options (Under ESC's whole system energy model)	Mmboe/d	Million Barrels of Oil Equivalent per Day
Capex	Capital Expenditure	NSTD	North Sea Transition Deal
CCC	Climate Compatibility Checkpoint	O&G	Oil and Gas
CCUS	Carbon Capture Usage and Storage	O&M	Operation and Maintenance
CfD	Contract for Differences	OFTO	Offshore Transmission Owner
CO_2	Carbon Dioxide	ONS	Office for National Statistics
COP26	Conference of Parties	Opex	Operational expenditure
CXC	ClimateXChange	RGU	Robert Gordon University
DA	Discontinuation Agreement	ROC	Renewable Obligation Certificate
DPA	Dispatchable Power Agreement	RSA	Revenue Support Agreement
Devex	Development expenditure	rUK	Rest of the UK
ESC	Energy Systems Catapult	SCA	Supplementary Compensation Agreement
EY	Ernst & Young LLP	ScotNS	Scottish North Sea
FAI	Fraser of Allander Institute	SG	The Scottish Government
FDI	Foreign Direct Investment	SIC	Standard Industrial Classification
FES	National Grid Future Energy Scenarios 2022	SOC	Societal Change Scenario (Under ESC's whole system energy model)
FID	Final Investment Decision	SNIB	Scottish National Investment Bank
FtF	Fuelling the Future	SNP	Scottish National Party
GDP	Gross Domestic Product	T&S	Transport and storage
GGR	GHG Removal	TEC	Technology Scenario (Under ESC's whole system energy model)
GHG	Greenhouse gas	TNUoS	Transmission Network Use of System
Gt CO_2e	Gigatonnes of carbon dioxide equivalent	Totex	Total expenditure
GVA	Gross Value Added	TWh	Terawatt-hour
GW	Giga Watt	UK	United Kingdom
IEA	International Energy Agency	UKG	The United Kingdom Government
INTOG	The Innovation and Targeted Oil and Gas	UN	United Nations
IPCC	Intergovernmental Panel on Climate Change	WACC	Weighted average cost of capital
k	Thousand		–

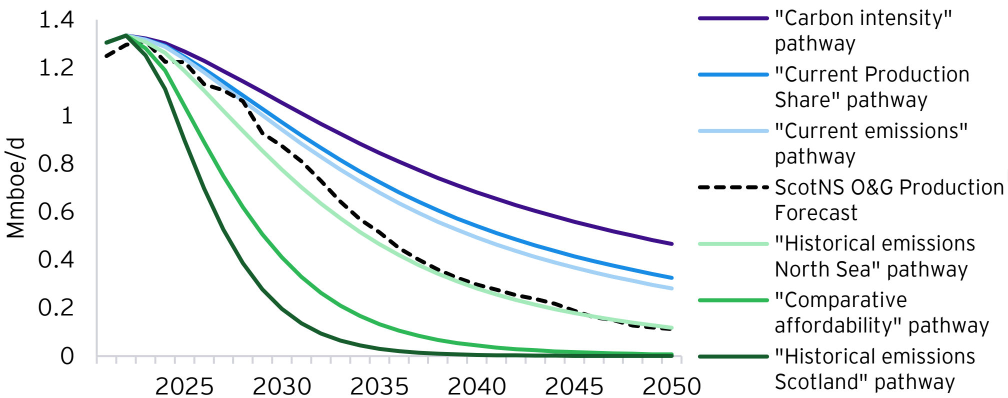
1 Executive Summary

Policymakers will need to actively manage the Just Transition and replace a declining O&G sector

As a mature basin, Scotland has a range of potential O&G decline scenarios, but Scotland's ability to impact these scenarios is less clear

- The Energy Transition creates a series of opportunities and challenges for Scotland, most notably, how Scotland can transition from the naturally declining O&G sector and take advantage of the emergence of Scotland's growing low carbon sectors, specifically wind, Carbon Capture Usage and Storage (CCUS) and hydrogen.
- Before exploring the positive impact of the new growth sectors, we assess a range of illustrative Scottish O&G decline scenarios which have been developed using EY's Fuelling the Future (FtF) model. The scenarios were derived from a baseline model where Scotland retains a constant share of global production, in line with the Paris Agreement. In reality there are a large number of scenarios that could result in a given CO_2 output, dependent on oil price, adoption rates, regulation and policy decisions, but the FtF model is constrained by UN carbon budgets to give the most credible mix of market assumptions. See Appendix B for detailed methodology on the development of the potential production pathways.
- Our analysis compares the ScotNS O&G production forecast (based on the NSTA stewardship survey) with the Scottish O&G production pathways, highlighting a wide range of possible outcomes. This also provides a basis for ensuring that just transition planning accounts for the dynamics between the sectors in decline and the growth in the low carbon sectors.

Scotland's potential production pathways



Source: EY analysis

[1] Please see Chapter 1 for a further details on the methodology use to develop these trajectories

- The O&G sector's decline will be determined by a variety of complex economic, legal and policy factors. The Scottish Government (SG) will therefore be unable to target a particular pathway as a matter of policy, even with greater devolved powers over the ScotNS O&G sector. The steepest-decline lines would involve actively curtailing production in ScotNS fields that are already sanctioned (over 80% of future production will arise from existing sanctioned fields).

However, for the purposes of this analysis, we have assessed the potential illustrative impact that these production pathways could have on Scotland

- Decline scenarios that are steeper than the ScotNS O&G Production Forecast could accelerate O&G production job and Gross Value Added (GVA) losses relative to shallower decline scenarios. These adverse effects would be particularly felt in the North East of Scotland where 98% of direct O&G jobs are located.
- Scottish O&G consumption is not driven by levels of domestic production. If Scotland's demand for O&G is not reduced, less domestic production may result in greater reliance on imported O&G, and depending on where those supplies come from, this could increase global emissions. A steeper pathway could mean Scotland contributes to reducing global emissions, as long as reduced Scottish O&G production is not replaced by more emissions-intensive international production.
- Scotland's ability to be a renewable energy leader and to be at the forefront of the energy transition is unlikely to correlate with the speed of the decline in the Scottish O&G sector. The scale of investment in the United Kingdom (UK) and global low carbon sector is already significant from companies involved in O&G and those only working in renewables, and there is no suggestion that a steeper decline in production would encourage additional investment. Several companies suggest continued O&G production is necessary to support additional investment in renewables.
- A more gradual pathway would allow more time for renewable energy supply chains to be established, for workers to be reskilled, and infrastructure repurposed.

	Steepest pathway (Historical Emissions Scotland)		Middle pathway (Historical Emissions North Sea)		Shallowest pathway (Carbon Intensity)	
	Jobs	GVA (£m)	Jobs	GVA (£m)	Jobs	GVA (£m)
2019	56,980	15,883	56,980	15,883	56,980	15,883
2030	8,353	2,078	33,127	8,242	44,995	11,194
2050	11	2	6,473	1,166	25,658	4,621

Note: Jobs and GVA is for direct and indirect jobs.

Scotland's low carbon sectors will continue to counteract decline in the lost jobs and GVA from the O&G sector - by 2049 all scenarios are expected to reach net job gains

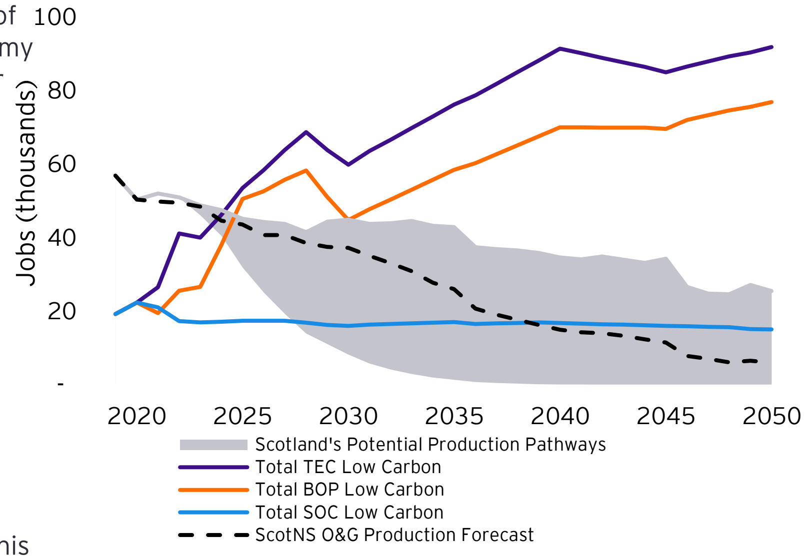
Scotland's low carbon sector already has an established economic footprint, but currently supports fewer, less well paid jobs than the O&G sector

- In 2019, Scotland's low carbon energy sector supported over 19,000 direct and indirect jobs (0.8% of Scotland's total employment) and contributed £2.9bn in direct and indirect GVA to Scotland's economy (1.6% of Scotland's total GDP). In comparison, 57,000 jobs were supported by Scotland's O&G sector and its supply chains in 2019, and corresponding £16.0bn GVA contribution.
- Nuclear power generation and decommissioning makes up roughly a third of the contribution to low carbon sector GVA. Of the £2.9bn direct and indirect sector GVA, an estimated £0.9bn related to nuclear power generation and decommissioning and the remaining £2.0bn related to the rest of the renewables sector (1.2% of Scotland's total GDP).

The sector's economic footprint could **eventually replace the jobs lost in the O&G sector**

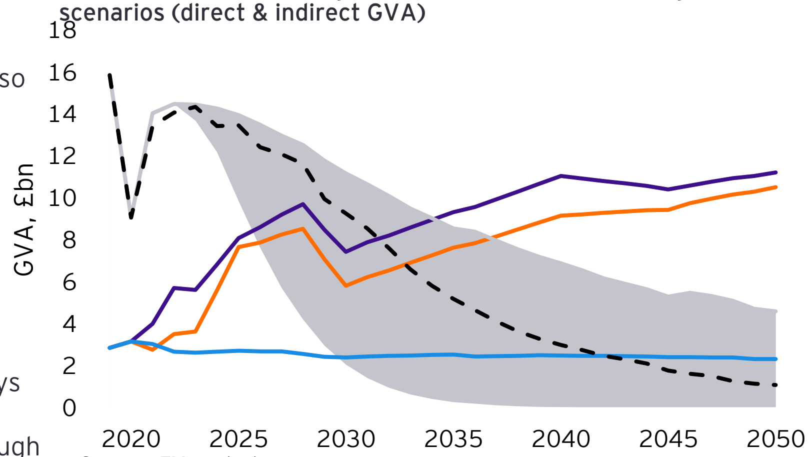
- To understand the expected growth in the low carbon sector, we based our analysis on ESC's "whole system energy model" which explores a range of scenarios for Scotland's future energy consumption (see appendix C for more ESC scenarios information). The scenarios analyse the implementation of Scotland's future low carbon technologies to 2050, focusing on the key areas of offshore wind, hydrogen and CCUS and the expected output (e.g. GW) from these technologies.
- We link the growth in these technologies to increases in economic output, offsetting the losses from O&G decline. Our economic analysis (jobs and GVA) also assumes that Scotland will gain a significant share of the future low carbon supply chain. Although Scotland has a world class O&G supply chain, this is not guaranteed for the low carbon sector.
- The graphs alongside demonstrate the rates of change for jobs and GVA vary across each ESC scenario, with growth in jobs and GVA in the 'Balanced Options' (BOP) and 'Technology' (TEC) scenarios, and a decline in the 'Societal Change' (SOC) scenario. The BOP is the central scenario striking a balance between technology innovation and the societal change needed to meet climate change targets. It also results in the closest outcome to net-nil job[1] losses under the ScotNS O&G decline scenario. The analysis shows:
  - When comparing the growth in low carbon jobs per the BOP model against the decline in jobs per Scotland's potential production pathways (EY analysis) four of the decline pathways result in an overall increase in total energy jobs from 2024 onwards. By 2049 all pathways are expected to reach net job gains (i.e. growth in low carbon jobs exceeds the loss in O&G jobs).
  - Under all O&G decline pathways, total Scottish energy GVA is expected to decline from 2030 onwards. This is due to O&G GVA per job exceeding the GVA per job in the low carbon sector.
  - Although our detailed economic analysis is based on the BOP scenario, there are multiple pathways for the growth in the low carbon sector, evidenced through the SOC and TEC scenarios.
  - Our analysis did not consider the impact on the wider economy of the energy transition, e.g. through increased retrofitting.

Decline in O&G jobs and growth in low carbon jobs using ESC scenarios (direct & indirect jobs)



Source: EY analysis

Decline in O&G GVA and growth in low carbon GVA using ESC scenarios (direct & indirect GVA)



Source: EY analysis

"Net-nil job losses" refers to a position where the gain in low carbon jobs fully offsets the loss of O&G jobs and there is a nil change in energy sector jobs across O&G and low carbon energy.

There is a potential for wind, CCUS and hydrogen to fill the gap left by O&G but significant and early investment and policy intervention is required to support this growth

Significant investment is required to support the growth in jobs and GVA

- We estimate the total level of investment required to 2050 in offshore wind, CCUS and hydrogen production to offset the loss of O&G jobs to be £33.3bn, split across the three key sectors: offshore wind (£21.5bn), CCUS (£1.9bn) and hydrogen (£9.9bn).
- The £33.3bn above does not represent the total investment required to implement the ESC BOP scenario, as our analysis is focused on three specific subsectors (wind, hydrogen and CCUS), whereas the BOP scenario contains a wider set of subsectors (including biomass, solar etc). Additionally, we have not profiled these investment figures over time, due to the absence of third party data from the ESC model.
- We calculate that offshore wind generation capacity would need to stand between 14 and 23 GW in 2050 in order to achieve net-nil job losses, or 33 and 46 GW to achieve net-nil GVA losses across the adjusted pathways. Levels of carbon captured in 2050 would need to reach between 16 and 26 $MtCO_2e$ to achieve net-nil job losses, or between 38 and 52 $MtCO_2e$ to achieve net-nil GVA. Similarly, between 6 and 9GW (42 and 71TWh) of hydrogen would need to be produced to achieve net-nil job losses, compared to 14 and 19 GW (101 and 140 TWh) needed to achieve net-nil GVA losses.
- The BOP scenario forecasts offshore wind generation to be 23 GW, carbon captured will be 26 $MtCO_2e$ carbon, and hydrogen production to be 9 GW in 2050. In all cases, the BOP scenario forecasts that net-nil jobs will be achieved, but net-nil GVA will be more challenging.

Each of the main low carbon sectors is likely to require a different investment model or an adapted model to allow for the scale of investment required

- We anticipate that several potential routes are needed to realise this investment, including a combination of government support, regulated models and private sector investment.
- **Offshore Wind: We expect the Contract for Difference (CfD) to be the best value for money** and most established model in the future. It is likely to be successful in attracting private sector investment.
- **CCUS: UKG has established a business model for CCUS investment.** The transport and storage (T&S) element will be economically regulated, and government will subsidise emitters through a set of business models based either on the CfD for industrial and waste emitters, or the Dispatchable Power Agreement (DPA) for power emitters. The economic regime for T&S and the contracts for emitters have not yet been completed and tested in the market, but promoters have indicated they are willing to commit equity. Acorn (the Scottish CCUS cluster) is currently on track 2 of the government's cluster sequencing process.
- **Hydrogen: this is the least mature business model.** A model for blue hydrogen is being developed that is based on the CfD, with a variable reference price depending on whether there is a market for low-carbon hydrogen. This will depend on there being suitable off-takers, but it is intended to be financeable taking into account the technology risk.
- Although these investment models either exist, or are in development, they will come at a cost. Additionally, the models, particularly CCUS, are being actively developed by UKG and bound to the UK energy system.

There is a potential for wind, CCUS and hydrogen to fill the gap left by O&G but several key issues must be addressed before the jobs and GVA are realised

- Scotland must invest in its Low Carbon sectors to meet its Net Zero targets by 2045. These sectors present opportunities for Scotland, help to create jobs, counteract a decline in GVA and support a Just Transition. However, to maximise the benefits, several issues must be considered and opportunities explored:
  - Wind technology is mature, cost effective and provides a potential route to meet Scotland's future electricity demands. The ScotWind leasing round, which secured 27GW of offshore wind generation capacity, highlights the sector's established nature. However, wind power alone suffers from intermittency[1] and currently relies on natural gas as a flexible back up. Tackling intermittency is a significant challenge for the sector, and will require the development of other low carbon technologies, such as wave and tidal, to maintain the base load. Currently these are more immature and much more expensive. There are also capacity constraints with the existing grid, which will need to be expanded to cope with increased electricity generation. Supporting the development of a supply chain that can meet this capacity is another vital opportunity to unlock.
  - Scotland has significant carbon storage potential with well-mapped, vacant O&G stores in the North Sea. Carbon capture technology can be implemented in high emitting sectors or to support hydrogen creation. However, the designation of a CCUS cluster in Scotland requires support from the UKG. Hydrogen may assist in the decarbonisation of hard to abate sectors such as industry and specific transport modes whilst also serving as a dispatchable low carbon energy source. Generating hydrogen is still expensive but there is growing international interest. The creation of green hydrogen would require upscaling of Scotland's renewable energy capacity to meet demand. The creation of this new industry would require government support.

[1] *The Crown Estate, the UK Energy Research centre and other bodies study annual wind . Some years, e.g. 2021, can be exceptionally calm with only a few months providing power above the long-term average. This variability also impacts prices.*

Policy interventions are required to stimulate growth in low carbon technologies, develop a supply chain, develop people/skills and ensure communities are not left behind

Policy recommendations to support growth in the Low Carbon sector

- Our report recommends SG policies and interventions that will help to achieve a Just Transition, building on the analysis across the three reports about the prospects for the O&G industry, how current patterns of consumption have evolved, and what the economic prospects are for new, low carbon, industries.
- It highlights that the growth in the low carbon sectors will help to replace the lost jobs and the economic output associated with the decline in the O&G sector. However, although growth in these sectors will replace many of these jobs, replacing the GVA associated the O&G sector will not occur immediately.
- To achieve this growth will require policy interventions to stimulate growth in low carbon technologies. Interventions are also crucial to develop a supply chain in Scotland which is capable of replacing the Scottish O&G supply chain in Scotland and subsequently securing Scotland's position as a major global player in the low carbon sector. To create a Just Transition, policies that support the development of people and skills will ensure no-one is left behind.
- Lastly, and importantly, policies are also needed to ensure that all communities in Scotland, including the North East of Scotland, are protected through the transition. A full list of the proposed interventions and their timescales has been developed in Chapter 3.
- To ensure that these pathways are achievable, decisions are required imminently to ensure the growth of the wind, hydrogen and CCUS sectors and the development of their supply chains.

Risks associated with the ESC BOP scenario

Our analysis utilises the ESC BOP scenario which contains several assumptions regarding Scotland's future energy scenarios. If the assumptions are not met, there is a risk that the future energy scenarios are not realised. The key risks are:

- The **timing and development** of the Scottish CCUS cluster.
- The development and implantation of a **successful hydrogen business** model and the need for available off-takers.
- The development of **capacity market to resolve intermittency** issued is developed at scale.
- The scale and speed of **rollout of the wind sector.**

The ESC energy scenarios are one indication of Scotland's future energy mix and this view is not necessarily definitive. Additionally, it is not directly comparable to the EY global energy mix presented in Chapter 1. This report does not seek to assess the reasonableness of the ESC model scenarios.

Executive Summary (cont.)

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2 Introduction and background

Introduction

Background and context

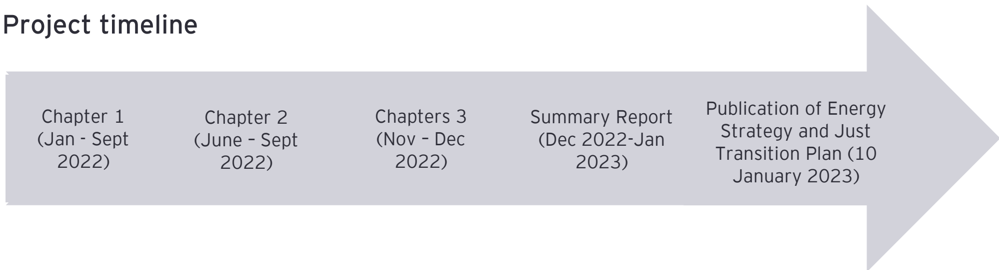
The climate emergency is one of the biggest issues facing the world. The need for a Just Transition requires the largest re-deployment of capital and step change in behaviours since the Industrial Revolution, and SG has put this at the forefront of its policy objectives. The Scottish National Party (SNP) and Scottish Green Party's Shared Policy Programme, published on 1 September 2021, states that, in order to achieve a Just Transition, it is crucial to baseline North Sea O&G production against the backdrop of the global climate emergency and Scotland's economic security and wellbeing – before then going on to take urgent proactive steps to deliver that transition.

Our work

There are four chapters to our work analysing Just Transition issues for SG. Chapter 1 set out the current and future state of the Scottish O&G industry and how it fits into the Scottish Energy system, including forecasts of production and the anticipated decline in O&G jobs and GVA that will result. Chapter 2 set out the factors that contribute to the current patterns of the consumption of that O&G (not exported to the rest of the UK (rUK) or further afield). This report, Chapter 3, explores the dynamics between the sectors in decline and the new low carbon sectors.

We have also provided a Summary Report which captures the key conclusions from our work in an accessible format to support the co-design of the Energy Just Transition Plan.

Project timeline



Report scope

This report focuses on transition across the key energy production sectors and their supply chains and facilitating activities, in particular: O&G, renewable electricity, hydrogen, CCUS. It provides insight on the potential transition dynamics between sectors in decline and new, growth sectors and the net effect on the Just Transition outcomes. This report covers the following three areas of scope:

1. Scenario development

In this section we explore the implications – including the environmental, economic, regional, investment, social, energy and emissions impacts, of the O&G 'Just Transition Scenarios' developed in Chapter 1.

2. Just Transition analysis

In sections 4, 5 and 6 we analyse the growth of the low carbon industries that are expected to offset the decline of the O&G sector in Scotland. This analysis is based on modelling undertaken by the Energy Systems Catapult (ESC) scenarios alongside SG policy commitments and ambitions. Our analysis examines:

- The Scottish economy, particularly focusing on macro indicators such as GVA, employment and the workforce. We also look at the expected movements in jobs and GVA as a result of the transition from O&G to the low carbon energy sector;
- Supply chain, highlighting opportunities for growth, barriers and risks;
- Affected communities and the distribution of impacts, highlighting where any regions or groups are more adversely affected than others;
- Consumers and the impact on household bills and costs; and
- The investment that will be required to achieve this transition, when it needs to be done, in what form and using what financing mechanisms.

3. Policy interventions

Lastly, we use the results from the Just Transition analysis to explore key insights and develop recommendations on government intervention specifics and timelines, i.e. what type of SG intervention is required and at what time to ensure a Just Transition is achieved.

Scottish low carbon energy economic footprint – Approach and scope of analysis and policy implications

EY's approach – Scottish low carbon energy economic footprint and forecasts

Our report provides an overview of the current level of employment and economic contribution supported by the Scottish low carbon energy sector. We will consider the extent to which the sector would need to grow to offset the expected reduction in employment from the O&G sector under the various decline scenarios, to achieve "net nil job losses" i.e. the breakeven point in jobs across the energy section, as well as the net GVA at position under net nil job losses. It also considers the policy and investment required to deliver these offsetting employment impacts.

Our approach is set out in the diagram below:

1. Review the forecast O&G economic footprint (GVA and jobs) under each decline scenario

- *Estimate the employment and GVA impact over time under each of the Chapter 1 O&G production decline pathways, and the net loss in O&G jobs and GVA from 2019 to 2050.*

2. Estimate the baseline low carbon energy economic footprint

- *Estimate the existing (2019) GVA[1] and employment of the low carbon energy sector, including the direct, indirect and induced impacts.*

3. Forecast the implied low carbon energy economic footprint based on a plausible scenario by ESC

- *Estimate how the economic footprint of the low carbon energy sector will evolve out to 2050, under the "Balanced Option" (BOP) scenario by ESC, which outlines a plausible path to 2050 for Scotland's growth in GW of electricity generation capacity over time, TWh production of Hydrogen and $MtCO_2e$ of carbon captured over time.*

4. Assess additional growth requirements against this scenario to offset losses from the O&G sector under different pathways

- *Estimate the level of low carbon energy activity required to achieve net nil job losses across the energy sector under each of the various pathways of decline in O&G production, and the GVA impact for each scenario based on net-nil job losses. We did this by adjusting the BOP scenario to offset O&G job losses in each pathway. We also considered the low carbon activity required for net-nil GVA losses, and the investment impact under each adjusted level of low carbon activity.*

5. Review policy implications for SG in ensuring a Just Transition

- *Consider policy interventions required to deliver the projected low carbon energy employment and a Just Transition.*

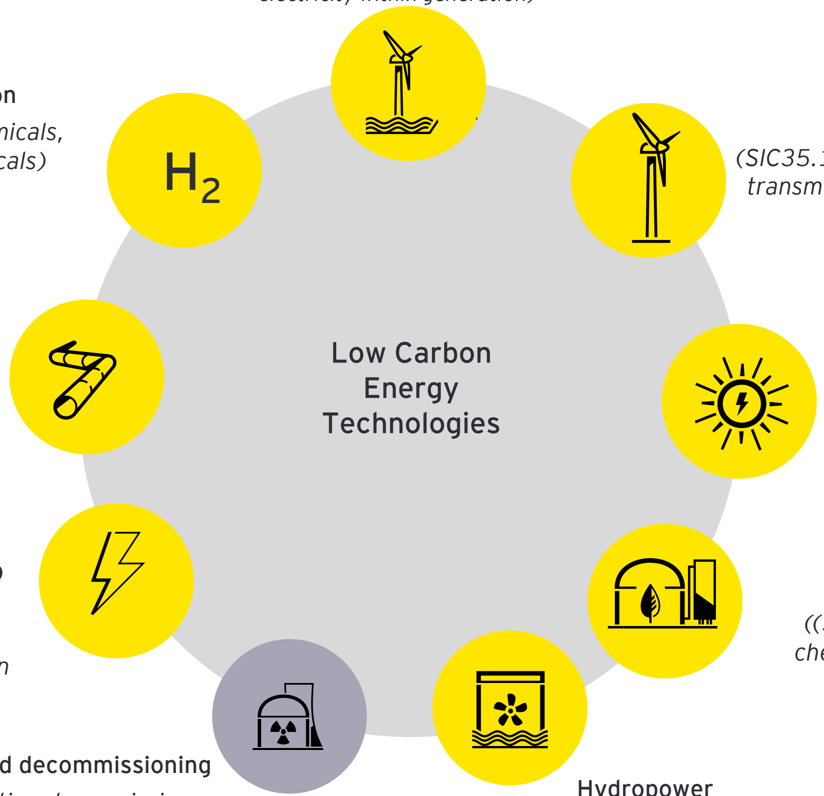
1. GVA is a measure of economic activity which can be viewed as the incremental contribution to GDP. It therefore provides a useful measure for understanding the economic contribution made by particular industries, or businesses.

Scottish low carbon energy economic footprint - Approach

Definition of Low Carbon Energy Sector

The low carbon energy sector has been defined across the following sub-sectors, which are assumed to primarily fall within the broader Standard Industrial Classifications (SIC) referenced below, although these low carbon sectors are not formally defined within a particular SIC code, and the SIC codes are broader than the low carbon sub-sectors.

Refer to section 4 and Appendix A for further detail on methodology for use of sector and SIC data.



3 Scenario development

Production forecasts introduction

Introduction

Chapter 1 utilised EY's Fuelling the Future (FtF) modelling framework, to model scenarios for the pace of energy transition. The FtF framework uses the Intergovernmental Panel on Climate Change (IPCC) 500Gt CO_2e carbon budget as a basis to project future global O&G production. The IPCC's 500Gt CO_2e carbon budget predicts a 50% chance of limiting global warming to 1.5°C and is consistent with meeting the goals of the Paris Agreement in limiting global temperature rises to 1.5°C. This scenario assumes that alternative energy becomes cheap enough quickly enough to displace existing infrastructure, and that climate change becomes a top priority for governments and consumers around the world.

Scotland's Current Production Share Pathway

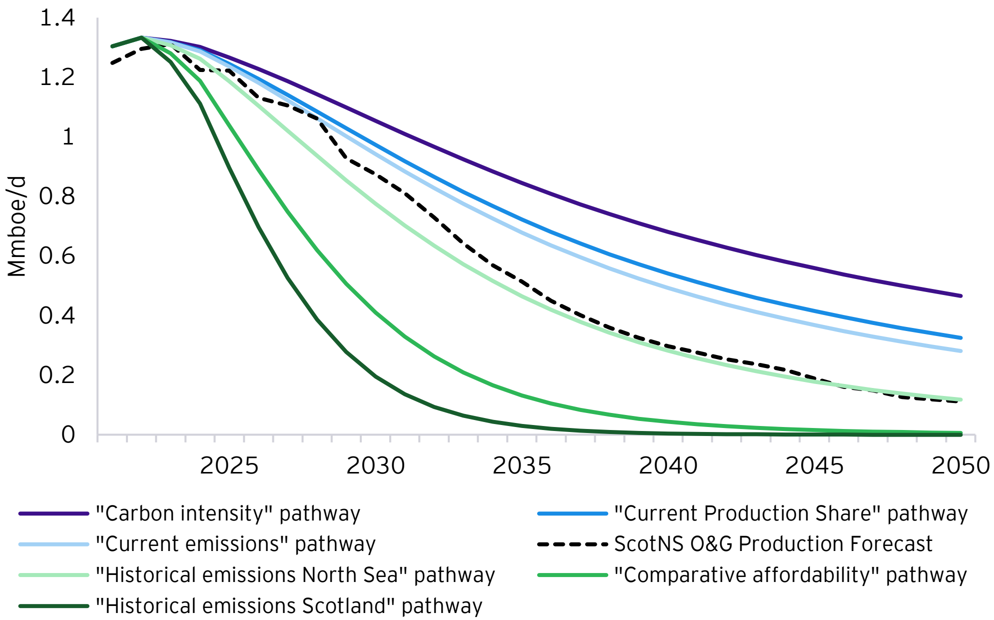
The graph alongside compares the ScotNS O&G production forecast with the EY FtF Scotland scenario (referred to as the Current Production Share Pathway).

The Current Production Share Pathway scenario represents Scotland's share of the global FtF production scenario and was arrived at by assuming that Scotland's production serves a constant portion of global demand. However, we acknowledge that alternative outcomes may arise given the many other factors in play, including oil prices, cost and regulation. Assuming no further exploration and significant discoveries, the natural decline of North Sea resources will result in the production forecast (shown by the ScotNS O&G Production Forecast, dotted line on the right) being below the Current Production Share Pathway.

In reality Scotland's future production and pace of energy transition will not remain constant relative to the global position. As a result, different production pathways for Scotland could be consistent with the 1.5°C Paris Agreement global goal, dependent on the action taken by other countries. Consequently, as part of Chapter 1 we developed a range of potential scenarios, which produce different production pathways by applying a factor to the Current Production Share Pathway. Analysis of each of the scenario pathways allows us to understand their relative impacts on jobs, GVA and wider society.

Scotland's actual production decline will be determined by a variety of complex economic and legal factors, and SG would therefore be unable to simply 'implement' a particular pathway as a matter of policy, even with greater devolved powers over the ScotNS O&G sector.

Scotland's potential production pathways



Source: EY analysis

The purpose of this assessment is to illustrate the impact that these production pathways could have on Scottish society, as requested by SG. For the purpose of this report, all pathways have been given equal consideration.

It should also be emphasised that these pathways relate to Scottish O&G production and do not reflect Scottish O&G consumption, which evidence does not suggest is correlated to Scottish O&G production. As such, lower Scottish O&G production does not necessarily mean lower emissions from a global perspective.

Finally, there is not a direct relationship between the rate of decline of O&G production and the rate of growth of renewable energy sectors, and so it cannot be said with certainty that a steeper ScotNS O&G production decline would accelerate energy transition.

Scenario development

Scenario development

This section of the report revisits the potential production pathway scenarios initially developed in Chapter 1. Each scenario is based on different considerations, such as relative emissions intensity of the ScotNS O&G sector, historical emissions caused, current emissions, and comparative affordability. On the following page we provide the definition of each scenario, a methodology for how each scenario will adjust the Current Production Share Pathway, and any assumptions or limitations associated with our approach.

In the remainder of this section, taking each scenario in turn, we analyse their economic impact (including jobs, GVA investment and GDP), and the implications for infrastructure, jobs and skills, energy security and energy costs, the environment and regional communities. Each scenario has been assessed separately, as requested by SG so that each scenario can be reviewed on a standalone basis.

Note that for the purpose of this report, we assume that each of these pathways are consistent with meeting 1.5°C Paris Agreement goal, on the basis that Scotland's pathway operates in conjunction with global O&G production. For example, if Scotland's O&G production follows the Carbon Intensity pathway, other countries with higher carbon intensity of O&G production will have to decline at a correspondingly faster rate (which would not necessarily happen in practice).

On account of Scotland's small share of global production, it should be noted that the direct impact of Scotland's pathway on the achievement of the 1.5°C Paris Agreement goal will not be material, although the signalling effect could have an impact.

Just Transition scenarios

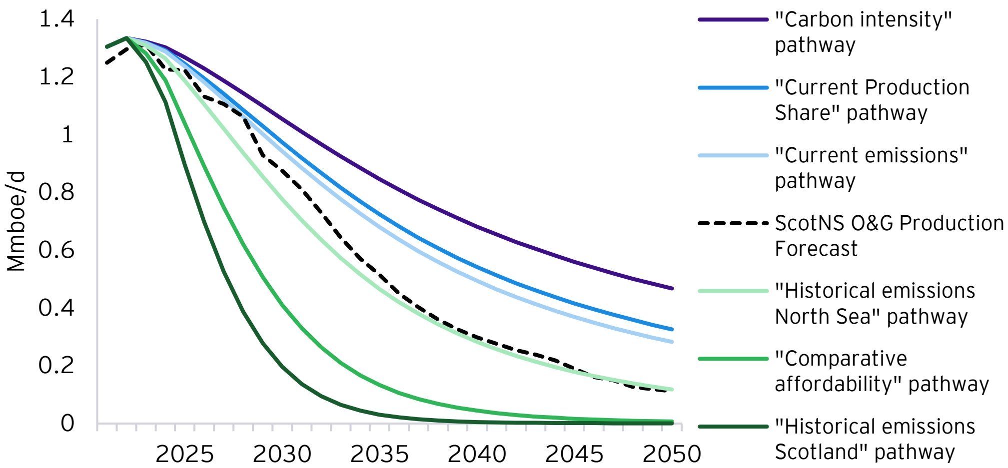
	Scenario	Definition	Methodology	Assumptions/limitations
1	Current Production Share Pathway	Scotland's share of global FtF production scenario to meet 1.5°C Paris Agreement goal	▶ Global FtF production pathway divided by Scotland's current share of global production	▶ Assumed that Scotland's production serves a constant portion of global demand ▶ In reality Scotland's future production will not remain constant relative to future global production
2	**Carbon Intensity (comparative carbon intensity of production)**	To minimise the environmental impact of O&G production, extraction should decline at a faster rate in areas that have a higher carbon intensity of production	▶ Obtained an emissions factor (how much greenhouse gas (GHG) is omitted per unit) for O&G producing nations ▶ Calculated the weighted average carbon emissions intensity of production across nations ▶ Compared UK carbon intensity to the weighted average ▶ Calculated in percentage terms how UK carbon intensity compares to the weighted average ▶ Adjusted the Current Production Share Pathway rate of decline by this percentage	▶ UK carbon intensity aligns with ScotNS carbon intensity ▶ Oil carbon intensity is a reasonable proxy for O&G carbon intensity ▶ Does not take into consideration how variable carbon intensity of production could be within each country or transportation emissions ▶ Current carbon intensity gives a reasonable expectation of future carbon intensity (does not account for national plans or deals to improve carbon intensity of production, e.g. North Sea Transition Deal (NSTD))
3	**Current Emissions (on per capita basis)**	Nations that have higher emissions per capita should transition at a faster rate	▶ Obtained CO_2 emissions data for O&G producing countries and calculated emissions per capita ▶ Calculated average current CO_2 emissions per capita for O&G producing nations ▶ Calculated UK CO_2 emissions per capita, applied an adjustment using Office for National Statistics (ONS) regional CO_2 emissions data to estimate Scotland CO_2 emissions per capita ▶ Compared Scotland CO_2 emissions per capita to the average across O&G producing nations, calculated in percentage terms how Scotland emissions per capita compare to the average ▶ Adjusted the Current Production Share Pathway rate of decline by this percentage	▶ CO_2 emissions are measured on the basis of 'production' ▶ CO_2 emissions are from fossil fuel use, including coal, and do not consider land use change (e.g. impacts of deforestation)
4	**Historical Emissions North Sea**	Countries that have produced greater quantities of O&G have made a greater contribution to emissions and have extracted more economic benefits. Production should therefore decline at a faster rate	▶ Obtained estimates of historical O&G production by country ▶ Applied emissions factor estimates to production volumes to calculate historical emissions caused by production ▶ Using 2020 population estimates, calculated historical emissions from production per capita ▶ Calculated the average historical emissions caused per capita across producing countries ▶ Calculated a factor by comparing UK historical emissions caused per capita to the global average ▶ Adjusted the Current Production Share Pathway rate of decline by this percentage	▶ Takes UK historical emissions per capita as the basis for the ScotNS – given that ScotNS O&G has been treated as a UK resource, the benefits have not been exclusively held within Scotland ▶ Does not consider emissions from production ▶ O&G extracted has a uniform emissions intensity irrespective of location
5	**Historical Emissions Scotland (UK factor used for factoring)**	Nations that have contributed a greater amount to historical global carbon emissions should transition at a faster rate	▶ Obtained data on historical CO_2 emissions for O&G producing countries and calculated historical emissions per capita ▶ Calculated an average historical CO_2 emissions per capita for O&G producing nations ▶ Compared historical UK emissions per capita to the average across O&G producing nations, calculated in percentage terms how UK historical CO_2 emissions per capita compared to the average ▶ Adjusted the Current Production Share Pathway rate of decline by this percentage	▶ UK emissions per capita are comparable to Scotland's emissions per capita ▶ All carbon emissions are of equal importance, therefore there is no weighting towards historical or recent emissions ▶ CO_2 emissions are measured on the basis of production ▶ CO_2 emissions are from fossil fuel use and do not consider land use (e.g. impacts of deforestation)
6	**Comparative Affordability (for producing countries)**	Countries that are more able to afford to transition from fossil fuels should transition at a faster rate	▶ Obtained GDP per capita for O&G producing nations ▶ Calculated the average GDP per capita for O&G producing nations ▶ Adjusted UK to Scotland figures by multiplying UK GDP per capita by the ratio of Scottish to UK GDP per capita, calculated using ONS data (Scotland GDP per capita / UK GDP per capita) ▶ Compared Scottish GDP per capita to the average across O&G producing nations, calculated in percentage terms how UK GDP per capita compares to the average ▶ Adjusted the Current Production Share Pathway rate of decline by this percentage	▶ GDP per capita is a reasonable basis for assessing different nations' ability to transition from fossil fuels ▶ Does not take into account how dependent a country might be on O&G and how diversified their economy is ▶ Further work is required to incorporate reliance on O&G into the affordability scenario

Impact of Just Transition scenarios on Scotland's production pathway

The chart below shows each of the potential production pathways. We also have included the ScotNS O&G Production Forecast from Chapter 1 for reference, as this shows the actual anticipated production levels.

