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Economic opportunities in Scotland's net zero and climate adaptation economy

March 2024

Contents

1.	**Introduction**	**3**
1.1	Aims and objectives	4
1.2	Selection of sectors	4
1.3	Report overview	6
2.	**Research synthesis**	**7**
2.1	Key findings	8
2.2	Options for action	11
2.3	Summary analysis	12
3.	**Strengths, Weaknesses, Opportunity and Threats analyses**	**25**
3.1	Onshore Wind	26
3.2	Offshore Wind	29
3.3	Wave and tidal	32
3.4	Hydrogen	35
3.5	Carbon Capture, Use and Storage	39
3.6	Low Carbon Fuels	42
3.7	Low Carbon Heavy Duty Vehicles	45
3.8	Forestry	48
3.9	Sustainable Building Materials	51
3.10	Renewable Heat	54
3.11	Professional Services	57
3.12	Sustainable Financial Services	60

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http://dx.doi.org/10.7488/era/4354

1. Introduction

A just transition to a net zero, climate resilient economy in Scotland and internationally, presents significant opportunities for businesses to develop in new areas. At the same time, some businesses will need to transition away from their current activities. The Scottish Government is committed to the net zero transition, and to maximising the economic opportunities that go along with it, as well as adapting the economy to the effects of climate change. A significant amount of work has gone into the development of strategies and plans to achieve the climate change targets and to prepare robust plans for adapting to climate change. Identifying and capturing the associated opportunities is central to Scottish Government's ability to achieve its climate and adaptation targets as well as its ambitions for economic prosperity, jobs, trade and investment. While the economic opportunities for Scotland are reflected in relevant policies and strategies, a deeper and more consistent understanding of the specific nature of those economic opportunities will help to shape and focus effective interventions and investment. The analysis in this report seeks to address this research gap.

1.1 Aims and objectives

The goal of this research is to identify and understand the potential economic opportunities Scotland could realise from the transformative shift toward a Net Zero and Climate Adaptation (NZ&CA) economy. This work provides an evidence base for the Scottish Government to use in identifying specific policy actions that it and its agencies can take to support the growth of sectors that hold strong opportunities, and to identify its role in removing barriers and enabling positive change. We do this by applying a consistent high-level evidence-based approach to a limited number of areas of the economy and drawing out a broader narrative as to Scotland's NZ&CA economy.

The aim of this work is not to provide in-depth sector analysis, nor is it to identify the areas of the economy which will be 'winners' and 'losers' of the next zero transition. Rather, it is to provide an updated coherent assessment of key potential opportunities for Scotland.

This is a complex task which necessitates grappling with numerous research questions to set out the many potential avenues for economic development. However, the project's scope is necessarily confined to economic considerations, dictated by data availability and programme constraints. Notably, it does not encompass factors such as the cost of inaction, emissions reduction, specific considerations for a just transition, or the implications of not safeguarding existing sectors from the impacts associated with climate change.

Consequently, the scope of analysis narrows down to a selection of key 'sectors'* assessed as offering the most promising economic opportunities at scale for Scotland. This selective focus arises from a categorisation methodology outlined in the Methodology appendix, and briefly described below. The outcome of this exercise yields insights into 12 sectors that are deemed to provide the greatest economic opportunities to the Scottish NZ&CA economy. This list does not define the sole set of priorities for the Scottish Government. Instead, by focussing in on the high potential sectors, the project is able to gain valuable, cross-cutting insights, not just into individual sectors but also into the broader economic landscape and the interconnectedness within the Scottish economy. The Research Synthesis section captures these insights.

**The term 'sector' is used here to reflect both market opportunities, technologies and traditional sectors. It should not be confused with standard sectoral definitions as outlined in official statistics.*

This work provides support for policy and decision-makers as they outline future strategies. It can contribute insights to draft Just Transition Plans, the Green Industrial Strategy, the draft Climate Change Plan, and the National Adaptation Plan as well as the delivery of the National Strategy for Economic Transformation and sector specific action plans.

1.2 Selection of sectors

The process of selecting sectors for analysis involved two steps. First, we defined what the NZ&CA economy means for Scotland. Then, we created a shortlist of sectors for further analysis.

Defining the NZ&CA economy for Scotland is complex, and we considered various perspectives and categorisations already in use for data collection and by Scottish Government.

The various perspectives were:

1. The 'Green economy' is a way of framing a number of key sectors/subset of the wider economy.
2. The 'Green economy' is a series of technology-led investment requirements to reach net zero.
3. The whole economy will be 'green' as all sectors of the economy will experience change, challenges & opportunities as the economy transitions towards net zero.

While the long-term goal for Scotland's economy sits in the third perspective here, the project focused on Perspective 1, with the green economy being a sub-set of the wider economy, as demonstrated in Figure 1 below. This figure does not however illustrate the ultimate end goal of having a whole economy and society undergo a just transition to a NZ&CA economy by 2045.

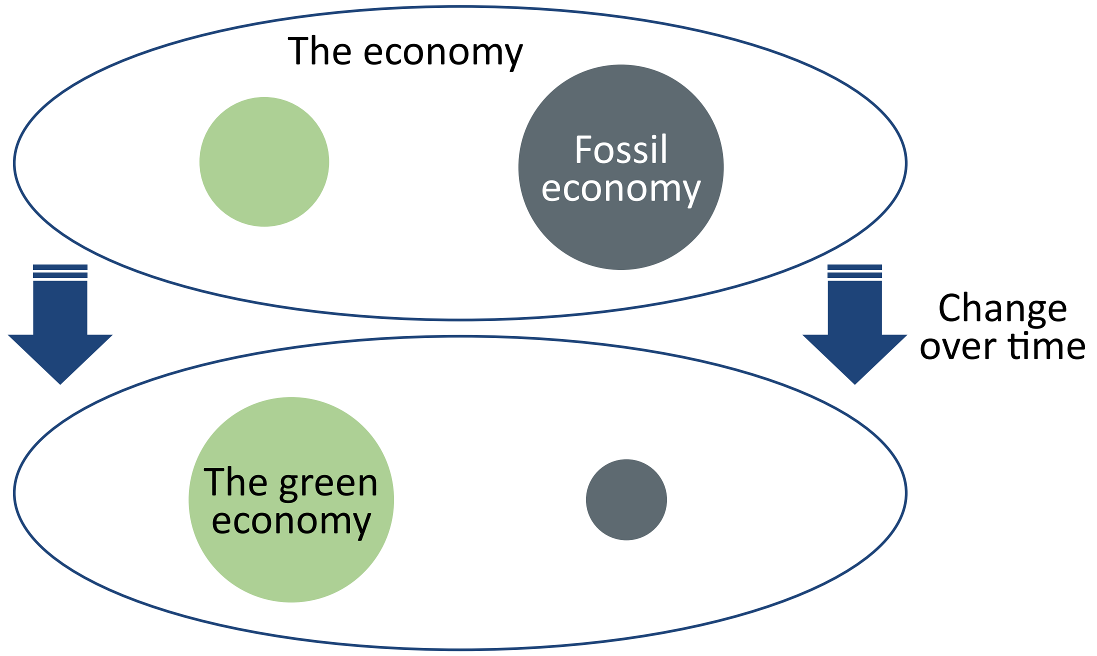


Figure 1 - Scotland's transition towards a more sustainable economy.

Figure 2 lists some of the categorisations of the NZ&CA economy which were reviewed. It demonstrates the complexity of the task by showing the many different industry, statistical and policy categorisations that could be included in a definition of NZ&CA. Most classifications include a mix of sectors crucial for our transition (like energy or fuels) and those that need to adapt (such as transport and agriculture). This exercise provided us with a long list of 'sectors' that were brought into our second step – shortlisting sectors for more in-depth analysis.

Figure 2 - Long-list categorisation of the Scottish Net Zero and Climate Adaptation Economy.

UK Standard Industry Classification (SIC)

- Agriculture, forestry and fishing
- Mining and Quarrying Industries
- Manufacturing
- Electricity & Gas Supply
- Water Supply & Waste Management
- Construction
- Distribution, Hotels and Catering
- Transport, Storage and Communication
- Business Services and Finance
- Government, and Other Services

National Strategy for Economic Transformation (NSET) opportunity areas

- Renewable energy
- The hydrogen economy
- The decarbonisation of transport
- Space
- The "blue economy"
- Sustainable farming & forestry
- Financial services and fintech
- Industrial biotechnology
- Emerging technologies such as photonics and quantum technologies
- Digital technology
- Life sciences
- Food and drink innovation
- Creative industries and tourism

Climate Change Plan

- Electricity
- Buildings
- Transport
- Industry
- Waste and the circular economy
- Land use, land use change and forestry
- Agriculture
- Negative emissions technologies

Climate Emergency Skills Action Plan (CESAP) priority areas

- Energy transition
- Construction
- Transport
- Manufacturing
- Agriculture and land use management

Low Carbon and Renewable Energy Economy (LCREE) categorisation, as per the Office for National Statistics

- Offshore wind
- Onshore wind
- Solar
- Hydropower
- Other renewable electricity
- Bioenergy
- Alternative fuels
- Renewable heat
- Renewable combined heat and power
- Energy efficient lighting
- Energy efficient products
- Energy monitoring, saving or control systems
- Low carbon consultancy, advisory and offsetting services

To choose the sectors to focus on more deeply, we used a decision tree approach, driven by quantitative data whenever possible and supplemented with qualitative information to validate and address any gaps. This framework was chosen because it lent a structured approach to shortlisting sectors for a comprehensive Strengths, Weaknesses, Opportunities and Threats (SWOT) analysis of the sectors with the greatest potential to deliver economic benefits. However, this method did not yield a definitive 'in or out' categorisation. Instead, we used it as a process to guide and document the shortlisting process, within which we could apply professional judgment where required. This step was tested with the peer review group for the project, who validated and shaped the final selection of sectors.

The decision tree consisted of a number of questions as shown in the figure below.

How broad is the economic NZ&CA opportunity in the sector?	This step considered the 'nature of the opportunity' and whether it might result in higher GVA, employment, turnover, business count, salaries, exports and imports. This was to ensure the sectors could yield economic potential at scale. The assessment results in "High" or "Low/Uncertain".
What is the Scottish supply chain capability?	This step uses Scottish Enterprise analysis* for available sectors, as well as a qualitative check of the depth of the Scottish supply chain (existing professional knowledge). For sectors with no SE metric (0-10), qualitative professional judgement is applied.
What is Scotland's export capability?	This step uses Scottish Enterprise analysis* for available sectors. For sectors with no SE metric (0-10), qualitative professional judgement is applied.
What is level of interdependencies with other sectors?	This step ensures interdependencies with other sectors is included in the decision making process- is the sector/ subsector a key enabler for another?
Consequential impacts/ other qualitative checks	This final step in the decision tree considers any additional qualitative information that might be relevant to the decision. For instance grid balancing impacts, energy security, innovation.

Figure 3 - Overview of the questions informing the decision tree framework used.

**Refer to Appendix A for a full methodology note*

Climate adaptation and circularity are crucial activities for our transition to a NZ&CA economy. They are not separate activities bounded in economic terms but play a vital role across the economy. As such the approach taken to these in the research differs from other categories of activity.

Climate adaptation will allow sectors to evolve and stay competitive and resilient in the NZ&CA economy, as well as safeguard and create work and wider economic opportunities. Adaptation actions involve infrastructure, new products and services and actions necessary for businesses to take to build their resilience. Assessing, designing, and implementing these changes will create economic opportunities. Simultaneously, as Scotland embraces net zero economic prospects, it must also prepare for and adapt to existing climate change impacts. While we set out to explicitly include the adaption economy in this research, we found that neither the data nor the stakeholders provided a clear picture of how this part of our economy is currently operating and what the economic opportunities are for Scotland. As a result, this research does not provide a picture of this part of our economy. The Scottish National Adaption Plan 3, published for consultation in early 2024, considers the associated economic opportunities in more detail.

Circular practices and the development of a circular economy present tangible economic opportunities for Scotland, across multiple sectors of the economy. As such these opportunities have been explored specifically in each sector SWOT.

The final set of selected sectors was as follows:

- **Offshore Wind**
- **Onshore Wind**
- **Wave and Tidal**
- **Hydrogen** - Production, end use, storage and distribution
- **Carbon Capture, Use and Storage (CCUS)** – Storage, transport and utilisation
- **Low Carbon Fuels (LCFs)** - synthetic fuels (including Sustainable Aviation Fuels)
- **Low Carbon Heavy Duty Vehicles (HDVs)**
- **Forestry**
- **Sustainable Building Materials**
- **Renewable Heat**
- **Professional Services** - Engineering, planning and environment, and digital and data
- **Sustainable Financial Services**

1.3 Report overview

The report is presented in three parts. The research synthesis outlines the cross-cutting themes identified by the project team, providing the key findings, the options for action and the summary SWOT analyses. The full SWOT analyses are then presented in turn with the methodology for all key steps in the research project outlined in the appendix.

2. Research synthesis

Scotland's shift towards a Net Zero and Climate Adapted (NZ&CA) economy demands a nuanced understanding of its economic landscape and strategic responses to seize emerging opportunities while tackling existing hurdles. This synthesis amalgamates insights from SWOT assessments across sectors, bolstered by extensive literature and data review. Highlighting the need to leverage strengths and address weaknesses, the synthesis offers key findings and actionable strategies for fostering economic growth and resilience.

Scotland's economy, predominantly service-centric with notable manufacturing presence, exhibits a mix of strengths and weaknesses. While possessing a strong legacy in Research, Development, and Innovation (RD&I) and a skilled workforce, challenges like limited manufacturing capacity and regulatory uncertainty persist. Recognising the pivotal role of policy frameworks in driving demand and spurring growth, the synthesis underscores the importance of aligning policies with NZ&CA objectives.

Moreover, the synthesis underscores Scotland's potential to seize early mover advantages, especially in emerging sectors like circularity and sustainable energy. By strategically investing in RD&I and promoting cross-sector collaboration, Scotland can maximise economic opportunities and position itself as a NZ&CA leader. Additionally, tapping into international markets requires targeted export strategies and workforce development initiatives.

The synthesis also emphasises the critical role of natural capital in supporting economic growth, advocating for sustainable resource management and nature-based solutions. Furthermore, it advocates for investment across various domains, from skills development to critical infrastructure, to unlock the full potential of identified economic opportunities.

Through focused actions such as enhancing quantitative data, bridging project delivery gaps, and boosting demand for NZ&CA products, Scotland can expedite its transition towards a resilient, sustainable, and prosperous NZ&CA economy.

2.1 Key findings

A number of cross-cutting themes have come out of the analysis undertaken as part of this research.

When analysed across all 12 sector SWOTs (provided later in this report) and following a wider literature and data review, a number of key findings that underpin potential actions emerge. These key findings suggest that any actions to grow Scotland's NZ&CA economy should:

- Understand the current nature of the Scottish economy and **start from where it is**: build on strengths and be cognisant of weaknesses.
- **Make effective policy** that drives demand to catalyse business confidence and growth, and use public sector purchasing power to drive up demand in priority areas.
- **Recognise and crowd in** behind Scotland's early mover opportunities.
- **Aggregate and combine** to maximise economic opportunities, recognising where aggregate opportunities are greater than the sum of their parts and considering system-based approaches to maximise the benefits.
- Build from Scotland's integrated and horizontal supply chains to **capture emerging opportunities** in different net zero markets.
- Recognise that Scotland's NZ&CA growth potential is greater than servicing domestic demand, Scotland must **target international growth markets**.
- **Secure Scotland's future workforce**.
- Recognise and capitalise on the **value of Scotland's natural environment**.
- Recognise the importance of **investment**, in a number of forms, to further support, drive and deliver the economic opportunities in relevant sectors.

Understand the current nature of the Scottish economy and start from where it is: build on strengths and be cognisant of weaknesses

The Scottish economy is mostly driven by services, with manufacturing making up about 10% of gross domestic product (GDP). Small and Medium-sized Enterprises (SMEs) dominate the business landscape. Scotland has a robust legacy in Research, Development, and Innovation (RD&I), and holds the seventh position in Higher Education R&D among the Organisation for Economic Co-operation and Development (OECD) countries and ranks twenty-fourth in Business Enterprise R&D. However, Scotland's business innovation investment, which is important for investing in new net zero technologies and processes, languishes far behind many other OECD countries. Scotland has a largely decarbonised electricity grid and a highly skilled workforce. Post-Brexit, changes in exports and skilled workforce imports pose challenges. That said, Scotland has been the most successful part of the UK, outside London, for attracting foreign direct investment in nine of the last 10 years. These factors create a mix of strengths and weaknesses, forming the foundation for the future economy in the context of NZ&CA transition in Scotland.

The multiple SWOT analyses reveal several recurring key strengths, weaknesses, opportunities, and threats.

- Key **strengths** encompass a wealth of diverse natural capital, strategic oil and gas infrastructure, innovative companies (despite their relative lack of business innovation investment), a highly skilled workforce that can deliver on international as well as domestic projects, a supportive policy environment, and government backing through well-defined strategies and targets. Notably, the general expectation among stakeholders engaged through this project is that both domestic and international demand for services related to achieving net zero objectives will experience significant and sustained growth.
- Currently, Scotland's **weaknesses** is a limited manufacturing base, posing challenges to supply chain resilience and vertical integration (across all elements of a particular supply chain). Supportive policies, while present, suffer from regulatory instability and delayed implementation. Insufficient domestic demand is impeding investments across various sectors. Infrastructure challenges, such as grid capacity limitations and port and harbour constraints, act as impediments to system wide development. Moreover, shortages in planning skills and resources further hinder project delivery. Scenario-based projections suggest that increases in GVA and jobs across many of the sectors considered are likely to peak in the 2030s, when construction and build out activities are underway, before then declining to steady-state. This highlights a possible longer-term weakness if these sectors are solely dependent on domestic demand.
- **Opportunities** abound in the form of substantial economic growth, job creation, and gross value added (GVA) domestically, especially in the period over which the additional renewable energy capacity is rolled out up to around 2035. Internationally there are opportunities from growing net zero markets, particularly in service exports. Numerous sectors such as hydrogen and low carbon fuels are experiencing escalating international demand, presenting Scotland with the prospect of securing a considerable share in these markets if the right supporting actions are taken early enough. For example, if Scotland builds hydrogen pipelines to mainland Europe and establishes a hydrogen sector, it has the theoretical ability to supply 10% of Europe's future hydrogen demand.
- Prominent **threats** on the horizon include fierce international competition and the impending retirement of a significant segment of the workforce within the oil and gas sector – an essential source of labour for many emerging sectors such as offshore energy and CCUS. Given the prevailing weaknesses, there exists a concern about Scotland's capacity to effectively address both latent domestic and potential international demand in the face of these challenges.

As Scotland transitions towards a NZ&CA economy, it's important to work with the country's present economic profile - primarily made up of the services sector. Scotland doesn't currently possess a large manufacturing base crucial to many identified NZ&CA sectors. Hence, some of the highest potential opportunities for Scotland come from enhancing and capitalising on the value from the services sector to reap early economic benefits.

The Scottish economy is characterised by a dominance of small and medium enterprises (SMEs). For instance, while established chemical manufacturing businesses are expected to significantly influence the low carbon fuels industry, most of the 220 active businesses in this area are SMEs. This can present both challenges and opportunities. For example, SMEs typically lack vertically integrated supply chains and may struggle with scaling operations to meet increased demand. However, an SME-dominated landscape can also offer growth opportunities through horizontal collaboration and knowledge sharing, with businesses leveraging their connections to potentially overcome scaling obstacles. Initiatives that facilitate peer-to-peer exchanges become crucial for economies such as Scotland and should be encouraged to provide valuable insights for successful scaling and internationalisation.

This can present both challenges and opportunities. For example, SMEs typically lack vertically integrated supply chains and may struggle with scaling operations to meet increased demand. However, an SME-dominated landscape can also offer growth opportunities through horizontal collaboration and knowledge sharing, with businesses leveraging their connections to potentially overcome scaling obstacles. Initiatives that facilitate peer-to-peer exchanges become crucial for economies such as Scotland and should be encouraged to provide valuable insights for successful scaling and internationalisation.

Managing fundamental factors such as grid issues, port infrastructure, and streamlining (and better resourcing) permitting and planning processes is critical to the transition pathway. These prerequisites are indispensable for realising the full spectrum of economic opportunities. Without addressing these, other initiatives may not meet their potential.

By strategically focusing its efforts, Scotland can reduce threats. Recognising Scotland's strengths and actively addressing weaknesses can turn the infrastructure and skills limitations into manageable challenges. With a realistic and focused approach, Scotland can effectively navigate these challenges, leverage strengths, and foster resilience and growth across sectors. Our in-depth SWOT analyses can inform decisions on prioritising sectors, sub-sectors, and other actions.

Make effective policy that drives demand to catalyse business confidence and growth

The level of policy support shows inconsistency across sectors, reflecting differences in the maturity of policy interventions and in some cases the divergence between Scottish and UK Governments. In many cases, this may be linked to the maturity of the sector. For example, the mature onshore wind sector benefits from a supportive policy environment in Scotland with well-established regulations, while the less mature hydrogen sector also benefits from a supportive policy environment but lacks well-established UK and Scottish regulations.

An additional layer of complexity emerges when questioning the effectiveness of existing policies in meeting net zero objectives. Notably, many supply chains transcend single sectors, with economic value intricately woven into integrated systems, such as the comprehensive energy supply chains and the fulfilment of both domestic and international demand.

The current siloed nature of policy fails to acknowledge this, likely overlooking significant economic opportunities such as efficiencies and growth opportunities for businesses across energy sectors. One example of note is the draft Energy Strategy and Just Transition Plan which seeks to set a system-wide approach to the energy transition and inform policy direction which could address some of these challenges.

An observation drawn from policy structures and interventions reveals a lack of comprehensive, system-focused thinking. There is a possibility that policies can encourage a more unified way of doing things by making it easier for different sectors to work together collaboratively. It becomes evident that future policy should reflect the importance of adopting a systemic perspective throughout the entire economy wherever possible.

It is recognised that many aspects of relevant powers, especially in the energy space, are reserved to the UK Government. Therefore, Scottish Government is limited to consider the areas where they have sole ability to drive policy change, while working with UK Government at the same time on reserved matters that impact the potential growth of these critical sectors, such as energy security, network investment and market regulation.

Recognise and crowd in behind Scotland's early mover opportunities

There are still potential first mover advantages within the NZ&CA economy in Scotland, and we have identified some areas where Scotland could gain first mover advantage. It is however important, as also noted in the recent Resolution Foundation paper*, to avoid over-optimism and resist presuming either inevitable success or the ability to achieve that success will come merely through positive discourse.

Potential opportunities have been identified within the circularity agenda, for example in refurbishing worn out components in wind turbines or in recycling of turbines in onshore and offshore wind. In this area Scotland has a potential first mover advantage as turbines are older than in other parts of the world. These opportunities provide Scotland with the chance to transform a current weakness in domestic manufacturing capacity (very limited Scottish content in onshore wind turbines) into a future manufacturing opportunity for commercial-scale business models centred around decommissioning and circularity. This strategic shift not only creates new opportunities but could also enhance the resilience of energy supply chains connected to critical raw materials.

R&D spend is critical in this regard. Its value has been demonstrated in offshore (floating) wind currently, and in the setbacks associated with initial advances in hydrogen development being lost. Stakeholders in the hydrogen sector have observed a downturn in the landscape of hydrogen research, particularly with projects failing to advance to higher levels of Technology Readiness Levels (TRL) and commercialisation, a contrast to the progress seen in other countries like the United States. They also noted the investment 'valley of death' that exists for many green technologies post prototyping and in the scaling stage. Focus and continued R&D investment will allow Scotland to capitalise on its strong innovation base and living lab status.

* https://economy2030.resolutionfoundation.org/reports/stagnation-nation/

However, as demonstrated in the wave and tidal SWOT, strong early R&D investment must be accompanied by a move to greater commercialisation and providing support to companies to access appropriate funding at all the development stages in that process.

Aggregate and combine to maximise economic opportunities

The substantial economic value in the NZ&CA economy stems from the combination of opportunities and pathways towards our NZ&CA objectives. While certain sectors like offshore wind showcase immense potential, it is important to see them as part of the larger energy system transition. To maximise economic opportunities, it is important to examine these sectors in relation to other parts of the transition pathway, such as hydrogen and Carbon Capture, Utilisation and Storage (CCUS).
Together, these sectors could secure long-term, sustainable economic benefits for Scotland through our energy transition, especially so when treated as parts of one system rather than siloed sectors.

In addition to greater sector aggregation and collaboration, the horizontally-aligned supply chains offer Scottish companies unique and substantial growth opportunities across diverse local sectors. One example of such collaboration is between hydrogen and offshore wind sectors, where electrolysers in proximity to offshore wind farms have the potential to make use of otherwise curtailed electricity production. The development and support of horizontal supply chain also presents greater opportunities for circularity, with operators working across sectors able to identify and capture circularity potential.

However, the policies in place, while acknowledging the individual strengths of various sectors, fall short of recognising the vast potential for cross-sector opportunities. The interconnectedness of these sectors provides an avenue for holistic development, fostering collaboration, innovation, and shared success.

In the transition process, it is suggested that Scotland requires an ‘orchestrator’ to support the maximization of economic opportunities. This role bridges different sectors by uniting various stakeholders, working with them to eliminate barriers and distribute necessary investment support and maximising efficiencies. Filling the collaboration gap between industry, supply chains, and government is crucial to unlocking opportunities and aggregating economic benefits over time.

Recognise that Scotland’s NZ&CA growth potential is greater than solely in servicing domestic demand, Scotland must target international growth markets

As set out above, domestic policy is a key market signal and driver of demand in both the short and longer term. However, the domestic opportunity is just one aspect of the wider economic potential from the global transition to a net zero and climate-adapted economy and will likely peak over the medium term as deployment of new renewable energy infrastructure is delivered.

Over the longer term, to sustain growth, it will be important for Scotland to continue to internationalise these sectors. The export opportunities identified across these SWOTs build on existing strengths across Scottish supply chains and focus attention on where Scottish companies can capture market share. For example, there is growing international demand for sustainable financial services and products which can be taken advantage of through the significant strength in the (already exporting) sector in Scotland.

Scotland already has internationally active companies across the NZ&CA economy which can be built on and supported to scale, particularly in the export of services and expertise. Stakeholders noted multiple examples of their international growth plans stemming from Scottish expertise and a clear international recognition of this. Therefore, a deliberate focus on internationalisation and commercialisation by the Scottish Government could help promote job growth, address regional and sectoral imbalances, and enhance the quality of jobs in Scotland as the economy undergoes a transition through both export opportunities and inward investment.

Secure Scotland’s future workforce

Scotland’s emerging sectors heavily rely on a skilled workforce, particularly with science, technology, engineering, and mathematics (STEM) competences. However, alongside the potential increased demand created by growth in many sectors, the gradual retirement of skilled professionals from the oil and gas sector introduces a heightened competition for the remaining talents. The potential transition of oil and gas skills to new roles in the NZ&CA economy, once seen as a strength, could now be a threat. The oil and gas sector is known for its attractive high wage rates and has been a key driver of substantial economic contributions. However, with the workforce aging and the shift to emerging sectors becoming less appealing due to lower expected wages, there is a growing risk to this driving force in the new NZ&CA economy.

As an example, the transition from the high-value domain of oil and gas production to potentially lower-value roles in Carbon Capture Utilisation and Storage (CCUS) poses a challenge. This transition is complicated by the fact that the latter may not be capable of providing wage rates on par with those in the former industry, particularly in a competitive global market further complicated by post-Brexit employment challenges. Furthermore, the decommissioning pace of the oil and gas sector is unlikely to align with the emergence of new sectors. This implies sustained job opportunities in oil and gas, both within domestic borders and internationally. This contrast highlights a significant hurdle, emphasising the intricate nature of workforce shifts and the nuanced economic considerations required for a successful just transition.

Challenges in securing the future workforce extend beyond those depending on skills from the oil and gas sector. The Construction Industry Training Board (CITB) projects a demand for 19,550 additional jobs in the Scottish construction sector by 2027, with recruitment identified as a major hurdle for the next five years and likely beyond. Addressing this requires a comprehensive strategy involving the attraction of diverse talent and the upskilling or reskilling of the existing workforce.

Recognise and capitalise on the value of Scotland’s natural environment

Scotland’s wealth of natural resources is a distinct strength. Scotland’s natural capital, both direct (e.g., forestry, where Scotland has accounted for 80% of new trees planted across the UK in recent years) and indirect (in terms of the value of natural landscapes in attracting talent to Scotland), is essential for sustained economic growth. However, the dependency and opportunities for capitalising on these resources vary across sectors.