The Historical Emissions Scotland and Comparative Affordability scenarios result in a significant adjustment to the Current Production Share Pathway, producing steeper O&G production declines. The Historical Emissions North Sea and Current Emissions scenarios produce less material factors, resulting in declines slightly steeper than the Current Production Share Pathway. Only the Carbon Intensity scenario results in a less steep decline than the Current Production Share Pathway. Note that all pathways show an initial increase in production until 2023 as production levels recover from COVID-19, before production decline commences at the varying rates.

Scotland's potential production pathways



Source: EY analysis

The remainder of this section discusses each scenario in detail, evaluating them with reference to the ScotNS O&G Production Forecast.

The table (right) shows the factors we have calculated for each scenario (presented in order of low to high) and provides a summary of what is driving the percentage factors. To facilitate our analysis, we have categorised the scenarios depending on how steep the decline of O&G production is relative to the ScotNS O&G Production Forecast.

	Scenario	Factor*	Decline vs Production Forecast	Analysis
1	Current Production Share Pathway	n/a	Shallower	▶ Pathway against which factors below are applied to produce other pathways
2	Carbon Intensity (comparative carbon intensity of production)	75%	Shallower	▶ UK O&G production emissions are more regulated than a number of other O&G producing countries ▶ North American production and North African producing countries typically have a higher carbon intensity which raises the global average
3	Current Emissions (on per capita basis)	110%	Shallower	▶ The UK's 2019 emissions per capita match the average for O&G producing countries ▶ Scotland's 2019 per capita emissions were 10% higher than the UK average ▶ Middle Eastern countries tend to have the highest 2019 emissions per capita, with India, Angola and Nigeria having the lowest
4	Historical Emissions North Sea	169%	In line	▶ There are large disparities across countries, with Middle Eastern countries typically having high levels of production relative to population size ▶ The global average is brought down by high population countries that are relatively modest producers of O&G such as China, India, Egypt and Indonesia
5	Comparative Affordability (for producing countries)	352%	Steeper	▶ The UK has the seventh highest GDP per capita of the O&G producing countries ▶ Scotland's 2019 GDP per capita was 7% below the UK average
6	Historical Emissions Scotland (UK factor used for factoring)	544%	Steeper	▶ The UK has the fourth highest cumulative emissions and second highest historical emissions per capita of all the O&G producing countries ▶ Factoring data is only available at a UK level, as such, we have assumed that the same factor is applicable to Scotland to develop our Historical Emissions Scotland scenario

**A factor which is greater than 100% accelerates the rate of decline in production relative to the Current Production Share Pathway.*

High-level implications of shallower versus steeper production declines

Below is a summary of the principal general implications of a shallower versus a steeper production decline, which informs our assessment of each of the separate pathways in the subsequent pages. Please note these implications depend on a number of future unknowns and as such should be considered as indicative only.

Shallower production decline

- Slower decrease in jobs and GVA from the ScotNS O&G sector.
- Greater tax receipts from the ScotNS O&G sector.
- Reduced likelihood of reliance on imports of O&G.
- More time for supply chain adaptation to the development and roll-out of renewable energy sectors and technology roll-out.
- Greater Scope 1 and 2 emissions from the ScotNS O&G sector (however, Scottish Scope 3 emissions would be largely unaffected).
- Potential negative environmental signalling effect to the rest of the world (which could be mitigated by simultaneous increased commitment to renewable energy sectors).

Steeper production decline

- Faster decrease in jobs and GVA from the ScotNS O&G sector.
- Reduced tax receipts from the ScotNS O&G sector.
- Increased likelihood of reliance on increased O&G imports.
- Risk that renewable energy sectors are not sufficiently mature (e.g., technology, supply chain) to support roll-out.
- Reduced Scope 1 and 2 emissions from the ScotNS O&G sector (however these might be replaced by higher Scope 1 and 2 emissions associated with O&G imports and Scope 3 emissions would be unaffected) .
- Potential positive environmental signalling effect to the rest of the world (however this could be undermined by economic impacts of steeper pathway, especially if this threatens energy transition in long term).
- Reduced economic and market stability.

The tables below show the years at which various production decline milestones are reached under each of the pathways, and the difference in years between the pathways relative to the ScotNS O&G Production Forecast.

Timings for reaching O&G production decline milestones, including the variance of each pathway's timing against the ScotNS O&G Production Forecast

Production as % versus 2022	90%	75%	50%	25%	10%	0%
Pathway	Year					
ScotNS O&G Production Forecast	**2026**	**2029**	**2033**	**2039**	**2048**	**>2050**
Current Production Share Pathway	2026	2030	2037	2050	>2050	>2050
Variance (in years) against ScotNS O&G Production Forecast	-	*1*	*4*	*11*		
Carbon Intensity	2027	2032	2041	>2050	>2050	>2050
Variance (in years) against ScotNS O&G Production Forecast	*1*	*3*	*8*			
Current Emissions	2026	2030	2035	2047	>2050	>2050
Variance (in years) against ScotNS O&G Production Forecast	*0*	*1*	*2*	*8*		
Historical Emissions North Sea	2025	2028	2032	2039	2049	>2050
Variance (in years) against ScotNS O&G Production Forecast	*(1)*	*(1)*	*(1)*	-	*(1)*	
Historical Emissions Scotland	2024	2025	2027	2029	2032	2034
Variance (in years) against ScotNS O&G Production Forecast	*(2)*	*(4)*	*(6)*	*(10)*	*(16)*	
Comparative Affordability	2024	2026	2028	2031	2035	2040
Variance (in years) against ScotNS O&G Production Forecast	*(2)*	*(3)*	*(5)*	*(8)*	*(13)*	

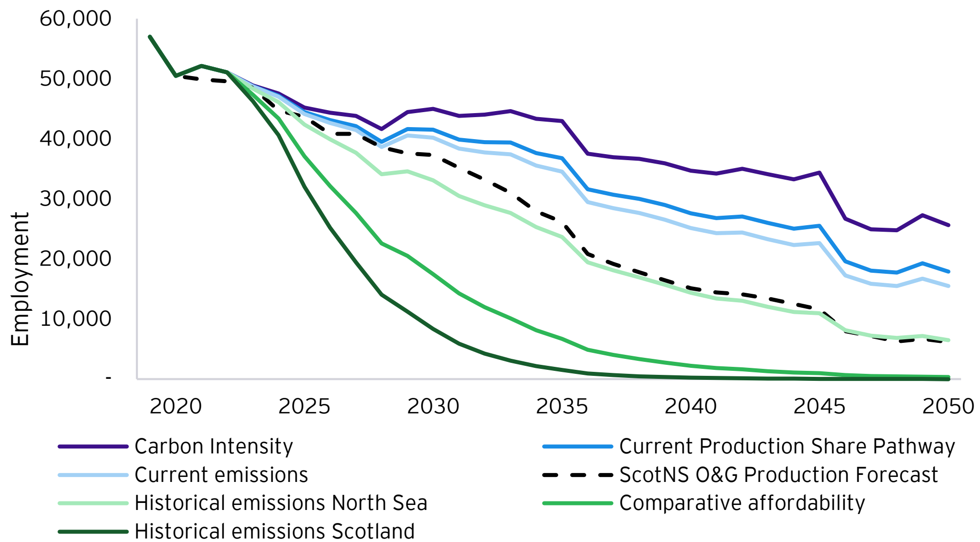
Source: EY analysis

Forecast jobs impact - Summary

Scottish O&G production pathways and reduction in jobs (direct and indirect)

- The mature nature of the ScotNS will result in a significant decline in O&G production in all scenarios. The shallowest decline scenario results in a 74% reduction between 2021 and 2050 (0.82 Mmboe/d) and the steepest decline scenario results in 100% reduction (1.21 Mnboe/d).
- As outlined in Chapter 1, an estimated total of 57,000 direct and indirect jobs were supported by Scotland's O&G sector and its supply chains in 2019.
- The table below shows that the range of expected decline in direct and indirect jobs over time (from 2019 to 2050) is between -31,322 and -56,968 jobs. The majority of this employment (98% of all direct jobs) is located in the North East of Scotland, so the job reductions will be felt predominantly in this region.
- See Chapter 1 for details of the methodology used for forecasting jobs. Note that for the purpose of this report, 'jobs' relates specifically to O&G production activities and does not include, for example, decommissioning activities which would create additional jobs in the case of all scenarios. The job figures in the table also do not represent specific individuals or roles, but are the indicative outputs of the methodology per Chapter 1.

Decline in O&G jobs (direct + indirect) under potential O&G pathways



Source: EY analysis

Total and reduction in O&G jobs (from 2019) for each O&G potential pathway (direct + indirect)

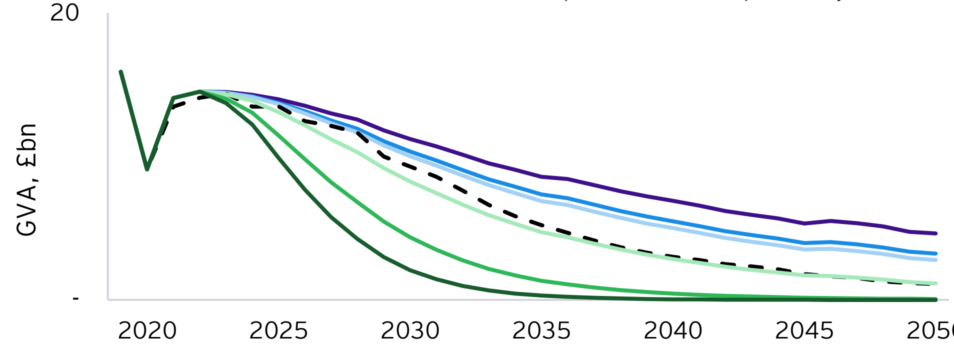
O&G production pathway	Actual jobs 2019	Projected jobs 2025	Reduction in jobs at 2025	Projected jobs 2030	Reduction in jobs at 2030	Projected jobs 2035	Reduction in jobs at 2035	Projected jobs 2040	Reduction in jobs at 2040	Projected jobs 2045	Reduction in jobs at 2045	Projected jobs 2050	Reduction in jobs at 2050
Current Production Share Pathway	56,980	44,463	(12,517)	41,530	(15,450)	36,789	(20,190)	27,588	(29,392)	25,556	(31,424)	17,912	(39,068)
Carbon Intensity	56,980	45,237	(11,743)	44,995	(11,985)	42,993	(13,986)	34,722	(22,258)	34,413	(22,567)	25,658	(31,322)
Current Emissions	56,980	44,156	(12,824)	40,209	(16,770)	34,546	(22,434)	25,141	(31,839)	22,662	(34,317)	15,493	(41,487)
Historical Emissions North Sea	56,980	42,370	(14,610)	33,127	(23,852)	23,666	(33,314)	14,377	(42,602)	10,999	(45,981)	6,473	(50,507)
Historical Emissions Scotland	56,980	32,019	(24,961)	8,353	(48,626)	1,524	(55,456)	244	(56,735)	57	(56,923)	11	(56,968)
Comparative Affordability	56,980	37,106	(19,874)	17,505	(39,475)	6,728	(50,252)	2,231	(54,749)	988	(55,991)	354	(56,625)
ScotNS O&G Production Forecast	56,980	43,664	(13,316)	37,313	(19,666)	26,151	(30,829)	15,158	(41,822)	11,623	(45,357)	6,163	(50,817)

Forecast GVA impact - Summary

Scottish O&G production pathways and decline in GVA (direct and indirect)

- As outlined in Chapter 1, Scotland's O&G sector and its supply chains in 2019 contributed £15.9bn direct and indirect GVA.
- Across the scenarios, direct and indirect GVA is expected to fall between -£11.3bn and -£15.9bn from 2019 to 2050 (as shown in the table below). As the majority of ScotNS O&G activity is based in Aberdeen and the North East of Scotland, this decline in GVA will have a significant impact on the region's local economy.
- See Chapter 1 for details of the methodology used for forecasting GVA. Note for the purpose of this report GVA relates specifically to O&G production activities. It does not include, for example, decommissioning activities which will result in additional GVA (for all scenarios).
- As covered in Chapter 1, direct GVA accounts for 75% of the total GVA contribution of the ScotNS O&G sector, a relatively high proportion that reflects the nature of the sector, in particular, the degree of commercial risk and price volatility (e.g. oil prices), and its capital intensity. A high proportion of direct GVA accrues to capital investors (rather than employees) and hence the high GVA contribution is either reinvested or paid to shareholders. This is reflected in the fact that the direct GVA per direct job of the O&G extraction sector is £1.1m, 15 times higher than the average for the Scottish economy as a whole. A significant proportion is also paid to UKG through taxation.
- As such, the GVA losses set out in this report in practical terms would represent lost private returns and tax receipts. Further consideration would be needed to estimate the proportion of value currently retained within Scotland and hence what the loss might mean for the Scottish economy.

Decline in O&G GVA (direct + indirect) under potential O&G pathways



Source: EY analysis

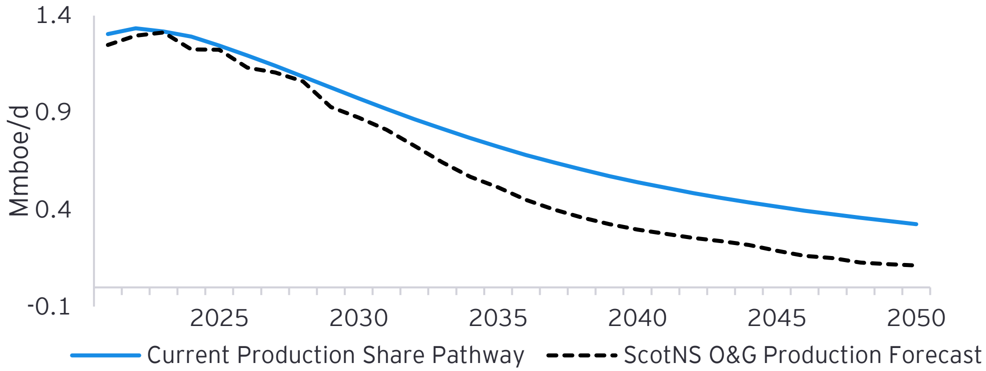
Total loss of O&G GVA (from 2019) for each O&G potential pathway (direct + indirect) (£m) *Source: EY analysis*

O&G production pathway	Actual 2019	Projected GVA 2025	Loss at 2025	Projected GVA 2030	Loss at 2030	Projected GVA 2035	Loss at 2035	Projected GVA 2040	Loss at 2040	Projected GVA 2045	Loss at 2045	Projected GVA 2050	Loss at 2050
Current Production Share Pathway	15,883	13,732	(2,151)	10,332	(5,551)	7,339	(8,544)	5,487	(10,396)	3,954	(11,929)	3,226	(12,657)
Carbon Intensity	15,883	13,971	(1,912)	11,194	(4,689)	8,577	(7,306)	6,906	(8,978)	5,324	(10,559)	4,621	(11,262)
Current Emissions	15,883	13,637	(2,246)	10,004	(5,880)	6,892	(8,991)	5,000	(10,883)	3,506	(12,377)	2,790	(13,093)
Historical Emissions North Sea	15,883	13,086	(2,798)	8,242	(7,642)	4,721	(11,162)	2,859	(13,024)	1,702	(14,181)	1,166	(14,717)
Historical Emissions Scotland	15,883	9,889	(5,994)	2,078	(13,805)	304	(15,579)	49	(15,835)	9	(15,874)	2	(15,881)
Comparative Affordability	15,883	11,460	(4,424)	4,355	(11,528)	1,342	(14,541)	444	(15,440)	153	(15,730)	64	(15,819)
ScotNS O&G Production Forecast	15,883	13,485	(2,398)	9,283	(6,600)	5,217	(10,666)	3,015	(12,869)	1,798	(14,085)	1,110	(14,773)

1. Current Production Share Pathway (shallower)

The Current Production Share Pathway sees O&G production declining at a shallower rate than the ScotNS O&G Production Forecast. This pathway is reviewed against each of the categories noted below:

Current production share pathway



Source: EY analysis

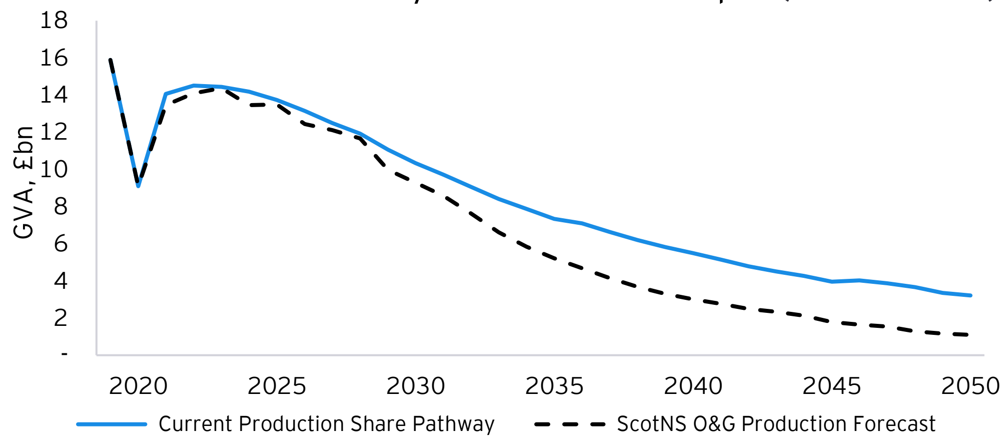
Economic Impact

O&G production makes a significant contribution to the Scottish economy. The industry is responsible for total direct & indirect GVA of £15.9bn, or 9% of Scottish GDP (2019). A Just Transition must consider the full implications of a decline in O&G production on the Scottish economy and minimise the negative impacts.

- A more gradual transition from O&G to renewables may allow time for a supply chain to be established to support the scaling of renewable energy projects, through repositioning of the O&G supply chain to service renewable energy sectors and investment from providers of new renewable technologies. This may result in capital expenditure (Capex) contracts being supported domestically, increasing GDP and GVA.
- A slower rate of transition may result in higher tax receipts and GDP to support a Just Transition through the protection of jobs and economic investment from energy companies. However, it is anticipated that additional SG support will be required as the sector declines, which contributes significantly more per job to Scottish GVA and GDP compared to other sectors. This includes support for the new low carbon supply chain, but also for affected regions and individuals. See section 7 for further detail on potential interventions.
- A reduction in domestic O&G activity in line with global O&G production could provide the market stability required to support large-scale investment in renewables by O&G multinationals in the region looking to diversify, meaning they do not relocate elsewhere, protecting GDP and GVA. However, it is still expected that significant investment will be required in the early stages of development to encourage investment in renewable technologies when demand is less established.
- The mean income and GVA per worker in the O&G extraction sector is significantly above the Scottish average (£88k mean income and £1.1m direct GVA per worker in O&G extraction, compared to the Scottish average of £29k mean income and £72k GVA per worker). Approximately 92% of GVA per job for the O&G sector is profit versus approximately 60% for the Scottish economy as a whole. Therefore, across all pathways the transition away from O&G could result not only in lower average incomes but could have a more significant impact on the Scottish economy as a whole. See page 41 of Chapter 1 for further detail. However, spreading this impact over a longer period of time may allow other sectors to mature and mitigate the loss in GVA.

The graph below models the impact of the Current Production Share Pathway to Scottish O&G GVA. This indicates that there would be a gradual GVA reduction over time with the O&G sector still contributing GVA beyond 2050. At 2030, total GVA is £763m higher under the Current Production Share Pathway versus the ScotNS O&G Production Forecast.

Current Production Share Pathway – Scottish O&G GVA impact (direct + indirect)



Source: EY analysis

1. Current Production Share Pathway (shallower) (cont.)

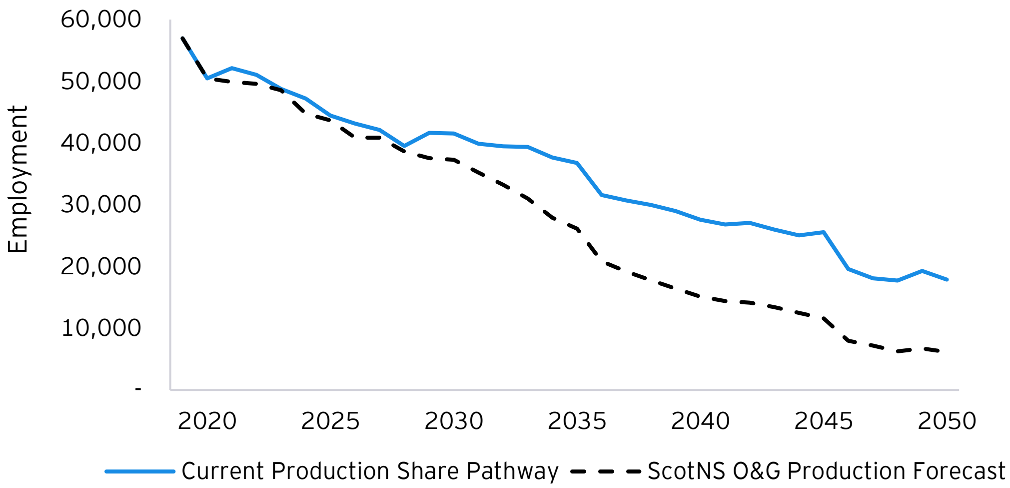
Jobs and skills

The O&G industry is a significant employer in Scotland, particularly in the North East. It is estimated that 56,280 direct and indirect jobs were supported by Scotland's O&G sector in 2019 – 2% of Scotland's total employment. Of these, 25,000 are direct jobs, 98% of which are located in the North East of Scotland. A Just Transition should facilitate the transition of the O&G workforce to more sustainable sectors.

- A slower decline in O&G production would provide more time for the reskilling and upskilling required for O&G workers to be able to transition to renewable energy sectors.
- Many of these renewable energy jobs will not be available for a significant amount of time due to the time necessary for the required technological developments (e.g. hydrogen). A slower decline in O&G production could therefore serve to protect jobs up to the point at which these longer-term renewable energy jobs are ready.
- Direct GVA per direct job in the ScotNS O&G production sector (£1.1m) is significantly higher than Scotland's average GVA per job (£72k). As a result, for all pathway scenarios more jobs (of lower GVA per job) will be required to replace the GVA lost as part of the O&G production decline.

The graph alongside models the impact on jobs of the Current Production Share Pathway – a gradual decline in jobs into the 2050s. At the 2030 mark, the Current Production Share Pathway results in 3,066 more jobs versus the ScotNS O&G Production Forecast.

Current Production Share Pathway – Scottish O&G jobs impact (direct + indirect)

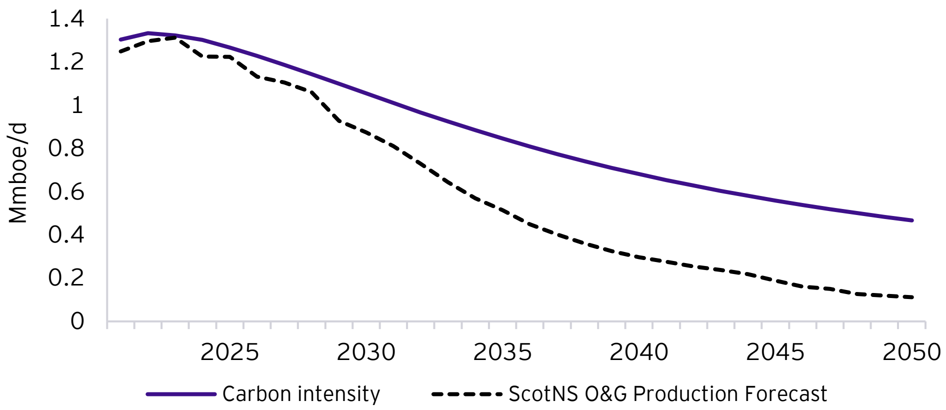


Source: EY analysis

2. Carbon Intensity scenario (shallower)

The Carbon Intensity scenario results in a factor which reduces O&G production at a slower rate to the Current Production Share Pathway, declining at a rate slower than the ScotNS O&G Production Forecast. The shallower pathway has similar impacts to the current share production pathway, with some exceptions highlighted below.

Carbon Intensity scenario – production pathway



Source: EY analysis

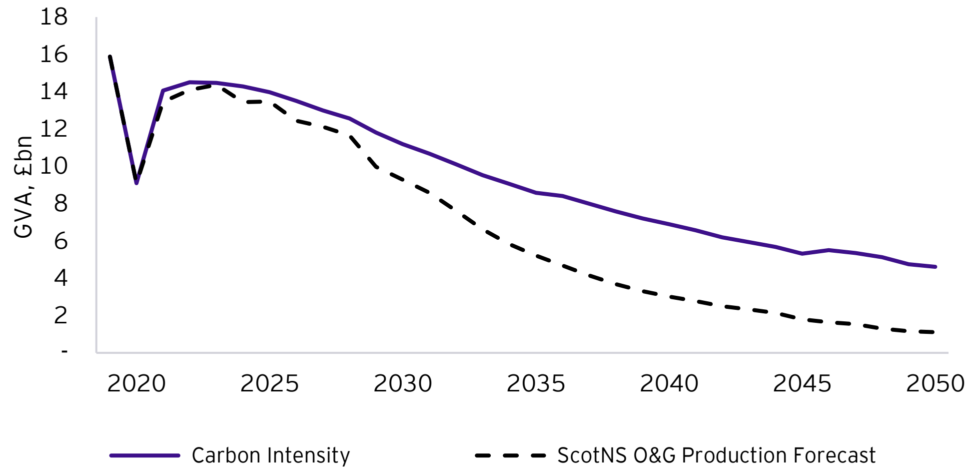
Economic, jobs and skills impact

The graph alongside models the impact of the Carbon Intensity scenario to Scottish O&G GVA. This indicates that there would be a gradual reduction over time in GVA with O&G contributing GVA into the 2050s. At the 2030 mark, GVA would be £1.606m above the ScotNS O&G Production Forecast.

A slower rate of transition may provide both governments with tax receipts to support a Just Transition, may allow time for a supply chain to be established and allow the low carbon sectors to mature and mitigate the loss in GVA from the O&G sector.

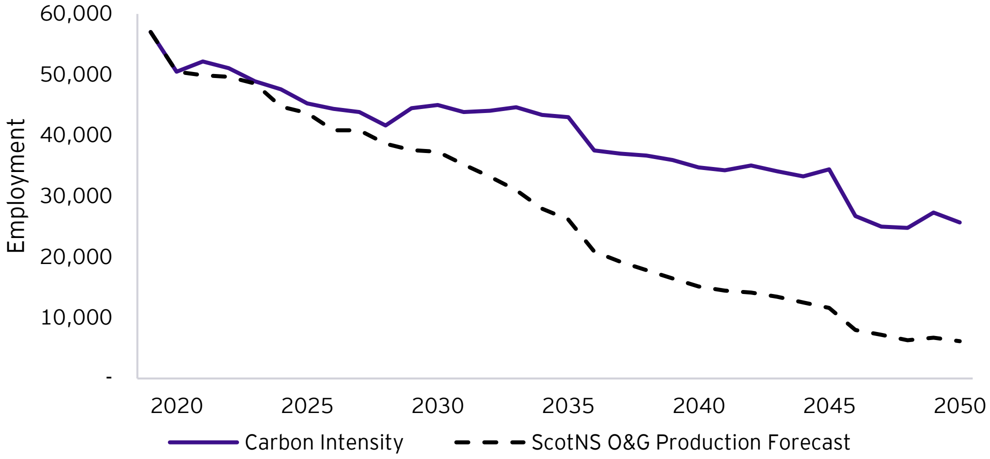
We also model the impact on jobs. The Carbon Intensity scenario results in a more gradual tailing off of O&G jobs with a number of jobs remaining in the sector into the 2050s. At the 2030 mark, 6,454 additional jobs remain in the O&G sector versus the ScotNS O&G Production Forecast. This scenario, like the other shallower trajectories, will provide more time for reskilling and upskilling O&G works and serve to protect jobs until a greater number of low carbon jobs are created.

Carbon Intensity scenario – Scottish O&G GVA impact (direct + indirect)



Source: EY analysis

Carbon Intensity scenario – Scottish O&G jobs impact (direct + indirect)

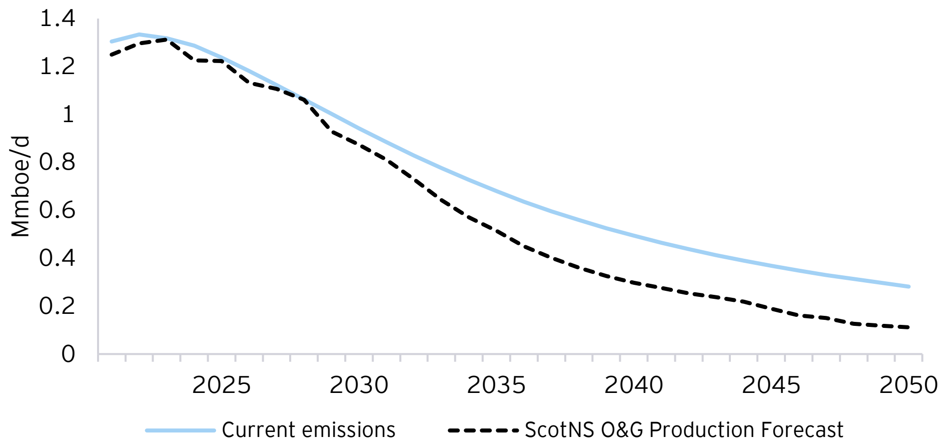


Source: EY analysis

3. Current Emissions scenario (shallower)

The Current Emissions scenario results in a factor which reduces O&G production at a slightly shallower rate to the Current Production Share Pathway, declining at a rate slower than but comparable to the ScotNS O&G Production Forecast. The pathway has similar impacts to the current share production pathway, with some exceptions highlighted below.

Current emissions – production pathway



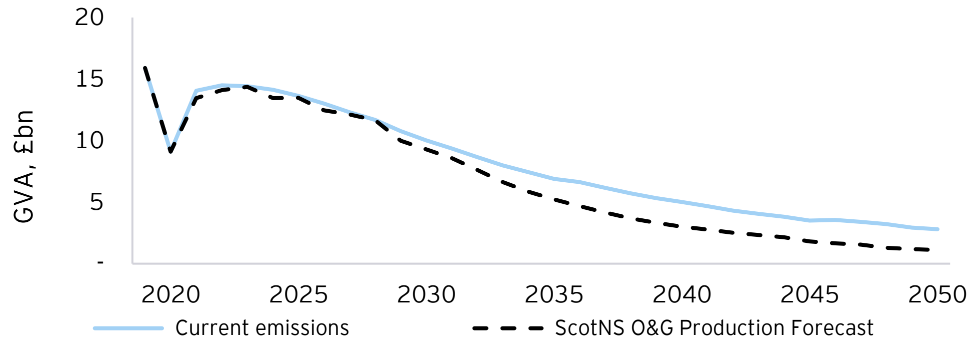
Source: EY analysis

Economic, jobs and skills impact

The graph alongside models the impact of the Current Emissions scenario to Scottish O&G GVA. This indicates that there would be a gradual reduction over time in GVA with the O&G sector contributing GVA beyond 2050. At the 2030 mark, GVA is £441m higher under the Current Emissions scenario versus the ScotNS O&G Production Forecast.

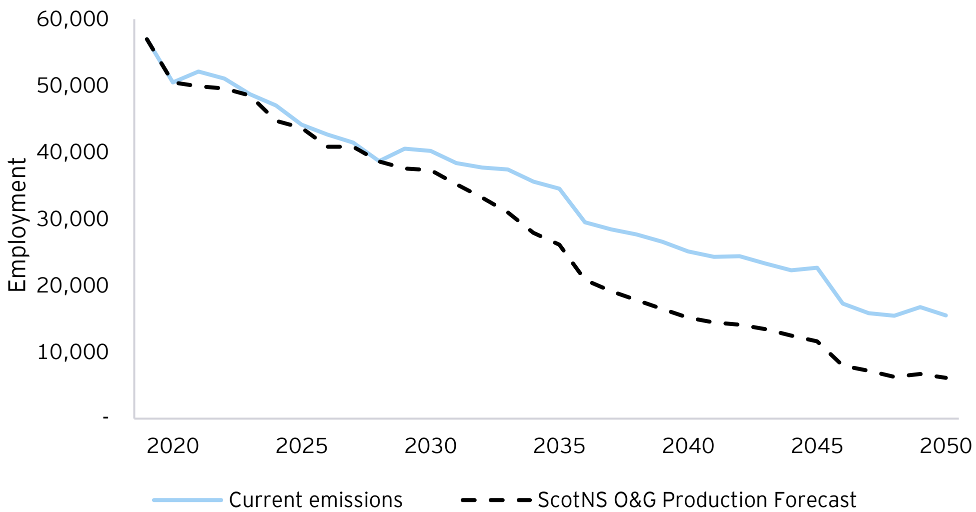
The graph alongside models the impact on jobs of the Current Emissions scenario – a gradual decline in jobs into the 2050s. At the 2030 mark, the Current Emissions scenario results in 1,775 more jobs versus the ScotNS O&G Production Forecast.

Current emissions – Scottish O&G GVA impact (direct + indirect)



Source: EY analysis

Current emissions – Scottish O&G jobs impact (direct + indirect)



Source: EY analysis

Shallower decline pathways – Other impacts

Energy security (including energy costs)

A Just Transition must consider how best to secure resilient and flexible supplies of O&G to meet ongoing domestic demand, without exposing consumers to extreme price increases. As at 2019, O&G made up 78% of all Scottish energy consumption and, although this is anticipated to decline as we move to Net Zero, O&G consumption will be necessary in the short and medium term to deliver the Just Transition. Chapter 4 suggests a potential risk assessment of Scotland's energy security position within the potential CCC. The IEA (International Energy Agency) defines energy security as the uninterrupted availability of energy sources at an affordable price, and so costs of energy are also a key consideration in the energy security discussion although, given Scotland's small share in global O&G production, the impact of the different scenarios to costs for Scottish consumers should be immaterial.

- Balancing the decline in the O&G sector and the growth in the low carbon sector may be achieved through the slower phasing out of O&G activity. This should ensure that domestic energy demands can be met and minimise energy security risks arising from insufficient replacement energy sources. Pathways that mirror the pace of the transition away from O&G of the rest of the world (the Current Production Share Pathway) perhaps offer the greatest likelihood of developing a self-sufficient renewable energy system for the long term.
- Longer-term reliance on O&G could leave Scotland more exposed to the volatile geopolitical climate, exposing Scotland to more energy security risk.
- For shallower production pathways to be achieved, additional O&G exploration and development activity would be needed and so CCCs for new licensing rounds and for consenting new production would be needed. The potential CCC energy security risk assessment (see Chapter 4) would need to consider shorter-term benefits and potential longer-term drawbacks of additional O&G production.
- A slower rate of O&G production decline should mitigate the risk of needing to increase imports to meet domestic demand. The costs of alternative fuels, such as hydrogen, and their supporting infrastructure would be passed on to the end user through increased energy costs. A slower rate of implementation may result in more mature, more efficient, and therefore cheaper technology being used, reducing the cost to the end user.

Environmental

A Just Transition is necessary to ensure that Scotland achieves Net Zero by 2045 whilst also retaining world-class energy talent and multinational employers.

- In theory, shallower production pathways could mean Scotland contributes to the 1.5°C Paris Agreement goal not being met through increased Scope 1, 2 and 3 emissions, assuming this additional production does not displace more emissions-intensive overseas production. Furthermore, a longer production timescale may result in a greater reliance on O&G as consumers are not forced to change their habits.
- If increased ScotNS O&G production displaces more emissions intensive overseas O&G production, these shallower pathways could result in net lower global GHG emissions, however, ensuring this displacement occurs may not be possible in practice.
- For ScotNS O&G production decline rates to result in overall reduced global emissions, they would need to be matched in the decline rate of global O&G consumption. The Current Production Share Pathway is deemed to mirror global demand and so overall global emissions would be reduced by this pathway. The Carbon Intensity pathway declines slower than global demand and so this excess production would need to be offset by faster declining production from more emissions intensive nations for the 1.5°C Paris Agreement goal to be met.
- It should be noted that Scotland's small share (<1%) of global production means that the direct impact of Scotland's production pathway on the 1.5°C Paris Agreement goal being met will not be material, although it could have an effect from a signalling point of view. Furthermore, the impact is further limited by the fact that Scottish and global O&G consumption is not affected by Scottish O&G production levels.

Shallower decline pathways – Other impacts (cont.)

Regional implications

A Just Transition should ensure that regions which are impacted most by a decline in O&G activity are provided with the necessary support to transition to renewable energy production, preserving jobs and continuing regional investment. However, a Scotland-wide approach is required to ensure the effects of a Just Transition are widespread to maximise the economic and environmental benefits.

- The gradual reduction of O&G production and scaling of renewables may support the infrastructure required to transport sustainable fuels and carbon for storage to/from the heavy industrial areas in the Central Belt from/to the areas designated for renewable energy projects in the North East.
- Economic activity of O&G services and the associated supply chain is concentrated in the North East and will decline in line with O&G production. O&G service companies and supply chain may need assistance to transition to serve the renewables sector – see section 5. A more gradual decline in O&G production would make it easier for companies to make this transition, retaining investment in the region. Grangemouth relies primarily on imported O&G, with only 30% of O&G processed coming from Scottish production, so the impact of these pathways will be less keenly felt at Grangemouth and the local area (see section 11 of Chapter 1).
- The North East of Scotland is a region historically dominated by O&G activity and is home to 98% of Scotland's O&G jobs and as such would bear the brunt of the economic and employment implications of O&G sector decline. Targeted investment in renewable activity (see section 5) alongside a gradual reduction in O&G activity may help ensure that the North East does not experience a disproportionate economic decline. Per section 5, it is estimated that jobs created by the low carbon energy sectors could have offset job losses by 2050 for all pathways, mitigating the risk of significant unemployment in the North East of Scotland; however, economic decline may be unavoidable due to the higher GVA per job of the O&G sector relative to the renewable energy sectors.

Infrastructure

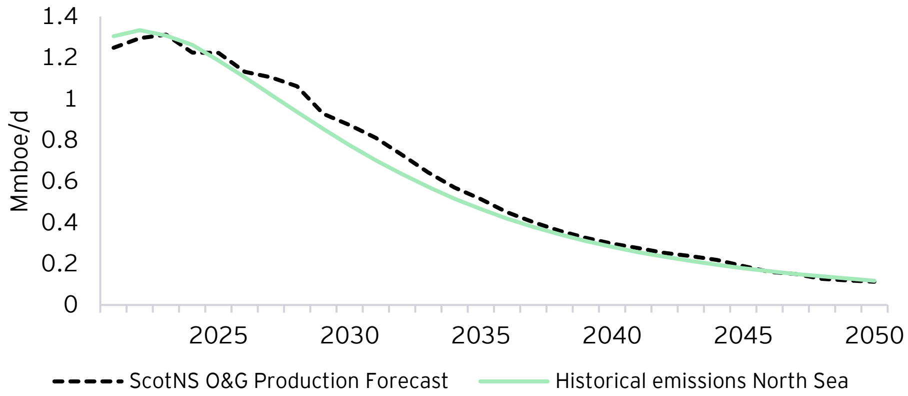
In order to deliver a Just Transition, the necessary infrastructure must be in place to support the delivery of energy resources to satisfy demand. See section 6 of Chapter 1 for further detail in respect of O&G infrastructure in the ScotNS.