Initially, natural capital was identified as an area of focus in our research but defining its boundaries for assessment proved challenging. For instance, there might be opportunities in delivering nature-based solutions (NBS) in Scotland - from peatland restoration reducing water treatment costs to its role in providing flood defence benefits.

While these solutions rely on our natural capital, their economic value could lie in the professional services involved in designing them or in the costs avoided by taking action to address climate change. From an investment perspective, natural capital also holds importance. The sustainable finance community is exploring monetisation opportunities in various forms.

Although natural capital is not identified as a distinct sector in the SWOT analysis, its economic value should be recognised as significantly supporting other sectors and influencing the overall quality of Scotland’s economic growth into the future. This is demonstrated throughout the SWOT analyses, especially in the forestry and land use SWOT and sustainable building materials SWOT, where the economic value of timber and timber products to Scotland is illustrated.

Investment

While our research did not focus on investment needs and opportunities in the NZ&CA economy specifically, the SWOTs reflect the importance of investment, in a number of forms, to further support, drive and deliver the economic opportunities in relevant sectors. This ranges from investment in skills, to company level support and the creation of critical infrastructure. Concerns were also identified around policy uncertainty reducing investment, and the need for strategic consideration of investment gaps to capitalise on the Scottish R&D spend and assist start-ups to scale-up. We note that the Scottish Government’s 2024/25 Budget set out £67 million to kick start its commitment of up to £500 million to anchor an offshore wind supply-chain in Scotland over a period of 5 years. This commercial and grant investment will aim to stimulate and support private investment in the infrastructure and manufacturing facilities critical to the growth of a world-leading offshore wind sector.

The realisation of the identified economic opportunities is clearly dependant on investment, across the stakeholder landscape. The Scottish Government could reflect on the various roles it can play in this regard, including through its ability to encourage external investment, in addressing these.

2.2 Options for action

Through this research several areas of action have been identified. These are directly linked to the realisation of the economic opportunities which have been identified in the SWOT analyses.

Improving quantitative data

Without the ability to quantify the impact of net zero activities, it is difficult to make new policy, learn “what works”, identify opportunities for the Scottish economy and measure progress. The data landscape does not support the analysis of the economy in a way that enables the NZ&CA aspects to be measured or monitored. While the Office for National Statistics’ Low Carbon and Renewable Energy Economy (LCREE) survey is a step in the right direction, it is not comprehensive and is survey-based, with a small sample for Scotland and therefore large confidence intervals.

Instead, LCREE and other sources could be drawn into a single data collection. An example of this is the ONS’ Environmental Goods and Services Sector (EGSS) publication which draws together official statistics, the LCREE and custom data to estimate (some better than others) seventeen different environmental sectors. The EGSS proves that it is possible to draw much of this information together into a single dataset to react to policy demand. However, the longer time lag of EGSS (published with a three year lag compared to the annually updated LCREE), coupled with the nascent and fast-growing nature of many of the sectors analysed in this report, meant that LCREE was selected as more appropriate for this report. While changes to LCREE are understood to be in train, what is required is a wholesale restructure of the data that is collected and reported, to support advancement in the NZ&CA economy and associated policy areas. This request reflects that of the Fraser of Allander Institute’s 2023 update of their annual “Economic Impact of Scotland’s Renewable Energy Sector” report, which is widely referenced throughout this report.

Closing the delivery gap

There is a recognised gap in project delivery to support the transition, evident from a range of stakeholder engagements undertaken as part of the project. This is largely a function of a gap in funding to move projects from pilot to construction or large-scale roll out. There is a role for Scottish Government to reduce the risk at certain parts of the process, act in a bridging capacity between stages or provide investment to enable this gap to be overcome and delivery sped up. These roles could be further investigated using the outputs of the SWOT analyses.

Creating demand for products

The SWOT analysis identified a lack of domestic demand for certain projects and services as a limiting factor to their growth, specifically in areas like hydrogen and sustainable building materials. This is causing a lack of confidence among private investors. Action by the Scottish and UK Governments in a number of areas to target public sector purchasing power to drive up demand could therefore help kick start and grow this demand, in the immediate term. If successful, this will improve confidence in the domestic market opportunities and therefore drive-up investment, job demand and wider economic contributions from these sectors.

2.3 Summary analysis

Presented here are the summary finding for each of the sector SWOT analyses undertaken. These are ordered as follows:

- Onshore Wind
- Offshore Wind
- Wave and Tidal
- Hydrogen
- Carbon Capture, Use and Storage
- Low Carbon Fuels
- Low Carbon Heavy Duty Vehicles
- Forestry
- Sustainable Building Materials
- Renewable Heat
- Professional Services
- Sustainable Financial Services

Table 1 provides an overview of the quantified data for each of the sectors analysed. This data is explained in the detailed SWOT analyses provided later in the report and provided here to enable a comparison between sectors.

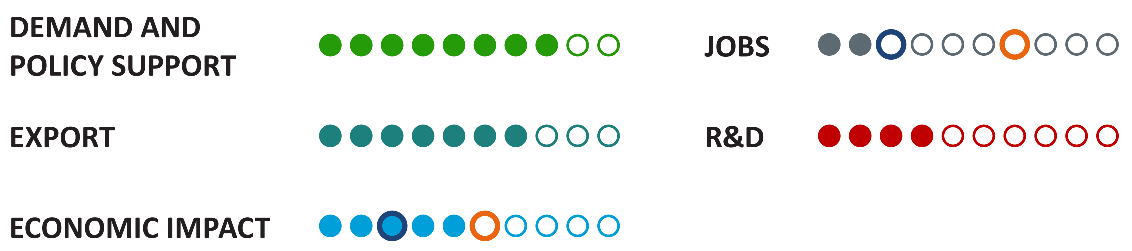
For each sector, the summary provides a definition of the scope considered in the analysis. Also provided is an indicative scale representation of the economic opportunities of each sector across each of the parameters assessed in the SWOT analyses. This is to support comparability across multiple sectors. Quantitative data is presented, setting out the best available estimates of current key economic indicators for each sector. Where available, the quantitative data includes scenario-based projections for the sectors, based on analysis carried out by Scottish Enterprise. These projections focus on the direct economic impacts arising from the delivery of Scotland's projected domestic transition and assume that existing relationships between key variables (such as turnover per head and GVA as a % of turnover) remain unchanged as sectors expand. As such, the projections do not account fully for potential increases in exports or Scottish content or for development of economies of scale or other dynamic shifts that may arise from improved technologies and processes. The summaries then go on to provide a summary overview of the outcomes of the SWOT analysis and presents the key strengths, weaknesses, opportunities and threats on quadrant diagrams.

Table 1: Overview of the quantified data for each of the sectors analysed

Sector	Scenario-based proj.	FTE/ headcount	Turnover	Business Count	GVA	Exports	Imports
Onshore Wind	2022	3,100	£4bn	5,000	£1.4bn	£121m	£233.5m
	2030	14,307	£6bn	-	£2.3bn	-	-
	2050	4,436	£1.9bn	-	£712m	-	-
Offshore Wind	2022	3,100	£4.2bn	1,000	£2bn	£832m	£1.6bn
	2030	23,518	£6.4bn	-	£3.1bn	-	-
	2050	4,436	£1.8bn	-	£874m	-	-
Wave and Tidal	2022	<500	£30m	200	-	-	£<0.5m
	2030	187	£12.2m	-	£6.2m	-	-
	2050	206	£13.4m	-	£6.8m	-	-
Hydrogen	2022/23	<500	£37m	100	£3m	-	-
	2030	5,191	£752.7m	-	£286m	-	-
	2050	3,793	£550m	-	£209m	-	-
CCUS	2022	<100	£4m	<500	-	-	-
	2030	1,016	£190m	-	£80m	-	-
	2050	804	£149m	-	£69m	-	-
LCFs	2022	290	£81.7m	-	£35m	-	-
	2030	5,700	£923m	-	£357m	-	-
	2050	5,463	£871m	-	£359m	-	-
HDVs	2020	<132	£25m	16	£12m	-	-
	2030	2,337	£441m	-	£209.8m	-	-
	2050	8,255	£1.5bn	-	£687.5m	-	-
Forestry (projections not available)	2019/21	5,700	£766.9m	1,146	£200.3m	£119.2m	£97.4m
Sustainable Building Materials (projections not available)	2017/22	8,000	£1.7bn	-	£580m	£759m	£188m
Renewable Heat	2022	1,700	£376.5m	500	£162m	£43.85m	£158m
	2030	13,461	£2.75bn	-	£1.08bn	-	-
	2050	9,664	£1.8bn	-	£774.9m	-	-
Professional Services (projections not available)	2022	4,500	£463.5m	2,677	£278m	-	-
Sustainable Financial Services	2021	71,300	£24.2bn	4,500	£11.2bn	£3.9bn	£985m

Onshore Wind

Sector definition: The production of electricity from onshore wind. Includes all value chain stages, including the operation and maintenance of the infrastructure for producing electricity from onshore wind, and the businesses supplying all goods and services involved in the development and deployment of onshore wind.



The scales show a Low to High opportunity (from left to right) and are based on a combination of qualitative and quantiative data sources.

Current

	FTE	Turnover	Business Count	GVA	Exports	Imports
2022	3,100	£4bn	5,000	£1.4bn	£121m	£233.5m

Scenario-based projections

	FTE	Turnover	Business Count	GVA	Exports	Imports
2030 ○	14,307	£6bn	-	£2bn	-	-
2050 ○	4,436	£1.9bn	-	£712m	-	-

Scotland's onshore wind sector has notable strengths, with abundant natural resources, a skilled workforce, and an established position owing to early adoption. Opportunities arise in service-based exports, circularity initiatives, and increasing domestic component content. However, in a capital-intensive sector where global supply chains are stretched, challenges for Scotland include limited exportability in many value chain stages, planning constraints, and grid connection and capacity capabilities. Addressing these weaknesses and threats, along with overcoming technical bottlenecks and competition for skills (particularly from other renewable electricity sectors), is crucial to realising Scotland's bold onshore wind ambitions and unlocking the potential domestic demand for goods and services to drive economic activity.

Strengths

- Well-established industry with supportive policy environment and strong public backing.
- Abundant natural resources suitable for onshore wind energy production.
- Scotland excels in exporting specialised engineering consultancy services, including wind farm design and financial due diligence.
- Strong economic impact owing to early adoption.
- Skilled workforce with strong capabilities across the supply chain, particularly in project development, installation, operation and maintenance, and specialised consultancy services.

Weaknesses

- Installation and operation and maintenance services are highly localised, protecting Scottish companies domestically but restricting export potential.
- Compared to sectors such as offshore wind, relatively few areas of the onshore value chain can be easily exported due to the importance of local expertise and content, and high transport costs.
- High capital investment required for new onshore wind developments.
- Scotland's lack of manufacturing infrastructure leave it reliant on imports for new projects, hindering the sector's growth.

Opportunities

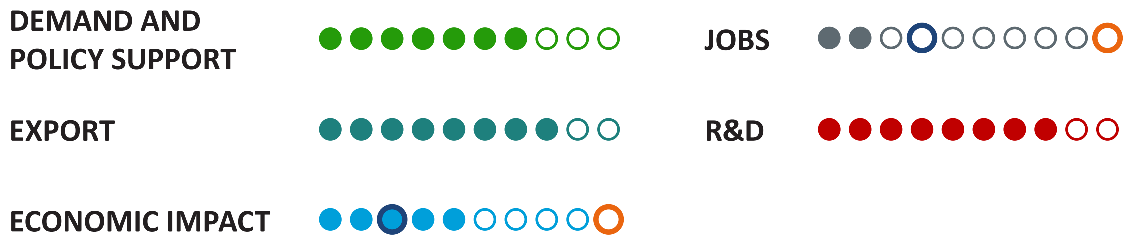
- Generally strong public support, facilitating the development of new sites and repowering of existing sites.
- High installation ambitions of 20GW by 2030.
- Opportunities to increase Scottish content in components.
- Onshore wind jobs are highly productive, particularly those in operation and maintenance, which are anticipated to grow as Scotland's onshore wind fleet grows.
- R&D advances are anticipated from recycling, repowering and decommissioning, as Scotland's fleet reaches its end-of-life earlier than some competitor countries.
- Significant growth potential in circularity, repowering, recycling, decommissioning, and other end-of-life value chain services.

Threats

- Grid connection and capacity constraints threaten the expansion of new projects.
- Existing and anticipated bottlenecks in planning and require resolution to achieve installation ambitions.
- High capital investment requirements leave the sector vulnerable to interest rate fluctuations.
- Strong competition for skills from other, often higher-paying, renewable electricity sectors.
- Levels of R&D spend in onshore wind are low compared to other, more nascent sectors.

Offshore Wind

Sector definition: The production of electricity from offshore wind. Includes all value chain stages, including the operation and maintenance of the infrastructure for producing electricity from offshore wind, and the businesses supplying all goods and services involved in the development and deployment of offshore wind.



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Current

	FTE	Turnover	Business Count	GVA	Exports	Imports
2022	3,100	£4.2bn	1,000	£2bn	£832m	£1.6bn

Scenario-based projections

	FTE	Turnover	Business Count	GVA	Exports	Imports
2030	23,518	£6.4bn	-	£3.1bn	-	-
2050	4,436	£1.8bn	-	£874m	-	-

The offshore wind sector in Scotland is operating from a strong, globally recognised base, and Scottish companies are already exporting both goods and services. Scottish and UK Government ambitions for offshore wind deployment are high, however recent increases in materials and energy costs pose a threat to the sector internationally. Scotland's ability to capture economic opportunities is constrained in some parts of the value chain, for example by currently limited Scottish major component manufacturing. Initiatives such as the strategic investment model (SIM) seek to address this and capitalise on the significant opportunities created by the rapid increase in the domestic market. The SIM identifies key, shared priorities with an initial focus on investment in ports and harbours infrastructure improvements, manufacturing, and fabrication. Scotland's specialist services, project development, operations and maintenance, and construction sectors are strong and have a role to play domestically and internationally. However, issues such as grid capacity and consenting processes in Scotland could be addressed to allow supply chain to grow further.

Strengths

- Established and well-recognized position in the global offshore wind industry, including floating wind.
- Abundant natural resources suitable for offshore wind energy production.
- Supportive policies and ambitious targets and demonstrated collaboration between industry and government.
- Well-established industry with robust supply chain capabilities and specialised competences.
- Contributes significantly to the Scottish economy, with an estimated direct turnover of £2.6 billion in 2021.
- Highly skilled and experienced workforce across the value chain.
- Public funding directed towards offshore wind R&D projects in Scottish universities is large compared to many other sectors.

Weaknesses

- The absence of offshore wind projects in a recent Contracts for Difference (CFD) allocation round reflects a perceived lack of support from the UK Government.
- Known issues such as port infrastructure and grid connection need to be addressed to fully leverage the potential of the offshore wind sector.
- The sector is reliant on imports due to the absence of a large-scale turbine manufacturer in the UK, indicating a dependency on external sources.
- Skills gap challenges in STEM and data science fields.
- There is uncertainty regarding whether current levels of R&D are sufficient.

Opportunities

- Scotland enjoys a first-mover advantage in floating offshore wind.
- Offshore wind is an enabler for transition in many sectors.
- Potential for economic savings through circular economy opportunities, such as reusing materials after decommissioning.
- Scotland stands to gain from rapidly growing international demand, especially in floating offshore wind.
- Co-locating offshore wind infrastructure with other renewable energy sources, such as hydrogen, presents economic opportunities.
- Existing offshore oil and gas business and labour force capabilities can be transferred to offshore wind.

Threats

- Existing and anticipated bottlenecks in planning and grid connection pose threats to the timely delivery of the offshore wind pipeline.
- The US Inflation Reduction Act and the EU's Green Deal Industrial Act may create competitive challenges for Scottish projects on the international stage.
- Anticipated longer-term shortages in key skill areas and competition from other sectors may pose challenges for sustained growth.

Wave and Tidal

Sector definition: The economic impact of the design, development, construction and/or production, specialised consultancy services, installation of infrastructure for producing electricity from marine renewables (wave and tidal) and their operations and maintenance.

DEMAND AND POLICY SUPPORT

JOBS

EXPORT

R&D

ECONOMIC IMPACT

The scales show a Low to High opportunity (from left to right) and are based on a combination of qualitative and quantiative data sources.

Current

	FTE	Turnover	Business Count	GVA	Exports	Imports
2022	<500	£30m	200	-	-	£<0.5m

Scenario-based projections

	FTE	Turnover	Business Count	GVA	Exports	Imports
2030	187	£12.2m	-	£6.2m	-	-
2050	206	£13.4m	-	£6.8m	-	-

Scotland is the world leader in Marine Renewable Energy (MRE) which includes both wave and tidal stream energy. Scotland has more MRE deployed than the rest of the world combined and the world's first and largest tidal array and the world's largest tidal energy converter. In addition, Wave Energy Scotland has overseen the pre-commercial procurement of Scottish wave energy converters, and component parts, building a competitive supply chain for MRE. The indigenous Scottish companies developing technology in these areas have built projects with the exceptionally high local content of up to 80% in individual projects. Test and demonstration of these technologies have taken place over the last 20 years at the European Marine Energy Centre (EMEC) in Orkney. The Scottish Government have implemented a one-stop shop for offshore consenting which, combined with Crown Estate Scotland's leasing processes, has made Scotland an attractive environment for the development and deployment of marine renewable energies.

Strengths

- MRE supports a more robust renewable grid.
- Activity is Scotland focused.
- Indigenous Scottish company base.
- Existing Scottish experience in MRE deployment.
- High value and green energy jobs in remote and rural locations.
- Existing innovation and academic infrastructure.

Weaknesses

- No specific policy driver beyond net zero target.
- High levelised cost of energy (LCOE) presently.
- Project pipeline impacted by hiatus in revenue support.
- Lengthy consenting process and long grid waiting times.
- Scale of current projects not enough to entice large investors.

Opportunities

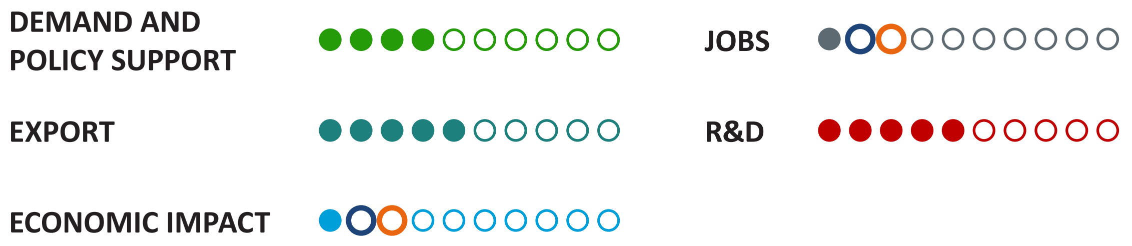
- Significant Scottish natural resources.
- Private wire and Power to X support community energy and hydrogen targets.
- High EU targets for deployment.
- Significant global resource.
- Export potential is high.
- Economic opportunities in GVA.
- Economic opportunities in jobs.

Threats

- No MW target set by government impacting visibility of route to market.
- Other markets keen to take lead on MRE.
- Challenging investment climate for necessary R&D.
- Challenging investment climate for MRE array construction.
- Availability of skills.

Hydrogen

Sector definition: The hydrogen sector includes blue and green hydrogen production, distribution, storage, and usage. Grey hydrogen is not included. Data often refers solely to green hydrogen, if this is the case it is noted in the text. LCREE data includes the production of fuels for low carbon and renewable energy use, which is not classified as bioenergy, Including hydrogen. Data included in this SWOT is therefore also partly covered in the Low Carbon fuels and the HDV SWOTs.



The scales show a Low to High opportunity (from left to right) and are based on a combination of qualitative and quantiative data sources.

Current

	FTE	Turnover	Business Count	GVA	Exports	Imports
2022/23	<500	£37m	100	£3m	-	-

Scenario-based projections

	FTE	Turnover	Business Count	GVA	Exports	Imports
2030	5,191	£727.7m	-	£286m	-	-
2050	3,793	£550m	-	£209m	-	-

Scotland's abundant wind resources ensure access to a substantial domestic renewable energy supply and geographical position underpins Scotland's potential to produce and export green hydrogen. Additionally, Scotland has established infrastructure from the oil and gas sector along with a skilled workforce, both of which are transferable to meet the demands of the evolving hydrogen landscape. Blue and green hydrogen are both in early stages of development globally, with blue hydrogen expected to grow rapidly initially and green hydrogen expected to scale in the longer term. Scotland's hydrogen sector is evolving and requires scaling pilot projects into full operations to build and grow the sector and to compete in the growing global hydrogen market. A critical near term challenge is the lack of domestic demand for hydrogen (in industry, transport or buildings) which means the sector is reliant on export orders to grow. Overcoming challenges like the absence of electrolyser production also presents threats to production or could be an opportunity to attract a producer to Scotland, which would create jobs, GVA and the potential for exports to UK and Europe. Simultaneously, fostering domestic demand is vital for initiating and sustaining sectoral growth.

Strengths

- Abundance in renewable energy and especially offshore wind closely linked to green hydrogen development.
- Established infrastructure from the oil and gas sector is transferable to meet the demands of the evolving hydrogen landscape.
- Government policy support from hydrogen action plan.
- Geographic proximity to key markets offers cost-effective export possibilities.
- Active participation in hydrogen-related service exports.
- Transferable skills, notably engineering skills from the oil and gas and chemical sectors.

Weaknesses

- The sector is not yet operational at scale.
- Specific UK and Scottish regulations for the hydrogen economy are yet to be fully established, lack of policy certainty.
- Not all parts of the value chain are represented in Scotland, for example electrolyser manufacturing.
- Vertical integration in the value chain is limited.
- Skills gap challenges in STEM and data science fields.

Opportunities

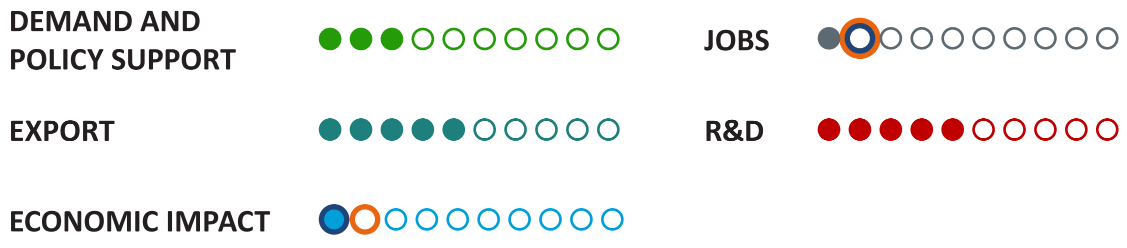
- Anticipated significant growth in hydrogen demand.
- Great positive climate impact in multiple sectors.
- Exploring alternatives for hydrogen storage.
- Net export potential to European and global markets.
- Plans for pipelines to mainland Europe.

Threats

- Lack of important infrastructure such as pipelines, both domestic and international.
- Limited grid capacity poses a potential obstacle to hydrogen production.
- Need for coordination between UK and Scotland as well as between government and industry.
- Fierce global competition to be expected.
- Competition for new and existing workforce from other net zero sectors.
- Public spending on hydrogen related R&D did not compare well to other EEA countries in 2021.
- Rate of commercialisation does not compare well to other countries.

Carbon Capture, Use and Storage

Sector definition: CCUS involves carbon capture from emitters and from the atmosphere, as well as storage, transport, and utilisation.



The scales show a Low to High opportunity (from left to right) and are based on a combination of qualitative and quantiative data sources.

Current

	FTE	Turnover	Business Count	GVA	Exports	Imports
2022	<100	£4m	<500	-	-	-

Scenario-based projections

	FTE	Turnover	Business Count	GVA	Exports	Imports
2030	1,016	£190m	-	£80m	-	-
2050	804	£149m	-	£69m	-	-

CCUS is a nascent industry with low commercial activity. However, it is key to achieve net zero and Scotland is demonstrating innovative strengths, with public and private sector engagement. An existing skilled workforce and legacy oil and gas infrastructure, as well as available CO2 storage potential, are important enablers.

Challenges in Scotland relate to devolved and reserved policy which stresses the importance of alignment between Scottish and UK governments, uncertainties in the CCUS value chain and a complexity that demands further research and the application of best practice.

Strengths

- Existing infrastructure from oil and gas sector can be used in deployment of CCUS.
- Funding to help businesses and organisations develop and commercialise the technology is available.
- Geographical position close to UK and mainland Europe.
- Skilled workforce.
- Private sector engagement in research and development projects.

Weaknesses

- No established market.
- Long distances between emission source and eventual offtakers of captured CO2.
- Stakeholders operate under low margins.
- High R&D need.

Opportunities

- Synergies with other markets such as green hydrogen.
- Scotland could provide a route for much of the UK's emissions to be safely stored, as well as functioning as a European carbon storage hub.
- GDP increase.
- Scotland stands to benefit from the potential opportunity in R&D and innovation as inward investors are inclined to invest in these areas
- Workforce transition from oil and gas sector.
- CCUS with sector coupling offers opportunities for integrated, sustainable solutions in carbon capture and utilization across various industries.

Threats

- UK dependence as CCUS policy is mostly reserved.
- A highly complex value chain raises questions regarding where, in Scotland, value will be added.
- Increased efficiency may limit the number of available jobs.
- Majority of research and development hinges on few projects.

Low Carbon Fuels

Sector definition: The economic impact of the production of gaseous and liquid LCFs of both a biological and synthetic nature, including their production facilities and infrastructure. Economic data are available and provided for the production of biogas, biofuels, blue hydrogen, green hydrogen, and sustainable aviation fuels (SAF). As such, there is some overlap with the Hydrogen SWOT, which also covers blue and green hydrogen production. The economic impact of the production of vehicles using LCFs is also excluded - for these figures, see for example the Low Carbon Heavy Duty Vehicles SWOT.

DEMAND AND POLICY SUPPORT

JOBS

EXPORT

R&D

ECONOMIC IMPACT

The scales show a Low to High opportunity (from left to right) and are based on a combination of qualitative and quantiative data sources.

Current

	FTE	Turnover	Business Count	GVA	Exports	Imports
2022	290	£81.7m	-	£35m	-	-

Scenario-based projections

	FTE	Turnover	Business Count	GVA	Exports	Imports
2030	5,700	£923m	-	£357m	-	-
2050	5,463	£871m	-	£359m	-	-

Low carbon fuels (LCFs) will be crucial to decarbonising transport sectors which will have difficulty fully electrifying, such as aviation, maritime and niche vehicles. Scotland boasts strengths in these sectors and can leverage expertise and infrastructure from its established oil and gas industry to scale up LCF production. Challenges include high capital costs, a lack of policy clarity, and competition for feedstocks (the renewable and biological raw materials used for fuels). Opportunities lie in locating facilities alongside renewable electricity production, utilising local expertise, and expanding green hydrogen infrastructure. Navigating these factors could expand Scotland's LCF industry while helping to protect its current refining market position.

Strengths

- Net Zero policy commitments necessitate LCF development.
- Availability of natural resources and existing infrastructure (e.g., refining facilities at Grangemouth, port and distribution networks such as Finnart Ocean Terminal).
- Strong aerospace sector with a clear decarbonisation pathway (low carbon fuels of biological origin in the short to medium term, hydrogen and synthetic low carbon fuels in long term) facilitates development of sustainable aviation fuels (SAF).
- Many secured skills, particularly in refining.
- Existing R&D strengths in CCUS, hydrogen and biorefining.

Weaknesses

- Sector not currently operational at scale.
- Perceived lack of detail within UK and Scottish policy on the specific timings of SAF adoption, the specific types and volumes of feedstocks which will be secured for production compared to other sectors, and the levels of funding available for potential plant producers.
- Lack of policy clarity for maritime LCF adoption.
- Fuel transport and toxicity complications (H2, NH3).
- High capital investment required to develop LCF production facilities and infrastructure.

Opportunities

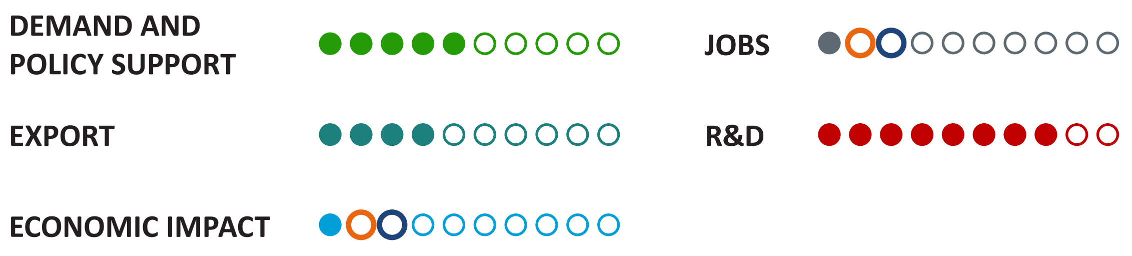
- Strong industry demand projected to last several decades, particularly in aviation.
- Net export potential due to international demand and current oil and gas exporting infrastructure.
- High renewable electricity availability facilitates co-location with renewable energy facilities.
- Plans for hydrogen pipelines to Europe.
- No global leader in LCF development, window of opportunity to become net exporter.
- Job creation opportunities, but also job retention potential at refining sites due to transferable skills.
- Sustainable Aviation Testing Environment (SATE) in Orkney facilitates the testing of sustainable aircraft.

Threats

- Current lack of supply of LCFs, requires capital investment.
- Competition with other sectors for feedstocks (the renewable and biological raw materials used for LCFs).
- Potential centralisation of UK LCF plants outside Scotland.
- Grid capacity currently limits synthetic LCF export capabilities.

Low Carbon Heavy Duty Vehicles

Sector definition: The economic impact of the design and manufacture of low carbon HDVs and their associated charging and refuelling infrastructure. Covers all large land vehicles excluding trains, from on-road heavy goods vehicles (HGVs), buses and coaches to off-road construction and agricultural vehicles. Economic data are available and provided for electric vehicle (EV) and hydrogen buses and HGVs, EV chargers and hydrogen refuellers. The production of hydrogen and low carbon fuels are excluded - for these figures, see the Hydrogen SWOT and Low Carbon Fuels SWOT, respectively.



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Current

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Scenario-based projections

	FTE	Turnover	Business Count	GVA	Exports	Imports
2030	2,337	£441m	-	£209.8m	-	-
2050	8,255	£1.5bn	-	£687.5m	-	-

Scotland's HDV production sector consists of a small number of companies manufacturing a diverse range of vehicles, with very different net zero transition pathways. Excluding buses, where Scottish company Alexander Dennis is manufacturing and exporting low and zero carbon buses at scale, the sector's decarbonisation has been limited by uncertainties, high costs and long development times. Some Scottish HDV manufacturers have developed low carbon vehicles but longer term, competition with large, international original equipment manufacturers (OEMs) will be a challenge. Supply remains limited, but Scottish HDV manufacturers are engaged and opportunities to decarbonise the on-road public sector fleet are strong. Whilst current levels of EV HDV production are low, the wider HDV sector is strong and will need to transition. The choice now is whether to invest in hydrogen or battery electric powered vehicles, and how best to protect and expand Scotland's HDV manufacturing base.

Strengths

- Government policy support through de-risking of commercial investment, strategies, task forces.
- Engaged industry stakeholders.
- Exports to UK, particularly in component manufacturing.
- Alexander Dennis a strong global company in the manufacture of low-carbon buses.
- Existing skills in niche HDV manufacturing (e.g., fire engines, construction vehicles).
- Strong public R&D investment, particularly in hydrogen fuel cell electric vehicles.

Weaknesses

- Very few HDVs currently low-carbon (only 0.14% of Scotland's HGVs, buses and coaches in 2021).
- High capital cost and long development times for new HDVs (although evidence growing that the total cost of ownership of low carbon HDVs is reaching parity with conventional vehicles, particularly for buses and smaller HGVs.
- Small Scottish company base of manufacturers remain dependent on larger international suppliers.
- Lack of clarity regarding decarbonisation pathways for many HDVs (H2 vs electrification).
- Limited market share, especially for off-road HDVs.

Opportunities

- Supply chain pressure increasing uptake of low carbon HDVs.
- Export potential of niche HDVs (e.g., fire engines, construction vehicles).
- Large GVA increase forecast, particularly in HDV production.
- Skills development opportunities (e.g., in remanufacturing, particularly in remanufacturing, and installation of low carbon infrastructure such as chargers.
- R&D developing alternative fuels (see low carbon fuels SWOT).

Threats

- Uncertainties surrounding durability, reliability and lifetime of nascent technologies.
- Current lack of HDV and infrastructure supply.
- Existing supply chain contracts may block new partnerships.
- Scaling issues exist currently – capital required vs size of companies.
- Need for dedicated HDV end-of-life treatment facilities.
- Anticipated longer-term shortages in key skill areas and competition from other sectors may pose challenges for sustained growth.
- US / EU incentives for localisation of vehicle manufacturing may impact Scottish exporters.
- Potential over-commitment on H_2.

Forestry

Sector definition: The cultivation, conservation, and management of forests for timber production, biodiversity conservation, forest tourism, and provision of ecosystem services (including carbon sequestration for carbon credits). Includes activities from forest planning and management to the extraction of timber through logging and initial processing stages like sawmilling or chipping. The further processing of wood into final consumer goods, typically categorised under manufacturing or construction, is mentioned for context only and is mostly covered in the sustainable building materials SWOT. Also note that the figures below only include private sector activities. The public sector is a significant producer and employer in the forestry sector and hence these figures are a significant underestimate of the total sector.

DEMAND AND POLICY SUPPORT	●●●●●●●●○○	JOBS	●●○○○○○○○○
EXPORT	●●●●●●●○○○	R&D	●●●●●○○○○○
ECONOMIC IMPACT	●○○○○○○○○○		

The scales show a Low to High opportunity (from left to right) and are based on a combination of qualitative and quantiative data sources.

Current

	FTE	Turnover	Business Count	GVA	Exports	Imports
2019/21	5,700	£766.9m	1,146	£200.3m	£119.2m	£97.4m

Scenario-based projections

No forecast data available for these sectors.

From carbon sequestration and biodiversity conservation to sustainable timber production, increasing the area of Scotland's forests will be crucial to meeting net zero goals. However, competing land use demands have increased the importance of balancing the economic, environmental, and social values of Scotland's forests. The sector faces structural challenges including an ageing and seasonal workforce. Research and development is also required to demonstrate the suitability and international competitiveness of Scottish timber for construction, and to drive maximum value from high-value wood products. By overcoming these challenges, Scotland can increase the economic value of the sector, particularly if it can service the soaring demand for timber in the rest of the UK as the carbon credit market expands further.

Strengths

- Majority (~80%) of UK planting takes place in Scotland, and the expansion of Scottish woodland is recognised as crucial to the UK's Net Zero ambitions.
- Exports to the UK are strong, particularly in wood products.
- Important role in the Just Transition, particularly in its ability to provide significant rural job creation benefits.

Weaknesses

- Limited planting 1980s-2010s has resulted in a relatively young current stock of woodland.
- International exports are limited due to many strong international competitors.

Opportunities

- The sector is reliant on and thus highly responsive to signals from government.
- Strong public support for woodland creation projects.
- Increased sectoral collaboration (e.g., increased timber in construction, renewable energy schemes like biorefining, agroforestry)
- Ambitious woodland creation targets of 18,000ha per year by 2024/25.
- Increased public and private investment, including a growing carbon credit market (WCC), corporate social responsibility (CSR) and potential into UK Emissions Trading Scheme (ETS).
- Circularity opportunities to reduce pressure on new woodland.

Threats

- Projected decline in timber availability from the late 2030s.
- Non-native, monoculture planting in previous years.
- Increasing land use competition.
- International timber competition may disadvantage Scottish exports.
- Ageing workforce and reliance on seasonal workers.
- Skills gap forecast in key competences.
- R&D tax relief remains underused across the sector, with many small businesses unaware of their eligibility.
- Relatively low levels of R&D spend compared to other industries.

Sustainable Building Materials

Sector definition: Sustainable building materials includes the production and manufacturing of timber products, the production and manufacturing of new low-carbon materials to replace high-carbon products (including low carbon cement, bricks, insulation materials), and the improved recycling of existing materials. Given the limitations of the available data, figures provided are for the manufacture of wood products. Note that although the construction sector is the largest user of these products, some manufactured wood products will be intended for other uses.

DEMAND AND POLICY SUPPORT	●●●●●○○○○○	JOBS	●●●●●○○○○○
EXPORT	●●●●●●●○○○	R&D	●●●●●●●●○○
ECONOMIC IMPACT	○○○○○○○○○○		

The scales show a Low to High opportunity (from left to right) and are based on a combination of qualitative and quantiative data sources.

Current

	FTE	Turnover	Business Count	GVA	Exports	Imports
2017/22	8,000	£1.7bn	-	£580m	£759m	£188m

Scenario-based projections

No forecast data available for these sectors.

The introduction of sustainable building materials is key to the decarbonisation of the construction sector in Scotland and internationally. Scotland has existing strengths including its production of timber and sustainable insulation products, a supportive policy environment and a focus on innovation in construction. However, whilst innovative sustainable materials are already technically feasible, scaling issues exist in a construction sector exposed to tight margins and variable material prices. The public sector can play a key role in driving demand for these goods and services.

Strengths

- Policy support – public procurement represented almost half of spending in the construction sector in Scotland.
- Availability of natural resources, particularly timber, which is used extensively in construction.
- Wood product exports to the UK.
- Export strengths in construction management services, including offsite manufacturing.
- Many secured skills.
- Many government-supported and higher education R&D initiatives (e.g., BE-ST, Construction Scotland Innovation Centre, Centre for Offsite Construction, Green Construction Board).

Weaknesses

- Low, variable material prices tighten margins and discourage sustainable practices.
- Lack of supply chain coordination in SME-dominated, parochial sector.
- Difficult to prioritise Scottish timber products over international products due to price and quality concerns.
- Exports held back by higher manufacturing costs.
- Limited medium-term timber potential due to young timber stock.
- Difficult to isolate economic data and therefore impact from wider construction sector.

Opportunities

- Dependence on public procurement means SG can have real influence in the sector.
- GHG reduction potential due to huge carbon
- No nation has 'solved' retrofitting, and Scotland's array of building typologies provides an advantage.
- Offsite manufacturing export opportunities.
- UK aiming to increase timber use in construction, presenting opportunities for Scotland which dominates UK tree planting.
- Economic opportunities from retrofitting need, particularly in insulation materials.
- Increased profitability from circular construction practices projected.
- Projected job increases – almost 20,000 in Scottish construction by 2027.

Threats

- Scaling issues for SMEs, who have a clear policy and environmental case for sustainable materials and practices but lack a clear business case.
- Fire safety concerns.
- Import reliance remains for many building materials (e.g., insulation).
- Need to overcome perception that there are timber grade issues to export to UK.
- Recruitment challenges expected.
- Declining business enterprise R&D in the construction sector in recent years.

Renewable Heat

Sector definition: Scotland's renewable heat sector can be described of as a collection of multiple niche markets. Heat pumps and heat networks are the focus of this SWOT given their prioritisation in multiple key documents.

DEMAND AND POLICY SUPPORT

JOBS

EXPORT

R&D

ECONOMIC IMPACT

The scales show a Low to High opportunity (from left to right) and are based on a combination of qualitative and quantiative data sources.

Current

	FTE	Turnover	Business Count	GVA	Exports	Imports
2022	1,700	£376.5m	500	£162m	£43.85m	£158m

Scenario-based projections

	FTE	Turnover	Business Count	GVA	Exports	Imports
2030	13,461	£2.75bn	-	£1.08bn	-	-
2050	9,664	£1.8bn	-	£774.9m	-	-

Scotland's renewable heat sector is made up of multiple niche markets, which have potential to grow and significantly contribute to Scotland's net zero economy. Ambitious decarbonisation targets are set to drive demand, but require rapid scaling of adoption and installation. Due to a complex set of factors, the main weakness is insufficient uptake, though there are signs this may be changing and the Scottish Government have recently consulted on proposals to improve consumer demand. Given the scale of delivery needed and an ambition to end the use of polluting heat in buildings before the end of 2045, there are opportunities particularly in job creation. However, the lack of coherence and clarity in policy is impacting demand, market confidence and speed of delivery. Transition in this sector is primarily about skills and employment, though uptake of renewable heat provides the opportunity to transition from being a net importer of natural gas to a more resilient, self-serving market with a better balance of trade. At present, Scotland imports much of the heat technology being deployed. Although it does have some manufacturing capacity for heat pumps, the majority of these manufactured products are currently exported. Further analysis is required on the potential to provide both the products and services needed to meet domestic needs alongside the international market.

Strengths

- Supply chain capabilities from existing manufacturers (Mitsubishi, Star Refrigeration), local installers and innovative developers of new technology.
- Ambitious targets and strong government policy support.
- Current sector export presence through Mitsubishi, and Star.
- Some signs of increasing demand through heat pump sales.
- High research and innovation funding, both UK and Scotland: SG support for Heat Network Delivery (£300m), SE funding for innovation (GHISP).

Weaknesses

- High level of intervention required- current policy and incentives have fallen short in creating demand at pace needed. There is a disconnect between policy and demand as well as a lack of clarity for consumers.
- High initial costs (both installation of heat pumps and CAPEX of heat networks).
- High reliance on imported goods.

Opportunities

- International demand likely to be high and existing exporters and innovators offer potential to export products as well as knowledge and services.
- Economic impact due to scale of needs (e.g. number of buildings to decarbonise).
- Expected number of jobs and upskilling opportunities.
- Quality and diversity of jobs, both geographically and in terms of role (installers will be needed across Scotland, consultancy, manufacturing and digital skills will be needed as well as installation).

Threats

- Lack of supporting infrastructure e.g., grid capacity and connections, as well as long planning timelines for heat networks.
- Lacking customer demand and attractiveness.
- High threat of international competition meeting UK and wider demand.
- High CAPEX (interest rate impact).
- Skills deficit and competition from other sectors.
- Innovation and efficiency improvements needed to improve attractiveness (heat pumps) and understand building needs.

Professional Services

Sector definition: The professional services sector spans the Scottish economy both horizontally across sectors and vertically along value chains. It includes engineering, planning and digital skills, and well as consulting and advisory services (financial services are analysed in their own SWOT). There may be overlaps with other parts of the NZ&CA economy due to difficulties disaggregating this data.

DEMAND AND POLICY SUPPORT	●●●●●●●●○○	JOBS	●●○○○○○○○○
EXPORT	●●●●●●●●●○	R&D	●●●●●●○○○○
ECONOMIC IMPACT	●●○○○○○○○○		

The scales show a Low to High opportunity (from left to right) and are based on a combination of qualitative and quantiative data sources.

Current

	FTE	Turnover	Business Count	GVA	Exports	Imports
2022	4,500	£463.5m	2,677	£278m	-	-

Scenario-based projections

No forecast data available for these sectors.

Addressing sustainability and the transition to a NZ&CA economy is an enormous systems level problem to solve. Consulting, technology, engineering and other services firms sit at the centre of these complex systems and have a crucial role to play in providing expertise, advice and solutions. In order to address these systems level challenges, there is a need for multidisciplinary innovation and Scotland's existing strengths across multiple sectors present a potential competitive advantage. Significant opportunities exist due to current and forecast demand increases for multiple sustainability services in Scotland and internationally. Scotland is well placed to meet this demand due to its existing experience in specific areas (such as securing consents in offshore wind), complemented by strengths in innovation. Scotland has multiple areas of competitive advantage including technical experience across sectors, as well as unique first mover advantages such as floating offshore wind. Scotland's planners, engineers and consultants will have the opportunity to export knowledge and expertise. International competition for the providing sustainability services will be high and Scottish companies and universities must ensure they remain attractive to talent, working to address inclusivity and retention in key sectors. Competition for skills is a serious threat from within the NZ&CA economy sectors but also from others such as space and ship building.

Strengths

- Existing expertise and cross sector spill overs such as finance and engineering.
- International and cross sector collaboration (clusters, wellbeing economy governments network).
- Global reputation.
- Current export scale and global reputation.
- Quality of skills.
- Innovation centres, clusters and knowledge sharing.

Weaknesses

- Disconnect between policy message and reality in the sector.
- UK Environmental and Sustainability consulting exports have been falling since 2017.
- Dependency on public sector in areas such as circular economy.
- Discrepancy in R&D performance between higher education and business enterprise.

Opportunities

- There is a need for multidisciplinary innovation in the NZ&CA context: Scotland's culture of knowledge sharing and innovation could be a competitive advantage.
- Expected future demand – over $240m in sustainability services revenues.
- Growing international demand for sustainability services.

Threats

- Evidence of sector issues with inclusivity and retention.
- International competition (e.g., India engineering and digital).
- Competition for skills within NZ&CA economy and wider (e.g., space).

Sustainable Financial Services

Sector definition: Sustainable financial services in Scotland include asset management, consultation on sustainable finance frameworks and investments, and related professional services. The sector comprises traditional banks, insurance, life and pensions businesses, and wealth management, all headquartered in the UK. Quantitative data are for the financial sector as a whole.

DEMAND AND POLICY SUPPORT	●●●●●●●●○○	JOBS	●●●●●●●●●●
EXPORT	●●●●●●●●●○	R&D	●●●●●●●●●○
ECONOMIC IMPACT	●●●●●●●●●●		

The scales show a Low to High opportunity (from left to right) and are based on a combination of qualitative and quantiative data sources.

Current

	FTE	Turnover	Business Count	GVA	Exports	Imports
2021	71,300	£24.2bn	4,500	£11.2bn	£3.9bn	£985m

Scenario-based projections

No forecast data available for these sectors.

Scotland is well positioned to develop a leading sustainable financial services sector, both as a location where green services are delivered for global clients and as an attractive destination for domestic sustainable investments. Scotland is well placed due to membership of the Glasgow Financial Alliance for Net Zero (GFANZ) and featuring in the Global Green Finance Index. This recognition, coupled with academic excellence and the UK's leadership in sustainable finance regulation provide credibility. Sustainable finance, and Environmental, Social and Governance (ESG) practices, are becoming firmly embedded in investing strategies, with demand only set to increase. To remain competitive, and given the competition to capitalize on this, Scotland must prioritise long term clarity and investor confidence, as well as fostering its culture of innovation. It is this combination of strengths, combined with local, investible assets in sectors such as energy, forestry and in agriculture and food, that positions Scotland to further develop opportunities in sustainable finance. As well as potential for economic growth and exports through innovative products and services, opportunities for growth in this sector stem from improved management of climate and nature-related risks, enhancing resilience and reducing exposure of asset portfolios.

Strengths

- Leadership and proximity to leadership in regulation.
- Scale and reputation of sector in Scotland.
- Different (though collaborative) culture to London – smaller networks.
- Micro and macro level demand for sustainable financial products and services.
- Existing R&D strengths in CCUS, hydrogen and biorefining.

Weaknesses

- Branding and market awareness of Scotland is low compared to other markets.
- Drop in global export rankings.
- Lack of confidence in ROI in sustainability space, need for clear policy.

Opportunities

- Growing number of investible assets in Scotland (e.g., through energy and forestry).
- Growing international demand for sustainable financial products and services.
- Potential to recapture export status through sustainability.
- Recommendation to shift tax to align with circular economy principles.
- Current financial services GVA and opportunity for export.
- Expected future demand is high.
- Promotes better risk management and resilience, benefitting the economy as a whole.

Threats

- Confidence in capital returns of project (ability to deliver on commitments profitably).
- Lacking clarity and confidence for investors in adaptation, natural capital and circularity.
- Competition from emerging (international) financial centres.
- Competition for skills (e.g., trading, tech).

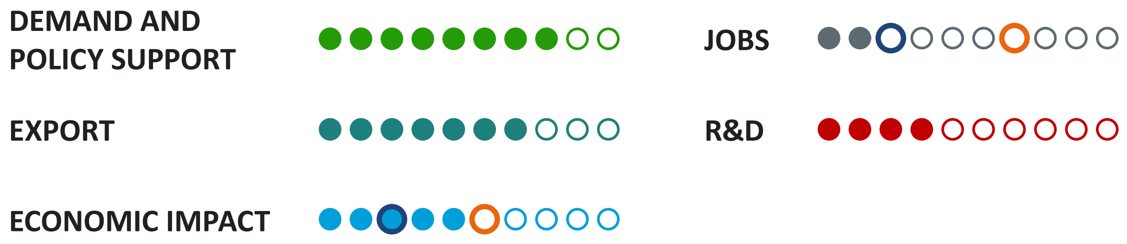
3. Strengths, Weaknesses, Opportunity and Threats analyses

This section presents each of the Strengths, Weaknesses, Opportunities and Threats (SWOT) analyses undertaken as part of the research. While the analyses are presented in a concise format, it should be noted that they are the product of significant literature review, research, and consultation.

Each SWOT is supported by Endnotes. These are presented in the appendix that follows them.

3.1 Onshore Wind

Sector definition: The production of electricity from onshore wind. Includes all value chain stages, including the operation and maintenance of the infrastructure for producing electricity from onshore wind, and the businesses supplying all goods and services involved in the development and deployment of onshore wind.



The scales show a Low to High opportunity (from left to right) and are based on a combination of qualitative and quantiative data sources.

Current

	FTE	Turnover	Business Count	GVA	Exports	Imports
2022	3,100[1]	£4.0bn[1]	5,000[1]	£1.6bn[2]	£120m[1]	£230m[1]

Scenario-based projections

	FTE	Turnover	Business Count	GVA	Exports	Imports
2030	14,000[3]	£6.0bn[3]	-	£2.3bn[3]	-	-
2050	4,400[3]	£1.9bn[3]	-	£710m[3]	-	-

Scotland's onshore wind sector has notable strengths, with abundant natural resources, a skilled workforce, and an established position owing to early adoption. Opportunities arise in service-based exports, circularity initiatives, and increasing domestic component content. However, in a capital-intensive sector where global supply chains are stretched, challenges for Scotland include limited exportability in many value chain stages, planning constraints, and grid connections and capacity. Addressing these weaknesses and threats, along with overcoming technical bottlenecks and competition for skills (particularly from other renewable electricity sectors), is crucial to realising Scotland's bold onshore wind ambitions and unlocking the potential domestic demand for goods and services to drive economic activity.

Demand and Policy Support

Scotland's onshore wind sector benefits from a supportive policy environment and strong public backing[4], bolstered by abundant wind resources and a mature domestic industry which accounted for 62% of Scotland's electricity in 2022 . However, although the Climate Change Committee highlighted that "all [carbon reduction] scenarios see new onshore wind generation being deployed by 2050"[6], challenges exist like technical and regulatory bottlenecks and grid connection issues, requiring solutions for sustained growth to meet high installation ambitions.

The onshore wind sector thrives within a supportive policy framework, evidenced by the industry and government-backed Onshore Wind Sector Deal for Scotland[7], and propelled by high installation ambitions[8] and substantial public backing[9]. The region boasts plentiful natural wind resources, establishing a robust domestic industry through early adoption, even by high UK standards[10]. This early adoption has cultivated expertise and local content (the use of local products and services) across the value chain, but particularly in project development, installation, and operation and maintenance. However, it is noteworthy that turbine manufacturing predominantly occurs internationally, creating a current and likely future reliance on global production networks[11].

The pipeline of consented projects in addition to the existing 9GW of installed onshore wind amounts to the ambition of 20GW of installed onshore wind capacity by 2030[12]. However, new developments are likely to be needed to achieve installation ambitions[13]. Commercial and technical challenges must be overcome to realise projects that are currently consented but unbuilt[14,15]. Additionally, the average consented lifespan of a wind farm of 25 years means that several sites will require repowering, extension, or decommissioning[16]. An analysis of the expected pipeline of new onshore wind projects, extensions to existing projects, life extensions and repowering projects between 2024 and 2030 was expected by the end of 2023[17].

To ensure economic opportunities are realised, addressing technical and regulatory bottlenecks is essential[18]. Prolonged project development stages currently pose a challenge to Scottish onshore wind ambitions, both regarding the time taken for decisions on consenting new sites, and regarding the time taken for projects to be built following consent. The current length and uncertainty of the consenting process risks the commercial viability of projects, as increased project development costs need to be recouped during the wind farm's operational life[19]. Second, Scottish Renewables highlight that the average time to obtain consent and deliver a wind farm currently takes seven years, which they describe as untenable if the nation is to achieve its 2030 installation ambitions[20]. Furthermore, grid connection and network upgrade issues, especially in rural sites where larger turbine developments are installed, necessitate prompt resolution[21]. The Scottish Government has recognised these bottlenecks in the latest Onshore Wind Sector Deal for Scotland, committing to reducing consenting decision times and to work with industry and stakeholders to streamline potential legislative, regulatory, and technical barriers[22].

Export

Scotland's main onshore wind exports are specialised engineering consultancy services like wind farm design and financial due diligence. Although only a few value chain elements are readily exportable, potential opportunities for Scotland's future lie in becoming a global leader in the recycling, repowering, and decommissioning of turbines, offering opportunities to export consultancy expertise in this area to enhance its international market presence.

Despite the strength of Scotland's onshore wind sector, only a limited portion of the value chain is readily exportable . Local, site-specific knowledge is valuable to onshore wind installation services. Similarly, quick access to wind farms is key to minimising downtime and productivity losses. As a result, both installation, and operation and maintenance services are highly localised value chain stages. This protects Scottish companies on domestic projects but limits export opportunities, and consequently LCREE data show onshore wind imports to be higher than exports for all available years since 2014[24,25].

The primary export opportunities lie in services around project development. Currently, Scotland exports specialised engineering consultancy services internationally, with a focus on project development.. These services encompass wind farm design, wind resource modelling, construction management, and financial due diligence, and constitute most Scottish onshore wind exports[26]. LCREE data show a considerable increase in onshore wind exports in recent years, from £62m in 2019 to £120m in 2022. The intervening years of 2020 and 2021 were likely influenced by the COVID-19 pandemic and registered just £30m and £60m in Scottish onshore wind exports, respectively[27].

Looking ahead, circularity emerges as a potentially valuable avenue for exports, if this opportunity can be realised and grown domestically. Due to the established nature of its onshore wind sector, Scotland's fleet will reach its end-of-life earlier than most nations[28]. As a result, Scotland has a key opportunity to learn lessons surrounding repowering, recycling, and decommissioning wind turbines, and the practical considerations of installing large turbines in place of smaller ones[29]. The scale of economic opportunity from this value chain stage is as yet unknown. Should onshore wind circularity expertise be translated into consultancy service exports, however, Scotland is well-placed to benefit[30].

Economic Impact

Scottish onshore wind generates substantial economic value. The sector contributed an estimated £1.6bn in direct GVA in 2022[31], a figure which scenario-based projections suggest could reach as high as £2.2bn in 2030[32]. Challenges like high initial costs, manufacturing supply chain constraints, and fierce competition for skilled professionals persist. Nonetheless, there are opportunities for enhancing domestic turbine component content and capitalising on the emerging end-of-life value chain stage through repowering and circularity[33].

Fraser of Allander Institute analysis suggests that onshore wind jobs generated approximately £640,000 direct economic output and £250,000 GVA per FTE in 2021. Each direct onshore wind job was also found to support a further 1.09 indirect and induced jobs, further enhancing the sector's economic impact across its supply chain[34]. Analysis of the Office for National Statistics' Low Carbon and Renewable Energy Economy survey suggests that the value chain stage with the highest productivity is operation and maintenance (due to the importance of minimising downtime), followed by installation[35].

GVA increases are anticipated, particularly in the medium-term. Scenario-based projections by Scottish Enterprise suggests potential onshore wind annual GVA of over £2.2bn in 2030, reducing to £710m in 2050[36], and The Onshore Wind Prospectus, produced by the renewables industry group RenewablesUK[37], suggests that deploying an additional 12GW by 2030 could result in a cumulative GVA equivalent of £28bn for Scotland.

Scotland faces obstacles in realising this potential GVA, however. The initial costs of developing and constructing wind turbines are substantial, posing a significant hurdle, and the sector remains sensitive to inflation and fluctuations in interest rates.

Another challenge Scotland must overcome to realise the economic opportunities of onshore wind development concerns the nation's relatively limited manufacturing supply chain for onshore wind. While the maintenance of onshore wind turbine components (particularly of small parts) has been identified as a key area to generate economic opportunity locally and enhance the circularity of the sector , the manufacturing of many components is still conducted abroad. This leaves Scotland heavily reliant on imports to fulfil new projects[39].

Competition for skills from similarly ambitious countries and other net zero sectors (particularly offshore wind), is another key challenge. The Global Wind Energy Council estimates that over half a million wind technicians are needed globally by 2026[40], and UK offshore wind employment alone is forecast to increase by over 220% by 2030[41]. Meeting both wind sectors' ambitions requires coordination, potentially using onshore wind farms as training sites for offshore wind, where demand for labour will peak later. There will also be competition with other sectors to attract skilled staff. This includes electrical backgrounds (e.g., automation, aviation), which are in high and growing demand, meaning the onshore wind sector will need to remain competitive against typically higher-paying industries. Nevertheless, there are avenues for growth, including the enhancement, potentially through circularity, of domestic content use in turbine components[42].

Jobs

In Scotland's onshore wind sector, an estimated 3,100 FTE jobs exist, predominantly in skilled roles such as installation, operation and maintenance, and specialised consulting services. Concerns persist regarding potential skill shortages, highlighting a need for careful workforce planning in the energy sector.