- With a more gradual decline in O&G production there is increased likelihood that the supporting infrastructure will be phased out at the same time as demand for renewable infrastructure is growing. As a result, O&G infrastructure is more likely to be retrofitted to support renewable energy. This could reduce costs and may be logistical challenge than decommissioning.
- Where existing O&G infrastructure is needed for renewable energy sectors that are not likely to be deployed for a significant amount of time, additional O&G production could be advantageous as it utilises infrastructure that would otherwise be decommissioned or potentially enter into a state of dilapidation.
- As production under this scenario would be greater than the ScotNS O&G Production Forecast, the importance of decarbonising the ScotNS O&G sector, principally through the electrification of O&G platforms, will be even greater. There is an increased possibility that NSTD emissions reduction targets would not be met due to higher O&G production levels than forecast.
- Additional O&G production could mean investment in additional infrastructure in the ScotNS which in the long term could be repurposed for use in renewable energy sectors.

4. Historical Emissions North Sea scenario (in line)

The Historical Emissions North Sea scenario results in a factor which reduces the O&G production at a rate that is comparable with the Current Production Share Pathway. This scenario is reviewed against each of the categories noted below:

Historical emissions North Sea – production pathway



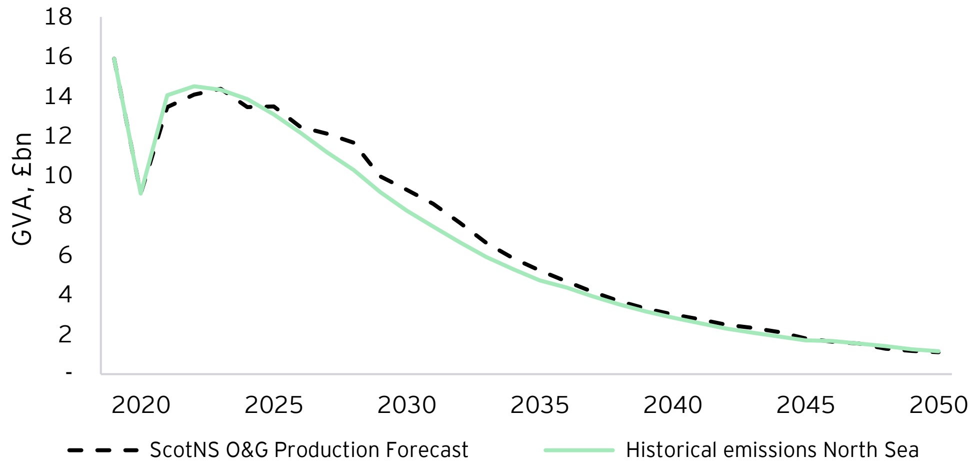
Source: EY analysis

Economic impact

- The transition from O&G to renewables will follow the forecast SCotNS O&G production forecast. This pathway, although not one of the "shallower" pathways, may give some potential for a supply chain to be established to support the scaling of renewable energy projects, this would allow the O&G supply chain to reposition and service renewable energy sectors and investment from providers of new renewable technologies.
- A slower rate of transition may result in higher tax receipts and GDP to support a Just Transition through preserving energy company jobs and economic investment. As with other pathways, it is anticipated that additional SG support will be required for the new low carbon supply chain and affected regions and individuals. See section 7 for further detail on potential interventions.
- A reduction in domestic O&G activity in line with global O&G production could provide the market stability to support large-scale investment in renewables by O&G multinationals in the region looking to diversify, preventing them from relocating elsewhere, protecting GDP and GVA. However, significant investment will be required in the early stages of development to encourage investment in renewable technologies when demand is less established.
- As we previously noted, across all the pathways, the transition away from O&G could result not only in lower average incomes but could have a more significant impact on the Scottish economy as a whole (see page 41 of Chapter 1).

The graph below models the impact of the Historical Emissions North Sea scenario to Scottish O&G GVA. This indicates there would be a reduction over time in GVA with O&G contributing GVA beyond 2050. At the 2030 mark, GVA is £1,284m lower under the Historical Emissions North Sea scenario versus the ScotNS O&G Production Forecast.

Historical Emissions North Sea – Scottish O&G GVA impact (direct + indirect)



Source: EY analysis

4. Historical Emissions North Sea scenario (in line)

Infrastructure

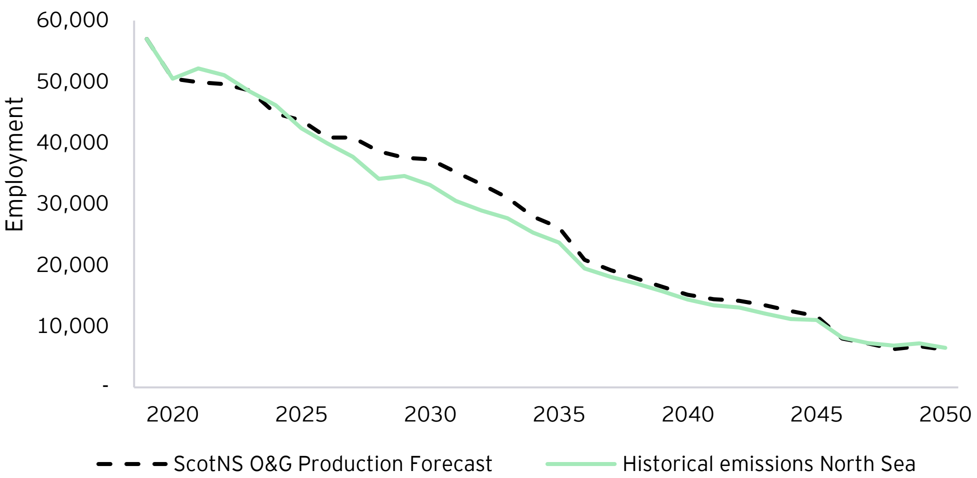
- With a decline in O&G production that is broadly in line with the ScotNS O&G Production Forecast, there is an increased likelihood that the supporting infrastructure will be phased out at the same time as demand for renewable infrastructure is growing. As a result, these is some potential for O&G infrastructure to be retrofitted to support renewable energy. This could reduce costs from decommissioning and installing new infrastructure and but there are significant practical challenges.

Jobs and skills

- The alignment of this scenario and the forecast ScotNS O&G production decline, will result in the same requirement for reskilling and upskilling of O&G workers to be able to transition to renewable energy sectors.
- The impacts of the energy transition are already being seen across the workforce, increasingly skills from the O&G sector are being sought in offshore wind or emerging sectors such as hydrogen and CCUS. There is some overlap in the skillsets for O&G and for renewable technologies, particularly those that involve offshore operations. However, many of these renewable energy jobs will not be created for a significant amount of time due to the time necessary for the required technological developments (e.g., hydrogen).
- Direct GVA per direct job in the ScotNS O&G production sector (£1.1m) is significantly higher than Scotland's average GVA per job (£72k). As a result, for all pathway scenarios, more jobs (of lower GVA per job) will be required to replace the GVA lost as part of the O&G production decline.

The graph above right models the impact on jobs of the Historical Emissions North Sea scenario – a decline in jobs into the 2050s. At the 2030 mark, the Historical Emissions North Sea scenario results in 5,160 fewer jobs versus the ScotNS O&G Production Forecast.

Historical Emissions North Sea – Scottish O&G jobs impact (direct + indirect)



Source: EY analysis

4. Historical Emissions North Sea (in line) – Other impacts

Energy security (including energy costs)

- Investment in alternative energy technologies may help to reduce O&G demand, protecting Scotland from O&G supply issues by reducing reliance on imports and sensitivity to changes in the geo-political climate.
- Any scale back of O&G activity without sufficient alternative sources of energy resources in place would threaten energy security. Whilst there are a number of oil reserves left and Scotland could import oil to satisfy domestic demand, only a few other locations around the globe supply gas. As explored in Chapter 1, Scotland already faces some pressure on energy security due to the level of existing gas imports from Norway, the fact that Scotland is part of a UK-wide gas grid, and because Scotland has no natural gas storage facilities. A further decline in production, even in line with the global decline, could increase Scotland's energy security risk if sufficient alternative energy is not in place to satisfy demand and gas imports have to increase as a result.
- For the Historical Emissions North Sea pathway which tracks in line with and just below ScotNS O&G Production Forecast, no future licensing rounds should be needed but additional production from fields under development may be required, therefore CCCs for licensing rounds would not be applicable, however they may still be necessary for consenting production from fields currently under development.

Environmental

- Scaling back on O&G production is required to ensure that Scotland meets its Net Zero targets. Renewable energy sources can be used as an alternative to ensure that Scotland's energy demands are met cleanly and sustainably.
- For ScotNS O&G production decline rates to result in overall reduced global emissions, they would need to be matched in the decline rate of global O&G consumption (which would be driven by the development of alternative energy that can replace O&G). This would be more likely of being achieved in these more moderate decline pathways; however, a risk remains that global O&G demand declines more slowly than these pathways, with the gap needing to be filled by more emissions-intensive overseas O&G production.
- It should be noted that Scotland's small share (<1%) of global production means that the direct impact of Scotland's production pathway on the 1.5°C Paris Agreement goal being met will not be material, although it could have an effect from a signalling point of view.
- It may take some time for domestic demand to normalise following a reduction in O&G, as a result, there may be a reliance on imported O&G, increasing emissions as O&G must be transported from overseas to satisfy domestic demand.

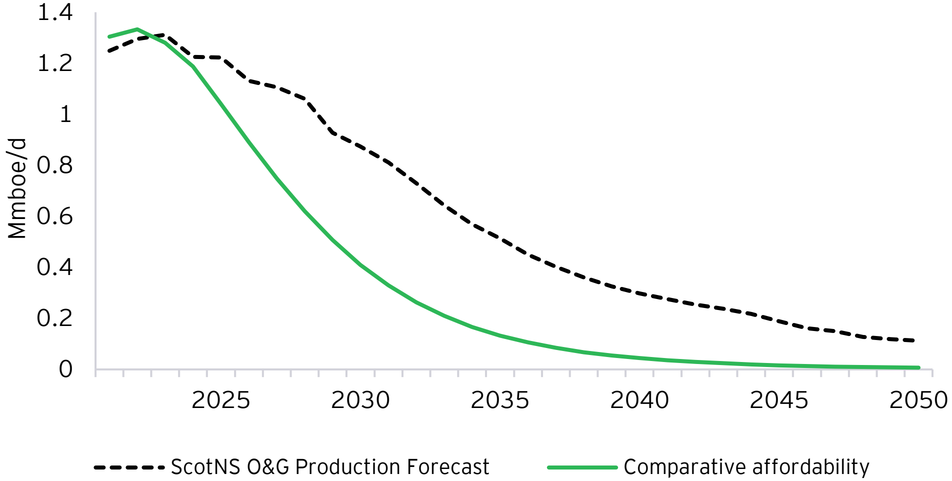
Regional implications

- The North East of Scotland is a region historically dominated by O&G activity and is home to 98% of Scotland's O&G jobs and as such would bear the brunt of the economic and employment implications of O&G sector decline. Targeted investment in renewable activity (see section 5) alongside a gradual reduction in O&G activity may help ensure that the North East does not experience a disproportionate economic decline. Per section 5, it is estimated that jobs created by the low carbon energy sectors could have offset job losses by 2050 for all pathways, mitigating the risk of mass unemployment in the North East of Scotland, however economic decline may be unavoidable due to the higher GVA per job of the O&G sector relative to the renewable energy sectors.
- Much of Scotland's heavy industry is concentrated across the Central Belt and this would need to be connected to renewable energy generation hubs in the North East in order for a Just Transition to be successful. A gradual decline in O&G production may allow time for the necessary infrastructure to be put in place to make this connection.
- Economic activity of O&G services and the associated supply chain is concentrated in the North East and will decline in line with O&G production. O&G service companies and supply chain may need assistance to transition to serve the renewables sector – see section 5. A more gradual decline in O&G production would make it easier for companies to make this transition, retaining investment in the region. Grangemouth relies primarily on imported O&G, with only 30% of O&G processed coming from Scottish production, so the impact of these pathways will be less keenly felt at Grangemouth and the local area (see section 11 of Chapter 1).

5. Comparative Affordability scenario (steeper)

The Comparative Affordability scenario also results in a factor which reduces the O&G production at a faster rate than the Current Production Share Pathway, declining at a rate materially faster than the ScotNS O&G Production Forecast. This scenario is reviewed against each of the categories noted below:

Comparative Affordability – production pathway



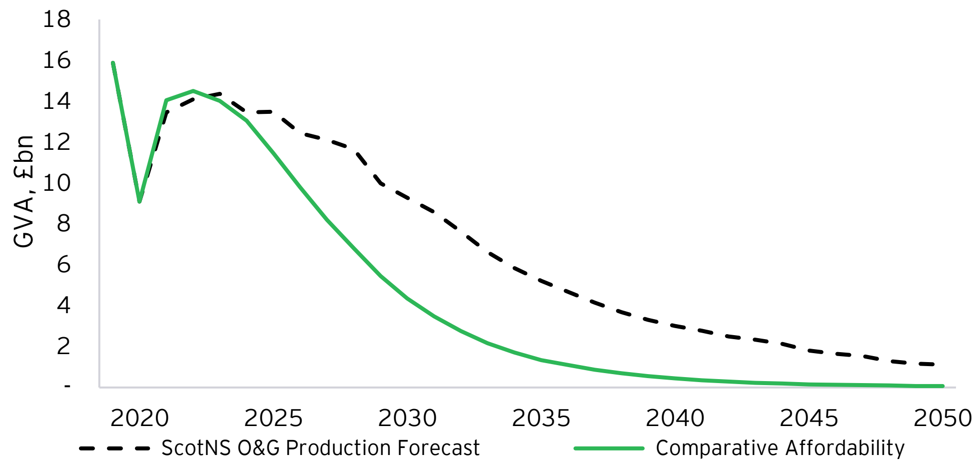
Source: EY analysis

Economic impact

- The renewable energy market may not be well enough established in the short term to support large-scale investment by O&G multinationals looking to diversify, ultimately resulting in them relocating elsewhere, reducing GVA and GDP.
- The renewable energy supply chain may not be mature enough to cope with the rapid scaling of renewable energy projects, required to replace the steep decline in O&G production, and the O&G supply chain may not be able to adapt sufficiently quickly. This may result in Capex contracts being procured overseas and the goods imported for final installation. As a result Scotland may lose out on some of the benefit of a boom in renewable energy investment.
- A rapid scale back of O&G production could result in insufficient funds being made available to government, through lost tax receipts, to facilitate a Just Transition through the targeted investment in renewable energy initiatives.

The graph below models the impact of the Comparative Affordability scenario to Scottish O&G GVA. This indicates that there would be a rapid drop-off in GVA in the mid-2020s reducing to near zero in the late 2030s. **At the 2030 mark, there is a reduction of £5.1bn compared to the ScotNS O&G Production Forecast.** As a result, there may be a requirement for additional economic support to ensure that the Scottish economy does not significantly contract.

Comparative Affordability– Scottish O&G GVA impact **(direct + indirect)**



Source: EY analysis

5. Comparative Affordability scenario (steeper) (cont.)

Infrastructure

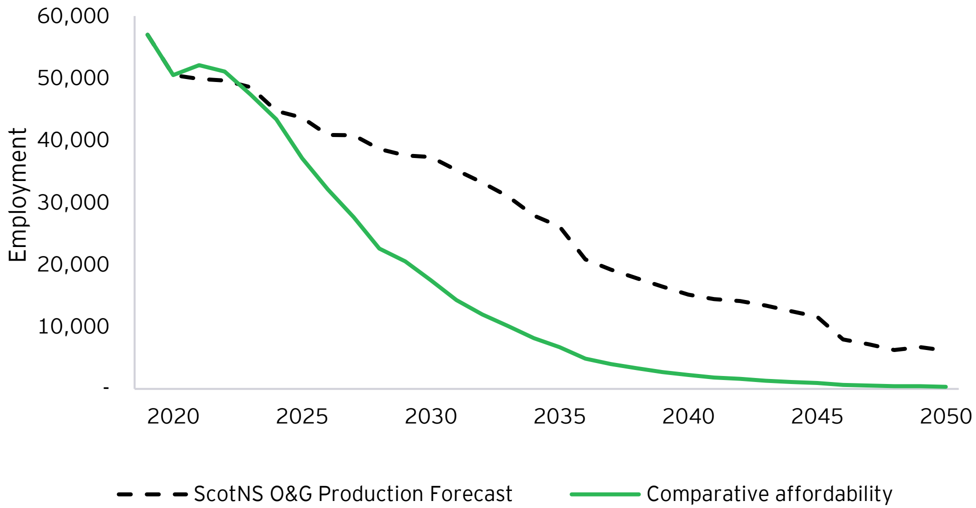
- It is unlikely, with a faster decline in O&G production, that the supporting infrastructure will be phased out at the same time as demand for renewable infrastructure is growing. As a result, O&G infrastructure is unlikely to be retrofitted to support renewable energy. This could pose a challenge as dilapidated equipment must be decommissioned and new infrastructure developed to facilitate renewable energy. This could come at a high cost.
- Investment in electrification of O&G platforms and other emissions abatement activity for the ScotNS O&G sector would be less viable given the shorter production timeframes envisaged under this pathway, meaning that O&G production may be more emissions intensive per barrel compared to less steep pathways. NSTD emissions reductions targets would need to be made more ambitious to reflect faster production decline.

Jobs and skills

- Many of these renewable energy jobs will not be created for a significant amount of time due to the time necessary for the required technological developments. A steep decline in O&G production could lead to significant job losses before sufficient new renewable jobs are created to mitigate unemployment.
- If there is a rapid reduction in O&G jobs, there is also a risk that O&G employees cannot be reskilled quickly enough to fill newly created renewables jobs, resulting in unemployment or skilled employees moving overseas reducing GVA.
- Direct GVA per direct job in the ScotNS O&G production sector (£1.1m) is significantly higher than Scotland's average GVA per job (£72k). As a result, for all pathway scenarios more jobs (of lower GVA per job) will be required to replace the GVA lost as part of the O&G production decline.

The graph to the right models the impact on jobs of the Comparative Affordability scenario – a significant decline in jobs from the mid-2020s which reduces O&G jobs to near zero in the 2040s. At the 2030 mark, the Comparative Affordability scenario results in 20,479 fewer jobs than the ScotNS O&G Production Forecast. Significant investment will be required to ensure that workers are able to find work elsewhere, preventing significant job losses.

Comparative Affordability – Scottish O&G jobs impact (direct + indirect)

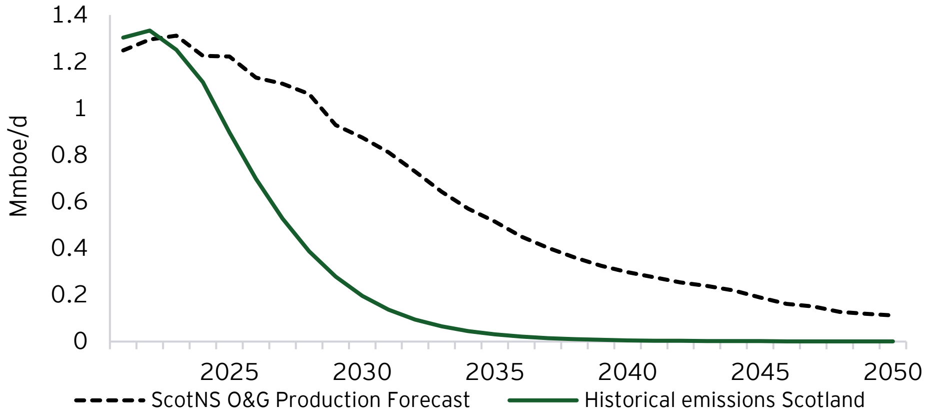


Source: EY analysis

6. Historical Emissions Scotland scenario (steeper)

The Historical Emissions Scotland scenario results in a factor which reduces the O&G production at a faster rate than the Current Production Share Pathway, declining at a rate significantly faster than the ScotNS O&G Production Forecast. This scenario is reviewed against each of the categories noted below:

Historical Emissions Scotland – production pathway



Source: EY analysis

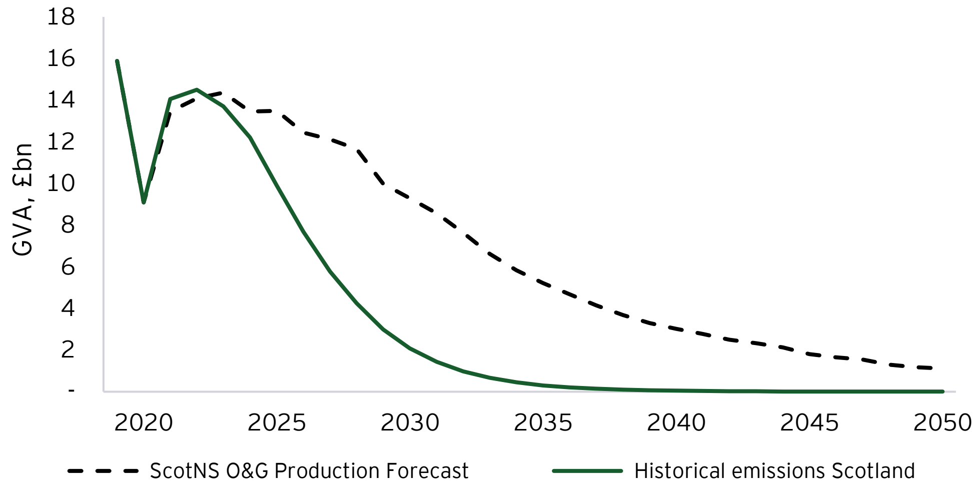
Economic Impact

The graph alongside models the impact of the Historical Emissions Scotland scenario to Scottish O&G GVA. This indicates that there would be a rapid drop-off in GVA in the mid-2020s reducing to near zero in the late 2030s. At the 2030 mark, there is a reduction of GVA under the Historical Emissions Scotland scenario of £7.3bn compared to the ScotNS O&G Production Forecast. As a result, there may be a requirement for additional economic support to ensure that the Scottish economy does not significantly contract.

Infrastructure

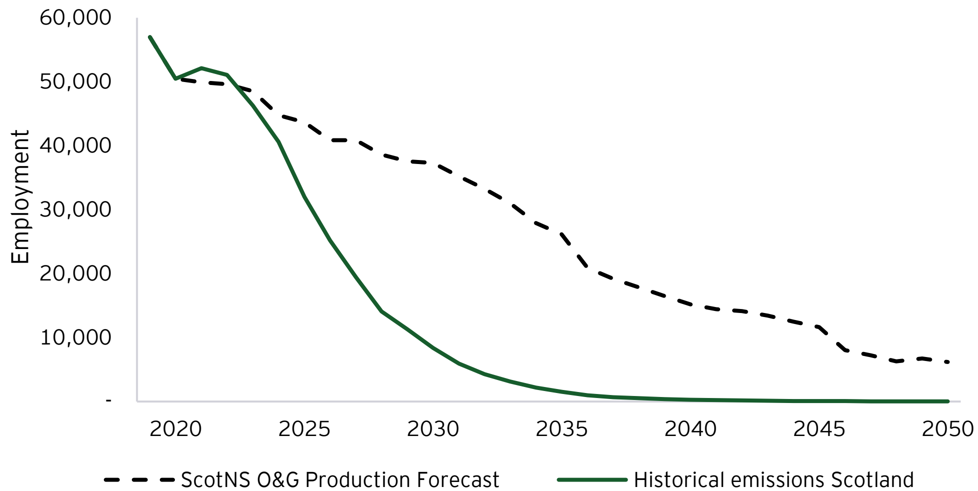
The graph alongside models the impact on jobs of the Historical Emissions Scotland scenario – a significant decline in jobs from the mid-2020s which reduces O&G jobs to near zero in the 2040s. At the 2030 mark, the Historical Emissions Scotland scenario results in 29,436 fewer jobs than the ScotNS O&G Production Forecast. Significant investment will be required to ensure that workers are able to find work elsewhere, preventing significant job losses.

Historical Emissions Scotland – Scottish O&G GVA impact (direct + indirect)



Source: EY analysis

Historical Emissions Scotland – Scottish O&G jobs impact (direct + indirect)



Source: EY analysis

Steeper decline pathways – Other impacts

Energy security (including energy costs)

- Any scale back of O&G activity without sufficient alternative sources of energy resources in place would threaten energy security. Whilst there are oil reserves left and Scotland could import oil to satisfy domestic demand, only a few other locations around the globe supply gas. As explored in Chapter 1, Scotland already faces some pressure on energy security due to the level of existing gas imports from Norway, the fact that Scotland is part of a UK-wide National Gas grid, and because Scotland has no natural gas storage facilities. A decline in production steeper than the global decline is likely to increase Scotland's energy security risk if sufficient alternative energy is not in place to satisfy demand and gas imports have to increase as a result.
- For steeper production pathways to be achieved, no additional O&G exploration activity should be necessary and existing development activity could be cut back rather than expanded. As such, CCCs for licensing rounds would not be needed; however, CCCs may still be necessary for consenting production from fields currently under development. Any CCC energy security risk assessment (see Chapter 4) would need to consider the risks to the Just Transition of an accelerated decline in O&G production.
- A rapid reduction in O&G production would require an alternative fuel source to be provided to Scottish consumers to avoid a significant increase in O&G imports. Alternative fuels such as hydrogen may be considered for use in the future, although this would require significant investment in infrastructure, the costs of which would be passed on to the end user through increased energy costs. Early adoption is also likely to result in the use of expensive and inefficient technology, resulting in increased costs. However, the magnitude of an increase to energy costs may be limited as prices are influenced by the global market, of which the Scottish share is small.

Environmental

- These steeper pathways would see Scope 1, 2 and 3 emissions from ScotNS O&G production decrease significantly; however, assuming global consumption levels do not decrease at the same steep rate, this demand for O&G would be met from other producers which may be more emissions intensive and would also give rise to O&G transport emissions. The impact could be an increase in overall emissions.
- It should be noted however that Scotland's small share (<1%) of global production means that the direct impact of Scotland's production pathway on the 1.5°C Paris Agreement goal being met will not be material, although it could have an effect from a signalling point of view.
- For such a steep decline in ScotNS O&G production to result in overall reduced global emissions, it would need to be matched by the decline rate of global O&G consumption (driven by alternative energy source development), which is considered unlikely.

Regional implications

- The North East of Scotland is a region historically dominated by O&G activity and is home to 98% of Scotland's O&G jobs and as such would bear the brunt of the economic and employment implications of the decline of the O&G sector. Targeted investment in renewable activity (see section 5) alongside a gradual reduction in O&G activity may help ensure that the North East does not experience a disproportionate economic decline. Per section 5, it is estimated that jobs created by the low carbon energy sectors could have offset job losses by 2050 for all pathways; however, a too fast decline of O&G production could threaten the creation of jobs in the renewable energy sectors.
- The North East has a significant concentration of economic activity in O&G servicing and the associated supply chain which will decline in line with O&G production. Assistance may be required to allow the O&G service companies and supply chain to transition to serve the renewables sector – see section 5 for further details. This will take time, and a steeper decline in O&G production will make it more challenging for companies to make this transition, resulting in a loss of investment in the region, reducing economic activity in the region. Grangemouth relies primarily on imported O&G, with only 30% of O&G processed coming from Scottish production, so the impact of these pathways will be less keenly felt at Grangemouth and its local area (see section 11 of Chapter 1).

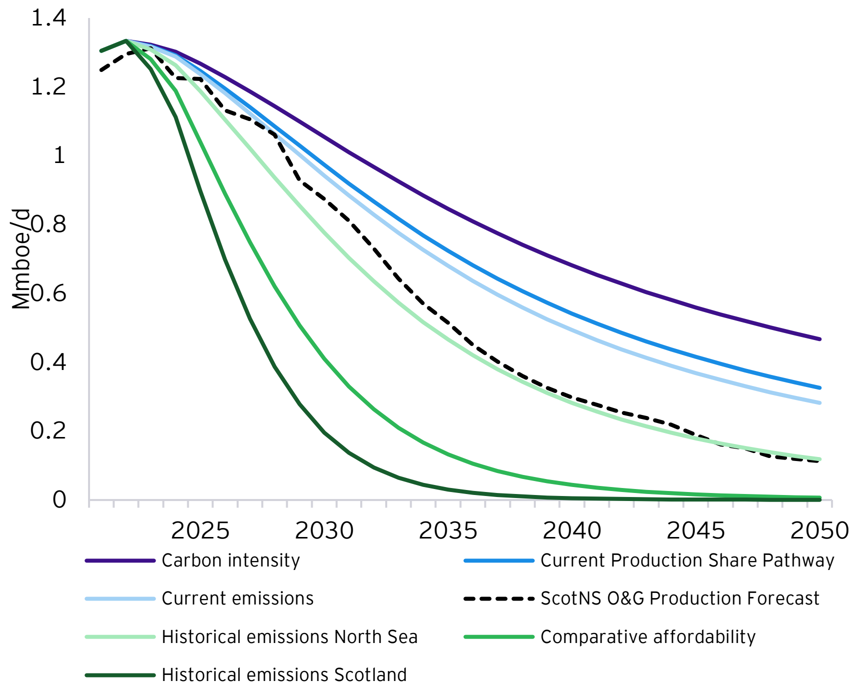
Conclusion

A steeper decline in Scotland's O&G production could in theory mean Scotland's emissions are reduced even quicker than required by the 1.5°C Paris Agreement goal, however only as long as this is not replaced by more emissions-intensive overseas production. The direct impact however would be minimal due to Scotland's small share of global production and the fact that Scottish consumption would be unchanged. The greater impact could be from a signalling perspective. Other implications of a steeper decline are as follows:

- Assuming replacement energy sources are not developed and available on the market, Scotland would need to increase O&G imports to meet its energy demand, which would mean increased energy security risks.
- A steeper decline would result in the sudden loss of many high paid and skilled O&G jobs (as set out in the table below). Assuming replacement energy sectors cannot provide new and equivalent jobs as quickly, this could lead to significant unemployment and economic deprivation that would be felt particularly in the North East of Scotland.
- A steeper decline would involve actively curtailing production in ScotNS fields that are already sanctioned, not just possible and probable new fields. In Chapter 1 we noted that over 80% of future production will arise from existing sanctioned fields. SG would need to understand the legal implications of stopping production in sanctioned fields, i.e. are they legally able to, and is there any policy justification for doing so.

A shallower decline, if not offset by faster rates of production decline from other countries, could contribute to the 1.5°C Paris Agreement goal not being met. However, for the reasons set out above, the direct impact would be minimal. A more gradual pathway would allow more time for renewable energy supply chains to be established, for workers to be reskilled and infrastructure repurposed, which is necessary for the successful delivery of a Just Transition.

Scotland's potential production pathways



Source: EY analysis

O&G jobs under each O&G pathway

Pathway	2025	2030	2035	2040	2045	2050
Current Production Share Pathway	44,463	41,530	36,789	27,588	25,556	17,912
Carbon Intensity	45,237	44,995	42,993	34,722	34,413	25,658
Current Emissions	44,156	40,209	34,546	25,141	22,662	15,493
Historical Emissions North Sea	42,370	33,127	23,666	14,377	10,999	6,473
Historical Emissions Scotland	32,019	8,353	1,524	244	57	11
Affordability	37,106	17,505	6,728	2,231	988	354
ScotNS O&G Production Forecast	43,664	37,313	26,151	15,158	11,623	6,163

Source: EY analysis

O&G GVA under each O&G pathway (£m)

Pathway	2025	2030	2035	2040	2045	2050
Current Production Share Pathway	13,732	10,332	7,339	5,487	3,954	3,226
Carbon Intensity	13,971	11,194	8,577	6,906	5,324	4,621
Current Emissions	13,637	10,004	6,892	5,000	3,506	2,790
Historical Emissions North Sea	13,086	8,242	4,721	2,859	1,702	1,166
Historical Emissions Scotland	9,889	2,078	304	49	9	2
Affordability	11,460	4,355	1,342	444	153	64
ScotNS O&G Production Forecast	13,485	9,283	5,217	3,015	1,798	1,110

Source: EY analysis

4 Just Transition: Current economic footprint of Scotland's low carbon energy economy

The current economic footprint of the Scottish low carbon energy sector

In order to understand the growth of low carbon energy we have considered the current size of the sector. This section considers a baseline estimate for the economic footprint of low carbon energy. 2019 data has been used on account of data availability and being pre-COVID-19 pandemic.

Existing 2019 low carbon energy economic footprint

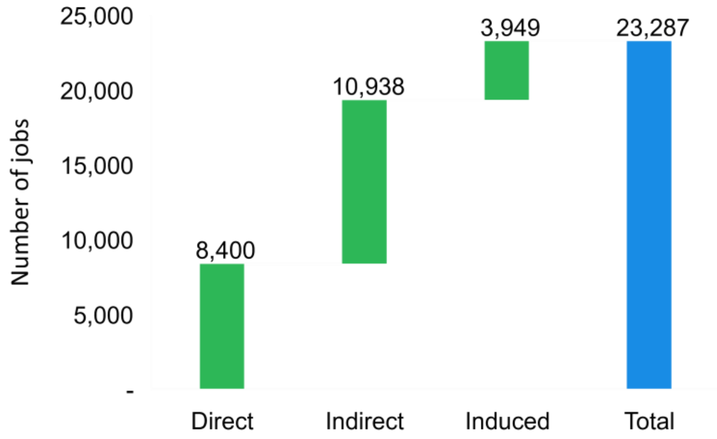
The current economic contribution of Scotland's low carbon energy sector has been assessed through the consideration of three elements:

- **Direct:** impacts resulting from the low carbon energy sector activities and spending.
- **Indirect:** economic activity that occurs through the low carbon energy industry's supply chain.
- **Induced impacts:** additional activity elsewhere in the economy, supported by spending of low carbon energy sector employees and those employed in the low carbon energy industry's supply chain.

Low carbon energy employment & GVA total impact

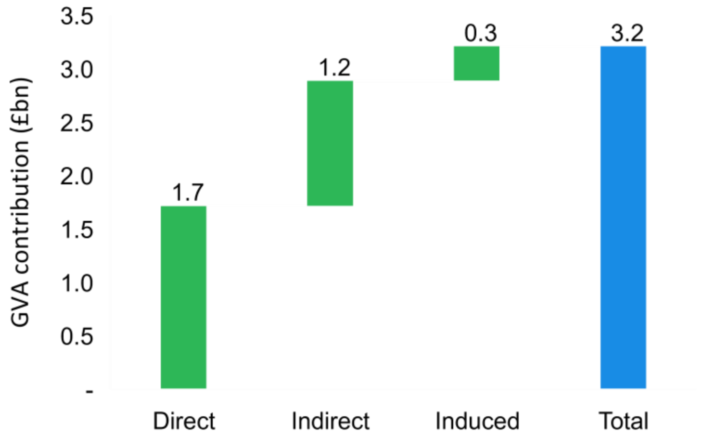
- It is estimated that over 23,000 jobs have been supported by Scotland's low carbon energy sector in 2019. This includes 8,400 direct, over 10,900 indirect and over 3,900 induced jobs. This contribution is equivalent to 0.9% of all of Scotland's total employment. Of the 21,000 low carbon energy jobs, an estimated 6,461 relates to nuclear power generation and decommissioning.
- The low carbon energy sector was estimated to have contributed £3.2bn in GVA to Scotland's economy in 2019 – £1.7bn direct, £1.2bn indirect and £0.3bn induced GVA. This contribution is equivalent to 1.8% of Scotland's total GDP. Of the £3.2bn GVA, an estimated £1.0bn relates to nuclear power generation and decommissioning and the remaining £2.2bn of the GVA relates to the rest of the renewables sector (1.2% of Scotland's total GDP).
- In comparison, Scotland's O&G sector and its supply chains supported an estimated total of 79,000 jobs in 2019, generating a corresponding £17.9bn GVA contribution.
- Nuclear power generation and decommissioning has been included within the scope of assessing the current low carbon energy footprint in Scotland sector. Nuclear generation in 2019 made up 63% of nuclear generation and decommissioning jobs; however, nuclear energy generation will decline to zero by 2030 as existing generation capacity shuts and SG policy precludes new nuclear build. As nuclear energy generation is phased out in the energy transition, a more significant role will be required for renewables in replacing the decline in employment and GVA from both O&G and nuclear generation. Although nuclear generation will decline, the decommissioning side is expected to be a growth area.

Low carbon energy jobs (2019 estimate)



Source: EY analysis, ONS

Low carbon energy GVA contribution (2019 estimate)



Source: EY analysis, ONS, Fraser of Allander Institute (FAI)

Scottish low carbon energy existing economic footprint – limitations of approach

Refer to Appendix A for further detail on the methodology for estimating direct, indirect and induced jobs and GVA in the baseline. This page outlines limitations with the baseline low carbon energy economic footprint estimation approach.

Limitations

- The ONS LCREE[1] for Scotland is used to estimate the number of direct low carbon energy jobs. This relies on surveys from companies and there could be inconsistencies with companies within the low carbon energy supply chain identifying as within the low carbon energy sector directly. As a result, direct jobs figures may include additional indirect jobs, which could overestimate the total jobs after applying multipliers.
- LCREE publish confidence intervals for employment data, and in our baseline we have used the LCREE central estimate. Taking employment data for each subsector at the upper and lower bounds will result in a total low carbon employment estimate (across direct, indirect and induced) ranging between 13,459 and 33,843 jobs, and total GVA range of between £2.0bn and £4.5bn (comparing to our baseline central estimate of 23,287 jobs and £3.2bn GVA).
- There are no published ONS estimates available for GVA. A study by Fraser of Allander Institute[2] (FAI) has been used to estimate GVA contributions using GVA per job figures derived from the study for each subsector, based on the turnover share for each sub-sector within its SIC code. The actual GVA of each subsector may differ to turnover shares.
- SG published multipliers have been used to estimate indirect and induced impacts. Therefore, the analysis implicitly assumes that the low carbon energy sub-sectors are as intensive in their use of supply chains as the broader industry group SIC codes. However, the LCREE data also has the limitation that each low carbon subsector employment may include jobs from multiple other subsectors (e.g. construction, energy). This may lead to over/underestimate of the indirect contribution due to the use of a single multiplier, depending on the extent to which actual intensity of supply chain use in Scotland differs from the wider sector.
- SG job multipliers assumed average leakage of 49% across SIC codes. This means that on average 51% of the supply chain and subsequent household spending remains within Scotland (calculated based on taking the average type 1 and type 2[4] Scottish job multipliers as a proportion of the UK multipliers).
- To estimate a varied "leakage" out of the Scottish economy from renewable sub-sectors, the sensitivities below were considered for higher leakages outside Scotland in the supply chain:

Supply chain leakage assumption	Total low carbon jobs estimate	Total low carbon GVA estimate (£m)
80% (sensitivity)	16,439	2.4
90% (sensitivity)	12,420	2.1
49% (baseline SG multiplier)	23,287	3.2

- To address the limitation of LCREE data containing a large number of construction sector jobs, we also applied the construction sector multipliers as a sensitivity and we compare this to the baseline. Based on using construction sector multipliers, total estimated 2019 low carbon energy jobs is 17,547, a decrease from 23,287 in the baseline. The total estimated GVA is £3.2bn, which is in line with £3.2bn in the baseline.