The onshore wind industry engages approximately 3,100 full-time equivalent employees, surpassing most other renewable energy sectors part from offshore wind, as reported by ONS in 2023[43]. The workforce is predominantly composed of highly skilled professionals. Scotland-specific data are not available, but at the UK level roles are approximately distributed across installation (36%), specialised consulting services (27%), and operation and maintenance (20%), with manufacturing jobs constituting a smaller proportion at 10%[44]. Due to bold installation ambitions, these employment figures are anticipated to rise further[45]. Scottish Enterprise scenario-based projections show that direct jobs in the sector may rise sharply to potentially as high as 14,000 by 2030, before reducing to approximately 4,400 in 2050 after the construction phase is complete[46]. The offshore wind sector is anticipated to see similar job projections, albeit with a slightly later peak of 2035-2040 (see the offshore wind SWOT).

There is a growing concern, however, that the demand for jobs and skills within the energy sector might outstrip the available supply. Careful workforce planning, and skills development strategies are crucial to address this challenge. These themes are further investigated in the Professional Services SWOT.

R&D

Scotland's R&D expenditure is characterised by strong Higher Education R&D (HERD) and relatively weak Business Enterprise R&D (BERD)[47]. The established nature of Scotland's onshore wind sector may work against it in this regard, as funding is concentrated towards more nascent technologies and offshore wind[48]. Recent research from Scottish Enterprise shows that public sector R&D investment into onshore wind was less than £150k, far lower than other renewable energy sectors such as offshore wind and tidal (both over £5m), solar energy (£3m) and biogas (£1.3m). Should investment into the end-of-life value chain stage materialise, however, R&D can become a key opportunity for Scottish onshore wind.

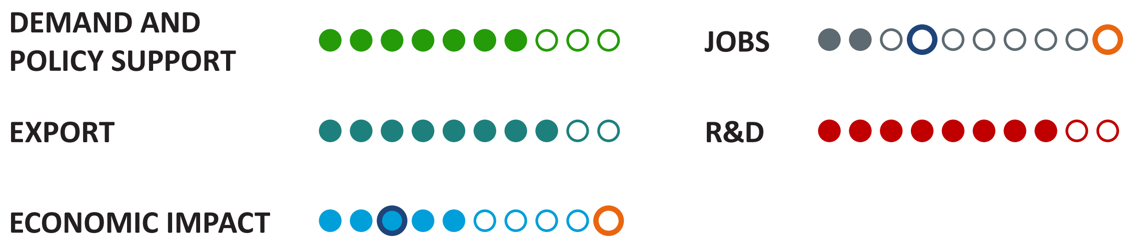
Targeted R&D investment will be needed to realise the opportunities presented within the sector. Specifically, those associated with the circularity in the maintenance and ultimately end-of-life value chain stage. As noted, this largely unexplored value chain thus far in which Scotland has an opportunity to utilise its first-mover advantage due to both the extent and the age of its fleet.

The Coalition of Wind Industry Circularity aim to drive the creation of renewable supply chains. They are working to unlock investment in R&D on circulatory in the sector. It is also expected that private sector investment into onshore wind will also come from companies not currently working in the sector[49].

The repowering, life extension and recycling of wind farms can take different forms, likely to bring advances in engineering, technology and environmental practices[50]. With a relatively older onshore wind fleet, Scotland could stand to benefit from these advances[51].

3.2 Offshore Wind

Sector definition: The production of electricity from offshore wind. Includes all value chain stages, including the operation and maintenance of the infrastructure for producing electricity from offshore wind, and the businesses supplying all goods and services involved in the development and deployment of offshore wind.



The scales show a Low to High opportunity (from left to right) and are based on a combination of qualitative and quantiative data sources.

Current

	FTE	Turnover	Business Count	GVA	Exports	Imports
2022	3,100[52]	£4.2bn[49]	1,000[49]	£2.0bn[53]	£830m[49]	£1.6bn[49]

Scenario-based projections

	FTE	Turnover	Business Count	GVA	Exports	Imports
2030	24,000[54]	£6.4bn[53]	-	£3.1bn[51]	-	-
2050	6,700[53]	£1.8bn[53]	-	£870m[51]	-	-

The offshore wind sector in Scotland is operating from a strong, globally recognised base, and Scottish companies are already exporting both goods and services. Scottish and UK Government ambitions for offshore wind deployment are high, however recent increases in materials and energy costs pose a threat to the sector internationally. Scotland's ability to capture economic opportunities is constrained in some parts of the value chain, for example by currently limited Scottish major component manufacturing. Initiatives such as the strategic investment model (SIM) seek to address this and capitalise on the significant opportunities created by the rapid increase in the domestic market. The SIM identifies key, shared priorities with an initial focus on infrastructure investment in ports and harbours critical infrastructure, and supply chain. Scotland's specialist services, project development, operations and maintenance, and construction sectors are strong and have a role to play domestically and internationally. However, issues such as grid capacity and consenting processes in Scotland could be addressed to allow supply chain to grow further.

Demand and Policy Support

Scotland has abundant natural resources, a strong market position, supportive domestic policies, and ambitious targets for an offshore wind sector that provided 16% of Scotland's electricity in 2022[55]. At the same time, the sector faces poor macro-economic conditions which are affecting project viability. Significant investment, strategic planning and coordination are all required to enable Scotland to deliver its projected installations and capitalise on the economic opportunities these present[56]. Offshore wind can help enable net zero transitions in hydrogen, energy storage, and oil and gas[57]. Existing offshore oil and gas business and labour force capabilities have a high degree of transferability to offshore wind, but there are challenges in achieving this transition.

Scotland's strong market position in offshore wind is well established. In particular, Scotland is acknowledged as a pioneer in floating offshore wind and is enjoying a first-mover advantage in the area, with the largest pipeline of floating offshore wind projects globally[58]. It has 2.6 GW of operational offshore wind and (accounting for the Scotwind and INTOG leasing rounds[59]), a current reported potential pipeline of over 40 GW of additional offshore wind projects[60]. Political backing for offshore wind is strong and Scotland has played a pivotal role in attracting investments and driving project deployments – including the £28.8bn associated with the 2022 ScotWind auction[61].

Delivery of the pipeline faces several threats. September 2023's fifth Contracts for Difference (CFD) allocation round saw no offshore wind projects awarded for the first time, with industry citing a lack of support by UK Government in the high inflation environment[62,63], as well as existing and anticipated bottlenecks in planning and grid connection[64]. The UK Government has been exploring introducing non-price factors (e.g., sustainability and capacity building) into future CFD allocation rounds, but these are unlikely to be introduced before 2025[65]. Internationally, the introduction of the US Inflation Reduction Act and the EU's Green Deal Industrial Act may create difficult competitive conditions for Scottish projects.

Scotland's existing oil and gas supply chain and skilled workforce presents an opportunity for the sector, driving further demand and policy support[66]. However, factors such as the current high oil price, salary disparities between oil and gas and offshore wind, and the fact that economic activity in the oil and gas sector is anticipated to remain strong to 2030 could all make the oil and gas sector a more attractive prospect, risking the growth of offshore wind in Scotland.

Export

The biggest opportunities for export are likely in high-value services, building on Scotland's comparative advantages (high-skilled labour force, first-mover advantage in floating offshore wind, established onshore wind and oil and gas sectors). There is also a small but highly specialised base of Scottish offshore wind goods and services provision, which in some cases have already become market leading.

The Scottish offshore wind sector's export potential is supported by the Scottish Government's commitment to increase exports across the renewables supply chain[67], as well as UK Government policy[68]. Scotland has several consultancies that have successfully moved into serving offshore wind markets in Europe, Asia, and the US. There are also numerous Scotland-based companies that have become established, and in some instances, market-leading international suppliers in both goods and services (including in operations and maintenance, ropes, construction, and access)[69]. Export data from LCREE has shown a mixed trend in recent years, ranging from £15m-£58m over the period 2014-2020, with a substantial increase to £830m in 2022.

Scotland stands to gain from rapidly growing international demand, especially in floating offshore wind. Installed capacity is forecast to grow by 8.9% globally 2021-2026[70]. Opportunities are therefore likely to be greater in the longer term as projects develop. Stakeholder interviews identified the manufacturing, fabrication and installation of floating offshore wind substructures, cables, anchoring and mooring solutions as a promising opportunity, leveraging Scottish subsea expertise. If known issues such as port infrastructure[71] and grid connection are addressed, Offshore Renewable Energy Catapult (OREC) estimate that under current installation assumptions UK offshore wind goods and service exports could reach £230 million annually by 2030 and £550 million by 2050[72]. Scottish clusters are anticipated to contribute significantly to this value.

Economic Impact

Rapid expansion in Scotland's installed offshore wind capacity and potential for increased share of Scottish content in the value chain provide opportunities for strong domestic economic growth. Offshore wind generates growing value in Scotland, with an estimated direct turnover of £4.2 billion in 2022[73]. Gross value added (GVA) in the sector was estimated at £2.0 billion in 2022 and scenario-based projections suggest it could increase to £3.1 billion in 2030 at the peak of the installation phase, before reducing back to £870m by 2050[74]. Opportunities to increase Scotland's economic impact in the sector centre around realising the projected pipeline of projects, co-location of infrastructure with other renewable energy sources e.g., hydrogen, and the end-of-life value chain stage, in repowering, recycling, and decommissioning and capturing export market set out above.

There are already approximately 1,000 active companies in the offshore wind value chain[75]. There is an opportunity to develop this base further by building on the experience, skills, and infrastructure from both onshore wind and oil and gas sectors. Businesses and investors are responding to the perceived opportunities from Scotwind and INTOG.

The sector remains heavily reliant on imports due to the absence of a large-scale turbine manufacturer in the UK. OREC suggest doubling UK content in turbines from the current 5% to 10% by 2030, indicating a pathway for growth and reduced dependency on imports[76]. There is potential to enhance Scottish production through developing the supply chain, as outlined by the Scottish Offshore Wind Energy Council.

ScotWind developers signed a Collaborative Framework Charter in May 2022 alongside Government and other public sector bodies. The primary output of that work was a Strategic Investment Model (SIM). The SIM was developed to support structured collaboration between industry and government and to help foster increased confidence to unlock infrastructure investment in ports and harbours, critical infrastructure, and supply chain. Towards the end of 2023 the SIM group (comprised of industry and public sector representatives) refined a SIM project pipeline with an estimated capital expenditure value of £6.5 billion.

The pipeline includes manufacture and fabrication of supply chain components (for example wind turbine generator components, foundations, cables and anchors). In 2024 facilitated discussions will take place between SIM project proponents, interested offshore wind developers and other potential funders to pool investment.

A review of sector intelligence conducted by Government during 2023 with enterprise agencies, the Scottish National Investment Bank, Scottish Futures Trust and Crown Estates Scotland concluded that there was strong alignment between SIM priority projects and the strategic public sector investment opportunities for Scotland.

The Scottish Government's 2024/25 Budget set out £67 million to kick start its of up to £500 million to anchor an offshore wind supply-chain in Scotland over a period of 5 years. This commercial and grant investment aims to stimulate and support private investment in the infrastructure and manufacturing facilities critical to the growth of our world-leading offshore wind sector.

There are also economic opportunities in circularity through decommissioning. According to Zero Waste Scotland the energy infrastructure sector in Tayside was worth £1.2 billion in 2018, with the potential for £186 million in economic savings through circular economy opportunities, such as reusing materials after decommissioning[77]. OREC (2021) cites a "real opportunity in decommissioning offshore wind farms" creating a circular economy and long-term employment[78].

Jobs

Scotland's offshore wind sector employed approximately 3,100 FTEs in 2022, a figure which projections suggest could increase to over 24,000 by 2030 before reducing to 6,700 by 2050. Most jobs in the sector are highly skilled, and Scotland boasts regional strongholds such as the largest energy skills cluster in the UK in its northeast[79]. However, competition for skills risks outpacing supply, hindering progress towards net zero.

By 2030, offshore wind is expected to create a substantial number of high-quality jobs. Looking across the UK, offshore wind employment is projected to increase by over 220% by 2030. Around 79% of these jobs are anticipated to be highly skilled, technical, and managerial roles[80]. The development of each future GW will require 21,000 FTE job years, equivalent to approximately 700 full-time jobs annually, to support the phases of development, construction, and operation[81]. Scottish Enterprise scenario-based projections suggest that direct jobs in the sector may rise sharply to potentially as high as 24,000 by 2030, before reducing to approximately 6,700 in 2050[82]. The onshore wind sector is anticipated to follow a similar trend, albeit with a slightly earlier peak in jobs of 2025-2030 (see the offshore wind SWOT).

Employment in this sector is focused in installation, specialised services manufacturing, operation and maintenance[83]. There is a competition for skills within the energy sector, raising concerns that demand might surpass supply. Closing skills and labour gaps will be important, either through training and creation of new roles or supporting transition of those in other industries such as oil and gas which have a high level of transferability[84]. The skills gap is within the STEM competences such as high-level electrical skills, digital expertise (data analytics, data science and engineering), consenting skills, and marine and port-oriented skills. Anticipated longer-term shortages include electrical technical and engineering skills, project management capabilities for large projects, high-level digital specialisms, logistics expertise (on and offshore), and construction resources, particularly for floating wind projects requiring a significant workforce in fabrication and welding[85].

R&D

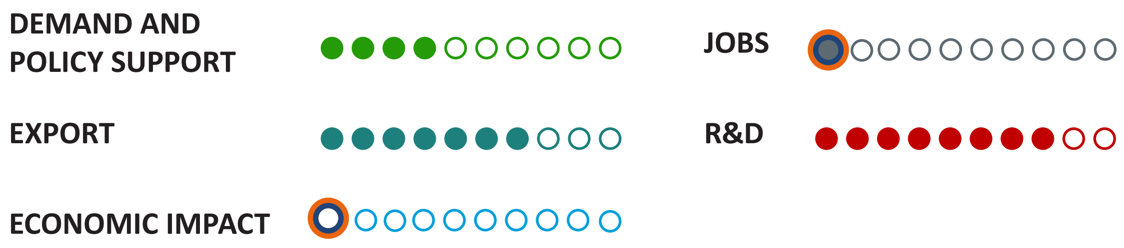
There are multiple R&D projects and initiatives ongoing in Scotland, some of which are mentioned below. The amount of public funding that goes into offshore wind R&D projects in Scottish universities is large compared to many other sectors. During the period January 2020 – October 2023, £5.2m in funds was awarded to this academic research field, excluding private and grant funding[86].

Scotland's Energy Transition Zone is strategically leveraging the innovation potential within the North East's existing oil and gas cluster. An extensive investment initiative is underway, focusing on providing ready-to-use properties and development sites for high-value manufacturing. This effort extends to the broader energy transition supply chain, featuring a marine gateway and dedicated campuses for offshore wind, hydrogen, innovation, and skills. The Energy Transition Zone is dedicated to fostering a supportive innovation ecosystem, facilitating the growth of businesses in these key sectors[87].

In 2020, the Floating Offshore Wind Centre of Excellence (FOW CoE)[88] was founded with funding from the Scottish Government to enhance the floating offshore wind industry. This collaborative venture involves industry, academia, and stakeholders. Within FOW CoE, the National Floating Wind Innovation Centre (FLOWIC) serves as a testing and demonstration facility, striving to expedite the development of floating wind technology. The Scottish Government, as part of a £9 million investment announced in 2022, has allocated £5.7 million from the Energy Transition Fund to FLOWIC. The facility, situated in the Energy Transition Zone, is expected to have testing equipment installed in January 2024 and officially open in February 2024[89].

3.3 Wave and tidal

Sector definition: The economic impact of the design, development, construction and/or production, specialised consultancy services, installation of infrastructure for producing electricity from marine renewables (wave and tidal) and their operations and maintenance.



The scales show a Low to High opportunity (from left to right) and are based on a combination of qualitative and quantiative data sources.

Current

	FTE	Turnover	Business Count	GVA	Exports	Imports
2022	<500[1]	£30m[1]	200[1]	-	-	£500,000[1]

Scenario-based projections

	FTE	Turnover	Business Count	GVA	Exports	Imports
2030	190[3]	£12m[3]	-	£6.2m[3]	-	-
2050	210[3]	£13m[3]	-	£6.8m[3]	-	-

Scotland is the world leader in Marine Renewable Energy (MRE) which includes both wave and tidal stream energy. Scotland has more MRE deployed than the rest of the world combined and the world's first and largest tidal array and the world's largest tidal energy converter. In addition, Wave Energy Scotland has overseen the pre-commercial procurement of Scottish wave energy converters, and component parts, building a competitive supply chain for MRE. The indigenous Scottish companies developing technology in these areas have built projects with the exceptionally high local content of up to 80% in individual projects. Test and demonstration of these technologies have taken place over the last 20 years at the European Marine Energy Centre (EMEC) in Orkney. The Scottish Government have implemented a one-stop shop for offshore consenting which, combined with Crown Estate Scotland's leasing processes, has made Scotland an attractive environment for the development and deployment of marine renewable energies. However, wave and tidal make up a small portion of our energy generation and projections for growth domestically, and internationally are still modest and highly dependent on a number of factors including costs coming down.

Demand and Policy Support

MRE is a supplier of renewable energy that will support the 2045 net zero targets in Scotland, and net zero ambitions globally. MRE is currently more expensive than other renewable energy, but with limited deployment to date, these costs are expected to reduce as capacity increases[91].

PPreviously supported under the Renewable Obligation, MRE has not secured any revenue support from the Contracts for Difference between 2017-2022. This impacted the sectors project pipeline. In the CfD's fourth Allocation Round, the UK Treasury ringfenced £20m for *Tidal Stream Energy*[92], which resulted in 41MW of supported tidal stream projects in Scotland and Wales[93]. The following allocation round (AR5) also had a budget minimum set for tidal stream, resulting in a further 53MW of projects coming forward[94]. Of the 94MW of tidal stream projects supported across the UK, 65MW is located in Scotland.

The industry response to the Scottish Government's Energy Strategy and Just Transition Plan consultation[95] sets out an ambition for 700MW of tidal stream and 200MW of wave energy by 2035.

A 2021 study set out potential for 12GW of wave and tidal (6GW each) by 2050 in the UK[96]. However, the study does not specify where the capacity will be deployed, and the 12GW figure contrasts starkly with the 200-300MW of MRE by 2050 assumed in this SWOT, which is based on SSE and SP Future Energy Scenarios.

Scotland has the first mover advantage in MRE due to strong public and private support from the early stages of the sector, indigenous technology companies, strong R&D capability, a diverse supply chain and significant natural resource. As a result, Scotland has seen the deployment of more MRE than the rest of the world combined, with circa 65% of current global operating wave and tidal stream energy projects[97].

The European Commission is actively supporting MRE with targets for wave and tidal stream as part of the Offshore Renewable Energy Strategy and has a target for 40GW by 2050[99].

Specific policy around MRE in Scotland and the UK has been lacking in recent years. The sector has no specific target or capacity ambition outlined within the energy strategy. Research has shown that the inclusion of MRE in the energy mix could reduce the overall grid dispatch cost and save more CO2 as, due to its generation availability, it displaces fossil fuels rather than other renewable energy[93].

MRE development in Scotland faces four key challenges in consenting, cost of finance, grid connection, and skills. Regarding consenting, it should be noted that Scotland is one of the few countries globally with a dedicated marine energy consenting process. However, consenting timelines can still present a challenge – the current process can take more than seven years, a period which could be shortened with a more streamlined process[100]. On the cost of finance, the early stage of MRE projects results in increased borrowing costs, given the higher risk of the debt. These costs are likely to come down as deployment increases, but this along with the high costs of insurance, add to the elevated levelised cost of electricity that we see currently. The third challenge is grid connection. As with other forms of renewable energy, MRE currently faces long waiting times for grid connections. This challenge is exacerbated for MRE, however, due to its natural resource locations being on the periphery of the national grid, where upgrades will be required. The final challenge for MRE development in Scotland is skills availability. This challenge is not unique to MRE, with the energy transition as a whole facing a skills shortage. Nonetheless, MRE will require skilled workers to support the development of the sector both within the technology companies as well as planning and consenting, high voltage electricians, amongst others[101]. Overall, stakeholders consulted noted that supportive policy and joint actions would help alleviate these challenges to deliver this growing sector and its economic benefit to Scotland.

Export

The global opportunity for wave and tidal energy has been estimated by the International Energy Association as 300 GW by 2050[102]. Deployment of MRE to date has largely been in Scotland, however there are a number of countries that are also starting their MRE journeys. Some deployments include Scottish-built machines that have been exported to Canada, France and Japan, for example Nova Innovation and SIMEC Atlantic Energy projects.

A study by the ORE Supergen Hub estimated that between the low and high scenario for ambition of supply chain retention, the UK could potentially capture 5-25% of the value of exports globally. This could potentially be worth a cumulative total of £6.8bn GVA by 2050[103].

Around half the capital and deployment costs of both wave and tidal MRE is related to the generator and other plant[106]. These areas include amongst others the power take off, device structure, blades, moorings, power electronics, etc. Of the existing projects these are largely manufactured and assembled in the UK, with approximately 60% of the supply chain value in Scotland (up to 80% of the value in some projects according to Marine Scotland Assessment), providing a base for Scottish supply chain firms to be able to export.

EMEC carried out an Economic Impact Assessment which concluded that £370m in GVA was delivered to the UK economy, of which £263m was accrued in Scotland. It also noted that to date £42m funding has been invested in the centre by public sector organisations. This provides a return on public spend of £8 to every £1 spent[106].

Economic Impact

Economic activity in MRE is generated by the technology and project developers, who are currently early stage or pre-revenue stage in the development cycle. There is therefore currently very little economic impact from this sector in Scotland. The local content is the highest of all the net zero energy sectors, with up to 80% seen in individual projects[104].

The ORE Supergen Hub report estimates that the potential value of the sector could be £11-41bn GVA for the UK economy between the low ambition and high ambition content-retention scenarios respectively by 2050. This is based on 12GW of deployment in the UK. These totals comprise of £5-9bn GVA from domestic (UK) deployments and £6-32bn GVA from UK content in international deployments by 2050. However, at levels of 200-300MW of installed capacity by 2050 as projected by SSE and SP in the Future Energy Scenarios, there would be limited economic contribution for Scotland, based on MRE's existing contribution.l[105].

Developers such as Orbital Marine Power, SIMEC Atlantis Energy, Mocean Energy and Nova Innovation have secured investment funding and grant funding to develop their technologies and projects. Orbital and Nova both recently secured Horizon Europe funding totalling €40m (£35m) for projects deploying tidal stream energy in Scotland[105,106]. Mocean Energy in addition to recent investment of £2.2m has also secured European funding from the EuropeWave programme worth €3.7m (£3.2m) for the design, build and test of its Blue Horizon device[107].

EMEC carried out an Economic Impact Assessment which concluded that £370m in GVA was delivered to the UK economy, of which £263m was accrued in Scotland. It also noted that to date £42m funding has been invested in the centre by public sector organisations. This provides a return on public spend of £8 to every £1 spent.

Jobs

The International Energy Agency's recent Ocean Energy and Net Zero report highlights that in achieving 300GW of MRE by 2050 could result in 680,000 jobs globally[105]. In Scotland, 12GW of MRE by 2050 could result in 28,000 jobs. Due to the physical location of the natural resource, MRE provides high value jobs often in remote and rural locations.

Estimates suggest that the UK MRE sector employed 1,700 FTEs in 2017[108], which coincided with the building of the two current tidal arrays – MeyGen Phase 1 in Orkney and Nova Innovation in Shetland. [94].

A 2023 ORE Catapult report outlines that job estimates for MRE are higher than those for wind and solar with 35-45 FTE-years/MW compared to 15-25[94].

R&D

Scotland has a strong innovation infrastructure and connections between the industry and universities. The European Marine Energy Centre (EMEC) was established in 2003 to test full scale devices in a real sea environment. The innovative FloWave circular test tank and FastBlade the world's first tidal blade fatigue test centre, both at the University of Edinburgh as well as other connections such as Strathclyde University, the University of the Highlands and Islands, Aberdeen University, Herriot Watt International Centre for Island Technology (ICIT) Campus, RGU, OREC campus.

The MRE sector has previously been supported by grant funding from the Scottish and UK Governments. Scottish Government funding has been focused on Wave Energy Scotland (WES) and their pre-commercial procurement of wave energy convertors and component parts.
Other funding has largely come from the European Commission where R&D has been funded at a variety of technology readiness levels (TRLs). Most recently this included two tidal array projects (totalling 20 devices and 13.6MW capacity). This may be increased following the result of the Horizon Europe wave array call later in 2024[109].

Innovation will be a key factor in bringing down the cost of energy for MRE. A recently published study highlighted the current funding in MRE in the UK and the EU[110]. The majority of recent R&D funding for MRE has been focused on the early TRL projects.[111].

3.4 Hydrogen

Sector definition: The hydrogen sector includes blue and green hydrogen production, distribution, storage, and usage. Grey hydrogen is not included. Data often refers solely to green hydrogen, if this is the case it is noted in the text. LCREE data includes the production of fuels for low carbon and renewable energy use, which is not classified as bioenergy, Including hydrogen. Data included in this SWOT is therefore also partly covered in the Low Carbon fuels and the HDV SWOTs.

DEMAND AND POLICY SUPPORT	●●●●○○○○○○	JOBS	●○○○○○○○○○
EXPORT	●●●●●○○○○○	R&D	●●●●●○○○○○
ECONOMIC IMPACT	●○○○○○○○○○		

The scales show a Low to High opportunity (from left to right) and are based on a combination of qualitative and quantiative data sources.

Current

	FTE	Turnover	Business Count	GVA	Exports	Imports
2022/23	<500[1]	£37m[1]	100[115]	£3.0m[3]	-	-

Scenario-based projections

	FTE	Turnover	Business Count	GVA	Exports	Imports
2030 ○	5,200[3]	£750m[3]	-	£290m[3]	-	-
2050 ○	3,800[3]	£550m[3]	-	£210m[3]	-	-

Scotland's abundant wind resources ensure access to a substantial domestic renewable energy supply and geographical position underpins Scotland's potential to produce and export green hydrogen. Additionally, Scotland has established infrastructure from the oil and gas sector along with a skilled workforce, both of which are transferable to meet the demands of the evolving hydrogen landscape. Blue and green hydrogen are both in early stages of development globally, with blue hydrogen expected to grow rapidly initially and green hydrogen expected to scale in the longer term. Scotland's hydrogen sector is evolving and requires scaling pilot projects into full operations to build and grow the sector and to compete in the growing global hydrogen market. . A critical near-term challenge is the lack of domestic demand for hydrogen (in industry, transport or buildings) which means the sector is reliant on export orders to grow. Overcoming challenges like the absence of electrolyser production also presents threats to production or could be an opportunity to attract a producer to Scotland, which would create jobs, GVA and the potential for exports to UK and Europe. Simultaneously, fostering domestic demand is vital for initiating and sustaining sectoral growth.

Demand and Policy Support

Hydrogen demand both domestically and internationally is currently low but expected to grow significantly in the coming decade. Policy support and certainty is required for demand certainty to enable investments in hydrogen production and its supply chain. Green hydrogen development is intrinsically linked to the development of abundant renewable energy, including offshore wind in Scotland and will rely on much of the same infrastructure and skilled labour force.

The hydrogen sector in Scotland is in early stages of development and depends on several variables to reach its growth potential, including: capturing the production capacity, market connectivity, distribution methods, enabling policy and domestic demand. The establishment of a robust domestic market for hydrogen (to industry, transport, buildings etc) is important to grow the domestic industry and build confidence in the supply chain when venturing into international markets.

The green hydrogen sector in Scotland is estimated to consist of between 70 and 160 operational companies. The range instead of a definitive number is due to disparities in the data provided by various sources[112]. Most companies focus on infrastructure development, with nearly half involved in operation, maintenance, and decommissioning, one-third in manufacturing, and one-fifth in installation. A smaller segment is dedicated to hydrogen distribution[113]. Approximately 20 companies have heat and hydrogen capabilities, including firms with general capabilities across the hydrogen value chain and key manufacturers like Scotland-based Cochran for boilers and Falcon Food Service that produces hydrogen fuelled commercial cooking equipment. Several hydrogen projects are underway in the distilling sector.

Companies with capabilities for hydrogen distribution include businesses such as Alexander Dennis, Farid Hillend, and HV Systems. Established manufacturers like Hydrasun also contribute to the hydrogen distribution sector[114]. A number of Scottish companies are identified as currently active in hydrogen related exports, including supporting the production of electrolysers[115]. Production facilities at Whitelee and Cromarty have received backing from UK Government's first allocation round for hydrogen business model support[116].

In addition, the Electrolysers Assessment report pinpointed 246 existing Scottish companies with potential to diversify into the hydrogen sector[117]. Likewise, Scottish Enterprise has registered close to 60 companies expressing interest in supplying to the hydrogen market in future. This indicates strong potential for the hydrogen sector to grow as companies adapt their existing offering for the hydrogen supply chain[118].

Stakeholders have however highlighted uncertainties in domestic demand, underscoring the necessity of reliable demand for production to gain momentum. Potential domestic uses for hydrogen include as a feedstock or energy source in industries like refining, ammonia production, and distilleries, as well as transport fuel and an energy carrier for heating, power storage, and generation[119]. In heavy-duty transport, especially in heavy-duty vehicles and certain rail network segments where full electrification is complex, hydrogen can complement electrification efforts (see the Heavy Duty Vehicles SWOT)[120]. Additionally, hydrogen can serve as a flexible energy storage solution.

Current use of hydrogen is limited, although it is used in minor quantities for direct and indirect heating processes and as a chemical feedstock in industries such as the chemical industry and refineries[121]. There are early initiatives related to green hydrogen. For example, Scotland is home to the world's first trial using green hydrogen to replace natural gas in home cooking and heating. In this trial, 300 homes in Fife will receive hydrogen heating systems and stoves/ovens for four years[122].

The potential of hydrogen in Scotland for emissions reduction varies across applications[123]. Some uses are expected to have a more substantial positive impact on the climate[124]. However almost all hydrogen used at present is produced with unabated fossil fuels, an issue that will need to be addressed in order to realise the climate benefits[125]. As mentioned above, hydrogen could be crucial in heavy industry, especially in metallurgy, refineries, chemical production, and fertiliser manufacturing, where high-temperature applications make electrification challenging. It can also decarbonise hard-to-electrify sectors such as maritime and aviation through hydrogen-based fuels. These issues are discussed further in the Low Carbon Fuels and CCUS SWOT analyses.

There are currently no operational hydrogen pipelines in Scotland connecting to domestic or international markets. However, stakeholders note ongoing efforts to convert the domestic gas infrastructure for hydrogen distribution. Some of the existing infrastructure from the oil and gas sector can be repurposed to fulfil requirements of the hydrogen landscape.

Despite lacking onshore deposits for hydrogen storage in salt caverns, Scotland is exploring alternatives like depleted gas fields and lined rock caverns. While the usage of depleted gas fields requires case-by-case evaluation on their suitability for hydrogen storage, lined rock caverns is a well-established and ready to use technology that can easily be scaled. Aquifers, with extensive sedimentary deposits in the Midland Valley, which stretches across Scotland north of Glasgow and Edinburgh, also show potential, although the technology is less mature than other underground storage techniques[126].

A challenge for green hydrogen production in Scotland is the absence of local electrolyser manufacturing capabilities, raising concerns about supply chain resilience and the potential for economic opportunities[127]. Limited grid capacity poses both a challenge and an opportunity for green hydrogen, as production requires a lot of energy. The process relies on renewable energy, water, and an electrolyser. While the National Grid faces constraints in renewable-rich areas, technologies like hydrogen and on-site battery storage provide solutions if placed next to renewable energy production sites such as offshore or onshore wind sites[128]. Coupling these with green hydrogen production not only provides hydrogen production with renewable energy but also allows Scotland to decrease grid limitations, enabling independent hydrogen production regardless of grid capacity[129]. The challenge, however limited, still exist as most hydrogen production sites are likely to require a back-up grid connection, depending on storage opportunities and business model.

However, specific UK and Scottish regulations for the hydrogen economy are yet to be fully established[130]. Those that exist are described as complex. There are also many different funding sources, which together with complex regulation, could hinder effective coordination between industry and government, impeding efficient transitions and economic opportunities. Fiscal sustainability concerns exist, relying on taxpayer and public funding for initial projects, posing a threat to scaling projects beyond pilot stages. The absence of established, viable business models and a straightforward regulatory regime could hinder the transition to large-scale commercial projects, limiting private sector investment[131].

Export

As European and global hydrogen demand increases, Scotland could be well-placed to export to these markets. Exporting hydrogen to Europe partly relies on development of a marine pipeline but there are also export opportunities in hydrogen goods and services. Global hydrogen markets are dynamic and competitive and European companies benefit from financial subsidies under the Green Deal Industrial Plan, while their counterparts in the United States receive financial support through the Inflation Reduction Act. Scotland would fall under the UKG Hydrogen Business model framework, which at the moment does not support hydrogen for export outside the UK[132]. This, coupled with the potential trade challenges posed by Brexit, raises a concern that Scotland may face a disadvantage in the global export arena.

Global demand is rising, particularly in the EU where demand is projected to reach 20m tonnes by 2030 and potentially 60m tonnes by 2050[133]. The Scottish Government aims to export 2.5m tonnes of green hydrogen annually by 2045, demonstrating a strong commitment to capturing a share of this international market. Scotland's geographic proximity to key European markets could offer cost-effective export advantages, particularly to nations like the Netherlands and Germany through marine pipelines. Stakeholders highlight the importance of cost, due to its uncertainty, and security of supply, they are particularly concerned with having confidence in orders in this market. Should Scotland be able to supply stakeholders with hydrogen through a pipeline infrastructure, it would confer a distinct comparative advantage in terms of supply security when compared with countries situated at greater distances. The European hydrogen market is increasingly competitive, with many countries increasing their hydrogen production targets[134]. The comparative cost dynamics with competitors remain uncertain at this point.

The Scottish Government is funding analysis of options for pipeline links for export to mainland Europe[135,136]. By investing in a marine pipeline to Europe, Scotland could enhance its prospects of capitalising on the hydrogen export market. Theoretically, this could meet up to 10% of Europe's hydrogen demand by the mid-2030s[137]. Given initial cost estimates of around £2.7bn, the availability of finance challenges poses a threat to the realisation of this initiative. Full financing could take the form of a public-private partnership, contingent upon the establishment of a robust hydrogen industry in Scotland. Without a pipeline there will be significant restrictions on the form in which hydrogen could be exported, likely around both ammonia and liquid hydrogen. Ammonia is used for making fertilisers and could be a future fuel for transportation. Liquid hydrogen might replace liquid natural gas (LNG).

As there are no LNG terminals within Scotland, but viable connections exist through established terminals in the UK and Wales, the UK emerges as a promising hydrogen export market for Scotland, anticipating significant demand growth reaching between 250-460 TWh or about 5.5m tonnes in 2050[138]. Scottish producers could use pipelines and gas interconnections to access these terminals, supplying them with hydrogen for ammonia production or to sell as liquid hydrogen.

Beyond the export of hydrogen as a feedstock, Scotland possesses the potential to export a range of hydrogen-related goods and services. As noted, Scottish companies are already participating in hydrogen-related exports, offering support to essential components such as electrolyser production. Furthermore, there are engineering consultancies involved in project development, strategically positioned within the international value chain, and sectors like specialised manufacturing in oil and gas are diversifying into hydrogen, signalling promising opportunities for cross-industry expansion[139].

Economic Impact

The hydrogen sector, though early in development, shows significant growth potential. While blue hydrogen is expected to take off earlier than green hydrogen, green hydrogen is expected to outgrow blue hydrogen in the long run.

As previously mentioned, the hydrogen sector is in its early stages and lacks substantial operational scale to have much economic value in Scotland's economy at present. However, scenario-based projects suggest that by 2030, GVA in the sector could reach £290 million, before reducing to £210 million in 2050[3]. TThese estimates illustrate a substantial growth for the sector.

According to scenarios developed in 'Scottish hydrogen: assessment report' for SG the gross impacts of the industry could range from 70,000 to over 300,000 jobs protected or created and potential GVA impacts of between £5 billion and £25 billion p.a. by 2045 depending on the scale of production and the extent of exports.

Jobs

Scotland's hydrogen sector, shows potential for substantial job creation, growing from an estimate of fewer than 500 full time equivalent jobs in 20221 to an estimated 5,200 jobs in 2050[3]. However, access to talent, particularly in STEM and data science fields is a threat to realising this potential. 90% of the workforce in the oil and gas sector possesses transferable skills, presenting substantial opportunities for Scotland's evolving hydrogen industry. However, dependency on this source also presents a risk.

In 2022, survey data suggests that Scotland's hydrogen sector employed fewer than 500 FTEs, indicating its early developmental stage. This does show an increase however on the previous 100 estimate in 2021, which in turn was an increase from 50 over the period 2018-2020[1]. These changes may not be statistically significant. This data presents an inconsistency with the estimated number of operating companies in this sector. It is improbable for there to be a similar number of employees and employers. A potential explanation for the comparatively low number of employees could be the survey is under-counting the number of employees currently employed in the hydrogen sector or the inclusion of only those employees directly involved with hydrogen-related tasks, with other employees in these companies engaged in other activities.

Research suggests significant job creation potential, with recent scenario-based projections by Scottish Enterprise proposing around 5,200 jobs in the sector in 2030 and approximately 3,800 jobs in 2050[140].

Challenges, especially a skills shortage, exist in the growing hydrogen economy as well as in other emerging sectors. The demand for existing STEM and data science skills at college and graduate levels may create a skills gap[141]. Additional skills gaps encompass areas such as customer insights, proposition design, electrical engineering, digital expertise, regulatory and external affairs, advocacy, as well as health and safety. Medium-concern areas, according to The Aberdeen Hydrogen Hub, include commercial and business development, value chain management, construction skills, control room operations, field operations, inspection and maintenance, social performance and community engagement, and environmental management and sustainability[142].

Scotland can capitalise on transferable skills in the labour market, notably engineering skills from the oil and gas and chemical sectors. Over 90% of the UK's oil and gas workforce possess medium to high skills transferability, making them well-suited for roles in adjacent energy sectors. Approximately half of the jobs in offshore renewables in 2030 are projected to be filled by individuals transitioning from existing oil and gas roles to offshore renewable positions, along with new graduates and external recruits, as indicated by research from Robert Gordon University[143]. These transferrable skills present a significant opportunity for Scotland's evolving hydrogen sector but also a risk given the competition with other energy sectors and in some cases aging workforce. According to the Draft Energy Strategy and Just Transition Plan, 35 percent of oil and gas workers are over 50 years old.

Moreover, the transferable skills of the workforce from the oil and gas sector to hydrogen as well as to the renewable energy sector in general present opportunities for a just transition[144]. To facilitate seamless job transitions to the hydrogen sector, Hydrasun, a player in providing integrated fluid transfer, power, and control solutions across diverse industries, including oil and gas, renewable energy, general industrial, and marine sectors, is collaborating with government, industry, academia, and accreditation bodies to establish the Hydrogen Skills Academy in Aberdeen. The academy is designed to meet the evolving workforce needs in what they call the "all energy" sector by closing the skills gap between traditional high-carbon industries and the emerging hydrogen sector. The primary focus is on cultivating, retaining, and enhancing existing talent, retraining individuals, attracting skilled young professionals, and rejuvenating future and non-energy specific skill sets[145].

R&D

Scotland faces challenges in hydrogen R&D funding. In 2021, the UK allocated 2.8% of its public sector energy R&D spending to hydrogen, lagging behind EU counterparts and reflecting a relative decline from the previous two years. Initiatives like the Hydrogen Innovation Scheme aim to foster innovation, but progress lags compared to the US and EU. This is raising concerns with stakeholders.

During the period January 2020 to October 2023 £4m was awarded to academic hydrogen research in Scottish universities, excluding private and grant funding. The Hydrogen Innovation Scheme, part of the Emerging Energy Technologies Fund, offers £10m in funding for renewable hydrogen projects from 2022 to 2026. It supports feasibility studies, technical demonstrations, and the development of test facilities and equipment[146].

However, there may be challenges in comparison to other countries. In 2021, the UK allocated 2.8% of its total public energy R&D spending to hydrogen, reflecting a decline from previous years (comparative data not available for Scotland). This places Scotland at a disadvantage compared to countries with similar strengths and average investment in hydrogen R&D across the EU[147]. According to stakeholders, projects are moving into commercial scales of delivery at a higher rate in other regions such as the US and EU countries, this may be due to higher levels of public spending on R&D.

3.5 Carbon Capture, Use and Storage (CCUS)

Sector definition: CCUS involves carbon capture from emitters and from the atmosphere, as well as storage, transport, and utilisation.

DEMAND AND POLICY SUPPORT	●●●○○○○○○○	JOBS	●○○○○○○○○○
EXPORT	●●●●●○○○○○	R&D	●●●●●○○○○○
ECONOMIC IMPACT	●○○○○○○○○○		

The scales show a Low to High opportunity (from left to right) and are based on a combination of qualitative and quantiative data sources.

Current

	FTE	Turnover	Business Count	GVA	Exports	Imports
2022	<100[1]	£4.0m[1]	<500[1]	-	-	-

Scenario-based projections

	FTE	Turnover	Business Count	GVA	Exports	Imports
2030 ○	1,000[3]	£190m[3]	-	£81m[3]	-	-
2050 ○	800[3]	£150m[3]	-	£69m[3]	-	-

CCUS is a nascent industry with low commercial activity. However, it is key to achieve net zero and Scotland is demonstrating innovative strengths, with public and private sector engagement. An existing skilled workforce and legacy oil and gas infrastructure, as well as available CO2 storage potential, are important enablers.

Challenges in Scotland relate to devolved and reserved policy which stresses the importance of alignment between Scottish and UK governments, uncertainties in the CCUS value chain and a complexity that demands further research and the application of best practice.

Demand and Policy Support

Existing infrastructure combined with natural resources provide favourable conditions for deployment of CCUS in Scotland. Increasing alignment with the UK Government and developing synergies with other markets such as renewable hydrogen could help drive the development of CCUS technology in Scotland.

Whilst CCUS is essential to the achievement of net zero targets, the technology is still in development. There is no established market for CCUS in the UK, and this will require revenue and capital support to develop. Key to the creation of this market are the UK Government revenue support business models, which are designed to provide revenue certainty to emitters and transport and storage companies. The UK Government's Cluster Sequencing process is the gateway to accessing the business model support and the establishment of a CCUS industry in Scotland is determined by the pace of this process. Another factor in the market development for CCUS will be the pace and scale that greenhouse gas removals are integrated into carbon markets, including the UK Emissions Trading Scheme (ETS) which is run jointly by UK, Scotland, Welsh and Northern Ireland governments[148].

The Scottish Government has established funding streams to promote CCUS technology, such as the Emerging Energy Technologies Fund (EETF) for development of the hydrogen sector and carbon capture and storage (CCS; meaning only the capture and storage part of CCUS), as well as the CO2 utilisation challenge fund, to help businesses and organisations develop and commercialise the technology[149].

The relationship between devolved and reserved policy in the UK presents a challenge: CCUS policy is mostly reserved[150]. As Scotland does not hold all the associated regulatory and legislative levers, the UK Government plays a critical role in the deployment of CCUS. There are ongoing activities to facilitate alignment, such as Scottish Government membership of the UK Government's UK CCUS Cost Reduction Taskforce and attending UK's Ministerial-led CCUS council which is taking forward deployment of CCUS in UK[151].

The Scottish Government has proposed actions for the UK Government to open up the market for international CO2. These would include enabling international trade of CO2 with bilateral agreements under the London Protocol and ensuring that barriers are addressed within the UK and EU to enable international trade of CO2 for storage of the greenhouse gas in Scotland[152].

CCUS projects, especially large-scale demonstrations, are costly and lack competitive benefits for first movers. This can slow down innovation and deployment, even more so as stakeholders within the industry and power sectors generally operate under low profit margins. This could be mitigated by significant policy support and the development of clear business models[153]. Increasing carbon prices can boost the feasibility and economics of CCUS, making it a more attractive option for emission reduction. Governments will play a significant role in promoting CCUS through grants, subsidies, carbon pricing, and risk mitigation measures, facilitating its widespread adoption.

Existing legacy infrastructure from oil and gas industries, depleted oil and gas fields as well as aquifers, offer carbon storage potential and an infrastructure that can be used in deployment of CCUS[154]. CCUS will benefit from growth of other markets and technologies utilising carbon dioxide as feedstock for other industries (i.e., a product which is used to produce something else in an industrial process). For example, it could be used to support the growth of the renewable hydrogen market, as hydrogen can be combined with CO2 to produce fuels such as methane and methanol. As regulations that inhibit emission of CO2 become stricter and the price of carbon under the UK ETS is expected to rise, alternatives to emitting CO2 directly to the atmosphere become more attractive, consequently driving market players to capture and utilise CO2. While this remains a possible avenue for CCUS, as set out in the Low Carbon Fuels SWOT, there are a number of significant risks to the successful deployment of low carbon fuels production in Scotland. Similarly, the likely future expansion of the UK ETS to include negative emissions technologies (NETs) and negative emission credits would be an opportunity to encourage greater deployment of CCUS in Scotland.

In the broader context, circular economy and CCUS are interconnected. A key focus should be placed on establishing robust policy frameworks to ensure effective integration of CCUS technologies. These frameworks serve as the foundation for deploying CCUS technologies and facilitating the conversion of captured CO2 emissions into valuable by-products, such as fuels or chemicals.

Export

Scotland's strategic location, existing infrastructure and experience within oil and gas are important building blocks that create export opportunities. The immediate focus will be on scaling domestic provision and on the potential for export of CCUS services and participation in an international CO2 market.

Scotland could provide a route for much of the UK's emissions to be safely stored, as well as functioning as a European carbon storage hub. For example, in the North Sea, storage potential could amount to over 50 GtCO2[155]. The industrial clusters in Grangemouth, Mossmorran and the Northeast of Scotland are linked by a network of pipelines to oil and gas fields in the North Sea. Hence, existing infrastructure provides an advantage for establishing CCUS. In addition, the strategic location of Peterhead Port provides opportunities for CO2 shipping and participating in an international CO2 market.

Existing experience in Scotland within oil and gas could be an advantage to developing CCUS[156]. Further strengths include the export of CCUS services and expertise to the UK and internationally as projects go into development and delivery.

Challenges still exist related to the distances between emission source and the eventual offtakers of captured CO2. These logistical challenges must be addressed to enable an effective exchange between supply and demand as well as a more clearly defined value chain for CCUS. This could either be addressed by building pipeline networks or securing transport in another way[157].

CO2 is increasingly used as a commodity. Captured carbon can be utilised as feedstock in industries, cooling, fire safety, waste-water treatment, concrete building materials and more. Hence, markets may emerge and grow within areas that are not well-developed today[158]. Some of these may present strong export opportunities.

Finally, global markets are emerging for trading in negative emissions which can be achieved through Bio Energy Carbon Capture and Storage (BECCS). However, market support and incentives to deploy BECCS are reserved to the UK Government[159].

Economic Impact

CCUS could contribute positively to the Scottish economy. However, investment is required to capture the full value chain of CCUS, and its complexity raises questions regarding where, in Scotland, the value will be added.

Scottish Enterprise's scenario-based projections suggest that GVA for CCUS could reach £81 million in 2030, and £210 million in 20503. The Scottish CCUS Economic Impact Assessment is more optimistic again and concluded that CCUS could contribute 1.3-2.3% (£3.8bn-£6.7bn) of GDP to the Scottish economy by 2045. This would crucially depend on the nature and scale of the industry, for example the extent to which Scotland will deploy blue hydrogen at scale or act as an importer of carbon dioxide. The same study shows that to realise the CCUS deployment and anticipated value chains, total cumulative investment of £9-30bn up to 2050 could be required[160].

Three factors are critical to delivering this potential GDP, namely: lowering costs for reaching net zero with access to blue hydrogen and CCS; demand for low carbon oil and natural gas driven by CCS and demand for blue hydrogen; and higher economic activity in energy intensive industry and fossil fuel production. Applying CCUS to achieve net zero could reduce the GVA of other sectors to varying degrees, hence its effect must be studied from a broader systemic perspective[161]. If the availability of CCUS technology stimulates fossil fuels activities that could otherwise have been avoided, it could produce negative environmental impacts, which will need to be addressed.

The development of CCUS requires collaboration between several stakeholders, particularly in defining the CCUS value chain. This means that any future effect of CCUS is complex to quantify. This presents both threats and opportunities as CCUS could affect development in certain sectors and vice versa. Current and future initiatives interconnecting multiple sectors are therefore central to understand the future of the technology and its economic implications for Scotland.

Jobs

Scenario-based modelling by Scottish Enterprise suggest that approximately 1,000 FTE will be needed in this sector in 2030, and 800 in 2050[3]. More efficient industrial solutions and low labour intensity in some parts of the CCUS value chain could mean that the potential for direct jobs in the sector in the future is limited.

While the current level of employment in this sector is low (less than 100 FTE), scenario-based projections suggest that this could increase to around 1,000 in 2030, and then decline to 800 by 2050[3]. As Scotland has an established oil and gas industry, there is a skilled workforce which constitutes a strength when deploying CCUS technology. This includes the offshore engineering skills and experience of the North Sea oil and gas industry. The oil and gas industry was estimated to support approximately 57,000 direct and indirect jobs, £16bn of GVA, and 9% of Scottish GDP in 2019[162]. Upskilling and cross-skilling can be utilised to build a workforce for the new economy, although challenges still remain around ensuring clear pathways for skills transferability, the critical timing of oil and gas skills transfer, geographical competition for construction skills amongst other large infrastructure projects, and retaining qualified trainers[163,164].

Local initiatives could support jobs in the future. According to Storegga, deploying direct air capture (the process of capturing carbon emissions from the air), low-carbon hydrogen and CCUS together could support an average of 15,100 jobs between 2022-2050, divided between 6,200 direct jobs and 8,900 supply chain jobs. The Scottish Cluster (led by the Acorn CCUS Project at St Fergus) could experience a peak jobs demand of 20,600 jobs in 2031[165].

It is worth noting that a potential increase in GVA impact does not necessarily result in an increase in jobs. Industries can find ways to become more efficient, for example through automation. Also, impact on jobs from carbon management and direct air capture is positive but low because labour intensity per tonne of CO2 handled is low[166].

As mentioned earlier, captured carbon has multiple areas of usage as a feedstock, within several different sectors. Hence, the CCUS supply chain presents multiple opportunities. However, quantifying the opportunities is complex and demands further assessment as they depend on the demand for CO2 in these individual sectors.

R&D

Public sector support for R&D in CCUS is centred on a few active projects of varying magnitude. Generally, significant spend on R&D is required and inward investments could be a way to boost R&D within the private sector.

The Scottish Government supports R&D within CCUS, having actively supported projects such as:

- ACT Acorn – using legacy of oil and gas in Northeast Scotland to re-purpose carbon capture and store in the sea.
- Align CCUS – research across different countries.
- Elegancy CCUS – research across different countries, combining CCS and H_2.
- NECCUS – formal entity to promote CCUS offering in Scotland, attract funding and secure first UK CCUS to be in Scotland[167].

Emerging private sector-led projects and initiatives include the above-mentioned Acorn project, Scotland's Net Zero Roadmap and Scotland's Net Zero Infrastructure[168]. The Roadmap concludes that R&D spend on scaling CCUS technologies is imperative to lower the cost of producing products with the captured CO2.

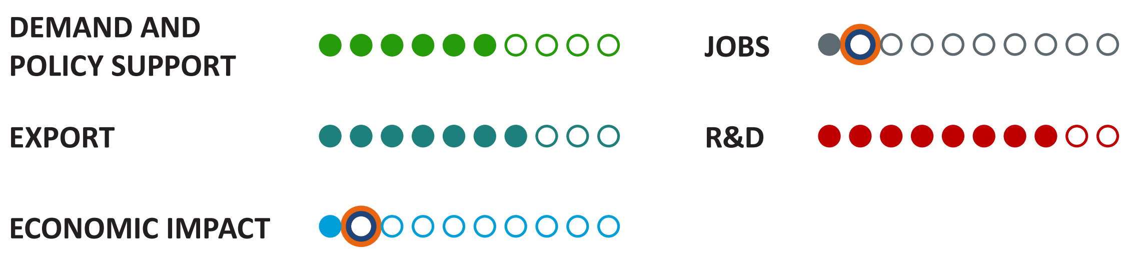
As CCUS is an emerging technology, there is a need for R&D investment. Since the CCUS value chain includes multiple stakeholders who will need to collaborate, interconnection of sectors is one important aspect to focus on within R&D.

Inward investors are more likely to spend money on R&D and innovation, meaning that there is an opportunity this can be attracted to Scotland[169]. Large local firms also have the potential to make a significant contribution, such as the firms involved in the Acorn project.

CCUS draws on various technologies, including pre-combustion, post-combustion, and oxyfuel combustion, in order to meet the needs of different industrial processes and capture scenarios. The complexity and variety of technologies in CCUS could present wider opportunities for further R&D spending to ensure CCUS develops to capture emissions from multiple different processes across varied markets. Moreover, direct air capture could present opportunities for Scotland but requires further R&D spent to confirm the nature of the opportunities.

3.6 Low Carbon Fuels (LCFs)

Sector definition: The economic impact of the production of gaseous and liquid LCFs of both a biological and synthetic nature, including their production facilities and infrastructure. Economic data are available and provided for the production of biogas, biofuels, blue hydrogen, green hydrogen, and sustainable aviation fuels (SAF). As such, there is some overlap with the Hydrogen SWOT, which also covers blue and green hydrogen production. The economic impact of the production of vehicles using LCFs is also excluded - for these figures, see for example the Low Carbon Heavy Duty Vehicles SWOT.



The scales show a Low to High opportunity (from left to right) and are based on a combination of qualitative and quantiative data sources.

Current

	FTE	Turnover	Business Count	GVA	Exports	Imports
2022	290[3]	£82m[3]	-	£35m[3]	-	-

Scenario-based projections

	FTE	Turnover	Business Count	GVA	Exports	Imports
2030 ○	5,700[3]	£920m[3]	-	£360m[3]	-	-
2050 ○	5,500[3]	£870m[3]	-	£360m[3]	-	-

Low carbon fuels (LCFs) will be crucial to decarbonising transport sectors which will have difficulty fully electrifying, such as aviation, maritime and niche vehicles. Scotland boasts strengths in these sectors and can leverage expertise and infrastructure from its established oil and gas industry to scale up LCF production. Challenges include high capital costs, a lack of policy clarity, and competition for feedstocks (the renewable and biological raw materials used for fuels). Opportunities lie in locating facilities alongside renewable electricity production, utilising local expertise, and expanding green hydrogen infrastructure. Navigating these factors could expand Scotland's LCF industry while helping to protect its current refining market position.

Demand and Policy Support

There is clear policy recognition, at the Scottish, UK and EU levels, of the need to incorporate low carbon and synthetic fuels (LCFs) into the current transport fuel mix, particularly into aviation and maritime sectors in order to meet net zero ambitions[170,171]. Industry stakeholders' opinions on the current level of policy support in Scotland vary[172], but the roadmap for deployment of LCFs is generally clearest in the aviation sector[173], with biologically-based sustainable aviation fuels (SAF) seen as the short to medium term solution and synthetic, hydrogen-based SAF seen as a longer-term solution enabled by technological advances[174,175]. There remains some debate as to the extent to which these fuels can offer the full decarbonisation solution or whether they have a purely transitional role. Across all sectors, successful LCF deployment will require concerted policy support across government with a clear understanding of different technologies, feedstocks (the renewable and biological raw materials used for fuels), and economic considerations including the pace of global demand[176].

The UK and Scottish governments recognise that zero-emission solutions are the preferred solution to decarbonising the transport sector (e.g., battery and fuel cell electric vehicles, and direct electrification). However, for larger vehicles that travel long distances or have a high energy use (i.e., heavy-duty vehicles (HDVs), aeroplanes, and ships), zero-emission solutions are not financially viable under current technologies (see, for example, the low carbon HDVs SWOT). In these situations, LCFs, which deliver at least a greenhouse gas emissions saving of 65% compared to fossil fuel comparators[177,178], may be more appropriate[179].

At present, two main LCFs are deployed in the transport sector in Scotland: bioethanol and FAME (Fatty Acid Methyl Ester) diesel. The deployment of these fuels has been driven predominantly by the Renewable Transport Fuel Obligation (RTFO) scheme and they are almost exclusively deployed in road transport, with their demand likely to decrease over time as the road transport fleet is electrified[180].

One sector where LCF deployment is expected to rapidly increase is in aviation. SAF is currently certified to be blended with conventional aviation fuel at volumes of up to 50%[181,182]. Scotland has several strengths which could leverage economic benefits from SAF. These include: the existing petrochemical complex in Grangemouth and associated oil and gas expertise (although there is currently uncertainty around the site's future); the number of Scottish companies that are, or could be, involved in the SAF supply chain from manufacturing of the components aiding the use of SAF to retrofitting aircraft to accommodate new fuels; a strong aviation sector including aerospace engineering expertise and the Sustainable Aviation Test Environment (SATE) in Orkney; academic and industrial expertise in carbon capture utilisation and storage (CCUS), hydrogen and biorefining; and strong domestic policy commitments to the net zero transition. Opportunities include Scotland's abundance of renewable electricity and potential to co-locate production facilities; strong industry demand for SAF (which is projected to last until at least 2050-70, dependent on the type of SAF being developed)[183]; and clear interest from SAF producers and the local supply chain[184].