1 Low Carbon and Renewable Energy Economy – available at https://www.ons.gov.uk/economy/environmentalaccounts/bulletins/finalestimates/2020; 2. https://fraserofallander.org/wp-content/uploads/2021/06/2021_FAI_Economic_Impact_of_Scotland_s_Renewable_Energy_Sector_original.pdf; 3. https://www.crownestatescotland.com/our-projects/scotwind; 4. Type I multipliers account for the direct and indirect impacts based on how goods and services are supplied within a region. Type II multipliers not only account for these direct and indirect impacts, but they also account for induced impacts based on the purchases made by employees.

Scottish low carbon energy existing economic footprint – Limitations of approach

Implications

The implications of these limitations is that the estimates of GVA and jobs of the low carbon energy sector may be overestimated (as shown by the sensitivities described in the previous slide). We have therefore considered other benchmarks, e.g., a study from the FAI that uses the hypothetical extraction method[1] (rather than multipliers) to estimate total GVA and jobs using ONS jobs and turnover data. This study estimates the total size of low carbon energy jobs for the same sub-sectors as our scope (excluding nuclear) to be 20,590 (3,763 higher than our estimate), and GVA at £2.15bn (£4m lower than our estimate). This is broadly in line with our baseline estimates.

In addition we consulted with the ONS Green Jobs team who confirmed there are no current plans to change the definitions of low carbon jobs used in LCREE data, so despite limitations with the data this is still a credible public source for historic low carbon jobs across sub-sectors. Our approach in using multipliers to estimate indirect and induced jobs is also compatible with our analysis of the O&G sector in Chapter 1.

Conclusion

There is limited data and estimates of the low carbon energy sector in Scotland. Based on our sensitivity analysis around LCREE data and multipliers; and benchmarking with other studies we conclude that the estimation of the baseline economic footprint of the low carbon sector in this study is credible and reasonable.

1. The Hypothetical Extraction Method´s approach (Dietzenbacher et al., 1993) observes the effects associated to the hypothetical elimination of an economic sector of the system

5 Just Transition: Future economic impact of the Just Transition scenarios

Scottish low carbon energy growth scenario – Energy System Catapult BOP scenario

This section explores the minimum required levels of low carbon energy investment and government policy to achieve a certain amount of low carbon energy activity and hence jobs to offset the decline in O&G jobs in each O&G production pathway scenario.

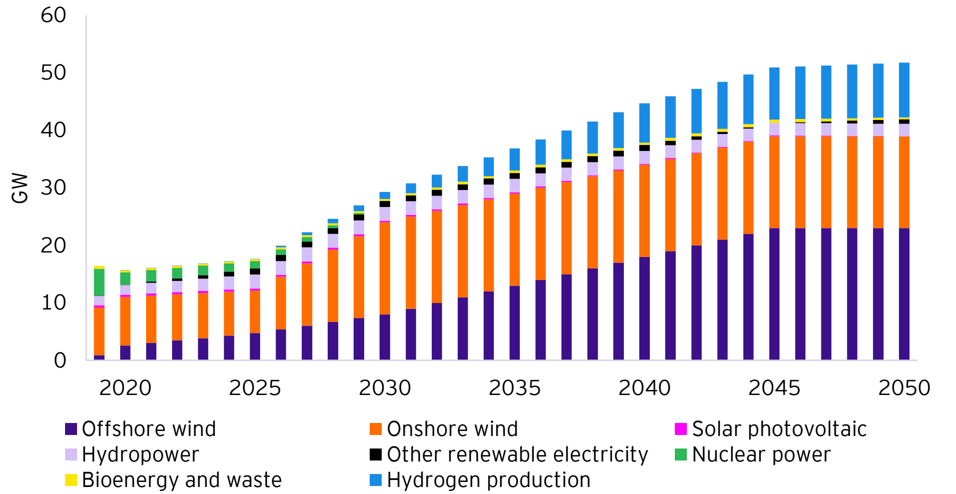
SG and the ClimateXChange (CXC) commissioned ESC to develop a set of Scotland-specific whole energy system scenarios. These scenarios demonstrate different routes for Scotland to meet its climate change targets, allowing different choices and potential implications to be explored. Please see Appendix C for detail on the different ESC scenarios.

ESC scenarios have been reviewed and adopted to create a plausible baseline scenario for forecasted growth of jobs and GVA in the low carbon energy sector. The BOP scenario has been used as a reference point and adapted to achieve net-nil job losses across each of the O&G decline pathways. This page outlines the low carbon electricity generation capacity under that scenario.

ESC scenario – Balanced Options[1]

- In reviewing the scenarios, we determined that the BOP scenario combined the appropriate balance of technology innovation with some degree of societal change to meet GHG targets in a more moderate way than the other scenarios, making it the most plausible of ESC scenarios.
- The low carbon energy activity forecasts in this scenario were used to estimate a forecast path of growth in GVA and jobs across low carbon energy, and resulted in the closest outcome to net-nil job losses under the ScotNS O&G decline scenario, compared to other ESC scenarios. Hence this scenario has been used as a starting point for further adjustments to the low carbon energy activity levels to achieve.
- The BOP scenario assumes significantly lower levels of solar and a higher proportion of wind compared to other global energy models. The individual fuel mix of every country (including Scotland) will differ and be highly dependent on a range of factors including local geography. We do not seek to assess the reasonableness of the ESC model scenarios. analysis assumes that costs of solar are expected to fall at a higher rate than the costs of wind power, hence why solar represents a larger share of the global mix. This report does not seek to assess the reasonableness of the ESC model scenarios.
- **More significant investment would be required to implement the ESC BOP scenario, compared to the £33.3bn we estimate.** This is because our analysis focuses on three subsectors (wind, hydrogen, CCUS), whereas the BOP scenario contains a wider set of subsectors (including biomass, solar etc). Additionally, we have not profiled these investment figures over time, due to the absence of third party data from the ESC model.
- **The key outcomes under the BOP scenario are listed below, further detail is provided in Appendix C:**
  - Total electricity generation capacity (across onshore wind, offshore wind, solar, hydropower, nuclear power generation and decommissioning, bioenergy and waste and tidal) would increase from 16.5GW in 2019 to 42.3GW by 2050.
  - Nuclear capacity reduces to nil by 2030.
  - Hydrogen capacity grows from nil in 2019 to 9.5 GW (70.6 TWh[2]) by 2050; under BOP scenario all hydrogen capacity is blue hydrogen.
  - The level of carbon captured grows in each scenario from nil in 2019 to 26.4 $MtCO_2$ by 2050.
  - There is limited growth in capacity of hydropower, solar, bioenergy and tidal over time in the BOP scenario. Refer to Appendix B.

BOP – electricity generation capacity and hydrogen capacity[2]



Source: EY analysis and ESC model

1. CXC - Scottish Whole Energy System Scenarios report, January 2022; 2. 2019 is based on historic data;

2. ESC scenarios outline hydrogen capacity in TWh, this has been converted to GW assuming a 86% load factor based on Scottish Government Hydrogen Assessment https://www.gov.scot/binaries/content/documents/govscot/publications/research-and-analysis/2020/12/scottish-hydrogen-assessment-report/documents/hydrogen-assessment-project-appendix/hydrogen-assessment-project-appendix/govscot%3Adocument/hydrogen-assessment-project-appendix.pdf

Scottish low carbon energy – ESC BOP scenario forecast jobs and GVA

The graphs below outline the estimated direct and indirect jobs and GVA over time in each low carbon energy sub-sector based on the low carbon energy activity under the BOP ESC scenario. Appendix B provides more details on the methodology, constraints and limitations of the approach used to estimate jobs and GVA.

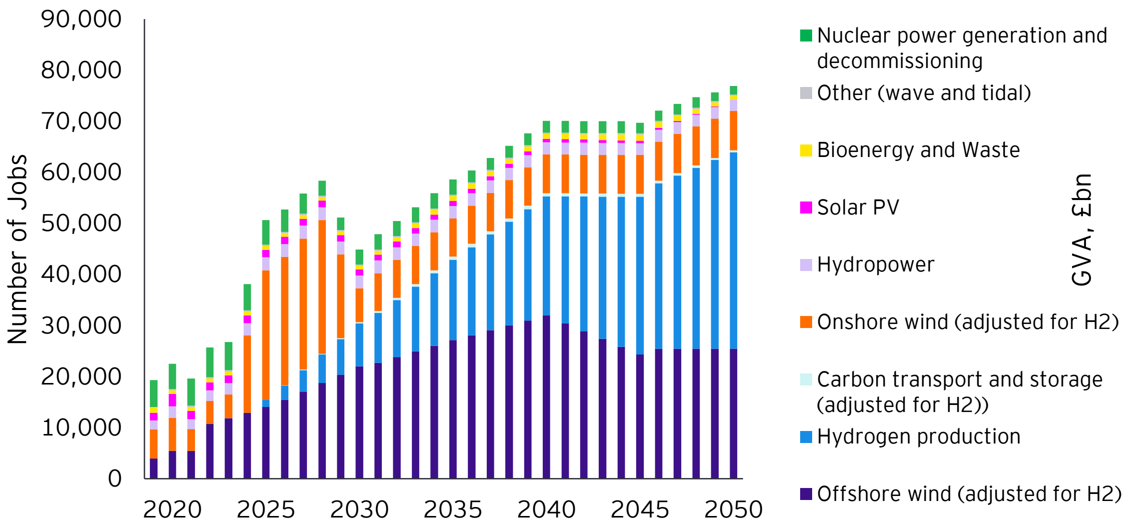
Forecast jobs[1]

- Under the BOP scenario, from 2019 to 2050 there is a total increase in direct and indirect low carbon energy jobs of 57,599 (more than 3 times increase from the level of 2019 jobs), to a total 76,937 jobs (direct + indirect) by 2050. The majority of long term change in jobs is from the hydrogen[2] and offshore wind sectors. 38,490 direct and indirect jobs are forecast in hydrogen production by 2050, and 25,443 in offshore wind. Onshore wind jobs peak in 2028 (26,186 direct and indirect jobs) associated with the forecast peak in construction costs, before jobs decline to a lower level of ~8,000 from 2033-2050.

Forecast GVA

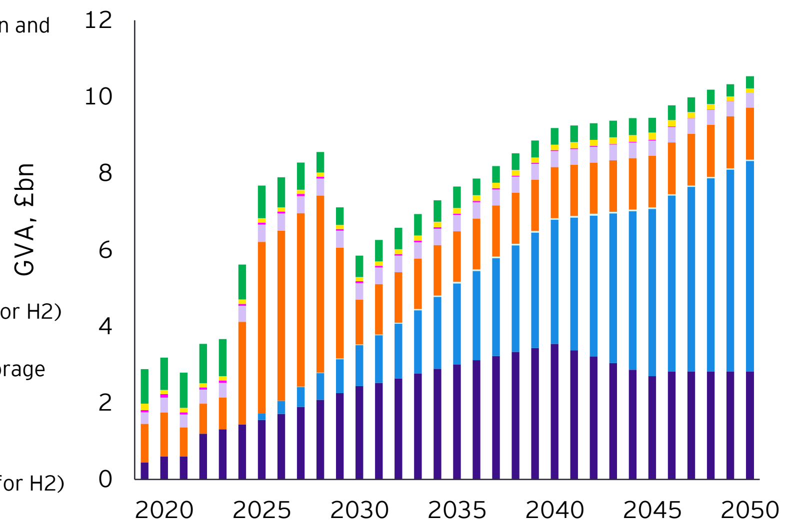
- Under the BOP scenario, direct and indirect low carbon energy GVA increases overall by £7.6bn from 2019 to 2050 (from a level of £2.9bn in 2019, to £10.5bn in 2050, including nuclear power generation and decommissioning). There is an overall growth in direct and indirect GVA, driven by growth of renewable energy sectors, particularly hydrogen production and offshore wind, but offset partly by the loss of nuclear power generation by 2030. By 2050, £2.8bn of the £10.5bn direct and indirect GVA contribution comes from offshore wind, with £5.5bn from hydrogen production. The direct and indirect GVA contribution from offshore wind actually peaks in 2040, because it is more capital/labour intensive during construction phases.

BOP low carbon energy jobs (direct + indirect)



Source: EY analysis

BOP low carbon energy GVA (direct + indirect)



Source: EY analysis

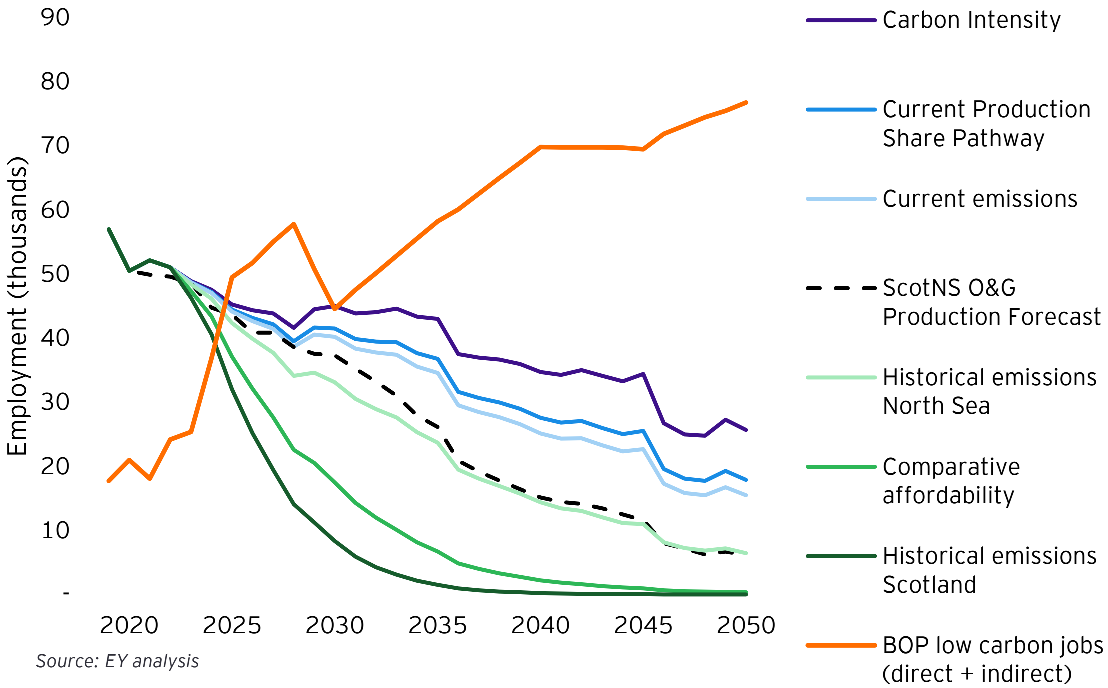
1. As this project examined the energy transition through an energy production lens, this chart as this excludes CCUS jobs used for blue hydrogen production and instead includes them within hydrogen production jobs, to avoid double counting. There is limited growth in CCUS jobs displayed in the chart as a result. 2. Hydrogen production jobs includes jobs within wind and CCUS relating to the production of hydrogen.

O&G adjusted production pathways compared to BOP scenario

Jobs and GVA across the energy sector (low carbon energy and O&G)

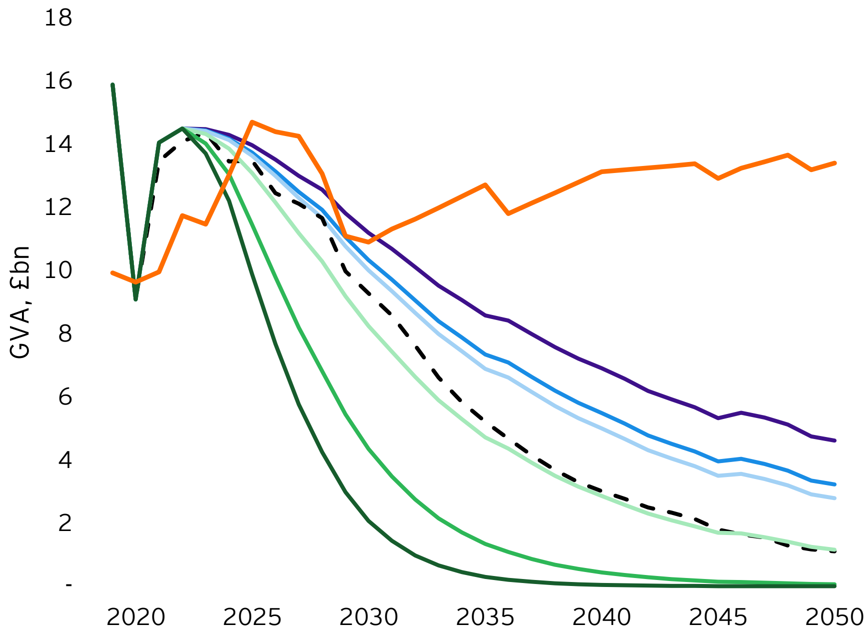
- The graphs below show the total (direct + indirect) jobs and GVA within the low carbon energy sector under the BOP scenario, as well as the jobs and GVA of the O&G sector under each O&G decline pathway.
- Refer to Appendix C for further detail on job figures by low carbon subsector under the BOP, and also under each O&G decline scenario.
- The BOP scenario has been used as a starting point to understand the net impact on jobs across energy in each O&G decline scenario. The page overleaf outlines the net change in energy jobs from 2019 across low carbon and O&G sectors, based on the decline in O&G jobs and growth in low carbon jobs shown below.

BOP scenario: growth in BOP low carbon jobs and decline in total O&G jobs (direct + indirect)



Source: EY analysis

BOP scenario: growth in BOP low carbon GVA and decline in total O&G GVA (direct + indirect)



Source: EY analysis

O&G adjusted production pathways compared to BOP scenario (cont.)

Net jobs and GVA across the energy sector (low carbon energy and O&G)

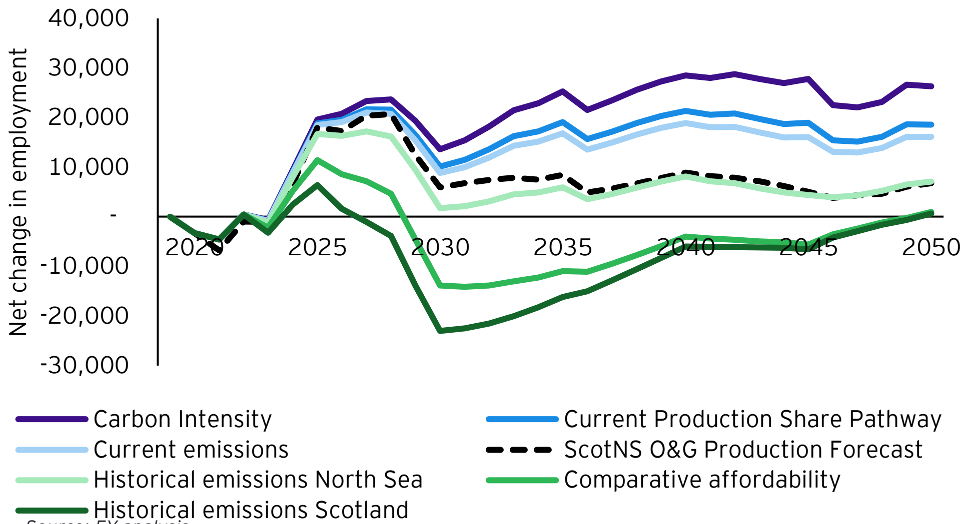
- The graphs on the right show the net energy jobs and GVA (direct + indirect) across each O&G decline production pathway when compared with the expected growth in employment and GVA in low carbon energy under the BOP scenario.
- For four of the pathways (Current Production, Carbon Intensity, Current Emissions and Historic Emissions North Sea) and the ScotNS production pathway, the net position against the BOP scenario for low carbon energy implies an overall increase in direct and indirect jobs in the combined Scottish energy sector from 2024 onwards. The Historic Emissions Scotland and Comparative Affordability pathways have a more rapid decline in O&G production, resulting in the fall in O&G jobs exceeding the gain in low carbon jobs until 2050. However, in 2050 all pathways are expected to reach net job gains, with total growth in direct and indirect low carbon jobs exceeding the jobs lost in O&G.
- Under all O&G decline scenarios the change in Scottish energy GVA (direct + indirect) is expected to become negative beyond 2030, with an overall decline between £3.6bn and £8.3bn by 2050. This is because growth in GVA from renewables is not expected to offset the decline in O&G GVA, and the phase out of nuclear power generation.
- This result is driven by higher GVA per worker currently observed in O&G and nuclear energy generation and decommissioning compared with renewables. Scotland's direct GVA per direct job in O&G extraction is £1.1m, whilst direct GVA per job in the nuclear industry is estimated to be £0.23m. In the existing renewable sectors (excluding hydrogen and CCUS) it is £0.15m.

Net change in Scottish energy jobs (direct + indirect) from 2019 under the BOP energy scenarios for each O&G adjusted pathways[1]

O&G decline pathway	2030	2040	2050
Current Production Share Pathway	10,123	21,347	18,531
Carbon Intensity	13,587	28,481	26,277
Historical Emissions North Sea	1,720	8,137	7,092
Historical Emissions Scotland	(23,054)	(5,996)	631
Current Emissions	8,802	18,900	16,112
Comparative Affordability	(13,902)	(4,010)	974
ScotNS O&G Production Forecast	5,906	8,917	6,782

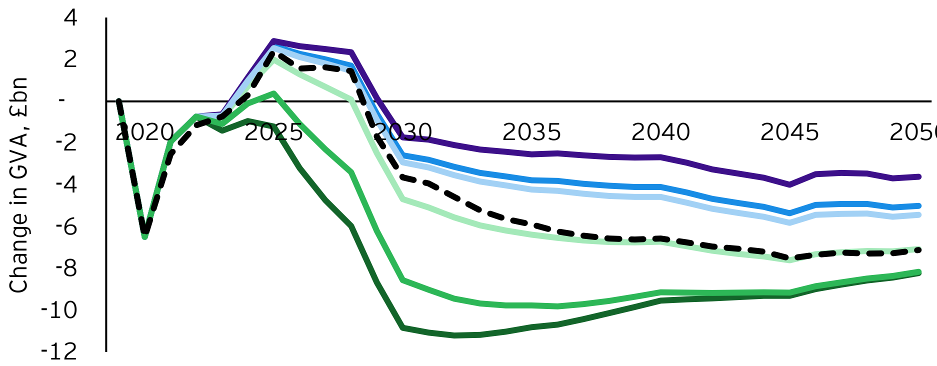
Source: EY analysis

BOP scenario – net change in direct and indirect Scottish energy jobs (low carbon energy and O&G) from 2019



Source: EY analysis

BOP scenario – net change in direct and indirect Scottish energy GVA (low carbon energy and O&G) from 2019



Source: EY analysis

1. Refer to Appendix C page 101 for further detail on the change in low carbon jobs and O&G jobs resulting in this net change across Scottish energy jobs shown above

O&G adjusted production pathways: Additional low carbon energy activity required for net nil job loss impact

Total low carbon energy activity levels under net nil job pathways

- To achieve net nil job losses across the Scottish energy sector (under each O&G adjusted pathway) the projections for low carbon energy production/capacity levels would need to vary from the levels in the BOP scenario, i.e. increase where there are net job losses, or activity levels in low carbon energy could be reduced where there are net jobs gained. We have considered how much low carbon deployment would be required to create a level of additional employment that offsets the decline in O&G jobs, driven by O&G production decline in each scenario.
- To illustrate the required change in low carbon deployment, activity levels for offshore wind capacity, hydrogen capacity and $MtCO_2e$ of carbon captured (CCUS) have been increased (or decreased) accordingly. These sectors were selected as they achieve the highest absolute growth under the BOP scenario. Please refer to Appendix C for further detail on the methodology used to calculate the activity levels required to achieve net-nil job losses.
- The table below show the total levels of offshore wind generation capacity, CCUS carbon captured and hydrogen capacity needed to reach net-nil Scottish job losses (direct + indirect) under each of the potential O&G decline pathways. For example in the Historical Emissions Scotland scenario, where there is a faster decline in the level of O&G production, a higher level of investment in low carbon generation is required – equivalent to deploying 14GW of offshore wind, 2GW (16TWh) of hydrogen capacity and $10MtCO_2$ of carbon captured by 2030.
- In 2030, offshore wind generation capacity will need to stand between 4 and 14GW to achieve net-nil job losses across the adjusted pathways. Additionally, the levels of carbon captured will need to reach between 3 and $10MtCO_2e$, and between 1 and 2GW (5 and 16TWh) of hydrogen capacity.
- By 2050, offshore wind generation capacity will need to stand between 14 and 23 GW to achieve net-nil job losses across the adjusted pathways. The levels of carbon captured will need to reach between 16 and 26 $MtCO_2e$, and between 6 and 9GW (42 and 71TWh) of hydrogen capacity.

Total offshore wind, hydrogen capacity and CCUS activity levels required for net-nil job losses (direct + indirect) under each O&G adjusted pathway[1]

Adjusted activity levels for net-nil jobs	Total Offshore wind production (GW)				Total Hydrogen capacity (GW)				Total CCUS carbon captured ($MtCO_2e$)			
O&G decline pathway	2020	2030	2040	2050	2020	2030	2040	2050	2020	2030	2040	2050
Current Production Share Pathway	3	5	11	16	0	1	4	7	0	4	12	19
Carbon Intensity	3	4	9	14	0	1	3	6	0	3	9	16
Historical Emissions North Sea	3	8	15	20	0	1	6	8	0	5	16	23
Historical Emissions Scotland	3	14	20	23	0	2	8	9	0	10	21	26
Current Emissions	3	6	12	17	0	1	5	7	0	4	12	20
Comparative Affordability	3	12	19	23	0	2	7	9	0	8	20	26
ScotNS O&G Production Forecast	3	6	15	21	0	1	6	8	0	4	16	24
ESC BOP scenario	3	8	18	23	0	1	7	9	0	5	19	26

Source: EY analysis

1. This table displays the total activity levels in each technology required for achieving net-nil job losses in each O&G adjusted pathway. This therefore does not remove the overlapping capacity required between offshore wind and CCUS which may be used in Hydrogen production. Total levels are displayed to outline the total size of each subsector, although in calculating jobs and GVA we have ensured no double-counting by excluding wind and CCUS jobs from these sectors which are used for hydrogen production

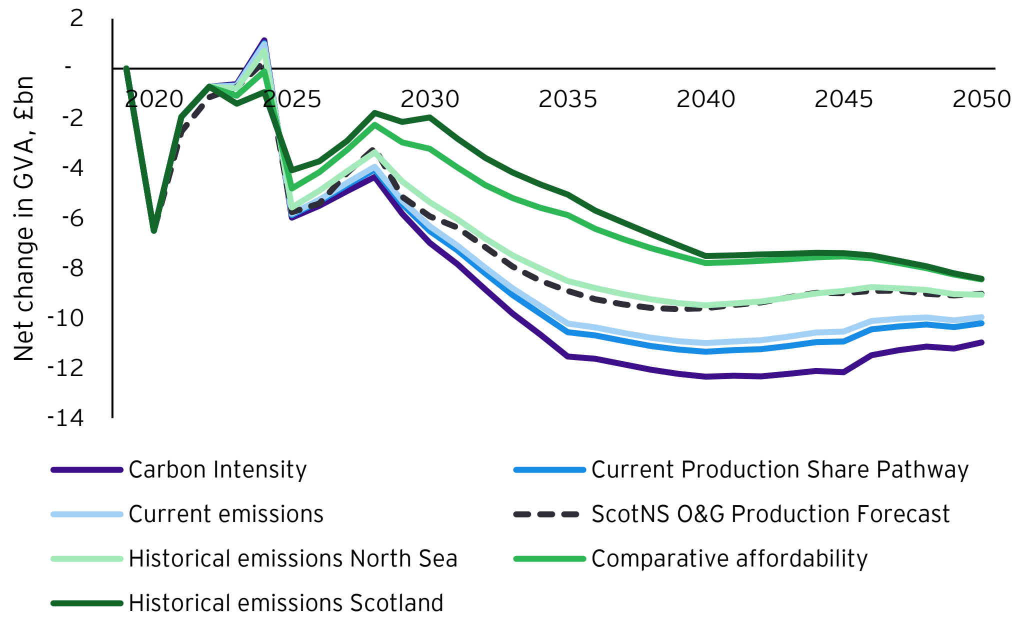
O&G adjusted production pathways: GVA impact under net-nil jobs

GVA impact under net-nil job pathways

- Increasing or decreasing low carbon energy activity levels from the BOP scenario to achieve net-nil job losses under each adjusted O&G pathway (to levels shown in the previous page), also results in a net change in Scottish energy GVA in each O&G production pathway.
- As can be seen in the graph below, under the low carbon energy scenarios that achieve net nil job losses in each O&G pathway, there is still a net loss of between £8.4bn and £11.0bn direct and indirect Scottish energy GVA across all the adjusted pathways by 2050 (between 5-6% of 2019 total Scottish GDP). This is because the loss of GVA from the O&G sector exceeds the GVA gained within low carbon energy, even if job losses are offset.

This shows that even in a position of net-nil job losses across low carbon energy and O&G with the energy transition, there will still be a net loss in GVA, as the low carbon energy sector jobs are of a lower GVA per job value than O&G.

Net change in Scottish energy GVA (low carbon energy and O&G) under net-nil job losses (direct + indirect)



Source: EY analysis

O&G adjusted production pathways: Change in investment levels for net nil job loss impact in each scenario

As previously outlined, we have considered how much low carbon deployment will be required to create a level of additional energy production employment that offsets the decline in O&G production jobs. The minimum level of low carbon activity to achieve net-nil job losses in each O&G adjusted production pathway varies, and hence requires a varied level of investment within low carbon energy. Where there is a faster decline in the level of O&G production, a higher level of investment is needed in low carbon generation to achieve fully offset job losses.

The total level of Capex within offshore wind, CCUS and Hydrogen production which is required to offset the loss of O&G jobs has been estimated in each scenario to 2050. The table below shows the total Capex in each scenario by sub-sector, as well as the £m change in total low carbon energy Capex from the BOP scenario. The variance in Capex compared to the BOP scenario indicates the additional (or reduction in) investment in low carbon energy required in each scenario to achieve net-nil job losses.

The Comparative Affordability scenario requires an additional £6.9bn investment in low carbon energy compared to the BOP scenario level. While the Carbon Intensity scenario requires a lower minimum level of investment in low carbon energy compared to the BOP scenario to offset O&G job losses (£11.9bn lower).

Capex was estimated based on the following methodology for each sub-sector:

- **Offshore wind**: Capex in each scenario was estimated as outlined in Appendix B.3, based on BEIS data on average costs for Capex and assumptions of a 4-year construction profile.
- **CCUS**: Estimated Capex for a notional CCUS project was obtained from the NSTA[1], and an assumption of £5m Capex spend per $MtCO_2e$ capacity was estimated and applied to the levels of $MtCO_2e$ capacity in each scenario to estimate total CCUS Capex required.
- **Hydrogen production**: The Capex required for each TWh unit of blue and green hydrogen production was estimated based on BEIS data[2], and applied to the levels of hydrogen production in each scenario. It was assumed blue hydrogen requires £10m Capex for a TWh of hydrogen production, whilst green hydrogen Capex costs will vary based on the source of electricity as well as the load factor of the electrolyser – for example, dedicated offshore wind has an average Capex of £12m per TWh of hydrogen produced, while curtailed electricity has a higher cost of £35m of Capex per TWh of hydrogen produced. In line with the BOP scenario, we have assumed investment in hydrogen production across all O&G pathways is within blue hydrogen; however, were there additional investment within green hydrogen (in particular using curtailed electricity) the Capex required would be larger.

Assumptions and limitations

- It is assumed investment in all other low carbon energy sub-sectors is constant across scenarios and in line with the BOP scenario.
- The approach has been to estimate investment based on average Capex spend assumptions from public data for each technology, rather than using ESC assumptions for cost – hence investment levels in the whole energy system under ESC's model may vary with these estimates.
- The investment required across the rest of the energy system has not been quantified, and the increase in activity levels in the offshore wind, CCUS and hydrogen sectors is considered stand alone.

Total Capex (£m) levels to 2050 (current prices) - Offshore wind, hydrogen production and CCUS Capex levels required for net-nil jobs losses (direct + indirect) under each O&G adjusted pathway

	Capex (£m) to 2050				Difference from BOP	
Adjusted O&G pathway	Offshore wind	CCUS	H2	Total offshore wind/CCUS/H2 Capex	%change from BOP	£m change from BOP
ScotNS O&G Production Forecast	23,476	1,672	8,600	33,748	1%	411
Current Production Share Pathway	18,517	1,247	6,400	26,164	-22%	(7,173)
Carbon Intensity	15,471	982	5,034	21,486	-36%	(11,851)
Historical Emissions North Sea	23,760	1,719	8,806	34,285	3%	947
Historical Emissions Scotland	25,802	2,261	11,409	39,471	18%	6,134
Current Emissions	19,469	1,336	6,858	27,663	-17%	(5,674)
Comparative Affordability	27,097	2,156	10,946	40,199	21%	6,862
ESC BOP Scenario	21,517	1,928	9,892	33,337	N/A	N/A

Source: EY analysis

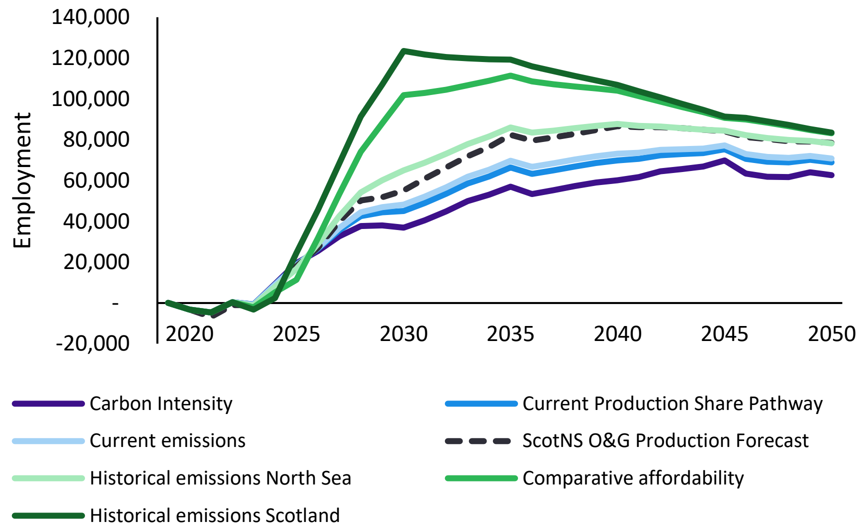
1. UKCS Energy Integration Final report Annex 2. Carbon Capture and Storage (nstauthority.co.uk); 2. Hydrogen production costs 2021 (publishing.service.gov.uk)

O&G adjusted production pathways: Feasibility of net-nil GVA pathways

Jobs impact under net-nil GVA pathways

- To achieve net-nil GVA loss across the Scottish energy sector (under each O&G adjusted pathway) the projections for low carbon energy production/capacity levels would need to vary from the levels in the BOP scenario, i.e. increase where there is net GVA loss.
- The table below shows the total levels of offshore wind generation capacity, CCUS carbon captured and hydrogen capacity needed to reach net-nil Scottish GVA loss (direct + indirect) in each O&G decline pathways.
- By 2050, offshore wind generation capacity will need to stand between 33 and 46 GW to achieve net-nil GVA loss across the adjusted pathways. Additionally, levels of carbon captured will need to reach between 38 and 56 MtCO_2e and between 14 and 19 GW (101 and 140 TWh) of hydrogen capacity will be required for net-nil GVA losses.
- The level of jobs associated with activity levels where there are net-nil GVA losses is shown in the chart on the right. This level of activity would be expected to support a net increase of between 62,628 and 83,437 direct and indirect energy jobs in 2050 (compared to 6,782 net increase in energy jobs in 2050 under BOP scenario in 2050)
- This level of low carbon activity is significantly above the BOP scenario in all years (i.e. capacity and investment required is significantly higher than BOP) and may not be achievable based on plausible levels of growth expected in the BOP scenario.

Net change in Scottish energy jobs (low carbon energy and O&G) under net-nil GVA loss (direct + indirect)



Source: EY analysis

Total offshore wind, hydrogen capacity and CCUS activity levels required for net-nil GVA losses (direct + indirect) under each O&G adjusted pathway

Adjusted activity levels for net-nil GVA	Total Offshore wind production (GW)				Total Hydrogen capacity (GW)				Total CCUS carbon captured ($MtCO_2e$)			
O&G decline pathway	2020	2030	2040	2050	2020	2030	2040	2050	2020	2030	2040	2050
Current Production Share Pathway	3	14	29	37	0	2	11	15	0	10	30	42
Carbon Intensity	3	12	25	33	0	2	10	14	0	8	26	38
Historical Emissions North Sea	3	19	36	42	0	3	14	18	0	13	37	49
Historical Emissions Scotland	3	33	43	46	0	5	16	19	0	22	45	52
Current Emissions	3	15	30	38	0	2	11	16	0	10	31	44
Comparative Affordability	3	27	42	45	0	4	16	19	0	19	44	52
ScotNS O&G Production Forecast	3	16	35	43	0	2	13	18	0	11	37	49
ESC BOP scenario	3	8	18	23	0	1	7	9	0	5	19	26

Source: EY analysis

O&G adjusted production pathways: Achieving net-nil GVA will be more challenging

Investment required for net-nil GVA pathways

- The table below estimates the additional Capex required above the BOP scenario levels for each O&G pathway to achieve net-nil GVA losses.
- The Historical Emissions Scotland scenario requires £62.5bn additional investment in low carbon energy compared to the BOP scenario to offset O&G job losses. While the Carbon Intensity scenario requires an additional £32.6bn investment in low carbon energy compared to the BOP scenario level. This has been estimated based on estimated capex per unit capacity assumptions for each sub-sector, and forecasted capacity levels in each scenario under net-nil GVA loss positions, in line with methodology outlined on page 50.
- The additional investment required to achieve low carbon capacity levels to offset GVA losses from O&G is significantly higher than the BOP level in all scenario. This further supports the conclusion that achieving net-nil GVA losses - with the GVA growth of the low carbon sector offsetting the loss of O&G GVA is implausible, and there is likely to be a net-loss in GVA across the energy sector with the energy transition.

Total Capex (£m) levels to 2050 (current prices) - Offshore wind, hydrogen production and CCUS Capex levels required for net-nil GVA losses (direct + indirect) under each O&G adjusted pathway

	Capex (£m) to 2050				Difference from BOP	
Adjusted O&G pathway	Offshore wind	CCUS	H2	Total offshore wind/CCUS/H2 Capex	%change from BOP	£m change from BOP
Current Production Share Pathway	53,372	3,238	16,597	**73,208**	120%	39,871
Carbon Intensity	48,494	2,849	14,617	**65,960**	98%	32,623
Historical Emissions North Sea	61,389	3,947	20,150	**85,486**	156%	52,149
Historical Emissions Scotland	66,672	4,837	24,299	**95,809**	187%	62,471
Current Emissions	54,966	3,370	17,266	**75,602**	127%	42,265
Comparative Affordability	66,902	4,646	23,489	**95,038**	185%	61,700
ScotNS O&G Production Forecast	61,045	3,861	19,790	**84,697**	154%	51,360
ESC BOP Scenario	21,517	1,928	9,892	33,337	N/A	N/A

Source: EY analysis

Conclusion

The BOP scenario was determined to be the most plausible ESC scenario as it has an appropriate balance of technology innovation with some degree of societal change to meet GHG targets.