Weaknesses limiting SAF development, although not limited to Scotland, are principally related to policy clarity and costs. While the recent SAF mandate[185] has increased policy clarity, there remains amongst industry stakeholders a perceived lack of detail within UK and Scottish legislation on the specific timings of SAF adoption, the specific types and volumes of feedstocks which will be secured for SAF production compared to other sectors, and the levels of funding available for potential plant producers[186]. Without clear policy incentives, the high capital costs of SAF (as a fuel relative to kerosene, but also regarding capital needed to build production facilities and to retrofit legacy aircraft to accommodate new fuels) inhibit the aviation sector's transition to these fuels[187].

As a result, the primary threats to SAF development in Scotland include the scale of capital investment required and attracting it to SAF projects/producers in Scotland amidst competition for feedstocks from other sectors and geographies[188].

Compared to aviation, there is less consensus on the decarbonisation of the maritime sector and the path to LCF deployment is less clear[189]. This is in part due to debates and uncertainties around the best technical option, the range of vessel sizes and uses, and a lack of current policy support beyond overall sector emissions reductions targets set by the International Maritime Organisation (IMO)[190]. As a result, demand signals from industry to adopt LCFs have largely been lacking. One exception is container shipping firm Maersk, who have begun running methanol-powered ships to support their long-term objective of operating their entire fleet solely on LCFs[191].

Green methanol, and to a lesser extent ammonia have been identified as the preferred LCF option for the maritime sector. Scotland has the capability to produce both fuels through its refining facilities, such as those located at Grangemouth. Significant expansion of Scottish green hydrogen infrastructure will be required to increase domestic supplies of both fuels, however[192].

Export

Scotland's existing crude oil refining industry and associated ports and distribution networks, such as the Finnart Ocean Terminal, provide advantages for the production and export of biological LCFs in particular[193,194] . With sufficient investment into plant development and the electricity grid[195] , Scotland can also grow its synthetic LCF export capabilities. Scotland has the potential to generate far more electricity than it needs, which could facilitate the production of hydrogen-based fuels at globally competitive costs to drive exports if a mechanism is in place to access this power.

While SAF production is already happening elsewhere, there is no clear market leader in SAF production, despite the high demand from industry and ambitious policy drivers[196]. This would present export opportunities for Scotland, particularly due to its established petrochemicals sector which exports chemical-based goods worth approximately £2.5bn per year[197]. Capturing this opportunity will require significant investment across the supply chain[198,199].

However, in the maritime sector, global shipping companies are investing in methanol-powered vessels[200]. The UK ambitions for clean maritime clusters could present an opportunity for e-methanol at Scottish ports for both local and international markets[201].

Economic Impact

Across biogas, biofuels, hydrogen production, and SAF, LCFs provided an estimated £35m GVA to the Scottish economy in 2020, a figure which may potentially increase to almost £358m in 2030, and remain this high until 2050[202]. LCFs offer significant economic potential across the supply chain, which is expected to grow considerably as the industry develops across different transport modes[203]. However, significant capital investment is required to meet this potential.

Quantifying the economic contribution of LCFs in Scotland is difficult due to the range of data classifications used across sectors such as bioenergy, alternative fuels, and petrochemicals[204]. Nonetheless, Scotland does have a footing in LCF production, hosting biofuel producers in Argent Energy and Celtic Renewables, small-scale synthetic fuel producers including Zeleno, Zero Petroleum and iGTL, and over 220 mostly small or medium-sized businesses involved in the manufacture of chemical-based goods annually[205,206].

The landscape of Scotland's LCF GVA is anticipated to change through to 2050. Currently, the top-contributing sub-sectors according to Scottish Enterprise analysis are biofuels and biogas, but these are both anticipated to be overtaken by SAF[207].

According to Scottish Enterprise analysis, GVA per employee is high across LCF subsectors, but is notably high in biofuels and biogas (£149,000)[208]. This analysis is in line with that of the Fraser of Allander Institute, whose analysis of the wider bioenergy sector for 2021 showed that the estimated £120m of GVA equated to £150,000 direct GVA per full-time employee (FTE)[209]. The GVA per employee in the Scottish petrochemical manufacturing sector was also £160,000, which is 45% higher than the general manufacturing productivity[210].

SAF currently addresses just 0.01% of the global aviation fuel market, but analysis suggests that this figure could grow to up to around 8% within the next five years[211]. This increase, coupled with the fact that the UK has the largest aviation network in Europe and the third largest in the world[212], represents huge growth potential. The issue is that current and planned LCF production facilities and infrastructure are unlikely to meet this demand – more need to be built[213].

Jobs

Scottish Government and industry investment in LCF production would generate jobs across the supply chain – in machinery, metal products, electrical equipment, engineering, construction and ongoing operation of new facilities, feedstock supply, and product distribution networks[214]. Existing Petroineos refinery infrastructure at Grangemouth presents a potential opportunity for the development of a LCF sector in Scotland and a potential transition pathway for the site following the recent announcement to begin preparatory works towards an import facility.

Scottish Enterprise analysis estimates 290 Scottish jobs across biogas, biofuels, hydrogen, and SAF production in 2020 – a figure which projections suggest could rise to 5,700 in 2030 (an increase largely driven by SAF production)[215]. The Office for National Statistics estimates that there are 1,200 FTEs across the bioenergy (1,000) and alternative fuels (200) sub-sectors in Scotland, although this includes non-LCF jobs such as biomass production[216].

The sector's impact is not limited to direct jobs; it also supports numerous downstream supply chain jobs. Additionally, industries like petrochemicals have transferrable skills. Research indicates that the related Scottish chemicals industry directly employs about 15,000 people with above-average salaries and indirectly supports around 70,000 more[217]. The dependence of these chemicals on North Sea oil presents a great opportunity to shift refining production towards LCF sources.

The UK as a whole can build on existing skills, expertise and infrastructure to scale up LCF production[218]. Establishing a UK SAF industry could support between 4,900 and 11,500 UK jobs by 2040, with up to 5,100 jobs directly associated with domestic production[219]. Recent research suggests that the production of synthetic LCFs could also create significant job and GVA benefits[220]. A typical plant producing synthetic crude could generate over 900 direct jobs during its construction phase and 1,100 jobs over the course of its operation, providing over £100m GVA per year. Similarly, a plant producing methanol could provide over 300 direct jobs in its construction phase and 1,800 jobs during operation, while generating GVA of over £180m per year[221].

R&D

Significant R&D progress is being made in sustainable fuels, with SAF receiving particular attention. Several Scottish universities including the University of Aberdeen, University of Edinburgh, and Heriot Watt University are exploring LCFs and CO2 utilisation[222], and several academic-industry collaborations are in place across Scotland e.g., the Aviation Impact Accelerator and the Supergen Bioenergy Hub[223].

SAF will be essential to decarbonise the aviation sector to 2050 and beyond, due to its ability to directly substitute for conventional fuels and the cost and long service lives associated with aircraft[224]. Hydrogen combustion, on the other hand, particularly liquid hydrogen, requires significant development time before it can enter the market and much longer before it can become mainstream due to its comparable energy density and current size and range limitations of hydrogen-fuelled aircraft. Scotland has an advantage in testing sustainable aircraft due to sites such as the Sustainable Aviation Test Environment (SATE) in Orkney[225].

R&D in LCFs for maritime operations is less developed than in aviation. However, with industry beginning to invest in specific fuel types, the sector is beginning to plan its pathway and invest further in R&D[226].

3.7 Low Carbon Heavy Duty Vehicles (HDVs)

Sector definition: The economic impact of the design and manufacture of low carbon HDVs and their associated charging and refuelling infrastructure. Covers all large land vehicles excluding trains, from on-road heavy goods vehicles (HGVs), buses and coaches to off-road construction and agricultural vehicles. Economic data are available and provided for electric vehicle (EV) and hydrogen buses and HGVs, EV chargers and hydrogen refuellers. The production of hydrogen and low carbon fuels are excluded - for these figures, see the Hydrogen SWOT and Low Carbon Fuels SWOT, respectively.

DEMAND AND POLICY SUPPORT

EXPORT

ECONOMIC IMPACT

JOBS

R&D

The scales show a Low to High opportunity (from left to right) and are based on a combination of qualitative and quantiative data sources.

Current

	FTE	Turnover	Business Count	GVA	Exports	Imports
2022	130[3]	£25m[3]	16[3]	£12m[3]	-	-

Scenario-based projections

	FTE	Turnover	Business Count	GVA	Exports	Imports
2030	2,300[3]	£440m[3]	-	£210m[3]	-	-
2050	8,300[3]	£1.5bn[3]	-	£690m[3]	-	-

Scotland's HDV production sector consists of a small number of companies manufacturing a diverse range of vehicles, with very different net zero transition pathways. Excluding buses, where Scottish company Alexander Dennis is manufacturing and exporting low and zero carbon buses at scale, the sector's decarbonisation has been limited by uncertainties, high costs and long development times. Some Scottish HDV manufacturers have developed low carbon vehicles but longer term, competition with large, international original equipment manufacturers (OEMs) will be a challenge. Supply remains limited, but Scottish HDV manufacturers are engaged and opportunities to decarbonise the on-road public sector fleet are strong. Whilst current levels of EV HDV production are low, the wider HDV sector is strong and will need to transition. The choice now is whether to invest in hydrogen or battery electric powered vehicles, and how best to protect and expand Scotland's HDV manufacturing base.

Demand and Policy Support

The diverse and fragmented nature of Scotland's relatively small HDV production sector[227], and its reliance on the international market (for components in particular) creates a challenge for policymakers to clearly legislate, enable, and incentivise decarbonisation beyond the on-road public sector fleet (such as buses, refuse collection vehicles and emergency vehicles). Despite the challenges of regulation and access to funding, the need to decarbonise Scotland's HDV fleet is well-recognised by Scottish Government[228]. Several strategies, task forces[229,230], and grants[231,232] are in place to encourage HDV manufacturers and license holders to switch from diesel, and the diverse sector has strengths which can ease its transition. Scotland has existing niche on-road HDV manufacturing experience[233], engaged industry stakeholders, good availability of renewable electricity for zero-emissions technology, and strong R&D programmes[234].

As of 2021, only 0.14% of Scotland's fleet of 52,000 heavy goods vehicles (HGVs), buses and coaches (weighing over 3.5T) were low carbon. The total number of other, 'non-road' HDVs used in construction and agriculture is currently unquantified but understood to be significant. The number of these which are decarbonised is also very low[235,236].

One estimate created to inform skills development suggests that potentially 5-12% of the HGV, bus and coach fleet could be low carbon (including zero emissions fuels such as battery electric and hydrogen, but also biofuels and other low carbon fuels (see the low carbon fuels SWOT)) by 2026, rising to 17-39% by 2032[237]. The source notes that these figures involved "a high level of qualitative judgement"[238]. This demonstrates strong potential near-term demand, however. To achieve, or exceed, this uptake, Scotland must overcome several uncertainties relating to low carbon HDV uptake including the cost, supply, infrastructure, and technologies behind new vehicles[239]. These uncertainties are all compounded by the higher (relative to non-HDVs) capital cost and development time of new vehicles, and their durability, distance, and payload requirements[240,241].

There is evidence that the total cost of ownership (TCO) of low-carbon HDVs is reaching parity with conventional vehicles, particularly for public buses and smaller HGVs[242,243]. Nonetheless, these uncertainties have naturally fostered a more-risk averse industry worried by stranding their assets[244] in a fragmented sector where around 90% of HGV license holders have 10 vehicles or fewer[245,246].

Scotland is not starting from the strongest market position in HDV manufacturing but does have on-road HDV strengths in Emergency One and Hillend Farid, plus construction represented by Volvo[247,248]. Alexander Dennis in Falkirk is a leader in the manufacture of low-carbon buses and coaches[249], and the four major commercial HDV manufacturers based in the UK (Dennis Eagle, London Electric Vehicle Company (LEVC), Leyland Trucks and Vauxhall) also use some Scottish suppliers for components[250,251]. Investment is required to increase the current manufacturing capabilities of most Scottish companies involved in the HDV supply chain[252,253].

Despite the uncertainties and limitations imposed by Scotland's market position and the nascent technologies involved, Scotland could increase its market share of production, and demand-side roll out of low-carbon HDVs[254,255]. Potential steps include technological development (including low carbon fuels – see the low carbon fuels SWOT)[256] , operational change within industry incentivised through measures such as clean air targets and blanket bans for combustion engines, modal shift enabled by investment into public and active transport[257], and wider behaviour change by producers and consumers[258,259]. Driving forward fleet decarbonisation in Scotland could increase demand for these vehicles if Scotland is an early adopter.

By 2040, HDV CO2 emissions could be reduced by up to 90% by using low carbon fuels in conventional internal combustion engines (see the LCF SWOT). However, to achieve net-zero, battery electric or hydrogen fuel cell technologies are necessary. Depot-based vehicles are more suited for battery electrification. For all HDVs, the choice of energy storage technology will be crucial for operational independence[260] and weight considerations[261].

Anticipating shortages and ensuring a stable supply of raw materials are paramount for fostering an environment conducive to the effective operation of the HDV sector. This imperative becomes even more pronounced, considering that over 20 million HDVs are currently used throughout Europe. There is a pressing need to establish comprehensive end-of-life regulations and extended producer responsibilities tailored explicitly to the HDV sector in Scotland. These regulations would be instrumental in steering the industry toward a more circular economy[262].

Export

HDV export in Scotland currently centres around on-road vehicles. Alexander Dennis is particularly strong in the export of buses, and eight other, smaller companies supply mostly niche vehicles such as Emergency One's electric fire engine. Further exports are generated from the supply of components for assembly by larger UK-based manufacturers.

A recent study for Scottish Enterprise identified nine original equipment manufacturers (OEMs) active in the HDV sector in Scotland, covering all powertrain technologies and including buses and coaches, HGVs, other on-road HDVs, such as RCVs, as well as off-road vehicles[263]. They noted that a lack of significant tier one suppliers (suppliers of final products) in Scotland means that OEMs are sourcing major components and systems from suppliers outside Scotland and the UK, which have their own wider supply chains. The unquantified yet significant number of wider Scottish HDV supply chain companies supplying into the automotive sector were mainly focused on the aftersales market including vehicle servicing and maintenance (59%)[264]. Most HDV supply chain companies have limited manufacturing capability, although some large HGV OEMs based elsewhere in the UK may use Scottish suppliers for components, as is the case for DAF Trucks, for example[265,266]. Volume manufacturing is normally outsourced to contract manufacturers outside Scotland.

Cumnock-based Emergency One, which recently launched the world's first fully electric fire engine, is a key example of a Scottish company poised to target international markets with a unique zero emission HDV[267]. However, it too will require investment such as the recent £7.9m grant from government and industry[268], to overcome scale issues to distribute domestically and compete in the international market.

Britain is home to two of the world's largest diesel engine manufacturers, Caterpillar and Cummins, both of whom have locations in Scotland and provide engines for many of the on and off-road vehicles manufactured domestically, as well as a wide range of other applications, including marine, rail and power generation, with many going for export[269]. These businesses will need to transition to service the net zero HDV market, providing an opportunity if government and industry investment can provide the enabling environment.

In the UK, approximately 43% of end-of-life HDVs are remanufactured, offering further export potential. However, exporting used HDVs raises environmental concerns, as they often end up in developing countries without proper disposal[270]. This situation highlights the need for dedicated HDV end-of-life treatment facilities, creating opportunities for sustainable management.

Economic Impact

Economic activity in HDV production in Scotland is generated by a relatively small number of companies, many of which rely on a wider international supply chain for components. Low-carbon HDV production GVA is concentrated in the vehicles themselves, rather than in their supporting infrastructure (EV chargers, hydrogen refuellers etc), a trend which is anticipated to continue into the future[271]. Scotland is strong in bus manufacturing due to the presence of Alexander Dennis but remains a relatively small presence in the wider UK HDV production market.

Data for electric buses and HGVs, hydrogen buses and HGVs, EV chargers and hydrogen refuellers suggest combined 2020 figures of £25m and £12m for turnover and GVA, respectively[272]. These figures are set to increase significantly by 2050, with turnover projected to reach as high as £1.5bn and GVA up to £690m. For both turnover and GVA, economic activity is expected to remain concentrated in the production of vehicles (particularly EV buses and HGVs), rather than their supporting infrastructure[273].

Regarding the wider HDV market in Scotland, Scottish Enterprise estimate the current turnover of the nine Scottish HDV OEMs at £820m, with around 1,800 employees. The largest of these by some distance is Alexander Dennis[274]. A further seven companies are involved in the manufacture of charging infrastructure in Scotland, although their FTEs and turnover are not available[275].

The Low Carbon Vehicle Partnership estimate the total turnover of the UK HDV OEMs at c. £8.2bn, split into £4.30bn for construction, £2.3bn for agriculture, and £1.6bn for on-road HDVs. Their analysis suggests Scotland represents a very small share of UK market activity at just 2.4%. Notably, however, their 'on-road' HDV classification excludes buses, focusing instead on HGV and specialist vehicles such as refuse collection, concrete delivery, and emergency support services[276]. As such, Scotland's strength in bus manufacturing is not captured by these data.

Jobs

Scottish Government's Transition Pathway for Transport paper notes Scotland's highly skilled workforce with a strong tradition in manufacturing, highlighting "particular expertise in niche and heavy-duty vehicles"[277]. Relatively few people currently work directly in this area. The nine Scottish HDVs employ approximately 1,800 employees and analysis suggests there are likely to be fewer than 150 FTEs working across low-carbon HDVs[278]. Jobs in the sector are expected to increase considerably, however, and there is considerable scope for skills development across the wider HDV landscape (including drivers, engineers, etc).

Scottish Enterprise estimate that fewer than 150 FTEs worked across electric and hydrogen buses and HGVs, EV chargers and hydrogen refuellers in 2020. Scenario-based projections suggest that this could increase considerably, potentially up to 2,300 in 2030 and over 8,000 by 2050, with electric buses and HGVs anticipated to make up most o f this increase[279].

There are over 87,000 employees across the wider HDV landscape in Scotland that are likely to require some level of skills development as low carbon HDVs are adopted into the fleet, as well as several thousand engineers required to install low carbon infrastructure such as chargers. Of this total, between 34,000 and 38,000 people are likely to require some level of skills development relating to low carbon HDVs by 2026 and between 41,000 and 53,000 by 2032[280].

Given that over 93% of materials from standard HDVs are reusable, incorporating more circular economy practices into the HDV industry may also provide job opportunities in remanufacturing and end-of-life value chain stages[281]. Zero Waste Scotland estimate that the potential growth of remanufacturing may provide up to 5,700 new jobs in Scotland, many of them in the transport sector[282].

R&D

To boost low-carbon HDV R&D, Scottish Government has provided numerous grants in recent years to innovative companies across the sector's supply chain[283]. Hydrogen fuel cell electric vehicles have seen particularly high levels of investment, with Scottish Enterprise research showing that R&D grants in this technology outweighed all other categories across 2020-2023. This presents opportunities for Scotland to become a market leader in hydrogen HDVs but presents a threat if battery performance increases to a level where electric vehicles, rather than hydrogen fuel cells, become the optimal solution for many vehicle types.

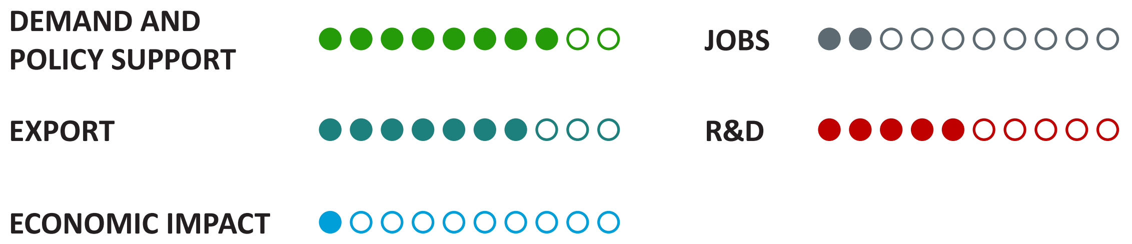
Scotland has R&D centres in areas relevant to the low-carbon HDV supply chain, including: the University of Strathclyde's Driving the Electric Revolution and Power Networks Demonstration Centre facilities; the University of St Andrews' Hydrogen Accelerator, ARA Battery Research Group, and Faraday Institute-funded consortium project with Cambridge, Lancaster and Sheffield Universities and UCL[284]; Heriot Watt University; the Michelin Scotland Innovation Parc in Dundee; and the Falkirk Investment Zone[285]. These centres are backed by supporting networks including Scottish Enterprise[286]. At the UK level, Eastern Scotland is noted as a hub for zero emission and autonomous vehicle innovation[287,288], although these are (excluding ferries) notably concentrated on on-road HDVs such as buses, refuse and emergency vehicles[289,290].

Specific examples of recent innovations include Emergency One's fully electric fire engine, Glasgow City Council's hydrogen-powered refuse truck, Alexander Dennis Ltd.'s zero emission buses[291], and CAVForth's autonomous bus capability between Fife and Edinburgh[292].

Leveraging R&D centres focused on the remanufacturing and end-of-life value chain will be pivotal in harnessing the potential of circular economy practices within the HDV industry. These practices present numerous opportunities for integrating cutting-edge technologies such as onboard vehicle communication systems to optimise industry processes. Furthermore, ongoing research initiatives within the HDV sector to enhance recycling and recovery rates from the initial design and development phases underscore the transformative potential of circular economy practices[293].

3.8 Forestry

Sector definition: The cultivation, conservation, and management of forests for timber production, biodiversity conservation, forest tourism, and provision of ecosystem services (including carbon sequestration for carbon credits). Includes activities from forest planning and management to the extraction of timber through logging and initial processing stages like sawmilling or chipping. The further processing of wood into final consumer goods, typically categorised under manufacturing or construction, is mentioned for context only and is mostly covered in the sustainable building materials SWOT. Also note that the figures below only include private sector activities. The public sector is a significant producer and employer in the forestry sector and hence these figures are a significant underestimate of the total sector.



The scales show a Low to High opportunity (from left to right) and are based on a combination of qualitative and quantiative data sources.

Current

	FTE	Turnover	Business Count	GVA	Exports	Imports
2019/21	5,700[294]	£770m[296]	1,100[296]	£200m[296]	£120m[295]	£97.4m[300]

Scenario-based projections

No forecast data available for these sectors.

From carbon sequestration and biodiversity conservation to sustainable timber production, increasing the area of Scotland's forests will be crucial to meeting net zero goals. However, competing land use demands have increased the importance of balancing the economic, environmental, and social values of Scotland's forests. The sector faces structural challenges including an ageing and seasonal workforce. Research and development is also required to demonstrate the suitability and international competitiveness of Scottish timber for construction, and to drive maximum value from high-value wood products. By overcoming these challenges, Scotland can increase the economic value of the sector, particularly if it can service the soaring demand for timber in the rest of the UK as the carbon credit market expands further.

Demand and Policy Support

Government regulations and funding greatly impact the forestry sector. The sector is thus reliant on and highly responsive to signals from government[296]. Corporate interest in the sector is growing, however, and as land availability is increasingly constrained, forestry's role alongside other land-based sectors such as agriculture will be a key consideration for policymakers seeking to meet ambitious planting targets. To service competing land use demands, the current forest stock must be appropriately and sustainably managed. Policymakers must also balance the rising demands for industrial timber products and quick carbon removal with the need to restore degraded ecosystems and conserve biodiversity[297].

Scotland dominates UK tree planting, accounting for approximately 80% of new trees planted in recent years[298], and has set ambitious woodland creation targets of 18,000ha per year by 2024/25 backed by generous grants and generally high public support[299,300]. Despite a significant rise in planting in the last five years, however, Scotland, like the rest of the UK, has not met its tree-planting targets in recent years[301]. Additionally, low planting rates from the late 1980s through to approximately 2010 – attributed primarily to a lack of grant funding – have resulted in a relatively young current stock of woodland which is forecasted to result in reduced timber availability from the late 2030s[302, 303].

Economic interest in the sector is growing for several reasons. First, global demand for timber is forecast to quadruple by 2050. Demand in the UK is expected to rise, in part due to the UK Government's commitment to promote timber use in construction[304,305]. Second, carbon credits such as in Woodland Carbon Code (WCC) projects[306] have seen increasing uptake in recent years from investment funds and other purchasers. The UK emissions trading scheme (ETS) recently announced exploration of the potential to bring greenhouse gas removals into the ETS market, which is likely to further increase interest in afforestation[307]. Third, corporate social responsibility (CSR) has seen corporations increasingly turn to woodland and peatland restoration in Scotland, as they bid to reduce their environmental impacts[308]. This investment is positive, but corporate demand for land must be managed so that it creates value beyond that of rapidly growing land transaction rates and retains local community support[309,310].

Alongside corporate demand for forested land, there is also the threat of competing land uses to consider. The Scottish land bank is ultimately finite and securing land for large-scale tree planting is becoming increasingly difficult, particularly when competing land uses such as agricultural production, peatland restoration and biodiversity conservation are considered[311,312]. Scotland's response to these challenges is set out in its Land Use Strategy and these issues are considered in the Land Use and Agriculture Just Transition discussion paper[313].

A circular economy approach, optimising resource utilisation and minimising waste, can help service these competing demands by reducing demand for new woodland creation[314,315]. Considerations will also be required for how forestry can complement other sectors – see for example the Integrating Trees Network (ITN), which promotes the benefits of tree planting to support agricultural businesses[316].

Export

Scotland is a net exporter of timber with a growing market to service in the UK. At an international level, however, Scotland's timber exports remain limited. Import and export values increase substantially when considering manufactured wood products, and these products are considered separately under sustainable building materials.

SScotland remains a net exporter of timber, primarily to the rest of the UK. Forestry exports in 2019 stood at £119m (£101m to the rest of the UK, £18m internationally), whereas imports were £97m (£68m from the UK, £29 internationally)[317]. These numbers increase substantially when considering manufactured wood products (see the sustainable building materials SWOT).

Timber is a globally traded commodity, and WTO rules prevent outright prioritisation of one country's stock over another[318]. However, the sheer amount of timber imported by the UK provides opportunities for Scottish firms. The UK imported 81% of all its timber in 2021, making it the second highest net importer of wood in the world[319]. This percentage is expected to rise further given government commitments to increase timber use in construction. If Scottish companies, can meet even a portion of growing UK demand, the Scottish forestry industry may benefit considerably.

The percentage of new build homes using timber frame construction varies widely across the UK – high in Scotland (83%), but low across the rest of the UK (23% in England, 31% in Wales, and 17% in Northern Ireland)[320]. As global demand for timber increases[321] and drives up the price of wood, Scotland has a key opportunity to feed UK demand for timber and reduce the UK's exposure to price fluctuations. To do this, however, Scotland must overcome its potential supply issues related to the young woodland stock and effectively demonstrate the quality of Scottish timber compared to slower growing Scandinavian wood. That said, there may be some room for downstream sectors (e.g., wood product manufacturing) to grow using imported wood.

In addition, while the carbon credit market remains relatively underdeveloped, the UK WCC provides a widely recognised and credible standard of carbon credits. Further investigation is required into the economic potential of this opportunity, particularly as WCC credits are currently only applicable to the offsetting of UK emissions. Nonetheless, the WCC market provides the UK's strongest potential foundation for the scale-up of voluntary carbon credit markets, both for direct carbon offsetting and for potential nature-based credit markets[322].

Economic Impact

When demonstrating the substantial economic value of the forestry sector's supply chain impacts and upstream industries such as wood product manufacturing, a 2015 report (due to be updated later this year[323]) is typically cited. This report estimates that most value in the sector is generated through forestry and timber processing ((£770m GVA annually), with forest recreation and tourism generating a further £180m[324]. Most value is also generated through public sector avenues. The Scottish Annual Business Statistics (SABS) assess private sector data only and calculated that the 1,100 companies operating in the Scottish forestry sector generated £200m GVA and £770m turnover in 2021[325].

Jobs

SABS data lists 5,700 employees working in the forestry sector in Scotland in 2021, although it should be noted this is private sector only and is headcount rather than FTEs as listed in other SWOTs[326]. With a sustainably managed increase in forestry planting and stock, Scottish forests could have a role in the Just Transition by providing additional jobs in rural areas with comparatively few alternative sources of employment[327].

Whilst these figures are the most recent available for the private sector aspects of forestry, their scope is limited and they do not include all aspects of the industry, in particular the substantial publicly owned elements. A wider study of the forestry sector from 2015 suggests that total direct FTEs are higher, at around 12,000, although these figures draw in associated sectors such as haulage and tourism[328]. The same report calculates the sector's GVA at £770m. Work is ongoing to update this report.