- It also resulted in the closest outcome to net-nil job losses under the ScotNS O&G decline scenario (compared to other ESC scenarios).
- The BOP scenario forecasts a net increase in direct and indirect jobs by 2050.

We considered the net change in Scottish energy jobs and GVA across different Scottish O&G production pathways, under the low carbon BOP scenario.

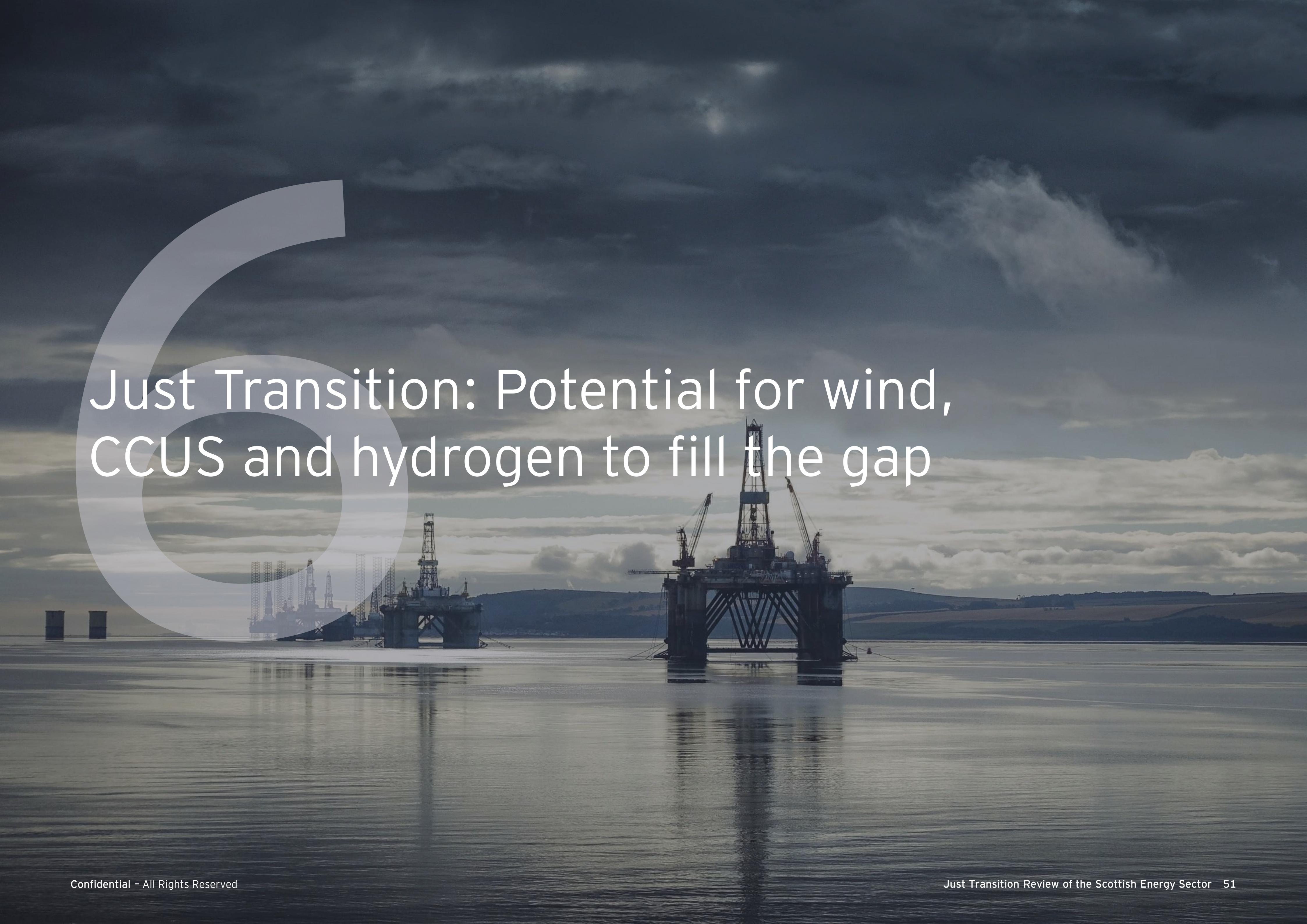
- For four of the scenarios (Current Production, Carbon Intensity, Current Emissions and Historic Emissions North Sea) and the ScotNS production pathway, the BOP scenario implies an overall increase in direct and indirect jobs from 2024 onwards.
- By 2050 all scenarios are expected to reach net job gains.
- Under all O&G decline scenarios Scottish energy GVA (direct + indirect) is expected to decline by 2050, as the low carbon energy sector jobs are of a lower GVA per job value than O&G.

In order to achieve net-nil Scottish job losses (direct + indirect) across the energy sector under each O&G decline pathways, we adjusted the total levels of Offshore wind generation capacity, CCUS carbon captured and hydrogen capacity from the levels in the BOP scenario. Under these adjusted low carbon levels:

- In 2030, offshore wind generation capacity will need to stand between 4 and 14GW to achieve net-nil job losses across the adjusted pathways. Additionally, the levels of carbon captured will need to reach between 3 and 10MtCO2e, and between 1 and 2 GW (5 and 16 TWh) of hydrogen capacity.
- By 2050, offshore wind generation capacity will need to stand between 14 and 23 GW to achieve net-nil job losses across the adjusted pathways. The levels of carbon captured will need to reach between 16 and 26 MtCO2e, and between 6 and 9 GW (42 and 71 TWh) of hydrogen capacity.
- Under the low carbon energy scenarios that achieve net nil job losses in each O&G pathway, there is still a net loss of between £8.4bn and £11.0bn direct and indirect Scottish energy GVA across all the adjusted pathways by 2050 (between 5-6% of 2019 total Scottish GDP). This is because the loss of GVA from the O&G sector exceeds the GVA gained within low carbon energy, even if job losses are offset.
- The Comparative Affordability scenario requires an additional £6.9bn investment in low carbon energy compared to the BOP scenario level. While the Carbon Intensity scenario requires a lower minimum level of investment in low carbon energy compared to the BOP scenario to offset O&G job losses (£11.9bn lower).

The level of low carbon activity required to achieve net-nil GVA losses across the energy sector for each O&G decline pathways may not be achievable based on plausible levels of growth expected in the BOP scenario

- By 2050, offshore wind generation capacity will need to stand between 33 and 46 GW to achieve net-nil GVA loss across the adjusted pathways. Additionally, levels of carbon captured will need to reach between 38 and 56 MtCO2e and between 14 and 19 GW (101 and 140 TWh) of hydrogen capacity.
- The BOP scenario forecasts offshore wind generation to be 23 GW, carbon captured will be 26 MtCO2e carbon, and hydrogen production to be 9 GW in 2050. In all cases, the BOP scenario forecasts that net-nil jobs will be achieved, but net-nil GVA will not.



6 Just Transition: Potential for wind, CCUS and hydrogen to fill the gap

Just Transition analysis

Introduction – Just Transition analysis

The economic contribution from Scottish O&G sector will decline as O&G production winds down. Our report highlights the extent to which Scotland's low carbon energy sector would need to grow to offset this decline. However, the consequences of this growth must also be understood from a Just Transition perspective.

This section analyses the opportunities and risks associated with the rollout of four key renewable energy sectors that are integral to offsetting the decline in the O&G sector: onshore wind, offshore wind, hydrogen and CCUS.

The four sectors have been identified by SG as being key to Scotland meeting its Net Zero targets by 2030. We have provided a short summary alongside.

For each sector we summarise:

- SG's ambition and policy objectives;
- Opportunities;
- Issues to be explored further;
- Supply chain;
- O&G infrastructure compatibility;
- Mapping of activity across the UK; and
- Ability to support a Just Transition in Scotland.

This analysis draws on the analysis in Chapter 1 (a baseline review of the O&G sector in Scotland), Chapter 2 (the demand drivers for the O&G sector in Scotland) and relevant SG policy commitments and ambitions.

Sector	Description
Onshore wind	Onshore wind is the more established wind energy generation technology in Scotland. Since the first windfarm was commissioned in 2006, projects have grown in size and generation capacity as turbines become larger and more efficient.
Offshore wind	Offshore wind is the newer wind energy generation technology in Scotland. Offshore wind is split between fixed offshore wind, with foundations on the seabed, and floating offshore wind, with floating foundations tethered to the seabed. Projects have grown in size over recent years with a number of new sites designated for development as part of the ScotWind and the Innovation and Targeted Oil and Gas (INTOG) leasing rounds.
Hydrogen	Hydrogen is currently being considered as a low carbon fuel of the future and could be used as a direct replacement for natural gas or as a fuel for vehicles. Hydrogen is split between blue hydrogen, which is generated using fossil fuels with carbon capture offsetting carbon emissions, and green hydrogen, generated entirely using renewable energy.
CCUS	CCUS is key to Scotland meeting its Net Zero targets by 2030. CCUS involves the capture of CO_2 emissions, the conditioning of CO_2 to make it suitable for transportation via pipeline and the storage of CO_2 in large vacant O&G stores under the North Sea. CCUS may be used in the generation of other sustainable fuels or the decarbonisation of heavy industry to support a Just Transition.

Onshore wind

SG's ambition

Scotland has an established and significant onshore wind sector. 61%[1] of Scotland's renewable electricity is generated from onshore wind and as a result onshore wind is key to meeting SG Net Zero targets by 2045. Since 2015, Scotland has significantly scaled up its onshore wind capability and now holds the majority of the UK's generation capacity. In order to meet Scotland's growing demand for renewable electricity, further upscaling of wind capacity is required. This is exacerbated by the loss of around 2.4GW of generating capacity from the expected shutdown of nuclear by 2028.

Following COP26, SG set an ambition of up to an additional 12GW of onshore capacity by 2030[2] to meet Scotland's growing energy demand, increasing onshore wind capacity beyond 20GW. With onshore wind dominating Scotland's renewable energy capability, it is anticipated that the sector will continue to play a significant role in Scotland's energy mix into the future.

Opportunities

SG expects onshore wind to play a central role in Scotland's Just Transition for several reasons:

- Onshore wind is more cost effective than gas generation due to a combination of increasing fuel and carbon costs for gas as well as falling renewable technology costs.
- Currently, Scotland exports more energy than it consumes. The expansion of onshore wind will support additional exports in the future, increasing GVA.
- Additional development of onshore wind could help Scotland meet its increasing electricity demand following the winding down of nuclear generation and fuel switching in key sectors. In the heat sector, it is anticipated that by the late 2020s, 200,000 heat pumps will be installed per annum, placing additional demand on the electricity network. In the transport sector, UKG committing to end the sale of internal combustion engine cars by 2030 coupled with further electrification of the rail network will increase demand.
- Infrastructure requirements for onshore wind are considerably cheaper than offshore wind, which results in a lower energy cost to the end user. Additional onshore wind investment may be considered as a way to reduce wholesale energy costs in the medium to long term.
- 91% of onshore wind jobs require skilled labour for Operation and Maintenance (O&M)[3]. As a result, onshore wind may prove to be an attractive option for O&G workers and support staff wishing to transition out of the sector, protecting jobs and GVA.
- Onshore wind projects are situated in areas with optimal wind conditions, this can result in projects being located far from centres of population. As a result, onshore wind projects may provide high paying and skilled employment to rural communities.
- Onshore wind projects are easier to access and service than those offshore, as such, there may be more opportunities to involve a variety of parties in the ongoing maintenance of the windfarms.
- Scotland has established itself as a leader in the onshore wind market. As a result, international companies are considering Scotland's potential to host their next onshore wind project. Capitalising on this has the potential to increase Scotland's GVA.
- A strong onshore wind sector will also support the development of a range of green hydrogen projects.

Issues to be explored further

To allow SG to scale onshore capacity by an additional 12GW, there are a number of risks which must be carefully managed:

- Onshore winds can be unpredictable, varying in both speed and direction. This can result in periods of intermittency whereby the wind turbines do not operate at their maximum efficiency or cannot be used at all. As a result, alternative energy sources may be required to meet demand, leading to a greater requirement for power sources which can be drawn on during periods of renewable intermittency.
- Existing grid capacity may not be sufficient to cope with increased energy generation from onshore wind projects, resulting in constraints to energy generation without significant upgrades to infrastructure.

1 Scottish Energy Statistics Hub
2 Onshore wind - policy statement refresh 2021: consultative draft
3. Green Alliance: Powering the labour market – skilled work in a low carbon energy system

Onshore wind (cont.)

Issues to be explored further (cont.)

- Without the presence of increased electricity system flexibility, growing renewable generation and constrained networks, could increase the frequency of negative pricing.
- A lack of certainty around Transmission Network Use of System (TNUoS) charges in remote areas may disincentivise investment in areas most suited to onshore wind generation. Furthermore, price disparities between TNUoS fees in Scotland and the rUK result in barriers to investment in Scottish onshore wind projects.
- Onshore wind projects are often limited as to their scale by planning regulations. This can result in smaller turbines being used than is technically possible, limiting energy generation.
- As wind turbines are made from a variety of composite materials, recycling obsolete assets can require a large amount of energy, therefore some obsolete assets find their way into landfill. This reduces the positive environmental impact of wind energy generation.
- Onshore wind projects are subject to much public scrutiny as they are perceived by some to be an eyesore and a risk to wildlife. As a result, it may be challenging to obtain public buy-in for projects, particularly if they are located close to areas of higher population.

Supply chain

The onshore wind supply chain continues to evolve to serve the increasing number of onshore wind projects during the Capex and O&M phases. However, the UK currently lacks the manufacturing facilities required to build specific turbine elements and continues to rely on imported goods to satisfy demand:

- Scotland is home to over 9,000 wind energy supply chain business offering training, consultancy and manufacturing services.[4]
- The mature onshore wind supply chain continues to support development of new projects and the O&M of existing projects. The English market, in the absence of new wind farm developments, relies on an established UK supply chain to provide O&M services to existing wind farms. In Scotland the UK supply chain continues to serve established wind farms with O&M services and is also involved in the construction of new projects.
- There are currently no major turbine components manufactured in Scotland. However, there are various examples of large multinational energy companies engaging with the local service providers to support the installation of turbines.
- There are currently only two blade manufacturing sites in the UK, in Hull and the Isle of Wight.

O&G infrastructure compatibility

Although onshore wind is well developed in the UK, infrastructure constraints exist which restrict the capacity of new projects:

- Existing grid capacity may not be sufficient to cope with increased energy generation from large onshore wind projects, resulting in constraints to energy generation without significant upgrades to infrastructure.

4. Scottish Development International

Offshore wind

SG's ambition

Scotland is home to some of the highest concentration of wind energy in the world. It has large areas of seabed suitable for offshore wind energy generation through a mixture of floating and fixed turbines, and offshore wind currently makes up 11% of Scotland's renewable energy capacity.[1] The recent ScotWind and INTOG leasing rounds aim to attract big business to the wind energy market in Scotland, taking advantage of the untapped potential off Scotland's shores, increasing offshore wind capacity and cementing Scotland's position as a leader in offshore wind generation.

SG has recently set a revised ambition to increase offshore wind capacity to 11GW by 2030 to support Scotland's goal of reaching Net Zero by 2045. It is hoped with targeted investment that offshore wind projects will help Scotland achieve a net export position for energy in the 2030s.

Opportunities

It is anticipated that offshore wind will contribute to Scotland's Just Transition for the following reasons:

- Offshore wind is more cost effective than electricity from thermal (mainly gas) generation due to a combination of increasing fuel and carbon costs for gas as well as falling renewable technology costs. The clearing price in the July 2022 wind CfD auction was £37.55 per MWh, significantly lower than the September 2022 spot price of electricity from thermal generation, which was between £282 and £580 per MWh.
- Currently, Scotland exports more energy than it consumes (per Chapter 1 - 71% of gas production and 82% of oil in 2019). The expansion of offshore wind will support additional exports in the future, increasing GVA.
- As with onshore wind, additional development of offshore wind could also help Scotland meet its increasing electricity demand in the heat and transport sectors following the winding down of nuclear generation and fuel switching in key sectors.
- Floating wind substructure designs are conceptually the same as those used in the O&G industry. There is therefore the potential for O&G manufacturing companies to pivot to serve the offshore wind market following the decline of O&G activity.
- Significant levels of support will be required during the Capex stage to install turbines and the necessary infrastructure for transmission. This is expected to be provided locally and is an opportunity for existing O&G companies to strategically shift to support offshore wind projects with much of the skillset being transferrable.
- If the scaling of renewable opportunities is met with an equal decline in O&G production, O&G service companies may wish to diversify and protect their position into the future by pivoting to support offshore wind O&M.
- A further major opportunity for expanding power demand is through O&G platform electrification, which could be served by offshore wind energy.
- Like onshore wind, offshore wind creates opportunities for scaling up renewable generation capacity.
- The European Offshore Wind Deployment Centre, located in Aberdeen Bay acts as a test bed for new offshore wind technologies which may be rolled out across Scotland.

Issues to be explored further

There are a number of risks which must be evaluated prior to the commencement of offshore wind development:

- Offshore winds can be unpredictable, varying in both speed and direction. This can result in periods of intermittency whereby the wind turbines do not operate at their maximum efficiency or cannot be used at all. As a result, alternative energy sources may be required to meet demand. Resulting in a greater requirement for dispatchable power resources.
- Existing grid capacity may not be sufficient to cope with increased energy generation from offshore wind projects, resulting in constraints to energy generation without significant upgrades to infrastructure.
- Without the presence of increased electricity system flexibility, growing renewable generation and constrained networks, could increase the frequency of negative pricing.

1 Scottish Energy Statistics Hub 2 SG Heat in Buildings Strategy

Offshore wind (cont.)

Issues to be explored further (cont.)

- A lack of certainty around TNUoS charges in remote areas may disincentivise investment in areas most suited to offshore wind generation. Furthermore, price disparities between TNUoS fees in Scotland and the rUK result in barriers to investment in Scottish offshore wind projects.
- The UK does not currently support certain construction activities related to floating offshore wind. As a result the steel and concrete substructures and the marshalling assembly are procured overseas. This may present a barrier to the construction of projects in the medium to long term as domestic demand in the rest of the world for wind components grows and exports to the UK reduce.
- The installation of offshore wind turbines has the potential to cause disruption to the marine environment. This may be mitigated through the use of floating offshore wind which occupies a smaller footprint on the seabed.
- Offshore wind projects can also interfere with ships' radar, a key constraint to development, as identified by SG.

Supply chain

As offshore wind is a newer renewable energy generation method, the supply chain is taking some time to develop:

- Currently only 15% of total spend during the Capex phase of turbine development occurs in the UK, compared to 70% of O&M activity. More investment is required to reduce the reliance on foreign Capex imports and increase domestic production, increasing jobs and GVA. Please see pages 51 and 68-70 for further discussion on investment.
- Research by ESC indicates that Scotland currently has the necessary capability to source aggregates and cements and is likely to be able to source formwork for offshore wind concrete substructures. However, there is no domestic supplier for post-tensioning and the requirement for rebar can only partially be fulfilled domestically. As a consequence, Scotland is not currently best placed to satisfy the entire materials need for offshore wind cement substructure construction and supplementary imports are required. However, it is anticipated that all of the above will be able to be sourced domestically by 2030.
- Scotland has a variety of ports which could be adapted to support offshore wind component manufacture. Hunterston, Kishorn, Port of Cromarty Firth and Ardersier are deemed to be high-potential facilities. However, there is likely to be strong competition for space and transport vessels at these ports with an increase in renewable energy.

O&G infrastructure compatibility

There is the potential for offshore wind to utilise existing infrastructure in the North Sea to support the development of new projects.

- Lift vessels and resources involved in the decommissioning of O&G assets may also be able to serve offshore wind projects, increasing efficiency and reducing costs. However, as demand for decommissioning activity increases, it is key that a sufficient supply of vessels and operators is available to satisfy demand.
- Existing platforms may be used as hubs to accommodate staff deployed in the development and maintenance of offshore wind farms.
- Deep water ports, used to support the decommissioning of existing O&G assets, may be able to support floating offshore wind activity subject to infrastructure upgrades.

Onshore and offshore wind

We have combined the Geographic and Just Transition analysis for onshore and offshore wind, as the conclusions are applicable to both sectors.

Geographic analysis

Supporting manufacturing, operations & maintenance and training facilities are spread across the UK.

Scotland does not currently produce any major turbine components. However, smaller scale manufacturing and O&M is facilitated across Scotland, with a concentration in the Central Belt, benefitting from its heavy manufacturing and engineering skill base. The North East is home to a cluster of training centres, conveniently positioned to reskill O&G employees into the renewables sector. However, it remains isolated from manufacturing areas in the south and currently has limited manufacturing or O&M facilities of its own. As a result, development and maintenance services must be transported from other areas, which remains challenging due to relatively poor transport links. It could be expected that with a decline in O&G activity, the many manufacturing and service companies based in the North East will wish to pivot to serve the renewable energy sector, should there be sufficient demand. A handful of manufacturing and O&M facilities serve rural wind energy locations in the Outer Hebrides and Shetland.

In the rUK, the majority of supply chain activity is clustered in the Teeside region and the Midlands. The heavy manufacturing capability and skills base in these regions is ideally suited to development of wind turbines and their component parts. Good transport links and a network of facilities spanning the country result in the ability to service projects with relative ease.

Supporting a Just Transition in Scotland

Scotland's geography provides ideal conditions for onshore and offshore wind generation. With a strong manufacturing and skills base in the North East and a number of projects based in the North Sea, it is anticipated that much of Scotland's wind energy supply chain will locate in the North East of Scotland, supporting a Just Transition as O&G production winds down. Furthermore, there is the potential to repurpose existing O&G assets in the North East to serve offshore wind projects, reducing costs and environmental impact. These reasons, combined with the already established manufacturing and O&M facilities across the Central Belt and the success of the ScotWind and INTOG leasing rounds, suggests a bright future for wind energy generation in Scotland.

However, the lack of manufacturing capability of UK-domiciled companies for key components such as blades and subsea structures results in profits flowing overseas. When mixed with capacity constraints, and higher TNUoS charges in Scotland compared to the rUK, Scotland's ability to maximise the impact on GVA and GDP is restricted. Additionally, alternative energy sources will still be required when demand outstrips real wind energy generation capacity where conditions are not suitable for wind energy generation. At present, many surges in demand are met by nuclear or natural gas, with the latter being at detriment to Scotland's Net Zero aims.

Mapping Wind Activity in the UK

Source: www.renewableuk.com

CCUS

SG's ambition

CCUS is key to achieving SG's Net Zero targets by 2045, with plans to use CCUS to capture CO_2 from industrial processes and transport it for storage in depleted O&G stores in the North Sea.

CCUS locations in Scotland require approval by UKG, with no areas in Scotland currently earmarked for approval. SG continue to push for approval for a Scottish CCUS cluster under the second cluster sequencing process.

Opportunities

CCUS technology is not yet widely implemented. However, there are a number of opportunities for Scotland when the technology is available for roll out:

- Scotland has significant storage potential with well-mapped, vacant O&G stores in the North Sea, capable of storing CO_2 in excess of Scotland's requirements. This may result in a market for the import of CO_2 for storage from jurisdictions without storage capacity, creating domestic jobs and increasing GVA.
- Carbon capture technology can be implemented in areas which emit the largest proportion of carbon emissions or to support hydrogen generation. The captured carbon can then be transported by road, rail or sea. As such, even without the repurposing of old O&G infrastructure, CO_2 from across Scotland can be transported and stored in the North Sea, ensuring those who would benefit most from the technology can make use of the technology, reducing overall CO_2 emissions.
- Whilst CCUS focuses on the extraction and storage of CO_2, there is the potential to expand the technology to include other pollutants which could also be removed from the atmosphere and stored in a similar way, further reducing the environmental impact.
- BEIS analysis indicates that CCUS could be competitively priced against the carbon price in the long term. As a result, this may incentivise corporations to undertake CCUS activity rather than pay carbon pricing penalties. This will help reduce carbon emissions and increase the demand for CCUS, creating jobs and increasing investment to increase GVA.
- EY analysis indicates that CCUS in Scotland could create 436 jobs by 2030 and 654 jobs by 2050.

Issues to be explored further

There are risks associated with CCUS technology being in its infancy:

- The designation of a CCUS cluster in Scotland requires buy-in from UKG. Scotland was not awarded any clusters as part of the initial phase of the cluster sequencing process. UKG aims to have a minimum of four clusters by 2030; the Acorn project in North East Scotland currently holds reserve status on the initial cluster sequencing programme. It is hoped that the second phase will see at least one CCUS cluster being designated in Scotland; however, the timetable for this is unclear.
- At present, the roll out of CCUS is not at a sufficient pace to allow Scotland to meet its Net Zero targets. The Acorn project is a relatively small scale project in its initial phases. For CCUS to contribute significantly to Scotland's Net Zero targets, rapid scaling of CCUS capacity is required.
- Changes to carbon pricing and allowances are required to make carbon capture comparatively cheaper than emitters paying the carbon price to stimulate demand for CCUS and encourage decarbonisation.
- International treaty changes are required to facilitate a thriving export market. Cross-border storage will require changes to the London Protocol (1996) which included CO_2 in the international dumping regime. Amendments were made in 2009 to permit the export of CO_2 for storage in overseas territories, although these have not yet been ratified.
- CCUS can result in high polluting industries reducing net CO_2 emissions. However, the introduction of CCUS may result in a reduced appetite for fuel switching or other CO_2 saving initiatives, resulting in no reduction in CO_2 output.
- There are cross chain risks due to interdependencies, and extreme risks such as leakages for transport and storage entities in CCUS, which may disincentivise players in the market.
- Potential for leaks during the transport and storage process mean a robust action plan must be implemented to prevent concentrated CO_2 being released into the environment as it could cause significant damage.
- The storage process has the potential to cause seismic activity, which may result in geological instability.
- Large amounts of energy are required to compress and maintain CO_2 at pressure for transport resulting in an energy intensive and costly process.

CCUS (cont.)

Supply chain

The CCUS supply chain will continue to evolve as CCUS projects are developed across the UK:

- It may be possible to repurpose existing O&G assets for CCUS. As there is an established O&G supply chain for the development and servicing of those assets, existing manufacturing and servicing companies may be able to pivot to serve CCUS projects as O&G production is wound down.
- The machinery required to capture CO_2 emissions is only just being developed. As a result, it will take some time for the supply chain to be established to serve the manufacturing and servicing of carbon capture equipment.
- The UK lacks facilities which produce gas turbines or other specialist rotating equipment required to compress CO_2 for transport. As a result, there is a reliance on imported equipment which may become challenging to obtain as demand for CCUS increases around the world.
- A large amount of investment will be required during the Capex stage onshore to design and build the necessary equipment to facilitate CCUS. However, the UK is not ideally placed to support work of this type. UK labour and raw material rates are higher than they are in other areas of the world. As a result, companies may find it cheaper to import goods for installation. Furthermore, much of the UK's manufacturing capacity has been developed around historical markets, largely focused on steel production. At a time when steel costs are high and many production facilities are closing as a result, there may be limited locations with the capacity and skills required to develop sophisticated pieces of equipment on a large scale.
- CCUS projects are based both onshore (for capture, processing and transport) and offshore (for storage). As a result, the supply chain must have the ability to interact at key junctions. With over half of total expenditure (Totex) occurring in the operational expenditure (Opex) stage, redefining the focus of the O&G supply chain could be beneficial. As an industry also operating both on and offshore, many of the skills will be transferrable to the delivery and ongoing maintenance of CCUS projects.

O&G infrastructure compatibility

Some of the O&G infrastructure may be repurposed to serve CCUS projects.

- Scotland's existing O&G infrastructure has the potential to be repurposed to support the transport of CO_2 from across Scotland to subsea storage locations in the North Sea, reducing Capex costs and the environmental impact of constructing new pipelines.
- Onshore terminals could be repurposed to facilitate the needs of the CCUS industry for the processing and transport of CO_2 to storage locations.
- Offshore O&G platforms could be repurposed to house control systems for CO_2 injection equipment, although it is anticipated that this could come at a relatively high cost.

CCUS (cont.)

Geographic analysis

Scotland currently has one potential CCUS cluster with Acorn in the North East which could expand to include a sister site at Grangemouth in the Central Belt. Acorn has the potential to offset carbon emissions from O&G activity in the North East whilst Grangemouth is ideally placed to offset emissions in the heavy industrial areas in Glasgow and Edinburgh.

Currently Scotland has no CCUS Clusters approved under UKG's CCUS sequencing programme, which is a prerequisite for deployment; however, Acorn holds reserve status under phase 1 and it is hoped that it may be sequenced during phase 2 of the sequencing programme.

In England, the East Coast Cluster and HyNet were sequenced during phase 1 of UKG's CCUS sequencing programme. Based in the heavy industrial areas of Teeside, Humber and Liverpool, these clusters are well placed to contribute to the UK's carbon reduction targets.

Other potential CCUS clusters in the South of England and Wales are competing against the two Scottish Clusters for sequencing during phase 2. However, the proximity to offshore storage locations, available transport infrastructure and skills base may present a compelling case for Scottish designation.

Supporting a Just Transition in Scotland

CCUS is an important element of Scotland's Just Transition strategy and the journey to Net Zero. The proximity to depleted O&G stores in the North Sea for storage and a highly skilled labour market present a strong basis for the successful roll out of CCUS in Scotland. In time it is expected that the cost of CCUS will eventually be less than the carbon price, resulting in increased demand for CCUS solutions with time.

However, the technology is in its infancy, resulting in a number of uncertainties. The UK may not have the appropriate supply chain capabilities in place to take advantage of investment during the Capex stage.

Finally, without UKG sequencing, CCUS in Scotland will not materialise which could result in Scotland failing to reach its Net Zero targets.

Mapping CCUS Activity in the UK

Source: iogpeurope.org; projectcavendish.com

Hydrogen

SG's ambition

Hydrogen has potential as a sustainable fuel to lower GHG emissions and support a Just Transition to Net Zero. Hydrogen technology is in its infancy but with applications in transport, heating and industry it presents an opportunity to facilitate the decarbonisation of a number of different sectors.

SG has set an ambition of 5GW of renewable and low carbon production by 2030, scaling up to 25GW by 2045.[1] Domestic hydrogen demand is anticipated to be met by 2030, so Scotland could begin exporting hydrogen by the 2030s.

Opportunities

As hydrogen is a new technology, there are a number of opportunities for its development in the medium to long term:

- Hydrogen will assist in the decarbonisation of hard to reach sectors such as industry and certain modes of transport whilst also serving as a dispatchable low carbon energy source. We discussed the potential role of hydrogen in detail in Chapter 2.
- SG aims to create a network of production and distribution hubs across Scotland. There is the potential to use the hydrogen hub established in Aberdeen as a test location for new hydrogen infrastructure and production technologies which could be rolled out to other areas across Scotland. As more hydrogen hubs are developed, they could provide employment for those moving out of the O&G sector as production winds down, preserving jobs and protecting GVA.
- Hydrogen technology may be used to store electrical energy for use when demand requires. Excess renewable energy could be used to electrolyse water to create hydrogen which could then generate energy during periods of peak consumption or for export. SG estimates that there are significant opportunities for the export of hydrogen to Europe in the medium to long term.[2]
- SG has earmarked £100m of the Emerging Energy Technologies Fund for hydrogen technology investment. This may assist in attracting investment in Scotland's domestic hydrogen programme, helping to increase innovation and create jobs.
- EY analysis indicates that a hydrogen economy could create 9,578 jobs by 2030 and 43,989 jobs by 2050.

Issues to be explored further

As with all new technologies, there are a number of risks associated with the roll out of hydrogen technology:

- The electrolysis process used to create hydrogen is energy intensive, leading to the use of grey hydrogen created from natural gas to keep costs low and encourage adoption amongst energy users. It is anticipated that, with time, the cost of electrolysis will reduce and fossil fuels will be replaced by renewable energy sources to create green hydrogen.
- There are few current markets for the consumption of hydrogen, given the high cost, meaning current demand for hydrogen is relatively low.
- In the interim, carbon emissions from fossil fuels used in the generation process could be captured through CCUS to create blue, carbon neutral, hydrogen. However, there are currently no CCUS clusters in Scotland and as a result, the generation of blue hydrogen cannot currently be achieved.
- The creation of green hydrogen will require upscaling of Scotland's renewable energy capacity to meet demand. RenewableUK expects that there will be spare wind generation capacity by 2050 to support electrolysis for the creation of green hydrogen. There is the risk that available green renewable energy capacity does not materialise quickly enough to generate green hydrogen at the scale required, reducing the decarbonisation effect.
- Unlike O&G, which is found in a finite number of areas globally, any area with sufficient energy reserves and a water supply can generate hydrogen, as observed in Italy and Spain. This, combined with a push for nations to self-satisfy their energy demands, may result in an overall reduction in demand for Scotland's exported energy to the rest of the world.
- The export of Scotland's energy resources is a key driver of national growth and GDP. As Scotland is a global leader in hydrogen technology, it will take some time to establish a market for hydrogen export. As such, hydrogen will not immediately replace the GDP gap left behind by the winding down of O&G activity. Work is already ongoing to establish trade links between Scotland and Europe for the export of green hydrogen with the Scot2Ger project highlighting the demand from mainland Europe which Scotland's exports could help satisfy.

1 SG Draft Hydrogen Action Plan
2. SG: Scottish hydrogen: assessment report

Hydrogen (cont.)

Supply chain

Ensuring there is a strong and resilient supply chain to serve hydrogen projects is key to supporting the development of hydrogen technology:

- As large scale hydrogen production is a relatively new technology in the UK, it will take some time to build an established supply chain.
- The UK already develops electrochemical technologies which are exported internationally and are being applied to small-scale domestic hydrogen projects. As the hydrogen roll-out gains momentum, it is hoped that companies within the existing supply chain expand and a critical mass is achieved which draws additional investment.
- As fossil fuels are still used in the process, the creation of blue hydrogen requires interaction with CCUS projects, of which there are none currently operational in Scotland, to ensure that carbon emissions are appropriately reduced.
- There are synergies between the supply chain requirements of O&G and hydrogen projects. As a result, the O&G supply chain may be able to pivot to serve blue hydrogen projects, retaining highly skilled, well paying jobs and supporting a Just Transition to Net Zero.
- The creation of green hydrogen is a less mature process, utilising newer technology to create hydrogen from renewable energy sources. As a result, the supply chain and infrastructure is less established and it is more challenging for the O&G supply chain to pivot to serve this industry. As a result, green hydrogen projects are currently more challenging to implement and service.
- There are few energy supply chain giants in the UK and creating such supply chain-led consortia with appropriate government support and funding could bring together the critical skills, technology, and capability to win business in the energy transition space, increasing jobs and GVA.

O&G infrastructure compatibility

Much of Scotland is served by existing natural gas infrastructure. There is the potential to adapt this to serve the hydrogen industry:

- Onshore terminals may be repurposed as hubs for processing and transporting hydrogen. The proximity of onshore terminals to existing industrial activity makes them well suited to facilitate the decarbonisation of industry.
- Existing O&G and domestic grid infrastructure may be able to be repurposed for the transport of hydrogen from offshore electrolysers to the mainland and for the transport of hydrogen onshore. However, it is anticipated that there will be a requirement for additional Capex to upgrade some existing equipment and add additional machinery to facilitate the transport of hydrogen. The potential required investment has been explored further on pages 51 and 68-70.
- O&G platforms may be converted to offshore electrolysis platforms to generate hydrogen with little electrical power loss due to the proximity to offshore wind farms. O&G platforms could also be used to accommodate staff working on offshore electrolysers.

Hydrogen (cont.)

Geographic analysis

Activity in Scotland is concentrated in the North East and the Central Belt. The North East is an area which historically benefited from O&G exploration. Acorn, based in St Fergus, North of Aberdeen is a blue hydrogen production plant planned to facilitate distribution across Scotland. The Dolphyn project is a green hydrogen production facility based off the North East of Scotland coast which aims to produce hydrogen at scale for distribution. The complimentary O&G supply chain and skills base in the North East are ideally suited to service both projects. Significant development in offshore wind off the North East of Scotland coast as a result of the INTOG and ScotWind leasing rounds presents the opportunity for wider scale green hydrogen creation, once capacity allows. Projects across the Central Belt include a hydrogen production and storage location at Whitelee wind farm as well as a green hydrogen production facility near Grangemouth. Other green hydrogen projects are proposed for the North of Scotland and Shetland Isles. Four of Scotland's projects are currently operational being Levenmouth Community Energy Project, Whitelee Windfarm Hydrogen Production and Storage Facility, JIVE Project and The Event Complex (Aberdeen).

However, the lack of available infrastructure to transport hydrogen across Scotland makes it challenging to deliver hydrogen to those who may benefit from the greatest decarbonisation effect. Small-scale pilot projects have largely focused on the decarbonisation of transport but there is the potential to trial the fuel switching for domestic heating or the decarbonisation of industry. SG plans to continue the roll out of hydrogen hubs across Scotland to create a network for generation and transmission.

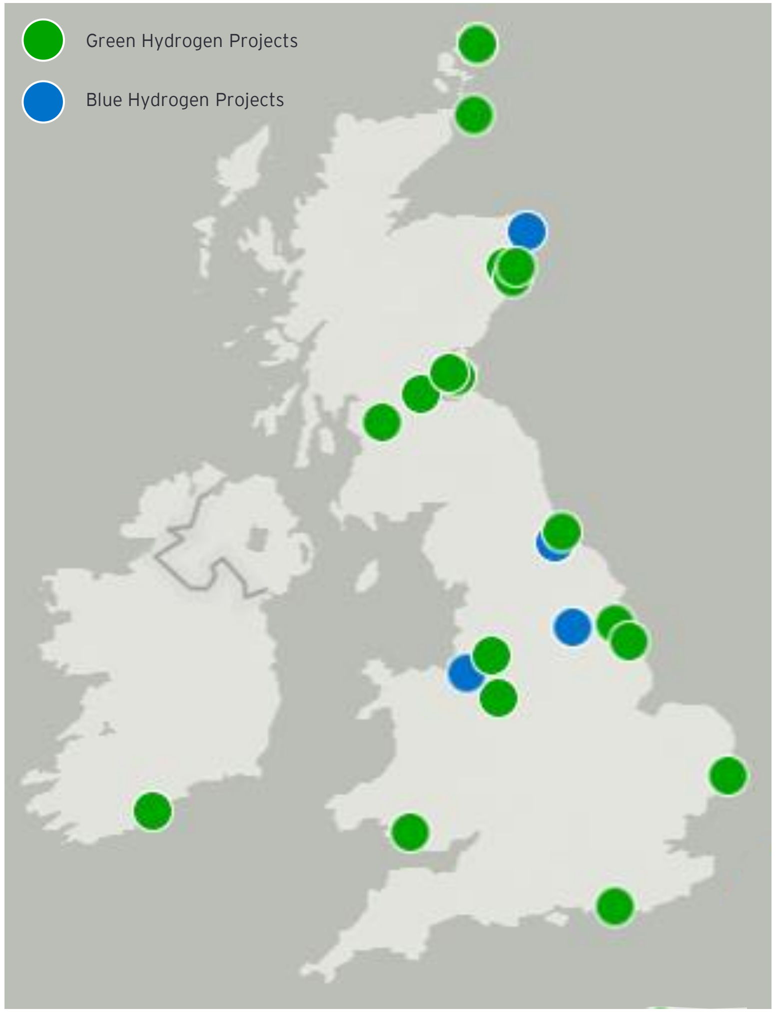
Across the rUK, hydrogen projects are situated in areas with greater economic activity. Their proximity to industry reduces logistical challenges in the delivery of hydrogen. Only two projects are currently operational being HyDeploy and Baglan Energy Park.