The top five employing activities listed in the forestry sector in 2015 report were:

- Saw milling, production of pallet slats, fencing posts – 3,500 total (2,200 direct) FTEs;
- Forest management (incl. ground prep., fencing, planting, nurseries etc.) – 2,900 total (1,700 direct) FTEs;
- Forestry Commission (including Forest Research) – 2,100 total (1,200 direct) FTEs;
- Harvesting, sales of wood and timber – 2,000 total (1,300 direct) FTEs; and
- Production of wood panels, board and pulp and paper – 1,800 total (1,100 direct) FTEs[329].

Given the demographics of a sector where many are approaching retirement age, new entrants are required across the forestry supply chain to meet planting targets. Forest managers, machine operators, nurseries, establishment and maintenance, and timber haulage have been identified as particular challenges. These jobs were estimated by CONFOR in 2022 to make up an estimated 9,000 FTEs, with some reliant on unpredictable seasonal labour[330]. Labour shortage risks, health and safety considerations, understaffing and excessive hours, and new and inexperienced staff also remain threats to the sector's growth[331]. The announcement of a new £1m comprehensive training programme for Scottish Forestry frontline staff to increase tree planting is encouraging[332], but if expanding forestry planting, felling and processing in line with global demand are to be achievable from a labour supply perspective, the composition of current activities would also need to change. Significant increases in investments in plant and equipment would help facilitate greater labour productivity and increased salaries[333].

Forestry also has an important role to play in the Just Transition, particularly in its ability to provide significant rural job creation benefits[334]. Over 2,000 enterprises involved in woodland related activities in Scotland in 2017 were microbusinesses employing fewer than ten people[335]. Together, these enterprises, an unconfirmed but substantial number of which were found to operate in the rural economy, are estimated to employ over 4,200 people in Scotland[336]. Stakeholders also highlighted job opportunities in the construction of social and rural housing from timber.

Scotland's woodlands also offer the opportunity to increase collaboration with other sectors, furthering job opportunities and skills development. For example, the CCC has recommended timber in construction increase to 40% by 2050 and called on the UK Government to introduce policy to support this[337], and Forestry and Land Scotland (FLS) is collaborating with the energy industry to create renewable energy schemes on FLS-managed land[338]. Further renewable energy opportunities may arise in the form of biorefining, should current firms based in England expand north of the border.

R&D

Being typically more reliant on the public sector and its leading research organisation Forest Research[339], the forestry sector tends to see low levels of business enterprise research and development (BERD)[340]. Targeted R&D investment is required from both government and industry to demonstrate the quality and suitability of Scottish timber for construction, increase circularity within the sector, and innovate new wood products (although the latter is largely covered in the sustainable building materials SWOT).

The need for further R&D investment in circularity is evident, particularly as land use competition grows. Greater integration with other industries, as well as greater collaboration with governments and research institutions may further drive R&D while enhancing the circularity of the sector[341].

R&D tax relief remains underused across the forestry sector, with many small businesses unaware of their eligibility[342].

Recent R&D initiatives launched in the forestry sector include an online climate change hub[343] and numerous cross-sectoral initiatives. These include the Integrating Trees Network (ITN) initiative[344] and a 50% increase in the agroforestry grant rate announced in 2023 which gives farmers more opportunity to participate in agroforestry by adapting the planting thresholds[345]. These initiatives aim to increase collaboration and between the forestry and agricultural sectors, particularly as competition for land use grows.

3.9 Sustainable Building Materials

Sector definition: Sustainable building materials includes the production and manufacturing of timber products, the production and manufacturing of new low-carbon materials to replace high-carbon products (including low carbon cement, bricks, insulation materials), and the improved recycling of existing materials. Given the limitations of the available data, figures provided are for the manufacture of wood products. Note that although the construction sector is the largest user of these products, some manufactured wood products will be intended for other uses.

DEMAND AND POLICY SUPPORT	●●●●●○○○○○	JOBS	●●●●●○○○○○
EXPORT	●●●●●●●○○○	R&D	●●●●●●●●○○
ECONOMIC IMPACT	○○○○○○○○○○		

The scales show a Low to High opportunity (from left to right) and are based on a combination of qualitative and quantiative data sources.

Current

	FTE	Turnover	Business Count	GVA	Exports	Imports
2019/22	8,000[346]	£1.7bn[347]	-	£580m[360]	£760m[348]	£190m[360]

Scenario-based projections

No forecast data available for these sectors.

The introduction of sustainable building materials is key to the decarbonisation of the construction sector in Scotland and internationally. Scotland has existing strengths including its production of timber and sustainable insulation products, a supportive policy environment and a focus on innovation in construction. However, whilst innovative sustainable materials are already technically feasible, scaling issues exist in a construction sector exposed to tight margins and variable material prices. The public sector can play a key role in driving demand for these goods and services.

Demand and Policy Support

A strong domestic enabling environment will be key to the development and uptake of sustainable building materials in a historically inflexible construction sector exposed to tight margins and a high reliance on public sector clients[349,350]. Public procurement accounted for £3.4bn in 2021/22, representing almost half of all spending in the construction sector in Scotland[351] . This underlines the influence of government's influence as a buyer which can provide industry with the confidence and investment it needs to create a market for sustainable alternative materials[352]. For the uptake of sustainable building materials to scale up, however, key weaknesses will need to be overcome. While some analysis suggests the cost of switching to using low-carbon and circular industrial materials and practices (notably steel, aluminium, and cement) could be relatively low[353], progress has historically been held back by design and demolition practices, disjointed supply chains and low non-sustainable material prices. This is particularly the case for cement and concrete, which have fostered excess material use and material intensive new-build housing over renovation and retrofitting[354].

Both the UK and Scottish governments recognise the importance of modernising housing, and numerous strategies and action plans have been published by both governments to capitalise on the economic opportunities associated with modernising construction[355]. The Scottish Government is increasing investment in modernising housing as part of its wider estimated £33bn infrastructure investment plan[356]. This modernisation of construction includes increasing the use of domestic wood products in construction[357,358], a commitment mirrored by the UK Government[359]. The recent publication of the Circular Economy Bill (June 2023) also represents a move towards more sustainable building materials and practices, as it gives ministers the powers to set local recycling targets; set statutory targets for delivery of a circular economy to measure progress in reducing waste and the nation's carbon footprint; and ban the disposal of unsold consumer goods, to prevent good products ending up in landfill[360].

Scottish Government has recognised the importance of creating the right conditions to enable innovative products, approaches and services to scale up. The Just Transition plan for the built environment and construction sector cites examples of Scottish innovations such as the K-Briq developed by Kenoteq[361] – a brick made from 90% recycled materials and created through a collaboration of academia and industry, including Built Environment – Smarter Transformation (BE-ST)[362].

The scale of what is required in terms of emissions reductions presents potential economic opportunity. The built environment and construction sector accounts for around 40% of Scottish emissions, and at the UK level the construction sector is estimated to use nearly 100Mt of materials in new infrastructure each year[363]. Of this, 82% are virgin resources (predominantly concrete). More than a third of landfill waste comes from construction and demolition[364]. While acknowledging that not all construction emissions are avoidable (particularly in cement manufacturing[365]) the CCC estimate that UK manufacturing and construction emissions can be reduced by 70% by 2035 and 90% by 2040 from 2018 levels, based on fuel-switching, CCS and improvements to resource and energy efficiency.

Noting that the most effective use of biomass currently is to use wood in construction (provided it is underwritten by strong forestry management)[366], their recommendations include increasing the use of timber in construction to 40% across the UK[367]. The Industrial Decarbonisation Strategy states that resource efficiency and material substitution measures have significant climate change mitigation potential, saving 9Mt CO2e per annum within the UK by 2050. In particular, individual measures with the most potential in reducing emissions are using more construction materials with low embodied carbon (such as timber), reusing construction materials and using electronics and vehicles for longer[368].

Export

The size of the UK construction market presents significant export opportunities for Scotland, and it excels in exporting manufactured wood products to the rest of the UK. However, while Scotland has notable strengths in exporting wider construction management services, stakeholders consulted highlighted that building material exports are held back by higher manufacturing costs. Timber products are a notable exception. Retrofitting expertise also presents export opportunities due to Scotland's expertise in construction services, wide array of building typologies and the lack of clear leader in the retrofitting market so far.

Scotland imports large quantities of building materials such as cement, lime and plaster from the rest of the UK (£340m in 2019)[369]. Scotland does have an advantage of the rest of the UK in timber and wood products, however (see the Forestry SWOT). While Scotland did import £190m worth of manufactured wood products in 2019[370] (of which £140m were imported from outside the UK), its exported wood products far outweighed this figure. Data for 2017 show that Scotland exported £702m of wood products to the rest of the UK, alongside a further £57m to the rest of the world[371].

The UK Government has committed to increasing the use of timber in construction, presenting export opportunities for Scotland which dominates planting at a UK-level and uses far more wood in construction than the rest of the UK (see the forestry SWOT)[372]. For this increase to materialise, however, several issues must be overcome including building regulations, plant and machinery costs, the need for innovation, and a lack of incentives to transition from current, material-intensive but profitable business models[373,374].

Although Scotland's primary market is within the UK, Scotland's international construction exports are still worth £125m (2019)[375]. TThese remain mostly in timber products, and Scotland remains reliant on imports for aggregate which limits its production of many building materials (sustainable or otherwise[376]), but with new enterprises such as the K-Briq growing in funding, there are opportunities to supply some of the huge UK construction market's demand[377].

The UK is a net importer of non-timber building products (including heat and sound insulation materials, bricks, tiles and other construction products), with imports of £580m and exports of £300m in 2022[378]. However, Scotland has an export opportunity due to the sheer size of the UK construction market. The UK imported £13bn of construction materials from EU countries in 2022, and £11bn from non-EU countries. The top 5 imported materials included electrical wires, >6mm thick sawn wood, air-conditioning equipment, structural steel units, and linoleum floor coverings, with the top import markets China, Germany, Italy, Spain, and Turkey. Regarding exports, the UK exported £5.0bn of materials (paints and varnishes, plastic pipes, air conditioning equipment, and linoleum floor coverings) with EU countries and £3.2bn to non-EU countries, notably Ireland, USA, Germany, Netherlands, and France[379].

Scotland also has potential growth opportunities in retrofitting. The vast majority of Scotland's 2.5 million occupied dwellings will still be occupied in 2045, and nearly all will require some form of retrofit activity[380]. This scale, coupled with one of the most varied typologies of building types in Europe, presents Scotland with an opportunity to become a true leader in retrofitting and export this knowledge internationally.

Economic Impact

Despite the construction sector's tight profit margins[381], the production of sustainable building materials, including sustainable insulation materials, energy-efficient windows made from recycled glass, or durable yet environmentally friendly flooring materials (such as bamboo or cork), could increase the sector's Gross Value Added (GVA). These products, while initially requiring more substantial investment, offer extended durability, reduced maintenance costs, and increased energy efficiency, thereby creating added value and potential cost savings over their lifecycle. Integrating such materials into construction aligns with sustainability goals, enhances market competitiveness, and drives economic growth in a sustainable and responsible manner.

There is no distinct data for sustainable building materials at either UK or Scottish levels, complicating the assessment of their economic impact. This economic value is generated across the sustainable building materials supply chain, from design and development to manufacturing and use of the materials. Should Scotland succeed in scaling up its sustainable building materials production, there is opportunity to supply its considerable construction sector, which generated £21bn in 2021, from which £8.5bn in GVA was generated[382].

One industry classification which could be used to estimate Scotland's sustainable building material production is the manufacture of wood products. Total output of the wood and wood product manufacturing industry in Scotland was £1.7bn in 2019. This resulted in an industry GVA of £580m[383], although it should be noted that construction was not the sole use of these products.

Stakeholders stated that after timber, insulation has the most potential within Scotland. The UK home insulation market is currently worth around £800m per year, but only 1% is currently made up of natural insulation products such as wood and natural fibres and animal fibres e.g., sheep's wool – products which are currently imported, typically from France and Austria, but are gaining prominence in Scotland[384].

There is also an opportunity for a more circular approach to construction materials. The business case for reusing materials is building, particularly in steel, masonry, and timber. Research suggests that circular construction business models, such as modern methods of construction which often involve offsite manufacturing, can also increase profitability and productivity while reducing costs[385]. If the materials required for sustainable construction increase in value as the global race to net zero continues, the case for circular construction models builds further.

However, costs differ between construction and retrofitting, meaning that a circular approach to construction is not necessarily cost competitive. Labour costs for deconstruction can be up to 20-50% higher than demolition more owing to, amongst others, added health and safety costs and the addition of third-party risk assessors, presenting potential complications to the growth of this market.

Jobs

Jobs in sustainable building materials are difficult to estimate, as they are tied to larger sectors such as Construction, Housing, and Forestry[386]. However, approximately 8,000 people worked in the manufacture of wood and products from wood and cork in 2022, making up 73% of total employment within the larger classification of building material manufacturing (11,000)[387].

Across the wider construction sector, employment in 2021 in Scotland was 150,000[388]. This sector is characterised by fragmented, complex supply chains, with a reliance on sub-contractors. There were over 47,000 businesses operating in the construction sector in 2022, of which 99% were small enterprises of 49 employees or less. This underlines that SMEs and micro-businesses will be the key enablers to delivering the transition[389].

R&D

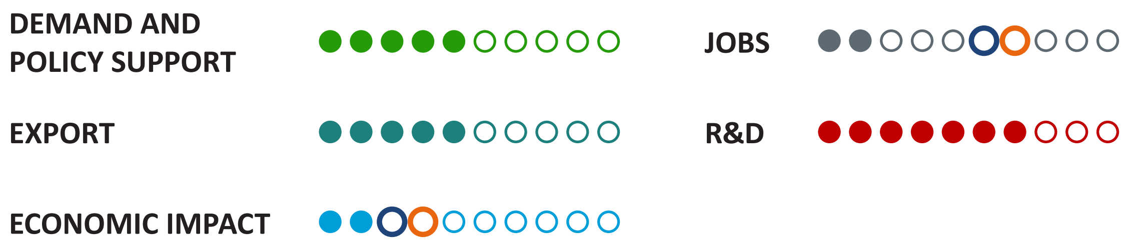
While Scotland has seen declining Business Enterprise R&D (BERD) in the construction sector in recent years[390], there are several organisations currently driving innovation in sustainable building materials in Scotland. These are particularly driven through government-supported and higher education initiatives, highlighting the importance of public investment to stimulate a sector which has historically lacked a financial incentive to switch to sustainable practices.

BE-ST (Built Environment – Smarter Transformation), a programme supported by the Scottish Government and delivered by a consortium of partners, is playing a leading role in driving innovation in sustainable building materials in Scotland through, for example: supporting the development of a new type of insulation made from recycled plastic bottles; promoting the use of timber frame construction in Scotland; and working with businesses in the construction industry to develop new circular economy business models[391].

Further organisations, typically involved with BE-ST, include The Construction Scotland Innovation Centre (CSIC), The Centre for Offsite Construction (COC), The Green Construction Board (GCB), The Scottish Timber Frame Association (STFA), The Innovation Centre for Building with Nature (ICBN) at the University of Dundee, The Institute for Sustainable Construction at Edinburgh Napier University, Scottish Forestry, and Zero Waste Scotland (ZWS) are also furthering the development of new sustainable building materials and practices in Scotland – notably low-carbon cements[392], sustainable insulation products[393], and increasing the use of Scottish timber in construction[394].

3.10 Renewable Heat

Sector definition: Scotland's renewable heat sector can be described of as a collection of multiple niche markets. Heat pumps and heat networks are the focus of this SWOT given their prioritisation in multiple key documents.



The scales show a Low to High opportunity (from left to right) and are based on a combination of qualitative and quantiative data sources.

Current

	FTE	Turnover	Business Count	GVA	Exports	Imports
2022	1,700[1]	£380m[1]	500[1]	£160m[395]	£44m[396]	£160m[397]

Scenario-based projections

	FTE	Turnover	Business Count	GVA	Exports	Imports
2030	13,000[3]	£2.6bn[3]	-	£1.1bn[3]	-	-
2050	9,700[3]	£1.8bn[3]	-	£780m[3]	-	-

Scotland's renewable heat sector is made up of multiple niche markets, which have potential to grow and significantly contribute to Scotland's net zero economy. Ambitious decarbonisation targets are set to drive demand, but require rapid scaling of adoption and installation. Due to a complex set of factors, the main weakness is insufficient uptake, though there are signs this may be changing and the Scottish Government have recently consulted on proposals to improve consumer demand. Given the scale of delivery needed (with an ambition to end the use of polluting heat in buildings before the end of 2045), there are opportunities particularly in job creation. However, the lack of coherence and clarity in policy is impacting demand, market confidence and speed of delivery. Transition in this sector is primarily about skills and employment, though uptake of renewable heat provides the opportunity to transition from being a net importer of natural gas to a more resilient, self-serving market with a better balance of trade. At present, Scotland imports much of the heat technology being deployed. Although it does have some manufacturing capacity for heat pumps, the majority of these manufactured products are currently exported. Further analysis is required on the potential to provide both the products and services needed to meet domestic needs alongside the international market.

Demand and Policy Support

Scottish Government has aimed to decarbonise heat for over 1 million homes and the equivalent of 50,000 non-domestic buildings by 2030[398], but, following a reassessment in light of the recent cost of living crisis and surge in energy prices affecting short-term delivery, they are focusing instead on delivering a much more even trajectory towards ending the use of polluting heat in buildings before 2045. Despite this ambition, a complex set of factors is creating uncertainty of demand.

While the regulatory framework to encourage low emissions heating is developing in the form of the Heat Network (Scotland) Act and forthcoming Heat in Buildings Bill, Local Heat and Energy Efficiency Strategies (LHEES) and Energy Performance Certificates (EPC) reforms, progress has been slow in comparison to what is needed to drive demand[399]. The perception amongst stakeholders is that government policy is not yet explicit about which technologies will need to be installed and by when. These factors are crucial in providing certainty of demand, which in turn impacts the scale and speed of delivery required to meet these targets[400]. The Heat Network Zoning Policy is noted as key in driving heat network development[401].

To maintain progress towards emissions reduction targets, over 200,000 new low or zero emissions heating systems need to be installed each year in Scotland throughout the late 2020s[402]. Differences across Scotland's building stock (around a fifth of Scotland's homes were built before 1919, and around 10% of the Scottish housing stock is listed or located in conservation areas) pose a challenge both in terms of understanding the need for different technologies, as well as skills to install them. This challenge is compounded by higher electricity prices in relation to gas[403,404].

Installation targets for renewable heat are ambitious, with an expected investment requirement of £33bn to decarbonise at the building level (not reflecting further costs for grid reinforcements etc.)[405]. This has potential to create high job demand. However significant market uncertainty is limiting spend and customer uptake.

Though the role of some technologies is becoming clearer (for instance recommendations for a much smaller role for hydrogen[406]), gaps and uncertainty remain around which technologies will be deployed under various circumstances. These includes a lack of financial incentives for both firms and consumers, as well uncertainty with regards the speed of the transition away from gas boilers[407].

From a customer perspective the journey to installing a heat pump remains complex and challenging, a threat which must be addressed in order to meet installation targets.

Public acceptability and creating customer confidence, as well as market confidence, is critical to ensuring uptake of renewable heat and realising the economic opportunities of the sector. A UK study found that while increasing energy costs were leading people to take an interest in their heating systems, most feel uninformed about alternative heating solutions[408]. This lack of information is market limiting and a current weakness, threatening future demand.

Supporting infrastructure is currently lacking intervention required both in terms of physical infrastructure (the grid) and financial subsidies to incentivise both customers and companies. A £300m heat network fund exists to support feasibility and capital costs and the SG Heat Network Support Unit provides technical assistance. But on top of that it is recognised that private investment and innovation are needed around financial models[409].

Export

The largest producer for heat pumps in the UK, Mitsubishi, is present in Scotland and is a major Scottish exporter of heat pumps to Europe. There are also export opportunities for renewable heat in terms of skills and knowledge[410], though limited comparative advantage for Scotland (due to other more established players in the EU and UK market).

CCurrently, there is some domestic provision of heat pumps in the UK from Mitsubishi in Livingston. There are also multiple other exporter companies in this sector in Scotland, and though it could be argued that short term focus should be addressing Scotland's building stock and decarbonisation needs, due to limited demand there is not enough of a domestic market to support these companies[411]. Given global, EU and the rest of UK decarbonisation needs, potential export and trade is a significant opportunity. There are notable examples of Scottish innovators exporting their products and knowledge globally such as Sunamp thermal batteries[412]. In terms of heat networks, export capacity exists for larger scale industrial heat pump manufacturing, i.e., Star Refrigeration, though it is noted that Scotland's domestic heat network products capacity is limited[413].

The UK currently exports approximately £80 million worth of heat pumps and £87 million worth of central heating boilers. The UK, however, is net importer in both heat pumps and boilers with imports of approximately £140 and £520 million respectively[414].

This gap in UK production between domestic demand and supply in heat pumps, implies that there is potential to both increase exports and reduce imports of heat pumps by increased domestic manufacturing. Though manufacturing of heat pumps is increasing, evidenced by the fact that Mitsubishi have switched from manufacturing 80% air con units to manufacturing 80% heat pumps and 20% air cons[415]. The majority of these are exported and not used to address Scotland's domestic heat decarbonisation needs.

As it stands, in relation to production of heat pumps, only 19% of domestic demand in the UK is supplied by UK firms[416], highlighting the weak domestic production in the UK and the reliance on foreign imports.

Considering the presence and scale of Mitsubishi, it is possible that Scotland could be better positioned to take advantage of this local production. It is, however, also plausible that because the UK is currently a net importer, there are other countries, and firms, who are in a much better position to capitalise on any increase in UK demand. There is therefore uncertainty regarding the capabilities of renewable heat exports and whether demand in Scotland will be met by domestic or international suppliers.

The performance of service-related exports was unclear at the time of this analysis. However, drawing upon Scotland's digital skills could provide further opportunity for knowledge and professional exports, for instance in relation to how technologies like heat pumps are used in the household and how they fit as part of an electricity system using renewable energy. There could be opportunity for competitive advantage if Scotland can realise a high level of digital competency and efficiency, running not only decarbonised homes but a highly-renewables grid quicker than others[417].

Economic Impact

The economic impact of transitioning to renewable heat is complex. Short-term costs include expenses for heat pumps and related services, but these lead to increased economic activity and employment, which is an opportunity for Scotland. However, the reduction in non-renewable heat sources like gas boilers will decrease economic activity and employment in those areas. In the medium term, the shift to renewable heating could potentially have a positive net impact due largely to the workforce required to deliver the targets.

Current heat pump demand in the UK is low compared to Europe, described as a "dormant market with signs of awakening[418]". These signs of awakening are reflected in the 5,000 heat pumps sold in Scotland in 2022, an increase of 95% in two years[419]. There is substantial demand for retrofit services expected over the next 30 years[420].

The net impact on gross output expected in 2030 is an increase of just over £2bn[421] ((equivalent to a 0.6% increase in the size of the 2017 Scottish Economy, and therefore a slightly smaller percentage increase in the (anticipated) larger Scottish economy of 2030). Although around half of this projected growth is attributed to utilities rather than increased manufacturing or installation activity.

There was an estimated direct GVA of £90 million in 2020 for the renewable heat sector in Scotland according to Fraser of Allander Institute (FAI)[422]. Using LCREE turnover data for 2022, the estimated value for GVA is £160m in 2022 illustrating growth in the sector.

Given Scotland's climate and longer heating season, demand for heat is higher than other areas of the UK. This poses an opportunity for companies providing renewable heat as annual costs of heating in Scotland are higher, and therefore customers may seek more efficient solutions to address this (relative to places where demand for heat is lower). This could drive up installations. The current reliance on gas to meet this demand is a weakness both from a trade perspective as ~30% is imported, and from a climate resilience, emissions reduction perspective.

Increased installation demand will create opportunities for a limited time and longer term the net economic impact will depend on maintenance and replacement requirements of these systems. Longer term, technology transition opportunities lie in reducing dependence on imported natural gas, enhancing resilience against price fluctuations, and ensuring energy access.

There are further opportunities for economic impact in renewable heat due to its overlap with other sectors such hydrogen, heat storage, construction, and sustainable building materials. There are also opportunities for circularity through waste heat[423], though this is less developed in Scotland than the rest of the UK. Further, there is an opportunity for renewable heat to contribute to grid balancing. Manufacturers are developing combined heat pumps and storage systems to absorb energy fluctuations reduce peak energy demand, but this remains a niche market[424].

There are multiple opportunities in the digital space, though collaboration across sectors will be key. Currently both Scotland and the UK lack a framework for data sharing and interoperability[425]. This poses a threat to future development.

Jobs

The renewable heat sector currently supports 1,700 jobs in Scotland[426]. Based on FAI analysis, it is estimated that for every direct job in renewable heat, there are an additional 0.7 indirect jobs, including the supply chain[427]. There is potential for job creation and demand for diverse skill sets across installation of heat pumps and networks (e.g. specialised welding), professional services (consultancy, engineering design)[428].

Forecasted job numbers in the sector are uncertain. However, it is expected that as a result of the switch towards low-carbon technologies, there will be a change in the type and number of heat and renewable heat jobs, with Scottish Enterprise scenario-based projections estimating over 13,00 jobs in 2030, and up to 9,600 in 2050.

O ne study, based on a scenario of decarbonising 1 million homes by 2030, estimates an increase of 23,000 new jobs in 2030[429], and after accounting for other factors such as retraining of existing gas boiler engineers, the net impact is estimated as positive - over 16,000 jobs. This figure assumes that Scotland will be involved in the manufacturing of heat pumps and also takes into account changes in energy generation. As with economic impact, the scale and permanency of these jobs once the building stock is converted is unclear. Another study, using scenarios developed by Change Committee, estimates 22,500 new jobs to 2028[430],however a third453 based on a scenario in which 1.3 millsion homes were decarbonised by 2030, suggests demand for heat pump installers could broadly be covered by the existing workforce. Uncertainty around job creation and availability of skills is a threat to Scotland delivering its targets and capturing the economic opportunities of the transition.

installers in Scotland. Currently there are 200 to 400 installers delivering approximately 5,000 installations per year. But based on the 170,000 low carbon heating installations required per year by 2030, to meet the former 1 million homes goal, an estimated 4,000 installers will be needed in Scotland by 2033. That represents a 15-20-fold increase (adjusting for productivity improvements)[431]. Evidence suggests heat pump installation skills can be trained in a relatively short time frame so there is the opportunity to retrain the experienced gas heating engineers in Scotland (currently an estimated 11,000)[432]. However, other crucial skills are more difficult and time consuming to train, such as: heat pump commissioning, hydraulics, heat network installation, operation and maintenance (including professions such as welders, and heating engineers with knowledge of larger heat distribution systems). Not addressing these skills requirements would pose a further threat to the sector.

The other aspect of the job-related opportunity relates to geographical distribution. Given the range of technologies and supply chains (in district heating consultancy, heat pump installers or even IT and digital jobs from an increase in smart metering), demand for infrastructure and retrofitting on a wide range of building types, the distribution of jobs will be wide, providing potential in both rural and urban areas and further contributing to a just transition.

R&D

Scottish capability in research, development and deployment for both heat pumps and heat networks fall behind other technologies and subsectors[433]. However, while heat pump technologies are reasonably well established and made of well-understood components (meaning less potential to innovate), improvements are required to enable wider uptake of the technology and reduce costs for consumers.

Firstly, there is a need to improve the customer journey, by providing greater understanding and advice on appropriate technological options (including supporting the consumer in factors such as available finance, size and tenure of property, ease of use and ongoing maintenance). The potential here is significant to enable uptake and increase domestic demand. As installation and maintenance of heat pumps constitutes the biggest proportion of cost to consumers[434,435], innovation in this area could improve installation time, maintenance processes and associated costs.

There are existing footholds and evidence of Scotland's innovation in air source heat pumps in Mitsubishi's Livingston factory[436] and the flagship district heating project Queen's Quay, using water source heat pumps manufactured by Star Refrigeration[437]. There are further examples of pilot projects and technologies in Scotland, but these have not translated to commercial projects yet[438].

There is a need for innovation in areas other than heat pump components. The Building Research Establishment (BRE) low carbon innovation needs assessment[439] notes that there is a "consistent view" that decarbonising heat could be achieved through various educational, market, fiscal and policy-based mechanisms, as opposed to technical innovation alone. Many stakeholders commented that technical improvements would typically only lead to incremental improvements. However, they did note need for work on smart metering and understanding building efficiency needs.