Supporting a Just Transition in Scotland

Hydrogen technology has the potential to attract inwards investment and preserve high paid and skilled O&G jobs which would ordinarily be lost when O&G production diminishes. The Acorn and Dolphyn projects in the North East of Scotland are the first step in creating a wider network of electrolyser and transport infrastructure to support the large scale adoption of hydrogen as a low carbon energy source.

However, the supply chain will take some time to establish and the high costs of production in the early stages will drive up end consumer prices, making early adoption challenging. Whilst the O&G supply chain and skills base is largely complementary to the generation of blue hydrogen, it is more challenging to pivot to support green hydrogen projects due to the technology being in its infancy. Finally, blue hydrogen projects are highly dependent on CCUS facilities being available, as there are currently no CCUS clusters in Scotland, blue hydrogen generation cannot be achieved at present.

Mapping Hydrogen Activity in the UK



Source: www.thehydrogenmap.com

O&G adjusted production pathways: Potential investment models

Funding and financing

There are broadly three categories of potential investment models for the large-scale energy projects in offshore wind, hydrogen and CCUS that sit at the heart of the Just Transition:

- **Government procurement:** funded through borrowing / taxation. While this has been considered for large-scale energy projects (with a view to selling on once higher-risk construction stages are finished), it is not common in regulated markets, such as energy. Various jurisdictions (e.g. UK, US, Belgium) have used government guarantees to facilitate debt funding.
- **Regulated models:** where government or a regulator guarantees that bill payers will pay for investment over the long term, giving confidence to investors. This model has backed the Renewable Obligation Certificate (ROC) and CfD models of investment in the UK and has been behind the rollout of wind and solar. The CfD model obliges bill payers through a levy to subsidise renewables providers when the wholesale price they receive for power falls below a 'strike price'. Renewable providers in turn pay their customers when the price they receive is above the strike price. Please note that UKG is currently seeking to move recipients of the older (and more expensive) ROC model to CfDs voluntarily.
- **Purely private investment:** this is likely to be significant in areas where there is an immediate need and clear demand – such as EV charging networks. There are also examples of private investment in renewables backed by power purchase agreements (PPAs) with entities (e.g. EY has a PPA with a privately-funded solar farm, which provides the secure revenue stream which will facilitate the investment needed).

The regulated mechanisms have consistently delivered high levels of low carbon investment in the UK since the 2000s. Further consideration will be needed for how the below specific models will work in the future.

Likely specific investment models

Each of the main renewable sectors is likely to require a different investment model or an adapted model to allow for the scale of investment required:

Offshore wind: the CfD is the most established model for the three technologies and is also used in supporting solar and other low carbon technologies. We would expect these to be the best value for money in the future, and strike prices for wind are currently well below the prices for thermal generation. However, given intermittency there will be times when more wind reduces prices (including to zero) as set out in Chapter 2, and there will be a need for capacity market mechanisms.

- The track record of investment and reducing costs mean we would not anticipate a problem with attracting the £21bn private investment into this market that the BOP scenario requires. While offshore wind prices now clear below the average for fossil fuel generation, project promoters value the hedge against volatility that the CfD provides, meaning that commercial model can continue to be used as the price differentials change between fossil and renewable power.

CCUS: UKG has established a business model for CCUS investment. The transport and storage (T&S) element will be economically regulated in the same way that electricity and gas networks are regulated, through a regulated asset value (RAV) model. UKG will negotiate a economic licence for the first regulatory period for each T&S Co., alongside an development plan. Acorn (the Scottish CCUS cluster) is currently on track 2 for negotiations.

- As the carbon price currently is too low to incentivise emitters to capture, Government will subsidise them through a set of business models based either on the CfD for industrial and waste emitters, or the Dispatchable Power Agreement (DPA) for power emitters. The economic regulatory regime for T&S and the contracts for emitters have not yet been completed and tested in the market, but promoters have indicated they are willing to commit to financing projects. There is sufficient liquidity in debt and equity to markets for this type of investment.

Hydrogen: this is the least mature business model. A model for blue hydrogen is being developed that is based on the CfD, with a variable reference price based on the price of natural gas – the closest alternative – depending on whether there is a market for low-carbon hydrogen. This will depend on there being suitable off-takers who are willing to enter into a long term contract to use the subsidised hydrogen.

- This has not been tested in the market but the model has strong precedents in supporting new industries and a number of projects have come forward in the UK with strong financial backing.

Both CCUS and hydrogen require management of supply and demand sides in order to be successful.

O&G adjusted production pathways: Potential investment models

Complexity of new models

We believe that it is possible for the different models to be privately financed if the funding model is delivered by government, as intended above. There are potential issues with private finance in high-risk areas where finance providers are taking technology risk, but the business models have been able to overcome these hurdles in the past, leading to the embedding of new technologies.

The CCUS and hydrogen models require both supply side and demand side to come to the table, which adds complexity and the level of cross-chain risk can be a barrier to investment. In order for the private market to respond, it will be important for the first projects to be successful and being able to develop a track record in the same way that offshore wind has already done in the UK.

Costs and new technologies

In assessing whether costs are likely to rise or fall and whether current estimates are accurate, there are four main issues to consider:

- Modelling techniques and premature assumptions can underestimate costs.
- Reductions in cost and risk as technology matures.
- Increases in infrastructure costs above inflation due to major project risks materialising.
- Integration and additional costs outside the specific technologies discussed here – for instance increased electricity transmissions costs.

Inaccurate assumptions

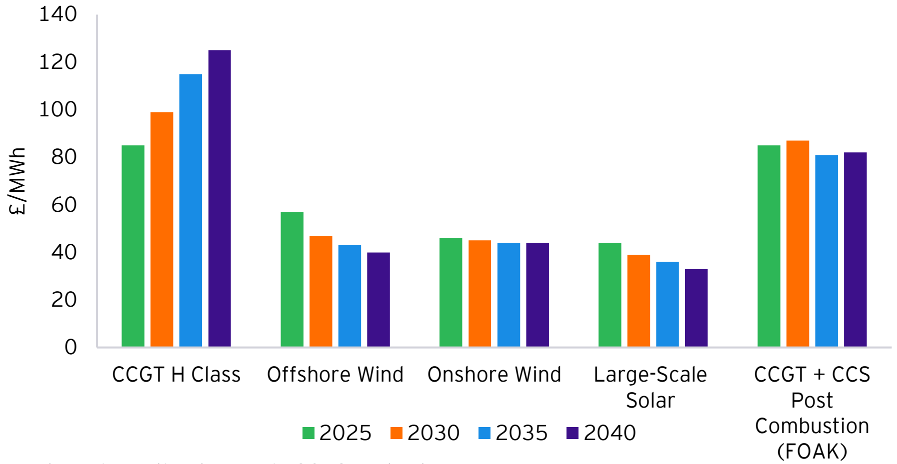
Model assumptions are likely to be simplified and those used in the BOP scenario will affect both the total and distribution of the different technologies, meaning the commercial markets that emerge may not respond in the way the model predicts.

Reductions due to technological maturity

Both cost and risk would be expected to reduce over time as new technologies mature. This process has already been seen with wind energy and to some extent with solar (although further technological progress is likely). The shift in risk, particularly for newer technologies, should see the cost of capital reduce and hence a reduction in cost to users. On the right we have set out the current BEIS projections of technology cost, as well as historic trends in offshore wind WACCs to show the shift in cost of capital.

WACC rates on pre-construction offshore wind projects earlier in the development phase (i.e. 2010) were in the range of 5-5.5% (pre-tax). Gearing levels of these early projects were as low as 50%. Mature projects have WACC rates of c.3.5% (pre-tax) and higher gearing levels between 70-75%.

Levelised cost estimates by technology type



Note: Price estimates are in 2018 real values
Source: [1]BEIS - Electricity Generation Costs (2020)
[2]CFD AR4 auction

	Debt	Equity	WACC (pre tax)
Early	50%	50%	5.5%
Mature	70%	30%	3.5%
Refinancing	90%	10%	2.0%

This reduction in cost with maturity is partly driven by technological maturity, but also the reliability of the business model. The CfD and DPA contracts have shown the ability to attract private investment over a long period of time, resulting in competition for financing which in turn reduces costs.

The business model for offshore wind is already well known and proven, and thus we would expect the financing of this sector to be generally more straightforward. We do however expect some technological issues with floating wind as this is a new technology.

O&G adjusted production pathways: Potential investment models (cont.)

Inflation risks

There are a number of inflation factors that could result in the BOP scenario costs of c.£33bn being underestimated:

- Changes in macro-economic conditions could mean that private sector investors require a higher rate of return to invest. In response to the financial crisis in 2008, The Bank Of England prioritised monetary policy which kept inflation rates low, resulting in a negative risk-free rate of return. As time passed they began to unwind this policy, causing the risk-free rate to switch from negative to positive. Higher inflation rates erode investors' nominal returns more quickly, and spreads on debt (i.e. the difference between borrowing and lending interest rates) have also increased. These factors have increased the marginal cost of investments, and further changes in macro-economic conditions could increase marginal costs further.
- Inflation for specific large infrastructure projects is rising more quickly than general inflation. Some project costs are also denominated in foreign currencies and are further impacted by the reduction in the value of the pound.
- The tendency for project cost estimates to rise over time. Both CCUS and hydrogen are relatively new in terms of large scale project implementation in the UK, and current BEIS budgets could underestimate the final costs given long timescales and uncertainty.

These factors mean it is likely for inflation to impact the Scottish rollout of the low carbon technologies, both in the short-term (over the next 5 years) and knock-on effects in the medium term.

Ancillary investment

Further investment in other industries is required alongside the investment in wind, CCUS and hydrogen. Most significantly transmission capacity needs to be improved and dispatchable power sources funded where intermittent renewables are used. This means the total cost of the energy transition is likely to be higher than the BOP estimate of c.£33bn.

Levies and control of costs

Governments' willingness to add to energy bills in order to pay for transition is limited (noting UKG has not updated the Control for Low carbon levies since 2017). These costs will also demand a greater share of income from those on lower incomes which could see limits imposed on funding.

In addition, electricity customers have borne the cost of the expansion of renewables; as electrification of heat and transport continue, it will be those who have made a transition to lower carbon technologies who will be paying for the extra costs involved.

UK and Scotland interaction

The UK and Scotland function as a single energy market (for both gas and electricity). The subsidies for renewables, hydrogen and CCUS are backed by UK consumers and taxpayers. Scotland is currently an exporter of renewable energy and this has been facilitated by the integrated market.

Given users outside Scotland benefit from Scotland's low-carbon power, there needs to be a mechanism for UK consumers to pay for it and pay for the dispatchable generation capacity that intermittent generators require. The current integrated market has delivered this and allows both renewable subsidies and capacity payments to be supported by a large market and gives investors confidence.

Key issues and questions

This analysis shows that there are key issues and questions remaining that will affect investment in the relevant technologies:

- Fairness and distributional impacts of levies.
- Potential for increased costs because of intermittency and zero pricing.
- The future of the integrated UK market under different circumstances.
- Investment in transmission assets to facilitate renewable investment in Scotland.
- Implications for zero pricing for renewable power as the proportion increases.
- Demand drivers for hydrogen / off-takers – for example, transport or industrial.
- Demand for CCUS / free allowances and link to the carbon price.
- Timing and ambition for track 2 of CCUS.

Conclusion

Conclusion

Investment in low carbon technology is required for Scotland to meet its Net Zero targets by 2045. The four key sectors of onshore wind, offshore wind, CCUS and hydrogen present a number of opportunities for Scotland, helping to create jobs, counteract a decline in GVA and achieve a Just Transition. However, to enable Scotland to maximise the benefits, a number of key issues must first be resolved.

Onshore and Offshore Wind

Opportunities for Scotland

- Wind energy is more cost effective than gas generation due to a combination of increasing fuel and carbon costs for gas as well as falling renewable technology costs.
- Currently, Scotland exports more energy than it consumes. The expansion of onshore wind will support additional exports in the future, increasing GVA.
- Additional development of onshore wind could help Scotland meet its increasing electricity demand following the winding down of nuclear generation and fuel switching in key sectors. In the heat sector, it is anticipated that by the late 2020s, 200,000 heat pumps will be installed per annum, placing additional demand on the electricity network. In the transport sector, UKG committing to end the sale of internal combustion engine cars by 2030 coupled with further electrification of the rail network will increase demand.

Key issues to resolve

- Onshore and offshore winds can be unpredictable, varying in both speed and direction. This can result in periods of intermittency whereby the wind turbines do not operate at their maximum efficiency or cannot be used at all. As a result, alternative energy sources may be required to meet demand. Resulting in a greater requirement for dispatchable power resources.
- Existing grid capacity may not be sufficient to cope with increased energy generation from wind projects, resulting in constraints to energy generation without significant upgrades to infrastructure.
- Without the presence of increased electricity system flexibility, growing renewable generation and constrained networks could increase the frequency of negative pricing.

CCUS

Opportunities for Scotland

- Scotland has significant storage potential with a number of well-mapped, vacant O&G stores in the North Sea, capable of storing CO_2 in excess of Scotland's requirements. This may result in a market for the import of CO_2 for storage from jurisdictions without storage capacity, creating domestic jobs and increasing GVA.
- Carbon capture technology can be implemented in areas which emit the largest proportion of carbon emissions or to support hydrogen creation. The captured carbon can then be transported by road, rail or sea. As such, even without the repurposing of old O&G infrastructure, CO_2 from additional areas in Scotland can be transported and stored in the North Sea, ensuring those who would benefit most from the technology can make use of it, reducing overall CO_2 emissions.
- BEIS analysis indicates that CCUS could be competitively priced against the carbon price in the long term. As a result, this may incentivise corporations to undertake CCUS activity rather than pay carbon pricing penalties. This will help reduce carbon emissions and increase the demand for CCUS, creating jobs and increasing investment to increase GVA.

Key issues to resolve

- The designation of a CCUS cluster in Scotland requires buy in from UKG, consistent with the BOP scenario assumptions. Scotland was not awarded any clusters as part of the initial phase of the cluster sequencing process. UKG aims to have a minimum of four clusters by 2030, the Acorn project in North East Scotland currently holds reserve status on the initial cluster sequencing programme. It is hoped that the second phase will see at least one CCUS cluster being designated in Scotland; however, the timetable for this is unclear.
- At present, the roll out of CCUS is not at a sufficient pace to allow Scotland to meet its Net Zero targets. The Acorn project, noted on UKG's reserve list, is a relatively small scale project. For CCUS to contribute significantly to Scotland's Net Zero targets, rapid scaling of CCUS capacity is required.
- International treaty changes are required to facilitate a thriving export market. Cross border storage will require changes to the London Protocol (1996) which included CO_2 in the international dumping regime.

Conclusion (cont.)

Key issues to resolve (cont.)

- Amendments were made in 2009 to permit the export of CO2 for storage in overseas territories, although these have not yet been ratified.
- There are cross chain risks due to interdependencies and extreme risks such as leakages for transport and storage entities in CCUS which may disincentivise players in the market.
- Changes to carbon pricing and allowances to make carbon capture comparatively cheaper than emitters paying the carbon price are required to stimulate demand for CCUS and encourage decarbonisation.

Hydrogen

Opportunities for Scotland

- As explored in Chapter 2, hydrogen may assist in the decarbonisation of hard to reach sectors such as industry and certain modes of transport whilst also serving as a dispatchable low carbon energy source.
- Hydrogen technology may be used to store electrical energy for use when demand requires. Renewable energy may be used to electrolyse water to create hydrogen which could then be used to generate energy during periods of peak consumption.
- SG aims to create a network of production and distribution hubs across Scotland. There is the potential to use the hydrogen hub established in Aberdeen as a test location for new hydrogen infrastructure and production technologies which could be rolled out to other areas across Scotland. As more hydrogen hubs are developed, they could provide employment for those moving out of the O&G sector as production winds down, preserving jobs and reducing the impact on GVA.

Key issues to resolve

- The electrolysis process used to create hydrogen is energy intensive, leading to the use of grey hydrogen created from natural gas to keep costs low and encourage adoption amongst energy users. It is anticipated that, with time, the cost of electrolysis will reduce and fossil fuels will be replaced by renewable energy sources, such as wind farms, to create green hydrogen.
- There are currently few markets for the consumption of hydrogen given the high cost of generation, meaning current demand for hydrogen is relatively low.
- The creation of green hydrogen will require upscaling of Scotland's renewable energy capacity to meet demand, as explored in section 5. RenewableUK expect that there will be spare wind generation capacity by 2050 to support electrolysis for the creation of green hydrogen. There is the risk that available green renewable energy capacity does not materialise quickly enough to generate green hydrogen at the scale required, reducing the decarbonisation effect.

7 Policy interventions

Policy overview

Overview and scope

The objective of this section is to provide recommendations on SG policies and intervention that will help to achieve a Just Transition, building on the analysis across the three reports about the prospects for the O&G industry, how current patterns of consumption have evolved, and what the economic prospects are for new, low carbon, industries. This will also explore the proposed timings of these interventions and whether SG has direct powers to implement the recommendations.

This analysis will help to provide insight on the transition by exploring the potential dynamics between sectors in decline and new growth sectors, and what types of policies will be required to support the development of new sectors. SG's Just Transition outcomes that need to be achieved will be used as a reference point.

This is not intended as a prescriptive exercise to determine a precise set of policies, but to draw on our analysis from Chapters 1, 2 and 4 to suggest a strategic approach to the different areas of policy that will be required to achieve a Just Transition.

Policy objectives and context

The economic analysis set out above identifies an outcome where the potential O&G decline (whichever pathway the Scottish O&G industry follows) can be matched for low carbon jobs, and possibly GVA.

Work undertaken by the Energy Systems Catapult and other analysis has set out a potential outcome of replacing O&G with a large scale renewable, hydrogen and CCUS industry in Scotland that can export power and capture services to rUK and beyond, increasing its contribution in GVA terms, while supporting high levels of high-quality employment. The charts overleaf set out what these trajectories might be.

The transition to this future should be managed so that the people and communities affected by the decline of O&G are able to take advantage of the new opportunities, find employment and deliver prosperity. To do this, Scotland needs to build on its strengths – not just the natural resources such as wind energy, but the current O&G supply chain which is among the most innovative globally, world class universities and capability for innovation.

SG's National Just Transition outcomes

1. Citizens, communities and place: support affected regions by empowering and invigorating communities and strengthening local economies;
2. Jobs, skills and education: equip people with the skills, education and retraining required to support retention and creation of access to green, fair and high-value work;
3. Fair distribution of costs and benefits: address existing economic and social inequality by sharing the benefits of climate action widely, while ensuring that the costs are distributed on the basis of ability to pay;
4. Business and Economy: support a strong, dynamic and productive economy which creates wealth and high quality employment across Scotland, upholds the United Nations (UN) Guiding Principles on Business and Human Rights, and continues to make Scotland a great place to do business;
5. Adaptation and resilience: identify key risks from climate change and set out actions to build resilience to these risks, ensuring our economy is flexible, adaptable and responsive to the changing climate;
6. Environmental protection and restoration: commit to act within our planetary boundaries while protecting and restoring our natural environment;
7. Decarbonisation and efficiencies: contribute to resource efficient and sustainable economic approaches that actively encourage decarbonisation, support low-carbon investment and infrastructure, and avoid carbon 'lock-in'; and
8. Further equality and human rights implementation and preventing new inequalities from arising: address fuel poverty and child poverty in a manner consistent with Scotland's statutory targets on each, while furthering wider equality and human rights across all protected characteristics.

Policy context and overall goals

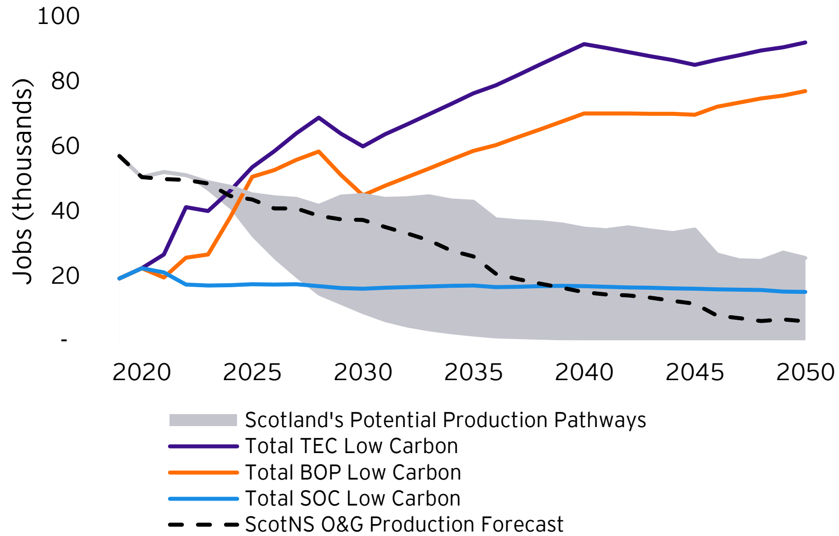
Policy objectives and context (cont.)

Scotland and the North East in particular face a set of complex interlocking challenges from the decline of O&G extraction from the ScotNS. While the expansion of the low carbon sector and associated technologies offer opportunities, rolling these out will not be straightforward. Even if a rapid expansion of these industries is achieved, ensuring that the transition works for Scotland and the regions and people directly affected, will require considerable effort and a co-ordinated approach.

Historically, many economic transitions have left people behind and achieved success only after a period of dislocation. Energy transition presents Scotland with a series of challenges:

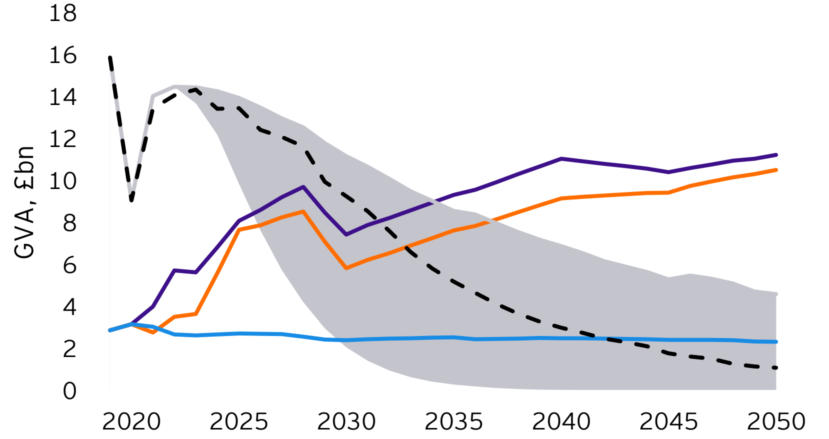
- In the context of an integrated UK energy market, SG will need to develop support for new investment. Decisions are currently made by UKG and regulators and where risks and funding are socialised across the UK. Please refer to section 5 for more detailed analysis on investment.
- Whatever choices are made by SG on implementing an O&G climate checkpoint, the decline in O&G is likely to be rapid and challenging. Jobs in the industry are long term, high value and concentrated in the North East of Scotland.
- Dislocation in declining industries can have impacts far quicker than an overall decline might suggest.
- It is easier to develop jobs related to the operations for wind energy, but this represents a small proportion of cost. None of the main manufacturers are UK based, and the experience of rUK in offshore wind is that proportions of local manufacturers are low, even with focused work on supply chains and foreign investment.
- It is not easy for people or firms to transition to new jobs or new markets, even where there is overlap between the markets and a potential re-application of skills and capabilities. The necessary re-training from old sectors to new growth sectors is a crucial element of the transition which should be explored further.
- The graphs on the right show a slower growth rate in GVA compared to jobs, which is explored further in Section 5.
- Section 5 also shows that the costs of rolling out new low carbon technologies are considerable. The costs of transition are not naturally progressively distributed, and will make not just heating but all forms of energy more expensive. This will have the greatest impact on those for whom energy costs are a high proportion of spending, i.e., those on lower income.

Decline in O&G jobs and growth in low carbon jobs using ESC scenarios (direct & indirect jobs)



Source: EY analysis

Decline in O&G GVA and growth in low carbon GVA using ESC scenarios (direct & indirect GVA)



Source: EY analysis

Policy context and overall goals (cont.)

Policy objectives and context

The future positive jobs and GVA trajectories (set out on the previous page) are reliant on overcoming this set of challenges. This can only happen with the adoption of an integrated strategy, such as the Draft Energy Strategy and Just Transition Plan published by SG in January 2023. Scotland is home to an established offshore wind sector and is well placed to capitalise on this experience, but the other low carbon sectors also have a significant role to play. The geology of the ScotNS and existing O&G exploration activity means that Scotland is one of the best places in the world where large scale deployment of carbon capture and storage can occur. The availability of CCUS and off and onshore wind means that Scotland is ideally placed for the development of the hydrogen industry.

As well as these natural advantages, Scotland has an existing workforce and supply chain that could service industries in the ScotNS. Although there is not a perfect match between existing skills / supply chain and those required in new growth sectors, Scotland also has a tradition of innovation within existing industries, which is further supported by several world-class universities that can act alongside industry to help innovate. SG's strategy needs to bring together these advantages to ensure that the new industries come forward and the benefits enable a Just Transition.

Some of these policies concern matters currently devolved to SG while others are retained at UK level, so part of any strategy will be to lobby UKG for action, or for further powers to come to Scotland. As the UK has an integrated energy system, the scope for independent Scottish action will need to be considered very carefully. SG's strategy needs to combine five critical interlinked components to support the Just Transition Outcomes:

1. **Policies to stimulate the right level of low carbon technologies**: the trajectories for new jobs and GVA depend on an ambitious volume of wind capacity, carbon capture and hydrogen production in Scotland. The energy transition will be very difficult if this is not achieved.
2. **Policies to develop the supply chain in Scotland**: unlocking economic benefit for Scotland will depend on a set of policies to deliver a good proportion of the supply chain in Scotland, similar to that currently enjoyed by the O&G industry. This will mean helping existing organisations to transition, creating a pipeline of innovation building on Scotland's strengths, and attracting the right foreign investment to Scotland to help replace jobs and GVA. Having a robust supply chain which is based in Scotland will also help energy security.
3. **Policies on skills and people:** managing the transition for people is important because economic transition can leave workers with outdated skills and no ability to participate in the workforce. A skilled workforce is a key attractor for businesses in the new potential supply chains and can ensure sure that more of the GVA created through new industries stays in Scotland. Regional impacts are also determined by employment and spending by high qualified workers.
4. **Policies to protect affected regions and communities**: even a successful rollout of new industries has the potential to leave some communities behind. New employment has the potential to be more distributed than O&G employment, meaning the North East of Scotland could lose relatively more jobs and GVA. Support will be required not just in adapting the existing supply chain but opening broader opportunities.
5. **Policies on resilience and grid enhancement:** it will be important to ensure that renewables can always been used when available, and that dispatchable power resources which can be used in case of intermittency are in place. This is also a crucial point for energy security.

Co-ordination and timing

Co-ordination of these policy areas will be critical: for instance supply chain mapping that enables investment confidence will require an understanding of the medium-term support for new industries; skills provision will need to assess what parts of the supply chain can be attracted to Scotland; regional policy and funding will need to support and be informed by the supply chain strategy. Unless it is possible to protect the vulnerable from the negative effects of transition, it can lose its legitimacy.

For each policy area we have explored indicative timings. The timing needed on many of these Just Transition policies is fairly urgent, with many required pre-2025, such as investment in the grid market, attracting FDI, funding for technology and early stage companies and business support. Although energy transition is a long term process, it is necessary to start implementing policies now in order to be successful.

Policy to achieve build out scenario

The focus of this section reflects the sectors in which the ESC scenarios forecast the greatest impact: hydrogen, wind and CCUS. ESC's model assumes that direct jobs per GW capacity remains constant for other energy technology sectors (solar, hydro, bio-energy and tidal) based on the limited growth expected for these areas.

Policy interventions to stimulate growth in low carbon technologies – Offshore / onshore Wind

Offshore / onshore wind - Issues for policy to resolve

Wind energy is one of the most established renewable energy technologies in Scotland with onshore wind dominating renewable electricity capacity. However, government intervention can support inherent constraints with its use:

- In order to meet Scotland's growing demand for renewable electricity, significant upscaling of wind capacity is required. This need is exacerbated with the loss of around 2.4GW of capacity from the expected shutdown of nuclear capacity by 2028.
- Scotland must also resolve the challenges associated with the intermittency of renewable sources and the resulting impact on the grid. Although Scotland is a net exporter of renewable electricity it is a net importer of non-intermittent electricity, which is dominated by gas generation.
- Scotland continues to grow its electricity exports to rUK and there is an opportunity to turn Scotland into a renewable energy hub. The grid needs to be upgraded to facilitate this, but this will come at a cost to consumers.

Policy Summary

	Policy	Timing
W1	Carbon Pricing	pre-2025
W2	Support for future renewable auctions	ongoing
W3	Development of the capacity/storage market	pre-2025
W4	Technology development	pre-2025
W5	Investment in the grid network	pre-2025

Policy interventions

Targeted policy interventions may be required to increase wind energy capacity and reduce barriers to investment:

1. **Carbon pricing (pre-2025)** – The UK Carbon pricing scheme results in an effective carbon price that is higher than other G20 countries. A high carbon price incentivises electricity generators to pursue low carbon solutions and helps create the correct merit order so that renewable power is used before switching on gas or coal generators. In order to further incentivise decarbonisation, SG could lobby UKG for a reduction in the supply of carbon certificates that will tend to increase the level of carbon prices. This would also reduce the comparative cost of renewable energy versus fossil fuel consumption. A higher carbon price would incentivise the long term dispatchable gas generators to use carbon capture without the need of further government subsidy, although consumers will pay these increased costs.
2. **Support for future renewable auctions (ongoing)** – SG established incentives through the design of offshore wind leasing rounds which can be used to stimulate growth in offshore wind, increasing jobs, GVA and energy capacity. However, rollout currently relies on UKG to agree levies for further renewable auctions for wind generation (CfDs). Although levelised costs are reducing, intermittency and price volatility (including negative pricing for renewables) means that CfD-type mechanisms are likely to continue to be required to support rollout. The UK framework currently supports the export of renewable electricity from Scotland to rUK, as the complementary capacity auctions are also at UK level, and it provides a mechanism for the rUK bill payers to support investment in Scotland. SG will either need to ensure that UKG delivers for Scottish renewables, or find an alternative set of mechanisms that can allow the export of intermittent renewable power outside of an integrated, balanced system.

Policy interventions to stimulate growth in low carbon technologies – Offshore/Onshore Wind (cont.)

Policy interventions (cont.)

3. **Development of the capacity/storage market (pre-2025)** – Intermittency of energy generation is a key challenge in the development of renewable energy sources. When demand is high, it is sometimes necessary to supplement renewable energy generation with dispatchable power sources. The first requirement is for sufficient capacity market auctions to take place to allow for the deployment of Scottish renewables; secondly, innovation is required. Unfortunately, most dispatchable power sources currently rely on fossil fuel so, to further reduce carbon emissions, low carbon dispatchable power sources are required. The last remaining operational nuclear power station in Scotland is the 1.2GW Torness Station which is expected to retire in 2028. In the 2017 Scottish Energy Strategy, SG confirmed its continued opposition to new nuclear stations (under current technology). This remains the case in the new Draft Energy Strategy and Just Transition Plan published in January 2023. The last remaining major operational gas plant in Scotland is the 1,180MW flexible gas-fired Peterhead Power in the North East of Scotland.

   SG could incentivise development in the capacity and storage market through targeted investment initiatives in storage technology such as pumped hydroelectric, batteries, thermal energy storage and hydrogen. SG should ensure that the costs associated with energy storage are spread amongst all energy users, this includes both domestically and importers of Scotland's energy.

4. **Technology development (pre-2025)** – Increased innovation funding can help promote further development in the cost effectiveness of renewables, although the improvements for wind are likely to be incremental rather than revolutionary. More significantly, innovation in low carbon dispatchable power and low carbon storage will be necessary in order to complement the low carbon intermittent renewables. One key technology is likely to be hydrogen, but alternatives such as different types of battery, liquification of gasses and other innovations will improve short and long term energy storage. Increased low carbon dispatchable power will mean that more wind generation will be genuinely low carbon in a wider range of circumstances.

5. **Investment in the grid network (pre-2025)** – restrictions on grid capacity currently limit the maximum energy generation potential of a number of wind projects and acts as a barrier to entry for new projects. SG should attempt to ensure that grid capacity is increased through infrastructure upgrades in areas where significant constraints exist currently, and where they could constrain Scottish renewables in the future (which could geographically be in England). Ofgem currently determines investment and grid investment for the UK and is independent of UKG and SG. The development of an offshore transmission network to support the development of offshore wind at scale and to minimise challenges around number of connections needed to shore, reducing development costs, could be promoted through the subsidy and Offshore Transmission Owner (OFTO) regulatory regime. Finally, SG could increase demand for electricity and incentivise decarbonisation in the O&G industry by supporting the electrification of offshore O&G platforms. Support could include addressing regulatory barriers such as the application of retail levies on O&G seeking to import power from shore.

Policy interventions to stimulate growth in low carbon technologies – CCUS

CCUS - Issues for policy to resolve

The roll out of CCUS is vital to Scotland meeting its Net Zero targets by 2045. CCUS allows the decarbonisation of hard to abate sectors such as gas processing and refining and is crucial to the implementation of blue hydrogen production in Scotland. With significant depleted O&G stores in the North Sea (and suitable geology for other storage) beyond the capacity required for domestic CO_2 storage, there is the potential to establish a flourishing export market in the long term. However, there are issues which need to be addressed which might prevent Scotland using CCUS to reach its Net Zero targets by 2045.

- Government subsidy is required to support a CCUS industry to decarbonise sectors with few alternative decarbonisation opportunities including gas processing and refining and dispatchable gas power.
- International treaty changes are required to facilitate a thriving export market as potential for CO_2 storage in the ScotNS is in excess of Scotland's CO_2 requirements.
- Changes to carbon pricing and allowances are required to make carbon capture comparatively cheaper than emitters paying the carbon price to stimulate demand for CCUS and encourage decarbonisation.
- There are cross chain risks and extreme risks for transport and storage entities in CCUS which may disincentivise players in the market.

Policy summary

	Policy	Timing
C1	UKG support for clusters	by 2026 (potential Acorn FID)
C2	UKG commitment to expansion phase for Acorn	by 2026 (potential Acorn FID)
C3	Devolved power and funding	pre-2025
C4	Regulatory regime set up for export	2025-2030

Policy Interventions

In order to support the development of CCUS in Scotland, SG could consider a number of policy interventions.

1. **UKG support for clusters (by 2026 – potential Acorn FID)** – The roll out of CCUS in Scotland currently requires UKG support. As a result, SG should continue to actively lobby UKG to ensure Phase 2 clusters are taken forward in a timely manner. SG should also continue to work with UKG during the set up phase to assist with the award of an economic licence (and Revenue Support Agreement (RSA), Supplementary Compensation Agreement (SCA) and Discontinuation Agreement (DA) contracts) to Acorn (including works necessary to prepare for future expansion), along with the required government subsidy support to the associated emitters.
2. **UKG commitment to expansion phase for Acorn (by 2026 – potential Acorn FID)** – To ensure that the Acorn project has the ability to scale in line with demand for CCUS, SG will be required to work with UKG and the economic regulator to review the economic licence granted to Acorn to allow for expansion in a timely manner. To facilitate expansion, a second set of emitters would need to achieve UKG support, and the regulator would need to approve further rounds of Capex.
3. **(Alternatively) Devolved or independent powers and funding (pre-2025)** – SG is currently limited in its ability to sequence its own CCUS clusters as the funding and awarding of the required economic licence is undertaken by UKG. As a result SG could consider seeking a devolution of power and funding to support the development of CCUS clusters in Scotland. However, this would come with additional risk to SG as UKG's business model results in Government taking on revenue risk as well as low probability but high cost geological risks. As a result, a large contingent liability would need to be borne by SG if powers and funding were devolved.
4. **Regulatory regime set up for export (2025-2030)** – To protect domestic customers, a robust regulatory regime must be set up for the storage of CO_2 from other territories in the North Sea. As a precursor to the development of an export market for CCUS, cross border storage will require changes to the 'London Protocol (1996)' which included CO_2 in the international dumping regime. Amendments were made in 2009 to permit the export of CO_2 for storage in overseas territories, although these have not yet been ratified. SG could follow Norway and apply for a provisional application of the amendments.

Policy interventions to stimulate growth in low carbon technologies – Hydrogen

Issues for policy to resolve

Hydrogen is likely to play a key role in Scotland meeting its Net Zero targets by 2045. As an energy vector, hydrogen can assist in the decarbonisation of hard to reach sectors such as industrial heat and transport and may also be used as a dispatchable power source to meet surges in electricity demand. However, there are a number of barriers to investment which must be mitigated to stimulate growth in hydrogen technology.

- Both green hydrogen (using renewable energy to electrolyse water) and blue hydrogen (methane reformation with CCUS) are expensive and the majority of current production is based on methane reformation (grey hydrogen), producing high emissions.
- There are few current markets for the consumption of hydrogen, given the high cost, meaning there is a supply and a demand side issue to be addressed. There are, however, some small isolated markets such as in Aberdeen for transport.
- When there is an excess of renewable energy, it may be possible to use this energy to generate hydrogen. This will depend on the potential to export electrical power to the rUK.

Policy Summary

	Policy	Timing
H1	Implementation of the blue hydrogen business model	by 2026 (potential Acorn FID)
H2	Development of a commercial model for green hydrogen	2025-2030
H3	Regulatory support for blending	to commence when Acorn production starts – assumed 2028
H4	Support mechanisms for off-takers	When low carbon hydrogen is widely available (assumed 2025-2030)

Policy interventions

Interventions are needed to support the development of a Scottish hydrogen sector that will meet Scotland's Net Zero targets. It should be noted that the roll out of Scottish low carbon hydrogen technology in the near term is largely dependent on the future clustering of the Acorn project in St Fergus. Therefore, the policies noted with regards to CCUS should be considered alongside those below:

1. **Implementation of the blue hydrogen business model (by 2026 - potential Acorn FID)** – Currently no business model has been implemented for the production of blue hydrogen in the UK. However, UKG is developing a business model for blue hydrogen. SG should lobby UKG to implement this model to allow hydrogen production to begin at the Acorn site in St Fergus.
2. **Development of a commercial model for green hydrogen (2025-2030)** – As costs reduce, the development of green hydrogen as an alternative fuel has the potential to contribute significantly to Scotland's Net Zero aims. Given the dependency on renewable generation, any model will need to address the issue of intermittency and alternative uses for the electricity generated. In the absence of a commercial model, there is no possibility of the industry developing. This model would be required to interact with the contractual mechanisms that support wind and other renewables.
3. **Regulatory support for blending (to commence when Acorn production starts – assumed 2028)** – In order to reduce carbon emissions, hydrogen can be blended with existing natural gas supplies (up to 20%) to serve existing gas customers and reduce emissions. However, this will require regulatory support and approval. Longer term, any potential 100% hydrogen gas grid alongside hydrogen-ready boilers will require transition planning and further support from government.
4. **Support mechanisms for off-takers (when low carbon hydrogen is widely available assumed 2025-2030)** – It is anticipated that the support provided for hydrogen production leaves a gap in the business case for implementation. As a result, SG / UKG may need to incentivise the adoption of hydrogen technology through targeted project or infrastructure subsidies or pilot projects to stimulate demand in the hydrogen market.

Policy interventions to stimulate growth in low carbon technologies – Supply chain

Supply chain

Issues for policy to resolve

Scotland is home to a high proportion of the UK's O&G supply chain (peaking at £40bn in 2013 and generating 40% of revenue through exports). The need for a local oil field services sector, which is in close proximity to the North Sea, results in global oil majors using Scotland's local supply chains. The decline in O&G production means the associated supply chain will reduce and some of it may be able to transition to serve new industries – particularly CCUS and the hydrogen industry. However, there are a number of supply chain issues which must be addressed to enable a Just Transition and maximise Scotland's ability to take advantage of the supply chain opportunities on offer.

- This established and local O&G supply chain may not be replicated in Scotland (or even the UK) for many of the new low carbon industries as some low carbon technologies will not require the same service industry and the focus (particularly for wind) will be on capital programmes rather than operations. Analysis conducted by the Offshore Renewable Energy Catapult[1] highlights that although the UK offshore wind operations and maintenance (O&M) market is expected to grow, it only represents a small proportion of the total offshore wind market. The analysis concludes that the total market value of the UK sector in 2030 is expected to be over £8bn, with O&M representing £1.1bn of this. The remaining value is associates with the Capex phase.
- Neither Scotland (nor the UK) is to a great extent a competitive manufacturer of the technology involved in wind energy, carbon capture or hydrogen production. UK supply chain is therefore less involved in the Capex phase of low carbon projects with the more of the supply chain involved in the O&M phase. As a result, Capex flows overseas with goods imported from abroad.
- Where Scotland does have existing strengths – for instance, on and offshore pipework, or wells, subsurface & reservoir design and engineering – Scottish firms will not be commissioning the relevant projects, so it will not be straightforward to ensure that they get the work.

	Policies and interventions	Timing
S1	Mapping of short and medium term supply chains	pre-2025
S2	Attracting FDI	ongoing
S3	Access to finance	pre-2025
S4	Infrastructure and enabling work	pre-2025
S5	Competitive funding	pre-2025
S6	Contractual mechanisms	pre-2025
S7	Hubs/catapult mechanisms	pre-2025
S8	Funding for technology and early stage companies	pre-2025
S9	Business support	pre-2025

Policy interventions

Specific policy interventions may help to address some of the problems related to the supply chain, maximising Scotland's ability to benefit from low carbon technology.

1. **Mapping of short and medium term supply chains (pre-2025)** – To understand the existing supply chain's ability to support the low carbon sector, and to inform policy making, the supply chain's capabilities should be mapped. This assessment should be used by SG to help guide targeted policy actions for instance in FDI and support for UK firms to expand. This can build on work done by organisations such as OEUK.

[1] Offshore Wind Operations & Maintenance Report

Policy interventions to stimulate growth in low carbon technologies – Supply chain (cont.)

Policy interventions (cont.)

2. **Attracting FDI (ongoing)** – Some of the gaps identified as part of the supply chain mapping exercise may be able to be filled through FDI. SG should engage with key manufacturers in the low carbon space, such as Dong, Siemens and GE, to position attractive FDI options to them. Further engagement should take place lower down the supply chain where gaps exist and domestic capability does not exist, making FDI options attractive.
3. **Access to finance (pre-2025)** – To address funding barriers and increase the pace and scale of supply chain growth, the Scottish National Investment Bank (SNIB) could undertake an initiative to provide funding for firms who may wish to expand their operations in Scotland or for earlier stage projects which may benefit the low carbon supply chain.
4. **Infrastructure and enabling work (pre-2025)** – To limit the extent to which infrastructure constraints stifle supply chain growth, SG should undertake a review to ensure that the necessary infrastructure is in place to support the low carbon supply chain. Where gaps exist, SG should consider targeted investment in these areas through regional and jobs policy.
5. **Competitive funding (pre-2025)** – To stimulate growth in certain areas of the supply chain, targeted support for specific firms could be provided by SG. This could be provided under a similar mechanism to the Regional Growth Fund.
6. **Contractual mechanisms (pre-2025)** – To allow Scotland to maximise the supply chain opportunities available, SG should review the current contract and licence mechanism (covering CfDs, DPAs and emitter contracts) to ensure local suppliers are given the best chance to be part of the low carbon supply chain. This exercise was performed at a UK level as part of the Hinkley Point nuclear power station development and should be considered for similar large scale infrastructure projects in Scotland.

Innovation support

While wind is an established industry, neither CCUS nor hydrogen have yet been deployed at scale in any jurisdiction. This means that there will be considerable development of new technology and improvement of processes, increasing efficiency and reducing cost. Part of the supply chain policies will be about adapting current suppliers and pushing for Scottish content, but ensuring a pipeline of innovation and potential new innovative firms will be important to retaining value in Scotland. Some policies speak directly to this need:

7. **Innovation hubs, e.g., catapult mechanisms (pre-2025)** – Policies to improve connections between research and commercial exploitation. This is already a crowded policy area, but would benefit from an energy transition focus to ensure that potential needs are being met. In order to stimulate innovation in the supply chain, SG should determine if the existing ESC in Birmingham is sufficient to meet Scotland's supply chain innovation needs. If not, there may be a case for seeking additional leverage of the UK system or the design of a new Scottish mechanism.
8. **Funding for technology and early stage companies (pre-2025)** – Innovation in the low carbon space is key to the successful development of the industry. As a result, SG may wish to consider funding for companies in the technology industry or at an early stage of development to maximise the likelihood of supportive technology entering the market.
9. **Business support (pre-2025)** – Existing firms could need support in making the transition to new technologies, even in cases where the new work is adjacent to previous activity. Support can be given in understanding new markets (building on the supply chain mapping exercise) and adapting businesses to them.

Policy interventions to stimulate growth in low carbon technologies – People and skills

People and skills

Issues for policy to resolve

Scotland's mature O&G industry provides employment for a number of highly skilled and high paying jobs. As part of a Just Transition, O&G workers must be afforded the opportunity to transfer to new work in the low carbon sector in order to prevent growing unemployment. To facilitate this, a number of issues must first be addressed.

- Skills and qualification gaps may make it challenging for O&G workers to transition to the low carbon sector.
- The wider workforce may not be currently sufficiently skilled to take advantage of new jobs in the low carbon sector.
- Workers must be available at the correct time and in the correct numbers to support the rollout of new tech and the supply chain in Scotland to prevent funds flowing overseas.

Policy summary

	Policies and interventions	Timing
P1	Forecasting and planning for future needs	pre-2025
P2	Alignment of qualifications	pre-2025
P3	Career path support	pre-2025
P4	Targeted skills funding	pre-2025

Policy interventions

Specific policy interventions may help to address some of the problems related to jobs and the supply chain; however, this area of policy is complex and funding pathways often overlap.

1. **Forecasting and planning for future needs (pre-2025)** – To ensure that the future requirements of the low carbon industry are met, SG should work with industry to create a common jobs taxonomy, to forecast skills requirements based on the future energy investment pipeline and the jobs required to deliver this, identify gaps and implement a plan to ensure that the workforce is appropriately skilled for the future. SG should ensure that education services are appropriately aligned to upskill and reskill the population for work in the low carbon sector. Being able to confidently predict future roles and skills will allow the industry and education providers to have the confidence to invest in the skills required for the future.
2. **Alignment of qualifications (pre-2025)** – There are currently similar standards/qualifications across offshore wind, O&G and organisations that provide engineering and technical skills to the energy industry. However, it can be challenging and costly for the workforce to transition from O&G to the low carbon sector as qualifications are not identical. The need to map and recognise these qualifications across the sectors and skill types is important to provide a simple and equitable transition for the existing workforce. Setting out SG's expectations to industry to make this simple and fair and provide the environment for industry and training bodies to align around this is important. OPITO is currently leading a coalition to map and recognise the standards and develop a skills passport to enable the workforce to identify career pathways and training requirements. SG should interact with OPITO to support this work for delivery at pace. SG, through the Just Transition Fund, has just granted £5m for the development of a skills passport for the energy industry.
3. **Career path support (pre-2025)** – To give the population a clear sense of the training and qualification requirements to work in low carbon industries, SG should implement a clear education and learning framework designed to support the high growth skills and jobs (linked to policy item 2). This will help to provide a clear route to skilled jobs for future generations and support a steady stream of workers for new growing industries.
4. **Targeted skills funding (pre-2025)** – As a result of the above, a number of targeted interventions will be required to upskill and reskill the population. SG should use current mechanisms to focus funding where it can have the most impact to make sure any skills gaps are reduced, ensuring the population is best placed to take advantage of skilled work in the low carbon sector, increasing jobs and GVA and establishing a low carbon supply chain in Scotland. For example, to support ScotWind development, targeting the upskilling technical roles in the production on turbines, etc. will be key. This can enable the upskilling of the Scottish workforce and maintaining these skilled roles within the country.

Policy interventions to stimulate growth in low carbon technologies – Regional and community impact

Regional and community impact

Issues for policy to resolve

For a Just Transition to be impactful, it is vital to consider the local needs of different areas and communities in Scotland. Regional support is needed, not only to support the transition away from O&G in the North East of Scotland, but also to support the development of the new low carbon industries across Scotland.

Additionally, there is a need to protect those most vulnerable to cost increases in gas or electricity bills. The current cost of living crisis is highlighting the significant issues of fuel poverty in Scotland. Fuel poverty is impacted by a range of social and economic factors, but the comparatively high cost of electricity (especially for some more rural areas of Scotland) means that the large scale electrification of the country may disadvantage some of the most vulnerable communities.

Lastly, there is a need to support those most directly affected by decline of O&G in the North East of Scotland. This support must include the communities who lose indirect economic benefits from the decline of O&G industry.

Policy Summary

Policies aimed a resolving community impacts, specifically fuel poverty:

	Policy and intervention summary	Timing
R1	Direct support for those in fuel poverty	pre-2025
R2	Support for those in fuel poverty to reduce energy bills	pre-2025

Other regional and community interventions:

	Policy and intervention summary	Timing
R3	Support for regional Infrastructure development	pre-2025
R4	Targeted investment as part of the Just Transition and other future regional funds	2025 - 2035
R5	Regional enterprise zones and Green Freeports	pre-2025

Policy interventions

1. **Direct support for those in fuel poverty (pre-2025)** – SG has a range of initiatives that provide direct support to people who have difficulty paying their fuel bills (for example, amongst others, Home Energy Efficiency Programmes for Scotland (area based schemes) and Energy Efficiency Scotland). Although SG's plans for the development of a national energy agency will help to centralise this support, direct support could be accelerated to help those most in need. Additionally, the introduction of subsidies and tax reliefs to encourage investment in energy efficiency measures and conversion to zero emissions heat technologies would provide further support to those in fuel poverty, although we note that existing relief schemes are delivered by the UK Treasury and SG has limited legal power in this area.
2. **Support for those in fuel poverty to reduce energy bills (pre-2025) –** Improving the support and the speed of the rollout for energy efficiency measures and replacing fossil fuel heating systems can help to reduce energy demand and energy bills. Exploring mechanisms to restructure or rebalance the environmental and social levies that are added to electricity bills, will help to reduce the cost of electrical heating. An exploration of the policy levers available to support the decarbonisation of heat can be found in Chapter 2.
3. **Support for regional infrastructure development (pre-2025) –** Public and private sector infrastructure projects will support the growth of the new technologies. For example, over the next decade the creation of regional hydrogen energy hubs will support the development of a strong hydrogen sector that will bring benefits to several regions in Scotland. Although hydrogen hubs are beginning to be developed in areas of existing industrial activity, government support will help specific regions in Scotland. For example, SG has already committed £15m to support the Aberdeen Hydrogen hub. Further government support can be used to stimulate different regional activity, especially where current supply chains and labour pools result in logical areas for new activity.

Policy interventions to stimulate growth in low carbon technologies – Regional and community impact (cont.)

Policy interventions (cont.)

4. **Regional funds (2025 to 2035)** – SG has already signalled its support for the North East of Scotland with the Just Transition Fund, a 10-year £500m fund. Although early tranches have been agreed, a long term strategy for this fund is needed. This should align with the future energy strategy and provide targeted support. As well as supporting low carbon infrastructure, direct support is required to stimulate low carbon technology and the supply chain and growing businesses in related sectors. Other enabling activity, such as specific transport infrastructure or business support activity (for example, business or technology support hubs) will also form the package of support.
5. **Enterprise zone support including the development of Scottish Green Freeports (pre-2025) –** Both enterprise zones and Green Freeports aim to target investment in specific regions. Enterprise zones in Scotland provide targeted tax breaks and superfast broadband for industries operating in the specific sectors of life sciences, low carbon and manufacturing, whilst Green Freeports offer both tax and customs incentives to stimulate regional economic activity. Green Freeport tax levers target development in underdeveloped areas with high levels of deprivation to promote regeneration, high-quality job growth and innovation whilst customs levers aim to stimulate economic activity by creating hubs for global trade and investment. So that the region is able to support additional economic activity, £25m is also made available to the Green Freeport operators for land assembly, site remediation and small-scale transport infrastructure. Both enterprise zones and Green Freeports aim to attract large-scale targeted investment in regions and communities to stimulate economic growth and support employment. SG and UKG are currently reviewing applications for two Green Freeports. Although there is a body of opinion that is sceptical of the value of freeports and economic zones and the potential displacement impact, it is possible that Green Freeports or economic zones operating under similar principles could be effective in supporting a Just Transition, and SG could consider additional enterprise zone support (with a specific focus on energy transition) or additional Green Freeport designation for regions with the potential and ambition to contribute materially to the Just Transition.

Conclusions

What can these policies achieve?

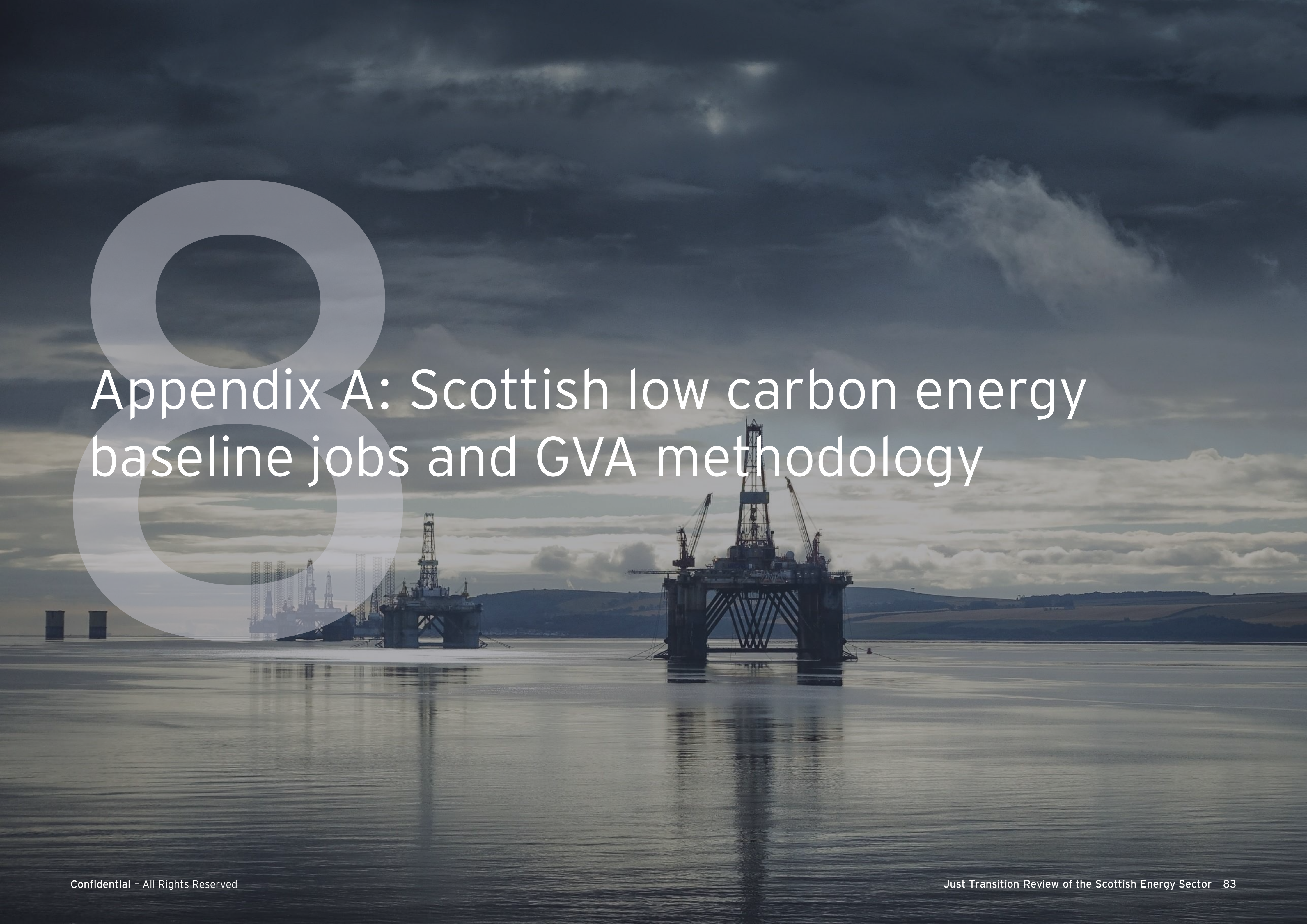
- This report provides recommendations to support a Just Transition, building on the analysis across the three reports about the prospects for the O&G industry, how current patterns of consumption have evolved, and the economic prospects for new low carbon industries. The table alongside highlights where the recommendations meet the Just Transition outcomes.
- Our analysis highlights that the growth in the low carbon sectors will help to replace the lost jobs and the economic output associated with the O&G sector's decline. However, although growth in these sectors will replace many of these jobs, replacing the GVA associated the O&G sector will not occur immediately.
- The forecasted growth in the low carbon sectors is also based on a number of assumptions. The BOP growth scenario assumes that Scotland will be able to grow its energy capacity and a suitable supply chain exists to support this growth. Without this, the growth in jobs and GVA will not happen. To highlight the scale of the challenge, our model forecasts that in 2030 the low carbon sector will support 44,000 jobs (increasing from 18,000 in 2019). For this growth to materialise, government intervention is required now.
- To achieve this growth we require **policy interventions to stimulate growth in low carbon technologies.** Interventions are also crucial to **develop a supply chain in Scotland** which is capable of replacing the O&G supply chain in Scotland and subsequently turning Scotland into a major global player in the low carbon sector. To create a Just Transition, **policies that support the development of people and skills** are necessary to ensure no-one is left behind. Lastly and importantly, **policies are also needed to ensure that all communities in Scotland**, including the North East of Scotland, are protected through the transition.
- The policies are designed to help Scotland achieve low carbon technology rollout of the BOP scenario, however, it is not a set of policies for the creation of a comprehensive energy system or designed to cover all environment areas.

When does this need to happen?

- In section 5, we analysed the growth in jobs and economic output associated with the growth in the low carbon sectors. However, we also highlight that these trajectories, and the underlying ESC model, make assumptions about policy interventions that are required to unlock this growth. To ensure that these pathways are achievable, decisions are required imminently to ensure the growth of the wind, hydrogen and CCUS sectors and the development of their supply chains.
- Our recommendations highlight the urgent need to implement policy this decade. Without this, the ability to replace jobs and economic output currently found in the O&G sector will not be achieved.

	SG's National Just Transition Outcomes	Which of our policies meet these outcomes?
1	Citizens, communities and place: support affected regions by empowering and invigorating communities and strengthening local economies.	R1, R3, R4, R5
2	Jobs, skills and education: equip people with the skills, education and retraining required to support retention and creation of access to green, fair and high-value work.	P1, P2, P3, P4
3	Fair distribution of costs and benefits: address existing economic and social inequality by sharing the benefits of climate action widely, while ensuring that the costs are distributed on the basis of ability to pay.	R2, S5, S6
4	Business and Economy: support a strong, dynamic and productive economy which creates wealth and high quality employment across Scotland, upholds the United Nations (UN) Guiding Principles on Business and Human Rights, and continues to make Scotland a great place to do business.	R5, S1, S2, S3, S7, S8, S9, C1, C2, C3, C4, H1, H2, H3, H4
5	Adaptation and resilience: identify key risks from climate change and set out actions to build resilience to these risks, ensuring our economy is flexible, adaptable and responsive to the changing climate.	W3, W4, W5
6	Environmental protection and restoration: commit to act within our planetary boundaries while protecting and restoring our natural environment.	W1
7	Decarbonisation and efficiencies: contribute to resource efficient and sustainable economic approaches that actively encourage decarbonisation, support low-carbon investment and infrastructure, and avoid carbon 'lock-in'.	R3, R5, W1, W2, S1, S4,
8	Further equality and human rights implementation and preventing new inequalities from arising: address fuel poverty and child poverty in a manner consistent with Scotland's statutory targets on each, while furthering wider equality and human rights across all protected characteristics.	R1, R2

Key
W - Wind policy
C - CCUS policy
H - Hydrogen policy
S - Supply chain policy
P - People and skills policy
R - Regional policy



8 Appendix A: Scottish low carbon energy baseline jobs and GVA methodology

A: Methodology for estimating the baseline economic footprint of the Scottish low carbon energy sector

Economic impact methodology

In order to assess the direct, indirect and induced impacts, a set of economic multipliers drawn from 'Input-Output tables' are applied to the direct GVA and employment of companies in the low carbon energy sector to derive the additional indirect and induced impacts.

A multiplier is an estimate of the extent to which each unit of output produced in the sector requires the production of a number of supporting units of goods and services in other sectors of the UK/Scottish economy as inputs into the low carbon energy sector's production. The production of each unit of input also requires the application of labour – e.g., it supports employment, and there are further impacts from spending of wages in the economy too.

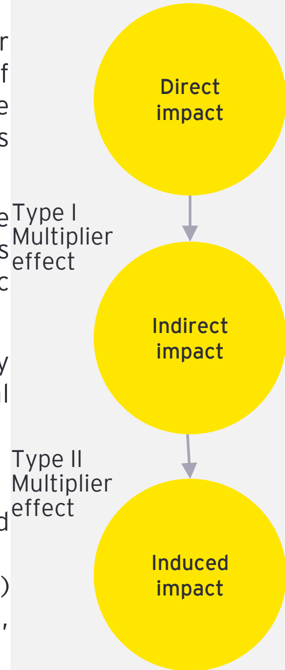
The ONS publishes a statistical report called the 'Input-Output tables', which outlines the relationships between different industries and how the outputs from one industry are used as inputs into another. Input-Output tables provide a consistent representation of national economic accounts, illustrating interdependencies between industries.

The methodology used in this study is based on the 'Input-Output' approach. It quantitatively estimates how a unit of GVA and employment in the low carbon energy sector leads to additional GVA and employment across the low carbon energy sector's supply chain and the wider economy.

Direct impacts

The direct impacts or contribution of the Scottish low carbon energy sector have been calculated as below:

- Employment: obtained 2019 ONS Low Carbon and Renewable Energy Economy (LCREE[1]) employment by sub-sector data for Scotland, which contains official estimates for employment, mid-point estimates have been used.
- GVA: as there is no official data published for low carbon energy sub-sector GVA in Scotland (and this is only accounted for within the broader SIC code within which these activities exist), for onshore/offshore wind, solar, hydropower, bioenergy and other renewable energy the 2019 GVA per job was estimated based on a report on the Economic Impact of Scotland's Renewable Energy Sector by the FAI at the University of Strathclyde[2], who estimated GVA for sub-sectors based on the proportion of turnover of each sector within the broader industry group. For nuclear power generation and decommissioning, GVA per job was estimated based on UK-wide direct GVA and jobs of the sector. These direct GVA per job estimates was applied to the direct employment data for each sub-sector to estimate direct GVA contribution. Note – nil GVA and jobs are assumed in 2019 for CCUS and hydrogen production.



Direct impact: Employment and GVA generated directly as a result of activities of companies within the low carbon energy production and support services sectors; i.e., direct employees of these companies and activities generating revenue.

Indirect impact: Additional impacts on the wider economy that occurs as a result of industries in the supply chain of the low carbon energy sector.

Induced impact: Impacts generated by increased employee income, through both direct employment in the low carbon energy sector and indirect employment in the supply chain .

Total impacts are captured through the use of multipliers, which measure linkages between industries of the economy.

The indicators for measuring impacts are expressed in terms of the direct, indirect and induced GVA and employment.

1. Low Carbon and Renewable Energy Economy – available at https://www.ons.gov.uk/economy/environmentalaccounts/bulletins/finalestimates/2020 - subsectors included: offshore wind, offshore wind, solar photovoltic, hydropower, other renewable electricity, carbon capture and storage and nuclear power. Hydrogen jobs have been assumed to be nil in the baseline, and hydrogen is not listed as a standalone subsector in LCREE baseline data.
2. https://fraserofallander.org/wp-content/uploads/2021/06/2021_FAI_Economic_Impact_of_Scotland_s_Renewable_Energy_Sector_original.pdf

A: Methodology for estimating the baseline economic footprint of the Scottish low carbon energy sector

Indirect & induced impacts

Scotland's indirect and induced impact has been calculated via the following steps:

1. **Obtaining estimates of Scottish low carbon energy sub-sector multipliers:** The UK GVA and employment multipliers of SIC35.1, SIC35.2-3, SIC20AC and SIC38-39 have been taken from SG's published Supply, Use and Input-Output tables[1], and assigned to each low carbon energy sub-sector:
   - The multipliers are driven by the underlying structure of the Scottish economy for these sectors. For instance, they reflect current intermediate consumption by firms (their supply chain spending) and final consumption expenditure (demand) by households. This data is collected and updated regularly by SG and the ONS which is then reflected in new releases of the Input-Output and Supply and Use tables.
   - As these SG multipliers are specifically for the Scottish economy, they already reflect leakages for spending outside Scotland, hence no further leakages have been assumed for low carbon economic footprint in Scotland when applying these multipliers.[3]
   - The multipliers are assumed to remain stable in our forecast. While it can be expected that the structure of the Scottish economy will change over time, this would be a gradual process, and precise changes are difficult to predict. Hence it is reasonable to use the latest multipliers for future projections.
2. **Calculating Scottish low carbon energy sector impact:** The type I and type II Scottish job and GVA multipliers are applied to Scottish direct employment and GVA figures (these direct figures are described on the previous page) to calculate the total Scottish impact (including indirect and induced).

Scottish Employment and GVA total impacts (2019)*

UK employment	Direct	Indirect	Induced	Total
Offshore wind	1,600	2,373	814	**4,787**
Onshore wind	2,300	3,411	1,169	**6,881**
Solar photovoltaic	600	890	305	**1,795**
Hydropower	700	1,038	356	**2,094**
Other renewable electricity	-	-	-	-
Carbon capture and storage	-	-	-	-
Nuclear power generation and decommissioning	2,400	2,911	1,150	**6,461**
Bioenergy	800	315	155	**1,270**
Hydrogen production	-	-	-	-
Total	**8,400**	**10,938**	**3,949**	**23,287**

UK GVA (£m)	Direct	Indirect	Induced	Total
Offshore wind	250	190	44	**485**
Onshore wind	574	437	102	**1,112**
Solar photovoltaic	32	24	6	**62**
Hydropower	172	131	31	**333**
Other renewable electricity	-	-	-	-
Carbon capture and storage	-	-	-	-
Nuclear power generation and decommissioning	557	353	110	**1,020**
Bioenergy	132	35	32	**199**
Hydrogen production	-	-	-	-
Total	**1,717**	**1,171**	**324**	**3,212**

**some figures may not sum due to rounding*

1. Latest available tables are 2018 – available at https://www.gov.scot/publications/input-output-latest/
2. An approximation for supply chain spend has been used as intermediate consumption data for SIC06 in official Scottish I-O tables does not include the offshore economy, source: https://www.gov.scot/publications/scottish-national-accounts-programme-whole-of-scotland-economic-accounts-project/
3. This approach varies from the multipliers used for O&G in Chapter 1, as O&G is offshore and hence not included in the SG IO tables. For O&G the UK multipliers were applied and a leakage assumption based on the supply chain in Scotland was applied.

A: Further limitations in estimating the baseline economic footprint of the Scottish low carbon energy sector

Multipliers limitations and sensitivities

- There are additional limitations with the approach of baseline estimation and use of SG multipliers potentially not being reflective of actual leakages in the low carbon supply chain.
- SG published multipliers have been used to estimate indirect and induced impacts. Therefore, the analysis implicitly assumes that the low carbon energy sub-sectors are as intensive in their use of supply chains as the broader industry group SIC codes. However, the LCREE data also has the limitation that each low carbon subsector employment may include jobs from multiple other subsectors (e.g. construction, energy). This may lead to over/underestimate of the indirect contribution due to the use of a single multiplier, depending on the extent to which actual intensity of supply chain use in Scotland differs from the wider sector.
- SG job multipliers assumed average leakage of 49% across SIC codes. This means that on average 51% of the supply chain and subsequent household spending remains within Scotland (calculated based on taking the average type 1 and type 2[2] Scottish job multipliers as a proportion of the UK multipliers).
- To estimate a varied "leakage" out of the Scottish economy from renewable sub-sectors, the sensitivities below were considered:
  - Offshore/onshore wind – Average ScotWind[1] commitments across projects was reviewed. It is estimated 38% of spending is committed to take place within Scotland (or 62% spending outside Scotland). This assumes a smaller leakage than SG multipliers (27% assumed spend within Scotland), and therefore a larger indirect impact. This ScotWind assumption has not been used in our approach due to the risk of overestimating impacts as the ONS direct jobs figures may already include a proportion of indirect jobs. SG multipliers have been used instead, as these assume a lower spend proportion within the Scottish supply chain and hence a smaller indirect effect, which can offset against the risk of overestimating the indirect effect. We consider sensitivities with larger leakages than SG multipliers below.
- A sensitivity assuming 20% of spending within Scotland (80% leakage) was applied to the UK multipliers for each SIC code and direct jobs and GVA in each sub-sector to estimate an alternative indirect and induced jobs and GVA impact. Under a 80% leakage assumption, total estimated 2019 low carbon energy jobs is 16,439, a decrease from 23,287 jobs in the baseline. The total estimated GVA is £2.4bn, a decrease from £3.2bn GVA in the baseline.
- A sensitivity assuming 10% of spending within Scotland (90% leakage) was similarly applied. Under a 90% leakage assumption, total estimated 2019 low carbon energy jobs is 12,420, a decrease from 23,287 in the baseline. The total estimated GVA is £2.1bn, a decrease from £3.2bn in the baseline.

1. https://www.crownestatescotland.com/our-projects/scotwind;; 2. Type I multipliers account for the direct and indirect impacts based on how goods and services are supplied within a region. Type II multipliers not only account for these direct and indirect impacts, but they also account for induced impacts based on the purchases made by employees.

9 Appendix B: Scottish low carbon energy forecast jobs and GVA sub-sector methodology

B.1: Scottish low carbon energy economic footprint methodology - Hydrogen

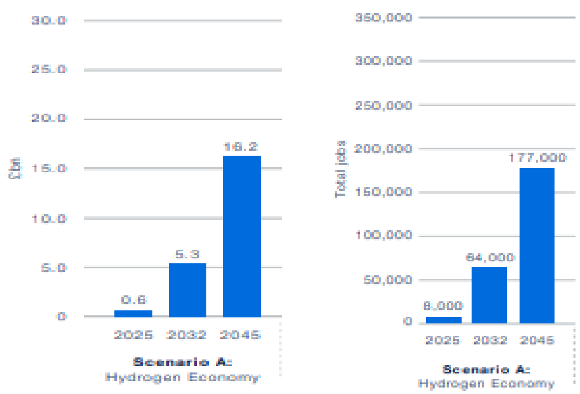
Methodology for estimating the economic footprint of hydrogen production

- Low carbon hydrogen production is not yet operational, the 2019 economic impact of the sub-sector is zero. To forecast the economic impact once the technology is rolled-out, direct and indirect GVA and employment projections are based on scenario forecasts made in SG's Hydrogen Assessment[1] (shown in the figure below right), and scaled down to align with hydrogen production (TWh) forecasts within ESC scenarios across the period.
- ESC scenarios were mapped to those made in the Scottish Hydrogen Assessment, based on the mix of blue hydrogen (i.e. hydrogen created from methane using CCUS) and green hydrogen (i.e. hydrogen produced from water using renewable power) production across scenarios. While we have anchored this report to the level of production in the Scottish Hydrogen Assessment, the split between blue and green hydrogen remains determined by the balance in the ESC BOP scenario. There will be a greater employment / GVA if hydrogen is principally green rather than blue, owing to the higher costs associated with green technology due it to being a less mature technology. The Scenario A: A Hydrogen Economy was deemed to be the most comparable to ESC BOP forecasts, hence these forecast assumptions have been used.
- A scaling factor is calculated by dividing ESC's forecasted production in 2045 (TWh) by the forecasted production in 2045 (TWh) in the Scottish Hydrogen Assessment. This scale is assumed for all years.
- SMR/ATR capacity factors are assumed to be around 86%. As such a 1 GW SMR/ATR operating at a 86% capacity factor over a year will produce 7.5 TWh of hydrogen energy[2].
- The Scottish Hydrogen Assessment created forecasts for 2025, 2032, and 2045. We have assumed a linear relationship between these years. The Scottish Hydrogen Assessment includes both direct and indirect hydrogen production jobs. Within the indirect category, it is assumed that offshore and onshore wind jobs are included within green hydrogen production supply chain and CCUS jobs within blue hydrogen production, therefore we have excluded those jobs within CCUS and Wind sub-sector, but included these jobs within hydrogen production. Note, the BOP scenario assumes there is only blue hydrogen production.
- The Scotland GVA and employment multiplier of SIC35.2-3 (gas sector) has been used to calculate induced effects. This is assumed to remain stable in our forecast period. While it can be expected that the structure of the UK economy will change over time, this would be a gradual process, and precise changes are difficult to predict. Hence, it is reasonable to use the latest multipliers for future projections.

Limitations

- As hydrogen production is not currently operational in Scotland, the industry does not map directly to a SIC code. We have therefore used the comparable SIC code multiplier for manufacture of gas; distribution of gaseous fuels through mains; and trade of gas. The limitation in this is that it assumes that the supply chain structure will be the same as that of gas, and that it will remain constant for the forecast period.
- Estimates of induced employment and GVA are sensitive to alternative estimation approaches for multipliers and assumptions over the share of hydrogen supply chain spend within Scotland, and to the split of blue and green hydrogen. Hence we have considered the impact on jobs when varying the blue and green hydrogen splits, as green hydrogen is more cost- and job-intensive.
- SG's Hydrogen Assessment provides GVA and job forecasts for 2025, 2032 and 2045, and we have assumed the impact is linear between these years; however, this may vary based on actual construction timelines.
- SG's Hydrogen Assessment is also subject to other limitations within its modelling such as the model not being a full or partial equilibrium model, and not representing a full energy system model (and only hydrogen activities are considered).

Scottish Hydrogen Assessment economic contribution projections



Source: SG

1. Scottish Hydrogen Assessment (www.gov.scot); 2. Scottish Hydrogen Assessment Supporting Appendices

B.2: Scottish low carbon energy economic footprint methodology - CCUS

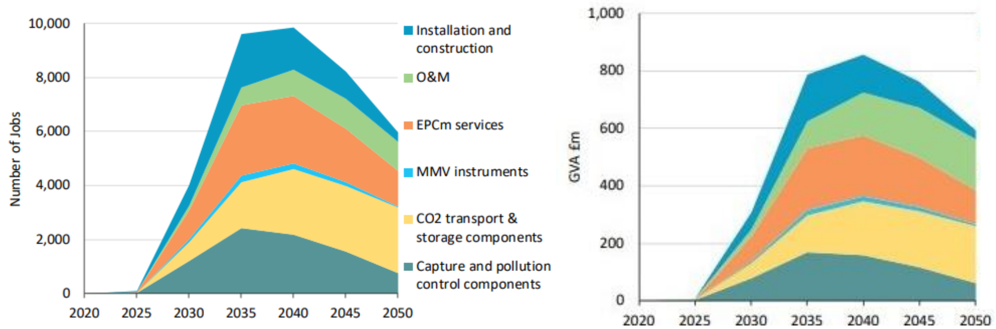
Methodology for estimating the economic footprint of CCUS

- As with hydrogen production, CCUS is not yet operational; direct GVA and employment projections are based on forecasts made in the Energy Innovation Needs Assessment commissioned by BEIS in October 2019[1]. The projections from this study for the UK have been scaled down to align with carbon capture forecasts made by ESC for Scotland.
- This scaling factor is calculated by dividing ESC's forecasted carbon capture in 2050 ($MtCO_2e$) by the forecasted production in 2050 ($MtCO_2e$) in the Energy Innovation Needs Assessment. This scale is assumed for all years.
- The Energy Innovation Needs Assessment shows charts with forecasts up to 2050. We have estimated GVA and employment figures from these charts, every 5 years from 2020 to 2050. We have assumed a linear relationship between these years.
- The Scotland GVA and employment multiplier of SIC35.2-3 has been used to calculate indirect and induced effects. This is assumed to remain stable in our forecast. While it can be expected that the structure of the UK economy will change over time, this would be a gradual process, and precise changes are difficult to predict. Hence, it is reasonable to use the latest multipliers for future projections.
- Within ESC $MtCO_2e$ forecasts across scenarios, we have excluded H_2 Carbon Capture, to avoid double counting with jobs included within Hydrogen Production. O&G jobs at the emitters are also not within scope for CCUS and have not been included.

Limitations

- As CCUS production is not currently operational in Scotland, the industry does not map directly to a SIC code. We have therefore used the comparable SIC code multiplier for Gas (SIC35.2-3). The limitation in this is that it assumes that the supply chain structure will be the same as that of gas, and that it will remain constant for the forecasted period. This SIC code is also most relevant for the transport and storage element of CCUS and is less relevant for power and industrial CCS.
- Estimates of indirect and induced employment and GVA are sensitive to alternative estimation approaches for multipliers and assumptions over the share of CCUS supply chain spend within Scotland.
- The BEIS assessment estimates the economic impact for the UK as a whole and timing and impact may vary across regions and countries. There are also specific assumptions around exporting and market share of CCUS at a UK level, and assumptions about UK deployment of a number of domestic projects across the next decade – some of these assumptions may be less applicable at a Scotland level.
- The BEIS assessment provides GVA and job forecasts for 5 year intervals. We have assumed the impact is linear between these years. However, this may vary based on actual construction timelines.
- We also note that there are other estimates of the CCUS economic footprint which will yield varied results based on assumptions around the multipliers, scaling factors and estimates of job per unit $MtCO_2e$ compared to the ESC scenarios and other assumptions used in this study. For example, Vivid Economics and Scottish Enterprise[2] produced a roadmap for growth and emissions reductions for Scotland which concluded that CCUS value chains considered in the scenarios would require between £9bn and £30bn in total cumulative investment up to 2050. This compares to an estimated £26bn cumulative investment up to 2050 required in CCUS under the BOP scenario.

CCUS jobs and GVA supported as reported in the Energy Innovation Needs Assessment



Source: BEIS, Vivid Economics

1. Energy Innovation Needs Assessment: carbon capture, usage and storage (publishing.service.gov.uk);
2. https://www.scottish-enterprise.com/media/4319/ccus-economic-impact-assessment-report.pdf

B.3: Scottish low carbon energy economic footprint methodology – Offshore wind and onshore wind (1/2)

Methodology for estimating the economic footprint of wind

- Totex was estimated for onshore and offshore wind capacity levels in each scenario based on BEIS data on average costs[1] (Capex, Opex, development expenditure (Devex) and assumptions of a 4-year construction profile, this was to develop and estimated spend profile. Jobs were then estimated for offshore and onshore wind as below:
  - **Offshore wind:** The average forecast jobs per GW within Offshore wind was estimated from a North East Scotland Energy Impact study by Robert Gordon University[2] (RGU). The Totex was also estimated for this GW capacity (based on BEIS cost estimates) to arrive at an estimated jobs per £1m Totex figure. An estimate for offshore wind jobs across years was obtained by applying a 4.82 average jobs per £m Totex assumption to the estimated Totex profile for offshore wind across ESC scenarios.
  - **Onshore wind:** Historic average jobs per £m Totex spend was obtained based on estimated 2020 Totex. This assumption of 6.2 jobs per £m Totex spend was assumed and applied to the estimated Totex profile for onshore wind.
- The GW capacity of offshore and onshore wind within the ESC scenarios was reduced to exclude the assumed GW required for green hydrogen production (as per the hydrogen production impact assessment) to avoid double counting, as these jobs are already included within hydrogen production.
- GVA has been estimated assuming the same fixed GVA per job as in the baseline. The electricity sector multiplier (SIC35.1) has been applied to estimate indirect and induced jobs and GVA.
- The approach of applying an estimate of jobs per £1m Totex spend was applied to recognise that jobs will vary with spending on wind projects over the life cycle of the project, i.e. higher jobs during the construction periods; and that jobs for wind projects will not be static with capacity levels – i.e. a constant level of jobs per GW over time is not assumed.

Limitations

- The BEIS cost data is estimated and may not align with RGU or ESC assumptions. The actual trajectory of jobs, number of windfarms and peaks in construction phase and short term jobs may vary.
- RGU jobs are just for the point in time in 2030 – average jobs per £ Totex may change over time with efficiencies or year by year.

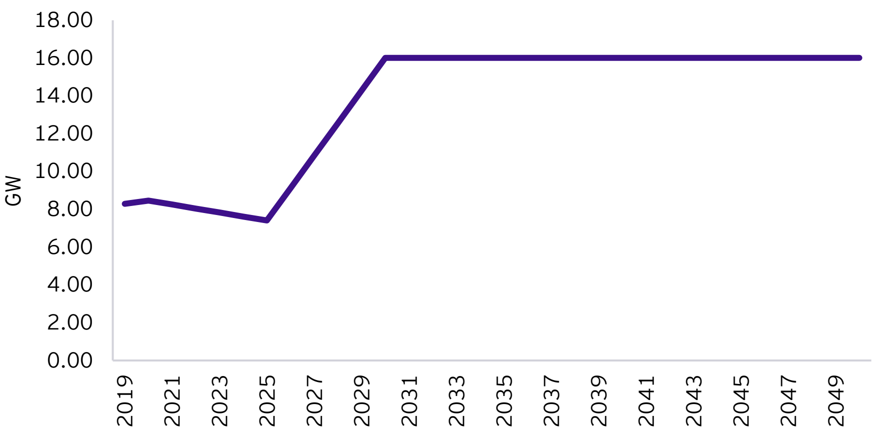
1.https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/911818/GC20_Key_Data_and_Assumptions.xlsx; https://www.gov.uk/government/publications/beis-electricity-generation-costs-2020

2. Making-the-switch-images.pdf (rgueti.com)

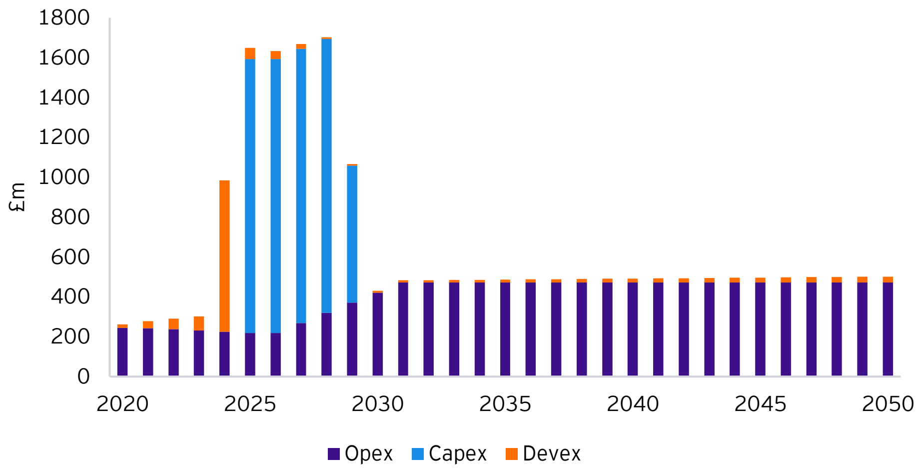
B.3: Scottish low carbon energy economic footprint methodology - Offshore wind and onshore wind (2/2)

- The figures show the onshore and offshore wind capacity levels over time under the ESC BOP scenario, and also the corresponding estimated Totex profile splits across Opex, Capex and Devex for onshore and offshore wind.

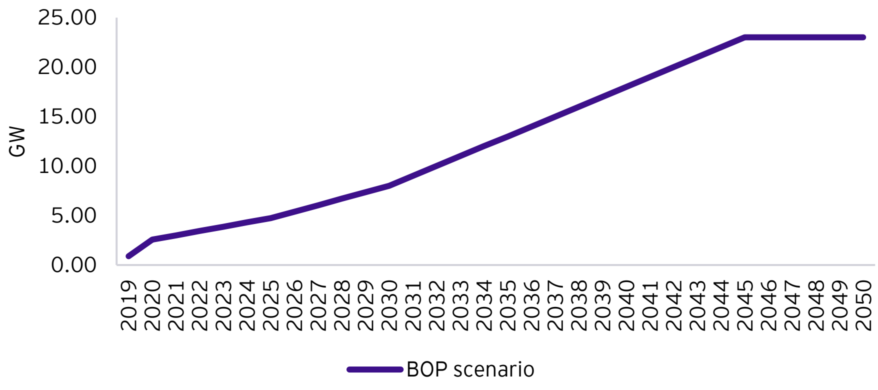
Scottish onshore wind capacity



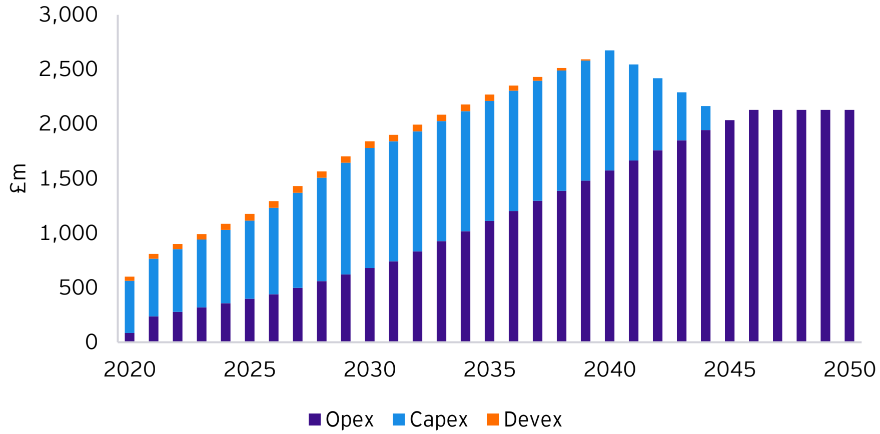
BOP scenario - Onshore wind spend profile



Scottish offshore wind capacity



BOP scenario - Offshore wind spend profile



Source: EY analysis

B.4: Scottish low carbon energy economic footprint methodology – Nuclear

Methodology for estimating the economic footprint of nuclear power generation and decommissioning

- Nuclear power capacity is forecast to decline to nil by 2030, with the closure of Scotland's last remaining power station (Torness) planned for 2030.
- Historic 2019-2021 direct power generation and decommissioning jobs within nuclear has been obtained from ONS LCREE data, and the breakdowns of jobs by power station has been obtained from the Nuclear Industry Association[1]. All power stations except Torness and Hunterston B are assumed to only have decommissioning jobs from 2019 onwards, and Torness and Hunterston B jobs are assumed to be within power generation from 2019-2021.
- Power generation jobs from 2022 onwards are estimated to decline proportionally to nil in line with nuclear capacity up to 2030.
- For newly decommissioned plants (Hunterston B and Torness) decommissioning jobs are assumed to remain at the level of power generation jobs within the early decommissioning phase of de-fuelling, 6 years after closure of the power station (2022 for Hunterston B and 2030 for Torness), and then at 160 jobs during the decommissioning deconstruction phase.
- It is assumed that there is a 60 year decommissioning timeline[2], and decommissioning jobs hold until the end of the 60 year decommissioning timeline from the plant closure. The end of the decommissioning period is 2049 for Hunterston A (at which point there are no longer decommissioning jobs at that power station), and the decommissioning period at other power stations is beyond 2050.
- Indirect and induced jobs have been deduced from these estimates for direct jobs over time using the SIC 35.1 and SIC38-39 (SIC35.1includes Nuclear power generation; and SIC 38-39 for Nuclear decommissioning) multipliers.
- Direct nuclear GVA has been estimated assuming the same fixed GVA per job as in the baseline. This is based on UK GVA per job of the nuclear sector of £231,884 – this estimate has been applied to both direct power generation and decommissioning jobs to estimate direct GVA. UK Nuclear GVA has been estimated to be £3.9bn in 2019, based on 17%[4] of UK energy (SIC35.1) GVA of £23.1bn. UK Nuclear jobs have been obtained from LCREE data. The SI35.1 and SIC38-39 GVA multipliers have been applied to the direct GVA estimates to estimate indirect and induced jobs and GVA.

Limitations

- The decommissioning timeline of specific plans may vary, with some plants decommissioning sooner or later than the assumed average.
- There is a limitation with the multiplier that has been used as it assumes that the supply chain structure for nuclear power generation as SIC35.1 and also nuclear decommissioning will be the same as that of SIC38-39 as a whole, and that it will remain constant for the forecast period.
- GVA per job may vary across the period, and also across power generation and decommissioning jobs. Applying constant GVA per job assumes decommissioning jobs generate as much GVA as the broader nuclear power industry in the UK on average; however, this may vary to the actual value decommissioning contributes compared to power generation. The assumption that decommissioning activity has a positive impact on GVA can be supported by a study using panel data obtained from the US Census Bureau, and cover the years 1975–2014, this study finds that "*nuclear decommissioning is associated with positive and statistically significant increases in employment and per capita income over time*."[3]

1. https://issuu.com/nuclear_industry_association/docs/jobs_map_2021_for_issuu

2. The companies that operate nuclear power plants can use one or both of two options1 to decommission their facilities: SAFSTOR (Safe Storage) or DECON (Decontamination). Generally, sites must spend no longer than 50 years in SAFSTOR to allow up to 10 years for decontamination. The entire process must be completed within 60 years. https://www.nei.org/resources/fact-sheets/decommissioning-nuclear-power-plants#:~:text=The%20Decommissioning%20Process,-The%20companies%20that&text=Generally%2C%20sites%20must%20spend%20no,an%20extended%20period%20of%20time.

3. The End of the Nuclear Era: Nuclear Decommissioning and Its Economic Impacts on U.S. Counties - Haller - 2017 - Growth and Change - Wiley Online Library

4. Digest of UK Energy Statistics (DUKES)

B.5: Scottish low carbon energy economic footprint methodology – Other sub-sectors

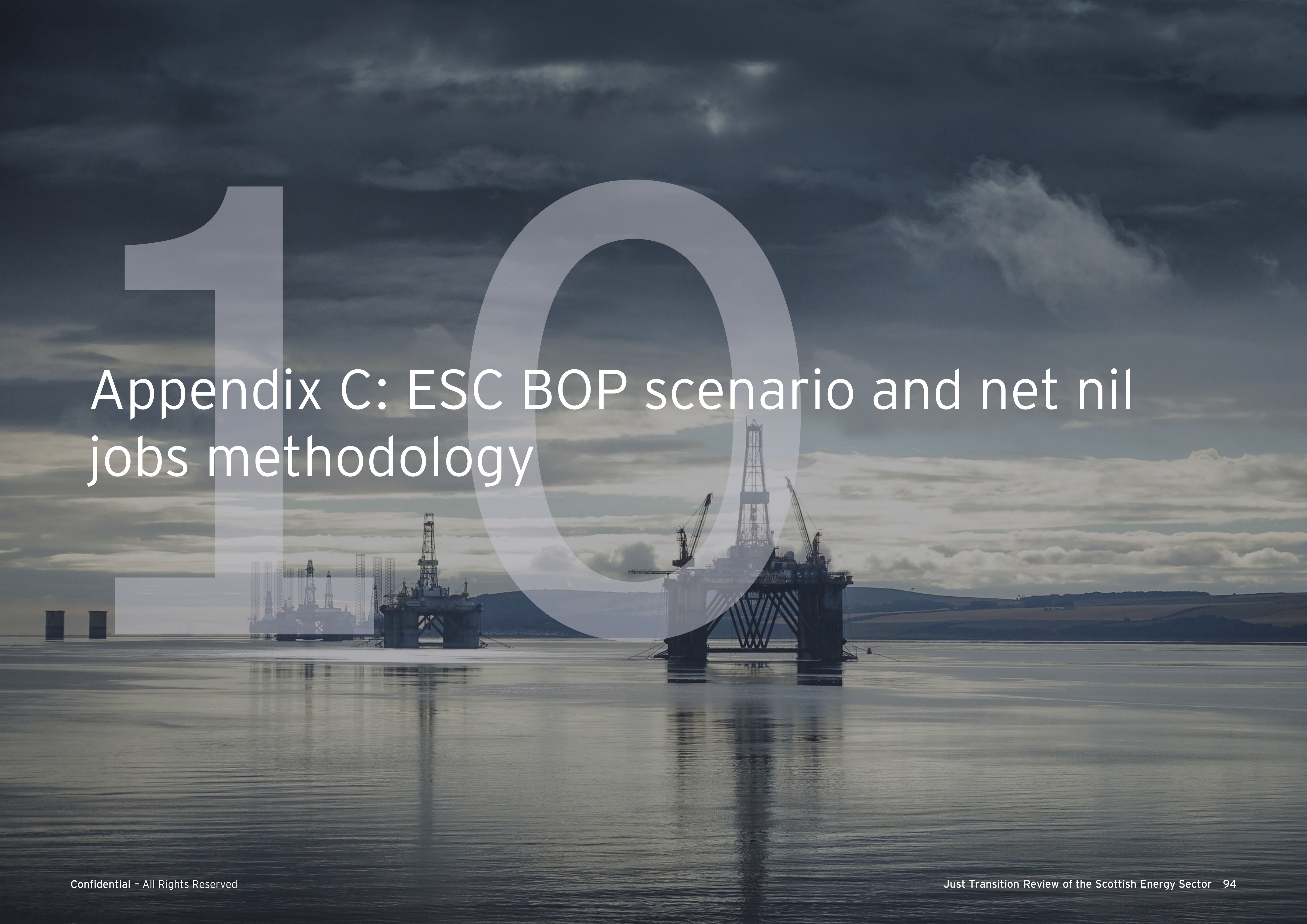
Methodology for estimating the economic footprint of other sub-sectors

- There is limited growth in capacity of hydropower, solar, bioenergy and tidal over time in the ESC scenarios.
- Historic 2019 direct jobs per GW capacity of each technology (solar, hydro, bioenergy, and tidal) have been estimated based on actual historic figures for Scotland on jobs and generation capacity for each subsector. It is assumed that the direct jobs per GW capacity for each of these subsectors remains constant over the forecast period because of limited efficiencies or change in capacity due to lack of investment in these technologies.
- These estimates for direct jobs per GW have been applied to ESC scenarios for GW capacity over time for each renewable technology to estimate direct jobs. GVA has been estimated assuming the same fixed GVA per job as in the baseline. The electricity sector multiplier (SIC35.1) has been applied to estimate indirect and induced jobs and GVA.

Limitations

- Jobs per GW may change over time across each technology.
- We note that wave and tidal are seen as a promising opportunity for Scotland[1] as a potential world leader in these forms of renewable energy. However, we have assumed limited growth in this sector in line with the ESC scenarios.

1. https://www.gov.scot/policies/renewable-and-low-carbon-energy/marine-energy/#:~:text=Scotland%20is%20a%20world%20leader,most%20powerful%20tidal%20stream%20turbine.



10

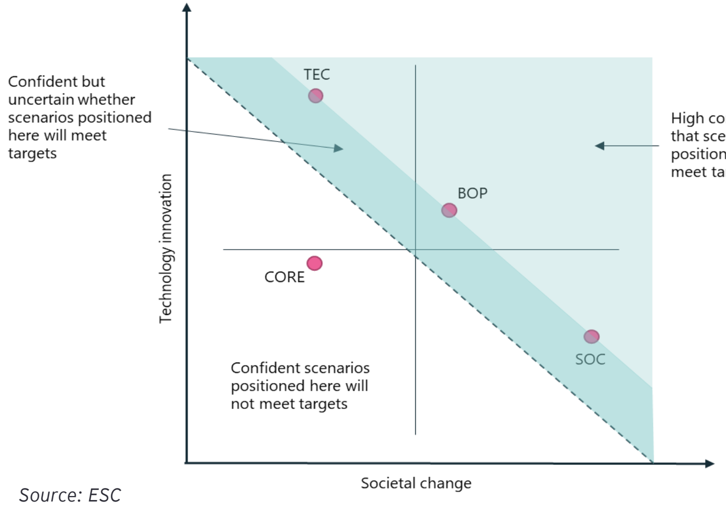
Appendix C: ESC BOP scenario and net nil jobs methodology

C: Scottish low carbon energy scenarios - ESC

ESC scenarios[1]

- SG and CXC commissioned ESC to develop a set of Scotland-specific whole energy system scenarios. These scenarios demonstrate four qualitatively different routes for Scotland to meet its emissions reduction targets, allowing different choices and potential implications to be explored.
  - Technology innovation refers to the extent of innovation in several key technologies important for net zero, including engineered GHG removal (GGR) and a well-established Scottish supply of biomass. Societal change on the other hand refers to the ability and willingness of people to adopt behaviours more consistent with the net zero transition, including reducing demand for heat, car and air travel and preference for a nature based GGR options.
- Using this framework four scenarios were developed, of which only three would successfully meet Scottish and UK GHG interim and Net Zero targets. These three scenarios are outlined below:
  - **TEC:** TEC was able to remove significant amounts of CO_2 by direct air capture and bioenergy with carbon capture and storage (BECCS) used to produce hydrogen and electricity. This reduced the level of societal change necessary to meet targets thus minimising the impact on people's lifestyles.
  - **SOC:** The lower energy demands assumed in SOC meant targets were achievable with far lower amounts of biomass and engineered removals of CO_2.
  - **BOP:** BOP combined some technology innovation with some degree of societal change to meet GHG targets in a more moderate way than TEC or SOC.
- In addition, there is a CORE scenario by ESC which is not 1.5°C compliant, and is hence excluded from the Just Transition.
- The BOP scenarios was determined to be the most plausible scenario and resulted in the closest outcome to net-nil job losses when compared to the ScotNS O&G decline scenario. Hence this scenario has been used as a starting point for further adjustments to the low carbon energy activity levels to achieve net-nil job losses across each of the O&G production pathway scenarios, and understand the minimum required amount of low carbon energy investment and policy in each O&G production pathway scenario.

ESC scenarios



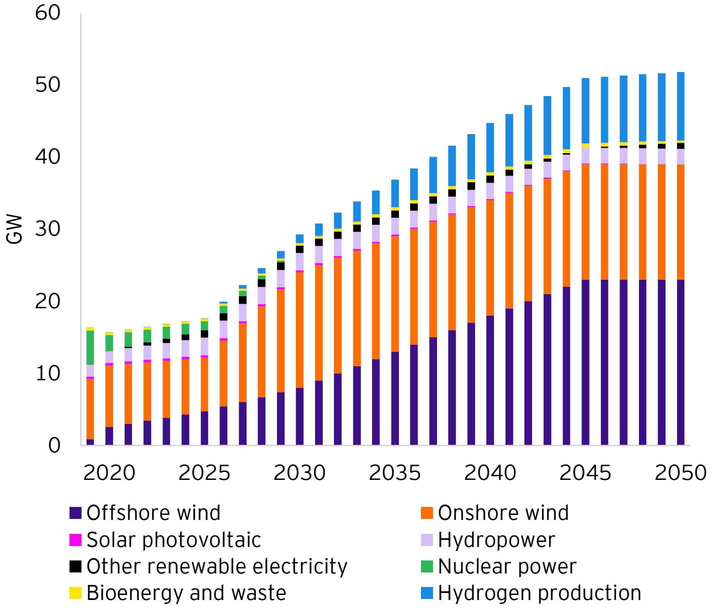
Source: ESC

1. ClimateXChange - Scottish Whole Energy System Scenarios report, January 2022

C: Scottish low carbon energy scenario - BOP scenario

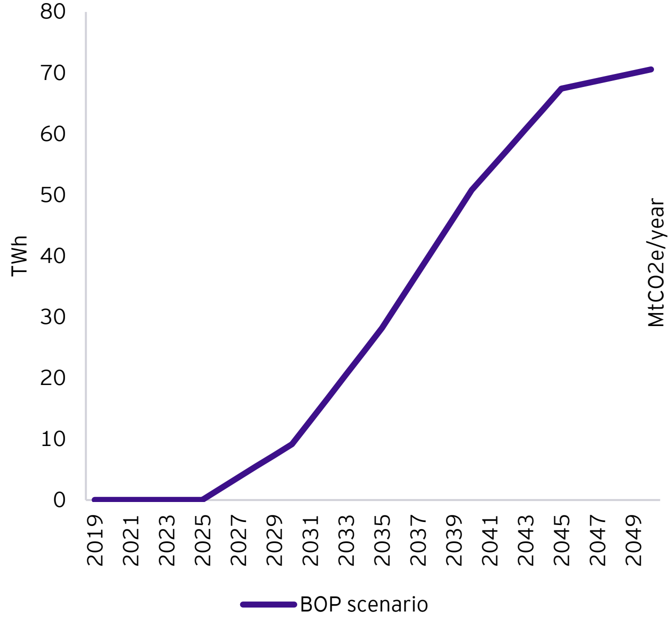
- **Electricity generation capacity:** the figure on the left below shows the forecast electricity generation capacity across onshore wind, offshore wind, solar, hydropower, nuclear generation and decommissioning, bioenergy and waste and other renewable electricity (tidal) in the BOP ESC scenario. Total electricity generation capacity (from low carbon energy) would increase from 16.5GW in 2019 to 42.3GW under the BOP scenario. Across the BOP scenario the majority of the growth in generation capacity comes from offshore wind, with some growth in onshore wind up to 2030. Nuclear energy capacity declines to nil by 2030.
- **Hydrogen Capacity:** the middle figure below outlines the growth forecast in total hydrogen capacity in TWh as per the ESC model. Hydrogen production capacity grows from nil in 2019 to 70.6TWh in 2050 under the BOP scenario. This is assumed to be equivalent to 9.5GW of hydrogen capacity by 2050, assuming a 86% load factor, this hydrogen capacity in GW is shown in the figure on the left below.
- **CCUS carbon captured:** the figure on the right below outlines $MtCO_2e$ captured each year, across industry, hydrogen and power sectors. The level of carbon captured grows from nil in 2019 to 26.4 $MtCO_2e$/year in 2050 under the BOP scenario.

BOP – electricity generation capacity and hydrogen capacity [1]

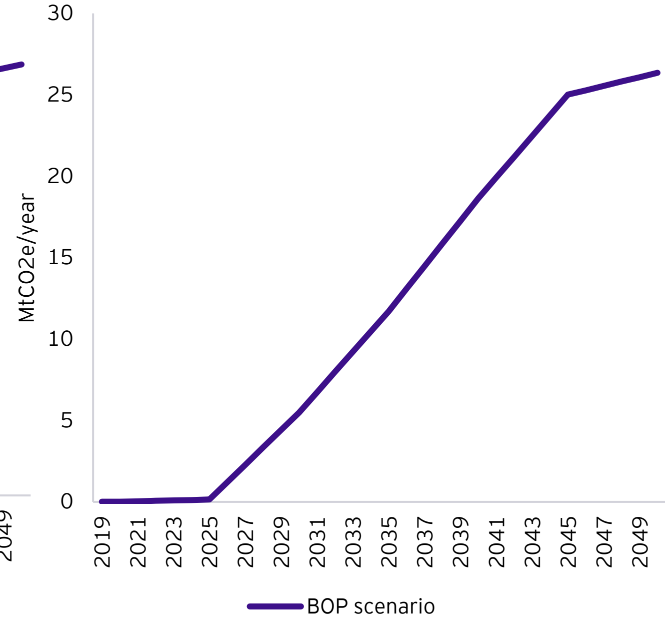


Source: EY analysis based on ESC

BOP – Hydrogen Capacity



BOP – CCUS carbon captured per year



[1] ESC scenarios outline hydrogen capacity in TWh, this has been converted to GW assuming a 86% load factor based on Scottish Government Hydrogen Assessment https://www.gov.scot/binaries/content/documents/govscot/publications/research-and-analysis/2020/12/scottish-hydrogen-assessment-report/documents/hydrogen-assessment-project-appendix/hydrogen-assessment-project-appendix/govscot%3Adocument/hydrogen-assessment-project-appendix.pdf

C: O&G adjusted production pathways – Economic footprint of BOP scenario breakdown

The tables below show the breakdown of low carbon jobs and GVA under the BOP scenario in terms of direct, indirect and induced.

Breakdown of low carbon energy jobs under the BOP scenario*

Direct	9,500	23,811	42,845	54,493
Indirect	13,041	21,100	27,232	22,445
Induced	4,618	8,932	13,415	13,936
Total	**27,159**	**53,843**	**83,492**	**90,874**

Breakdown of low carbon energy GVA under the BOP scenario*

£m	2020	2030	2040	2050
Direct	1,862	3,879	6,704	8,425
Indirect	2,383	2,875	3,188	2,625
Induced	1,007	1,135	1,370	1,402
Total	**5,252**	**7,888**	**11,262**	**12,452**

**some figures may not sum due to rounding*

C: O&G adjusted production pathways compared to BOP scenario

The tables below show the breakdown of low carbon jobs (direct + indirect) under the BOP scenario, and O&G jobs under each adjusted pathway. Also the net change in Scottish energy jobs from 2019, across both the low carbon sector and O&G in each adjusted pathway. This outlines the net gain or loss in energy jobs under the BOP scenario.

Total and change in low carbon energy jobs (direct + indirect) under BOP

	Total low carbon jobs				Change in low carbon jobs from 2019		
Low carbon energy direct & indirect employment	2019	2030	2040	2050	2030	2040	2050
Offshore wind (adjusted for H2)	3,973	22,002	31,961	25,443	18,029	27,988	21,470
Hydrogen production	-	8,380	23,314	38,490	8,380	23,314	38,490
Carbon transport and storage (adjusted for H2)	-	265	656	398	265	656	398
Onshore wind (adjusted for H2)	5,711	6,632	7,566	7,719	921	1,854	2,008
Hydropower	1,738	2,502	2,365	2,228	764	627	490
Solar PV	1,490	1,202	714	-	- 288	- 776	- 1,490
Bioenergy and Waste	1,115	694	927	719	- 422	- 188	- 397
Other (wave and tidal)	-	248	248	248	248	248	248
Nuclear	5,311	2,985	2,326	1,692	- 2,326	- 2,985	- 3,619
Total BOP low carbon energy jobs	**19,338**	**44,911**	**70,078**	**76,937**	**25,573**	**50,739**	**57,599**

Total and change in O&G jobs (direct + indirect) under each adjusted pathway

	Total O&G jobs				Change in O&G jobs from 2019		
O&G direct & indirect employment	2019	2030	2040	2050	2030	2040	2050
Current Production Share Pathway	56,980	41,530	27,588	17,912	- 15,450	- 29,392	- 39,068
Carbon Intensity	56,980	44,995	34,722	25,658	- 11,985	- 22,258	- 31,322
Historical Emissions North Sea	56,980	33,127	14,377	6,473	- 23,852	- 42,602	- 50,507
Historical Emissions Scotland	56,980	8,353	244	11	- 48,626	- 56,735	- 56,968
Current Emissions	56,980	40,209	25,141	15,493	- 16,770	- 31,839	- 41,487
Comparative Affordability	56,980	17,505	2,231	354	- 39,475	- 54,749	- 56,625
ScotNS O&G Production Forecast	56,980	37,313	15,158	6,163	- 19,666	- 41,822	- 50,817

Net change in Scottish energy jobs (direct + indirect) from 2019 under the BOP energy scenarios for each O&G adjusted pathways – *Sum of total change in low carbon jobs and change in O&G jobs from 2019 as above*

O&G decline pathway	2030	2040	2050
Current Production Share Pathway	10,123	21,347	18,531
Carbon Intensity	13,587	28,481	26,277
Historical Emissions North Sea	1,720	8,137	7,092
Historical Emissions Scotland	(23,054)	(5,996)	631
Current Emissions	8,802	18,900	16,112
Comparative Affordability	(13,902)	(4,010)	974
ScotNS O&G Production Forecast	5,906	8,917	6,782

Source: EY analysis

Source: EY analysis

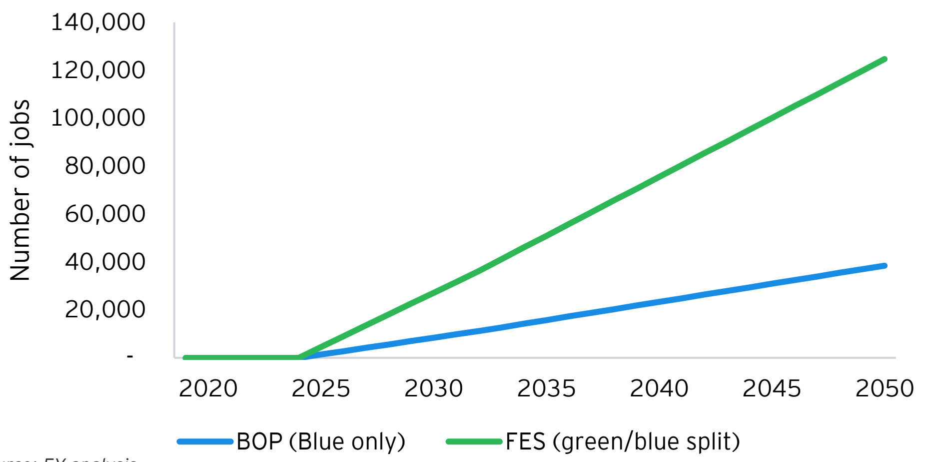
C: Scottish low carbon energy - Alternative hydrogen green and blue splits

- Blue hydrogen relates to the production of hydrogen from methane with CCUS, while green hydrogen is produced from water using renewable power. These are distinct from the grey hydrogen produced by fossil fuels. SG Hydrogen Impact Assessment which has been used as a basis to estimate jobs and GVA (see Appendix B) assumes that there will be a greater employment / GVA if hydrogen is principally green (and using offshore wind) rather than blue, owing to the higher costs associated with green technology as a less mature technology. The below table displays the 2045 direct and indirect GVA and jobs per TWh of hydrogen production within onshore green, offshore green and blue hydrogen production, based on SG's Hydrogen Impact Assessment.

Hydrogen production - deployment and operation	Direct + indirect GVA per GW (£m)	Direct + indirect Jobs per GW
Onshore Green	144	1,916
Offshore Green	947	10,579
Blue	481	3,406

Source: EY analysis

Hydrogen production – direct and indirect jobs, under green/blue scenarios



Source: EY analysis

- The ESC BOP scenario assumes hydrogen production consists entirely of blue hydrogen. We have altered the split of green and blue hydrogen within this scenario, based on the National Grid Future Energy Scenarios 2022 (FES) "Leading the Way" scenario for hydrogen1, to understand the impact on jobs and GVA where there is a greater proportion of green hydrogen. The split of blue and green hydrogen under FES is displayed in the table below:

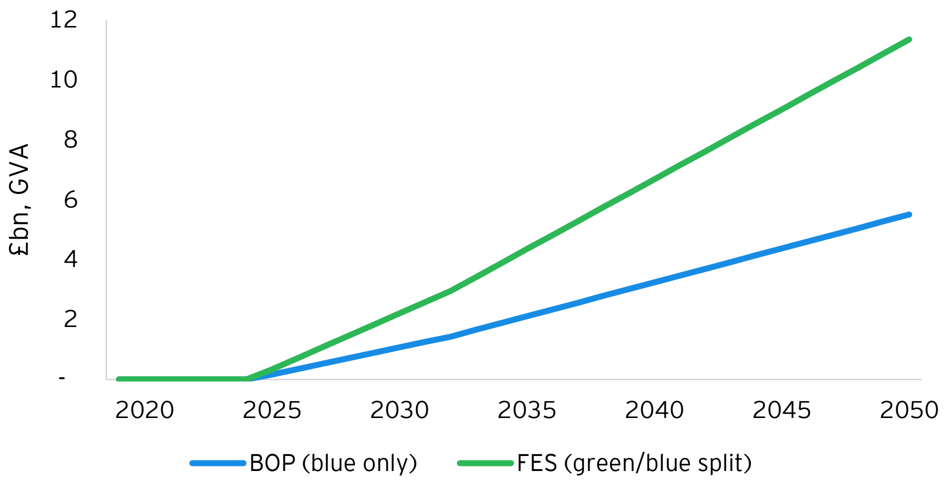
	2020	2025	2030	2035	2040	2045	2050
Green	100%	100%	83%	63%	73%	84%	87%
Blue	0%	0%	17%	37%	27%	16%	13%

Source: EY analysis

Forecast jobs and GVA under FES 2022 green/blue hydrogen splits

- Applying the blue/green split per FES 2022 to total hydrogen production levels in the BOP scenario, there is a total increase in direct and indirect jobs of 86,105 (223%) in 2050, and a total increase in direct and indirect GVA of £5.8bn (over 1300%) in 2050, compared to the original ESC scenario with 100% blue hydrogen.

Hydrogen production – direct and indirect GVA, under green/blue scenarios



Source: EY analysis

[1]. https://www.nationalgrideso.com/document/263876/download

C: O&G adjusted production pathways – Methodology for net nil job loss activity levels

Methodology for estimating low carbon jobs and activity levels under a position of net nil job losses

- "Net nil job losses" refers to a position in which the gain in low carbon jobs fully offsets the loss of O&G jobs, and there is a nil change in energy sector jobs across O&G and low carbon energy.
- Under the Scottish O&G adjusted pathways, the rate of decline in O&G production varies. This leads to a varied number of O&G job losses across each pathway. Under the BOP scenario of low carbon jobs, there are resulting net gains or losses across Scotland's energy sector. The net change in energy jobs under the BOP scenario is shown on the previous page.
- Certain adjusted pathways show projected net job losses in Scotland's energy sector with the transition away from O&G. This indicates that further jobs need to be created within low carbon energy in order to reach a net nil jobs position, and fully offset lost O&G jobs. This can be achieved through further investment in low carbon energy technologies, e.g., to increase the electricity generation capacity, hydrogen production or carbon capture. On the other hand, O&G pathways that show net positive job gains within energy show that net nil job losses could still be achieved at lower levels of low carbon energy investment.
- The level of activity in low carbon energy that is required to fully offset the decline in O&G jobs is based on the growth in low carbon jobs being equivalent to the loss in O&G jobs over time. To understand the level of low carbon activity required at this level of jobs (for net nil job losses), we have followed the steps below:
    1. We calculated the change in jobs required in low carbon energy to offset O&G decline in jobs for each O&G production pathway.
    2. We have assumed any change in low carbon energy jobs (above or below the BOP scenario) required to reach net nil job losses, will be based on variations in jobs in offshore wind, hydrogen production and CCUS sectors only.
    3. We have assumed any additional or reduction in jobs within these three renewable sub-sectors will be based on current percentage splits of jobs within each subsector (in a year) under the BOP scenario. Jobs in other low carbon sub-sectors are assumed to stay constant from BOP levels and have not been adjusted.
    4. We have then estimated the activity level within each low carbon sub-sector associated with the adjusted level of low carbon jobs (required for net nil job losses across energy). The adjusted low carbon sub-sector jobs has been multiplied by a ratio of activity per job (assumed from the BOP scenario) in each year. This arrives at an estimated level of offshore wind capacity, CCUS capacity and hydrogen production required for net-nil job losses in each O&G production pathway.
    5. The low carbon sector GVA under net-nil job losses, has been estimated by assuming a fixed GVA per job for each sub-sector and multiplying this with the adjusted level low carbon energy jobs (under net nil job losses). We also calculated the change in O&G GVA from 2019, and deducted this from the change in low carbon GVA, to understand the net energy sector GVA impact where O&G job losses are fully offset.

11 Appendix D: Transmittal letter

Building a better working world

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Just Transition Review of Scottish Energy Sector – Chapter 3

01 March 2023

Dear Sir/Madam

In accordance with our engagement letter dated 22 October 2021, we have prepared our report in relation to the Scottish Government's Just Transition review of the energy sector. This report, Chapter 3, is an analysis of the anticipated transition across the key energy production sectors, their supply chains and facilitating activities.

Purpose of our report and restrictions on its use

This report was prepared on your instructions solely for the purpose of the Scottish Government and should not be relied upon for any other purpose. Because others may seek to use it for different purposes, this report should not be quoted, referred to or shown to any other parties except as permitted under the Engagement Letter. Additionally, we have agreed that you may publish the whole of this report as a single document without amendment or redaction as a portable document format (pdf) file on the world wide web.

In carrying out our work and preparing our report, we have worked on the instructions of the Scottish Government. Our report may not have considered issues relevant to any third parties. Any use such third parties may choose to make of our report is entirely at their own risk and we shall have no responsibility whatsoever in relation to any such use.

Scope of our work

Our work in connection with this assignment is of a different nature to that of an audit. Our report to you is based on inquiries of, and discussions with, the Scottish Government. We have not sought to verify the accuracy of the data or the information and explanations provided by the Scottish Government.

This report provides an assessment of the risks and opportunities associated with each of the O&G production pathways, identified in Chapter 1, analysis of each of the key renewable energy sectors (offshore wind, onshore wind, hydrogen and Carbon Capture Usage and Storage), review of the level of investment required in renewable energy to achieve a Just Transition and assessment of the various policy interventions available to SG to assist in achieving a Just Transition. Any subsequent policy decisions will be informed by the full package of analysis completed from all of the phases of the project and not just the conclusions of this report.

If you would like to clarify any aspect of this review or discuss other related matters then please do not hesitate to contact us.

Yours faithfully

Ernst and Young LLP