Scottish Enterprise launched the 'Can Do Innovation Green Heat Feasibility Challenge' as part of the £17.5m Green Heat Innovation Support Programme. 16 projects were successful in securing between £30 to £50k funding to cover of a variety and scale of solutions across retrofit, heat pumps, geothermal and new business models[440]. Since the BRE study was published and through the feasibility challenge, there is evidence that that the market is responding to signals and companies are innovating around products such as air to air heat pumps and boilers with built in storage, in order to bring forward new products designed for the UK housing stock.

3.11 Professional Services

Sector definition: The professional services sector spans the Scottish economy both horizontally across sectors and vertically along value chains. It includes engineering, planning and digital skills, and well as consulting and advisory services (financial services are analysed in their own SWOT). There may be overlaps with other parts of the NZ&CA economy due to difficulties disaggregating this data.

DEMAND AND POLICY SUPPORT	●●●●●●●●○○	**JOBS**	●●○○○○○○○○
EXPORT	●●●●●●●●●○	**R&D**	●●●●●●○○○○
ECONOMIC IMPACT	●●○○○○○○○○		

The scales show a Low to High opportunity (from left to right) and are based on a combination of qualitative and quantiative data sources.

Current

	FTE	Turnover	Business Count	GVA	Exports	Imports
2022	4,500[441]	£460m[461]	2,700[461]	£280m[461]	-	-

Scenario-based projections

No forecast data available for these sectors.

Addressing sustainability and the transition to a NZ&CA economy is an enormous systems level problem to solve. Consulting, technology, engineering and other services firms sit at the centre of these complex systems and have a crucial role to play in providing expertise, advice and solutions. In order to address these systems level challenges, there is a need for multidisciplinary innovation and Scotland's existing strengths across multiple sectors present a potential competitive advantage. Significant opportunities exist due to current and forecast demand increases for multiple sustainability services in Scotland and internationally. Scotland is well placed to meet this demand due to its existing experience in specific areas (such as securing consents in offshore wind), complemented by strengths in innovation. Scotland has multiple areas of competitive advantage including technical experience across sectors, as well as unique first mover advantages such as floating offshore wind. Scotland's planners, engineers and consultants will have the opportunity to export knowledge and expertise. International competition for the providing sustainability services will be high and Scottish companies and universities must ensure they remain attractive to talent, working to address inclusivity and retention in key sectors. Competition for skills is a serious threat from within the NZ&CA economy sectors but also from others such as space and ship building.

Demand and Policy Support

Demand for professional services in sustainability is increasing around the world as countries and businesses seek to align their activity to a transitioning economy and adapt to the effects of climate change. The need for expertise is expected to grow in engineering consultancy, planning, and environmental studies, as well as in digital energy efficiency solutions and legal advice. With existing strengths in professional services and direct expertise spanning multiple projects and disciplines, Scotland is well positioned to take advantage of these opportunities. However, clarity and support is needed particularly for SME's to be able to contribute.

Research suggests that the global Environmental, Sustainability and Governance (ESG) consulting market will see a compound annual growth rate (CAGR) of 17% until 2027. At that point the market will have grown by 156% from its 2021 size of USD$6.2 billion, equating to growth of almost $10 billion[442].

While Scottish data is not available, on a UK level a different source shows the environmental and sustainability consultancy market grew 5.1% in 2020, reaching a record value of £2bn[443]. The five-year forecast for the UK environmental and sustainability market to 2025 was a CAGR of 6.2%, lower than the global forecast, but an increase from previous predictions of 2.5%. Many of the UK top firms are multidisciplinary engineering, design and consulting firms, with environmental and sustainability revenues representing approximately 17% of their aggregate group revenues, up from 15% in 2017. The environmental and sustainability component of these services firms has grown at a faster rate than the overall group rate, increasing 6.5% as opposed to an overall decline of -0.6%[444]. While data is not available for Scotland, given many of the top 29 firms listed in the study (and all of the top 10) have a presence in Scotland, there is no reason to assume a different trend.

Scotland has a strong presence in legal, accounting and management consulting which, contribute to the wider green finance ecosystem and create positive spill overs effects. Well-established strengths in these sectors may help enhance the UK, and Scotland's international position in sustainable finance[445]. In particular, these complementary services, if combined with a deep level of knowledge of the growing UK and international regulatory requirements, could mean Scotland's professional services sector is primed to export expertise to financial institutions and clients around the world. For instance, the UK is leading the way in transition planning and Sustainable Disclosure Regulation (SDR) through both the Transition Plan Taskforce and the Financial Conduct Authority (FCA), seeking to build on existing Task Force on Climate-Related Financial Disclosures (TCFD) structures and learnings from the EU Sustainable Finance Disclosures Regulation (SFDR). Professional services firms establishing a deep knowledge of these requirements, collaborating across sectors could better and more quickly support their clients and establish an advantage.

Globally, looking specifically at sustainability consulting, technology, and business services firms one study estimates a growth of 240% in revenues and 210% in clients over the next two years[446]. 18 leading firms currently turn over more than £13bn and manages 22,000 clients. Broadening this to include "pure management consultants, technology and platform giants, engineering powerhouses, and services firms"[447] outside the leading 18, the sustainability services market is estimated at $50 billion and growing which indicates growing export opportunities for Scotland and the UK.

Leading sustainability services firms have observed consistently increasing demand across the value chain, from supply chain and procurement (+4.7 on a scale of -5 to +5) to demand for data platforms (+4.6)[448].

Initiatives such as Zero Waste Scotland's Circular Economy Business Support service exist to offer tailored technical advice to professional services firms. The potential to drive circular principles through public sector spending, amounting to about £11 billion annually, offers a significant avenue for the professional services sector to contribute to sustainable practices.

Export

The export-oriented professional services sector relies on Scotland's human capital, technology, and research capabilities. Scotland's advantage is in its culture of innovation and collaboration, evidenced through its many clusters and supported by a presence of multinational organisations and world-leading universities.

Scotland is a net exporter in low carbon consultancy, advisory, and offsetting services, with exports of £7 million in 2022[449]. This figure includes any services directly related to renewable energy and other low carbon sectors, excluding any overlapping professional services in unrelated sectors. It is therefore an undervaluation of Scotland's export performance within this field.

UK exports for the environmental goods and services sector[450] were £108 million in 2020. However, UK level data has shown the proportion of UK environmental and sustainability service revenues generated from overseas projects has fallen year on year since 2017, from 12.8% in 2017 to 9.2% in 2020[451]. Possible factors could include changes in global market conditions, shifts in environmental policies, or fluctuations in demand for these services overseas. Additionally, the impact of Brexit and the COVID-19 pandemic may have also played a role, as they have significantly affected international trade and business operations. It's worth noting that during this period, the overall output and Gross Value Added (GVA) of the UK environmental and sustainability service industry also experienced a decrease.

A differentiator for Scotland is its culture of innovation combined with the professional, technical knowledge and experience of challenging environments such as the North Sea[452]. This expertise is relevant and exportable in a range of engineering and consultancy services across the value chain. Threats from international competition exist from a number of countries, including India and China[453,454], and while there is opportunity to hire international talent and export services, this has been made more challenging as a result of Brexit.

Economic Impact

Scotland is recognised as a service economy. Scotland's entrepreneurial landscape exhibits achievements and challenges in the professional services sector. Beyond the NZ&CA economy, the ascent of prominent scale-ups like FreeAgent, Rockstar North, and Current Health exemplifies Scotland's exceptional capacity for fostering innovation and substantial growth. This trend underscores the dynamic landscape, signalling promising opportunities, also within the realm of professional services. However, the lag in entrepreneurial dynamism emphasises the need for strategic interventions within the NZ&CA economy, and in turn, professional services.

Oxford Economics forecast that GVA in the overall Professional Services sector was around £2.9bn in 2023, generating 1.9% of Scotland's total economic output. GVA in the Professional Services sector is forecast to grow on average 1.4% each year between 2023 and 2033, slightly above Scotland's average[455]. Other sources with different definitions of the professional services sector point to a larger GVA figure so potential economic impact may be higher.

Jobs

As a uniquely difficult market to quantify given overlapping skills across industries, there are an estimated 1,100 working specifically in low carbon consultancy, advisory and offsetting services according to the most recent LCREE data. This figure increases to 4,500 considering professional services roles relating to renewable energy LCREE sectors, though this is likely to be higher when considering broader sustainability consulting, digital and others. Considered another way, 32% of people in professional occupations are in green jobs, though this also includes overlapping roles in energy sectors. Notably, this proportion is higher than skilled trades, which is the next highest job group at 20%[456]. This demonstrates the crucial role that professional occupations play in the transition.

Scotland's total professional services sector[457] employs approximately 59,500 people accounting for 2.3% of Scottish employment. This figure is expected to grow to 62,800 people in 2026, an increase of 5.6%[458]. This is significantly higher than the expected Scotland wide increase of 2.2% over the same period and consist of a large share high value jobs such as engineers and economists that work with for example permitting or other consultancy services.

Geographically, in terms of the proportion of all professional services jobs to total employment, the sector was most prominent around Scotland's cities, in Glasgow City (4.0%), City of Edinburgh (3.7%), East Dunbartonshire (3.6%) and Aberdeen City (3.2%)[459] .

The total professional services sector has shown resilience in terms of employment, with a 0.2% increase in the workforce during the Covid-19 pandemic (2019-2021). In contrast, the Scottish workforce declined by 2.2%[460].

Scotland's professional services sector is highly skilled, with a greater proportion of the workforce educated to Scottish Credit and Qualifications Framework (SCQF) levels 7 and above - equivalent to advanced higher or first year of a degree - in comparison to Scotland as a whole. However, 45% of those with undergraduate degrees across all sectors feel overqualified for the work they are doing[461], suggesting a possible mismatch of skills that should be investigated. In a competitive skills landscape, the sector experiences a less pronounced skills gap compared to vocational sectors during the shift toward a NZ&CA economy.

Inclusivity and retention of women in a number of professional services subsectors is a threat[462] to realising full economic opportunity (in particular engineering and IT). A gender gap also exists in business start-up rates[463].

Collaborative efforts and adaptability across various sectors and disciplines will play a crucial role in unlocking the potential opportunities presented by the transition to sustainable professional services. This not only addresses current challenges but also sets the stage for future opportunities in this evolving landscape. Traditional regulation and professional licensing systems is noted by stakeholders[464] as restrictive and an impediment to working in an evolved, digital landscape with multidisciplinary demands.

R&D

Scotland's emphasis on fostering innovation through collaboration between businesses, academia, and the public sector holds significant implications for the professional services sector.

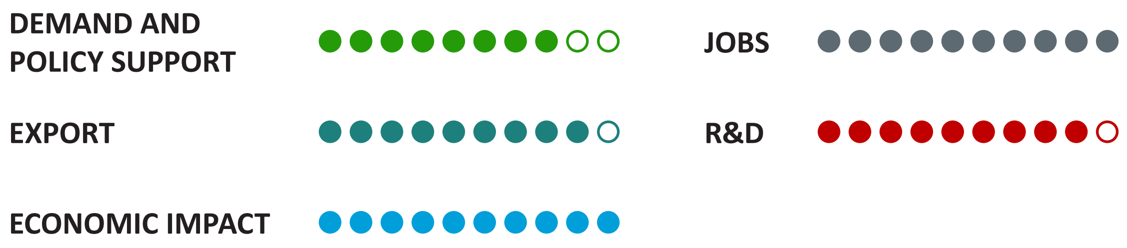
Scotland's network of Innovation Centres and clusters offer opportunities for the industry to engage in cutting-edge research and development. In addition to this, the smaller nature of Scotland has been highlighted by stakeholders as a strength as it means relevant groups can collaborate more easily. The Scottish Cluster Ecosystem alliance is a unique strength and example of knowledge sharing: a joined-up approach with the aim of delivering greater impact and better outcomes across the tech sector[465].

Scotland's sectoral innovation strengths include scientific R&D, information technology, business services, professional services, architectural, engineering and technical activities, health, energy, emergency technologies (including fintech, health tech and nanotechnologies) and space[466]. This highlights a particular strength in services, as opposed to manufacturing, when it comes to innovation and competitive edge.

Compared to the UK, Scotland has a higher proportion of innovation active businesses in traditional economic sectors including 'financial intermediation', 'electricity, gas and water supply', 'computer and related activities and ICT' and 'scientific research and development'[467]. Though the extent to which these apply or could apply to the NZ&CA economy remains unclear, the evidence of innovation relative to the UK means Scotland is well placed to take advantage of opportunities relating to the transition, considering the scale of innovation required. Scotland's threefold approach to fostering new businesses, supporting start-up growth, and cultivating entrepreneurial mindsets aligns with the professional services sector's need for a dynamic and innovative ecosystem[468].

3.12 Sustainable Financial Services

Sector definition: Sustainable financial services in Scotland include asset management, consultation on sustainable finance frameworks and investments, and related professional services. The sector comprises traditional banks, insurance, life and pensions businesses, and wealth management, all headquartered in the UK. Quantitative data are for the financial sector as a whole.



The scales show a Low to High opportunity (from left to right) and are based on a combination of qualitative and quantiative data sources.

Current

	FTE	Turnover	Business Count	GVA	Exports	Imports
2021	71,000[469]	£24bn[470]	4,500[471]	£11bn[491]	£3.9bn[491]	£990m[491]

Scenario-based projections

No forecast data available for these sectors.

Scotland is well positioned to develop a leading sustainable financial services sector, both as a location where green services are delivered for global clients and as an attractive destination for domestic sustainable investments. Scotland is well placed due to membership of the Glasgow Financial Alliance for Net Zero (GFANZ) and featuring in the Global Green Finance Index. This recognition, coupled with academic excellence and the UK's leadership in sustainable finance regulation provide credibility. Sustainable finance, and Environmental, Social and Governance (ESG) practices, are becoming firmly embedded in investing strategies, with demand only set to increase. To remain competitive, and given the competition to capitalize on this, Scotland must prioritise long term clarity and investor confidence, as well as fostering its culture of innovation. It is this combination of strengths, combined with local, investible assets in sectors such as energy, forestry and in agriculture and food, that positions Scotland to further develop opportunities in sustainable finance. As well as potential for economic growth and exports through innovative products and services, opportunities for growth in this sector stem from improved management of climate and nature-related risks, enhancing resilience and reducing exposure of asset portfolios.

Demand and Policy Support

Scotland's sustainable finance sector benefits from the existing scale and reputation of the broader Scottish (and UK) financial sector and the existence of enabling organisations such as the Scottish National Investment Bank (SNIB). Understanding new and upcoming voluntary and regulatory standards[472] for sustainable finance can, in the short term, pose challenges for Scottish financial institutions and asset managers, but in the long-term drive consumer confidence and verifiably sustainable investments. Scotland also benefits from its proximity to and relationships with key players in UK's sustainable finance sector. For instance, the UK is home to organisations and taskforces leading the development of key frameworks and regulation (Glasgow Financial Alliance for Net Zero, Transition Plan Taskforce), and is directly applying learnings from the EU Taxonomy and SFDR. While Scotland is clearly benefiting from the UK connections, greater collaboration with the UK in this sector could be advantageous, easing some transitional challenges and enabling confidence for firms and customers pursuing sustainable finance[473].

The reputation of the Scottish financial sector globally is a strength. With a longstanding history of asset management (£500bn current assets under management) and multinational firms establishing significant regional hubs (Barclays, Blackrock and JP Morgan)[474], Scotland is a recognised centre of excellence globally. Building upon the ethical finance conference held in Edinburgh each year, the sector aims to host an annual global 'Green and Sustainable Finance Davos', to be held in Scotland[475]. The innovative, collaborative culture and smaller nature of Scotland was noted by several stakeholders as a strength and distinguishing factor compared to busier centres like London. Scotland lends itself to "considered reflection and long-term thinking"[476] and with London losing out to New York in global rankings since 2018[477], sustainable finance and Scotland's differentiation could present an opportunity. Edinburgh and Glasgow also rank highly in the Global Green Finance Index (an initiative to develop a ranking of the quality and depth of Green Finance activity in financial centres, placed 14th and 46th place respectively).

Scotland has significant opportunity to lead in the sustainable finance space, building upon its existing global presence and leadership from hosting COP26, the birthplace of the GFANZ. With the goal of transforming the entire financial system by 2050, GFANZ stands at the forefront of driving positive environmental change through concerted efforts within the financial industry[478]. The Scottish Taskforce on Green and Sustainable Financial Services seeks to coordinate industry to secure Scotland's place as a globally recognised green finance centre.

Scotland, the UK, and Europe are pioneering some of the world's most ambitious green finance regulations, such as mandatory Taskforce for Climate related Financial Disclosure (TCFD) reporting and upcoming Sustainability Disclosure Requirements (SDR) and transition plans. This regulatory maturity directly benefits reporting and client needs by providing clear requirements. The knowledge gained from these experiences could enable Scotland and the UK to seize transition opportunities more effectively or swiftly[479].

Threats to the sector include low confidence in returns and the risks associated with large projects, new technologies, nascent supply chains or weaker demand signals. There are opportunities for considerable private investments in infrastructure, buildings, and natural capital. CCC estimate this as £5-6bn a year by 2030[480]. However further, feedback from stakeholders identified a lack of availability of costed and well-scaled plans, for instance at the national level, to make investment desirable. There are also development capacity issues at the local authority level.

There is high and growing demand in Scotland for sustainable investment products: more than half of Scottish people surveyed indicated the importance of considering ethical, environmental and social issues in their investment decisions[481]. 36% of Scots surveyed in the same study were willing to sacrifice some financial return to invest in companies with a positive environmental impact.

The pace of change and level of investment required to meet net zero goals has already led to an increase in demand for green finance products, both at the institutional and the individual scale. New products, such as the first ever green loan through UK Export Finance[482] can enable support for critical businesses and technology across the supply chain. From sustainability-linked loans, green bonds, green mortgages, to funds with sustainability-related labels, there will be a need for established financial sectors with high innovation to meet demand for these products. Meeting this demand will not only create GVA, but continue to diversify the offer, increasing resilience.

The development of the Scottish National Investment Bank (SNIB) in 2020 was a significant move for this sector in Scotland. One aspect of its mission is to support the just transition to net zero emissions by 2045. State funding via organisations and funds like SNIB and the Circular Economy Investment Fund (CEIF) is vital for de-risking and attracting private investment in circular innovations[483]. CEIF has invested £12m in more than 60 circular economy projects, created over 70 local jobs and attracted £35m in match funding for innovative businesses. The Circular Economy Business Support service aids over 200 companies in critical sectors, fostering circular practices. Though they are early stages, there are also calls to align fiscal incentives and taxation to align with circular economy approaches. If adopted, these would further enable the net zero transition, and provide opportunities (e.g., advisory, consulting) in sustainable finance.

Export

Scottish financial services exports amounted to £3.9 billion in 2019, according to the Office for National Statistics. Scotland's sustainable finance exports rely on being an established global player in this broader financial services sector. With Scotland's finance sector demonstrating robust growth[484], exporting financial services from asset management to pension services will continue to be a strength of the Scottish NZCA economy[485].

Scottish financial exports have nearly doubled since 2011. Scotland is well positioned not only to export financial expertise, but also has a strong consulting and auditing presence, meaning a deep level of knowledge and requirements, as well as providing opportunities for firms to cross-sell other services to customers.

The sustainable finance export opportunity for the UK could be worth £8.6bn by 2030, as estimated by Confederation of British Industry. This demand is particularly from the EU where an estimated €470bn of green finance will be required each year by 2050[486]. Given another source cites Scotland's total financial and related professional services exports as £9.2bn in 2021[487], the share of the sustainable finance prize for Scotland could be significant.

As a result of the sector strengths and enabling environment, there is opportunity for Scotland to develop a first mover advantage in sustainable finance. For example, building on the strengths, if Scotland can become home to all elements of the investment cycle, it can support green technology companies to avoid the investment dessert which currently exists for scaling of innovations. Stakeholders noted that if the current gap in equity investors in green technologies is not bridged, there is a risk that our innovation

Economic Impact

Financial services contribute significantly to the Scottish economy, worth over £11bn, GVA in 2021. The transition to a NZ&CA economy provides significant opportunity for continued strong economic performance, through new sustainable investment products and services, better risk management though lower portfolio exposure to climate and nature risks, and addressing demand from other markets such as the EU. To do so, there needs to be confidence on the return on investment in terms of the pipeline of investible assets, and continued innovation and skills development to remain competitive.

The growth in sustainable finance in Scotland not only addresses individual and market demand but also improves resilience, as frameworks such as TCFD and the Taskforce on Nature-related Financial Disclosures (TNFD) promote robust risk management and adaptation to the changing economy. There are specific calls to action for pension funds and others to assess portfolio exposure to climate and nature related risks[488]. The threat of not addressing these risks could be catastrophic to any economy. The Bank of England estimated £110bn in additional losses for UK banks (projected out to 2050) in their disorderly transition scenario, and 50-70% higher losses for UK insurers in their highest climate risk scenario[489].

There has been dramatic growth in the global green finance market, from USD$5.2bn to $540.6bn between 2012 and 2021. In the UK green bond issuance grew from $1.1bn in 2012 to $37.4bn in 2021[490]. Scottish Financial Enterprise's (SFE) new finance sector growth strategy seeks to secure some of this opportunity by acting as an incubator for innovative product ideas, including establishing a net zero investment fund and exploring options for long-dated green infrastructure bonds.

The UK and Scotland's leadership in establishing regulatory frameworks and driving consumer and investor confidence is likely to provide opportunities for the Scottish financial sector. However, there is increasing competition from emerging financial centres, such as Singapore[491], most of which also share an ambition to lead in this area. Scotland needs a coordinated approach seize this opportunity in a way that is strategic and engages the wider economy.

In the short to medium term, attracting private finance will require a high level of public finance to mitigate these risks. Updates to UK schemes, such as Contracts for Difference, as well as other targeted blended finance tools can help lower risk and 'crowd in' lending and investment[492].

While local projects and assets are not crucial to a successful sustainable finance sector, there are clear co-benefits as well as an appetite from Scottish firms to invest locally where possible. There is also opportunity, and current evidence of, these local projects attracting international investment, with FDI into Scotland up 3.3% in 2022, compared to a UK decrease of 6.4%[493].

Jobs

Scotland's robust financial sector, spanning numerous businesses, demonstrates potential in both traditional and sustainable finance. It aspires to global leadership, attracting diverse job roles and distinguishing itself from hubs like London.

The Scottish financial services sector currently employs over 71,300 people across 4,500 businesses. Though the sector is already well established, employing a substantial amount of people, an increase in demand for sustainable finance has the potential to create and diversify jobs. This would also likely include growth in the services related to the financial sector, primarily auditing and regulatory services. The extent to which these jobs would offset or replace existing roles in the sector is unknown and requires further investigation. Scotland's Fintech roadmap[494] aims to create to deliver an additional 20,000 fintech related jobs, increasing from 8,500 in 2021.

If Scotland capitalised on its early mover position, and uses its tight knit community to its advantage, it could attract both a steady base of traditional finance jobs as well potential new jobs relating to sustainability.

Availability and quality of skills is a notable strength for Scotland's sustainable finance sector. According to QS rankings[495] Scotland has 3 of the top 100 universities in the world, each of these world class institutions offer a postgraduate course in sustainable finance. England, by comparison, has 8 universities ranked in the top 100 according to QS, with only 1 offering a postgraduate degree in sustainable finance. It is clear that, in the UK, Scotland is the leading centre of academic research and development in the field, providing both training for future employees and advantages for the Scottish sustainable finance sector.

Scotland therefore has the potential to become a destination for sustainability finance specialists. However, attention is needed for success to continue. In early 2022, Edinburgh was rated fifth in the world for human capital in the GFCI survey; it has since dropped to 16th. This downward trend has been captured in the new SFE strategy as a metric for improvement, but it will require action from more than just the sector itself if this issue is to be addressed across the economy.

R&D

Scotland's global recognition in financial innovation is fuelled by its leading Fintech clusters, academic prowess, and R&D tax benefits. Its smaller size facilitates networking and collaboration. The blend of top-tier universities and a robust finance sector fosters both theoretical and practical R&D in sustainable finance. With over 190 firms, Scotland's growing Financial Technology (or FinTech) hub presents an opportunity to position Scotland as a global leader in sustainable finance[496].

The UK has the joint most generous capital allowance regime in the OECD with a policy of full expensing from 1 April 2023 to 31 March 2026[497]. In 2023, the UK announced a higher rate of R&D Expenditure Credit, meaning that the UK's R&D tax relief for large companies has the joint highest uncapped headline rate in the G7 – and an increased rate of relief for loss-making R&D intensive SMEs. This impacts both the finance and related professional services and digital sectors but also the wider firms key to the net zero transition. Fostering a culture of innovation and using R&D to drive efficiency is crucial to meeting climate and nature targets. There was £305m invested in Fintech in 2022, a 200% increase on the previous year, and Fintech Scotland's target is for this to grow year on year[498]. The British Business Bank named Edinburgh, Fife and Midlothian region as the UK's second-top innovation cluster (by number of deals). In addition, Fintech Scotland has achieved Silver Cluster status as accredited by the European Secretariat for Cluster Analysis (ESCA)[499]. The recognition of these clusters demonstrates a strength for Scotland in financial innovation.

The combination of Scotland's universities and their sustainable finance and related courses, industry clusters and private sector organisations is another strength that can drive innovation and distinguish Scotland as a leader.

Finance and Nature Capital

Sustainable finance has an important role to play in the transition to a Net Zero and Climate Adaptation economy, through attracting and allocating capital on both a micro and macro level. The development of sustainable investment asset classes that allow investors to actively supporting firms and industries that are making headway to the NZ&CA economy presents a unique opportunity for Scotland to establish itself as a leader in sustainable finance.

Insurance companies have been pioneers in natural capital solutions funding[500], with notable examples in the UK like Aviva and AXA leading the way, although Scotland's presence in this area is not as prominent. Investment in this area requires a dual approach: bringing all funding sources to the table and finding ways to make them work together effectively.

The Scottish Government are committed to develop a values-led, high-integrity market for responsible private investment in natural capital. This commitment is supported by the Interim Principles for Responsible Investment in Natural Capital, which have been cited as illustrating good practice by the UK's Finance Nature Recovery initiative, and by the launch of the Facility for Investment Ready Nature in Scotland (FIRNS), a £1.8 million investment readiness fund.

Opportunity exists in carbon and nature credits market given Scotland's high-quality forest and peatland relative to the rest of the UK. Furthermore, the Woodland Carbon Code and the Peatland Code are internationally recognised high-quality standards for Nature-Based Solutions (NBS) projects and there is potential for them to underpin more developed carbon markets.

An enormous financing gap exists for nature preservation, to the scale of billions of pounds[501]. As the demand for high quality carbon offsets increases, if these offsets are structured with nature-related co-benefits, there is a win-win opportunity, helping to secure both decarbonisation and nature preservation, driven by Scottish financial institutions. Currently, there is a significant risk in terms of the opacity of the voluntary carbon market which must be addressed.

There is a threat that without providing investors with clearly defined targets, opportunities in nature-related investment will not be realised to their full potential. Similarly, the low awareness of circular economy principles in the investment community could limit investment into businesses focussed on circularity.

Appendix A Methodology

Project structure and stakeholder engagement

This project was structured with four distinct phases: Scoping, Mapping, Analysis (including stakeholder interviews), and Reporting. Throughout all phases a steering group, made up of Scottish Government and Scottish Enterprise staff, were consulted and guided the development of the project. In addition, a Peer Review Group was put together to provide a wider perspective at key points in the project. The purpose of this peer review group was to act as a strategic level sounding board, support wider engagement on the project outcomes and check the direction of the analysis and the overall conclusions. Their role was not to analyse or test the detail, nor was it to act as a decision-making body or sign off on the final report.

The peer review group membership was as follows:

- Just Transition Taskforce
- Prosper
- Scottish National Investment Bank
- Zero Waste Scotland
- Sniffer
- Climate Emergency Response Group
- Future Economy Scotland
- Highlands and Islands Enterprise
- Scottish Renewables
- Scottish Futures Trust
- Nesta

**Not all organisations participated in all Peer Review Group meetings*

In addition, a wide range of stakeholders were consulted in the drafting of the SWOT analyses. The organisations represented by these stakeholders are listed below, grouped by sector. Note some organisations and individuals were contacted for multiple sectors, and multiple Scottish Government and internal Ramboll experts were also consulted for numerous sectors.

- Onshore wind
    - Scottish Renewables
    - Scottish Enterprise
    - South of Scotland Enterprise
    - BVG Associates
- Offshore wind
    - Scottish Renewables
    - Scottish Enterprise
    - South of Scotland Enterprise
    - Net Zero Technology Centre
- Wave and Tidal
    - European Marine Energy Centre
- Hydrogen
    - Scottish Enterprise
    - Scottish Hydrogen and Fuel Cell Association
    - NECCUS
    - Net Zero Technology Centre
    - Energy Technology Partnership
- Carbon Capture, Use and Storage
    - NECCUS
    - Scottish Enterprise
- Low Carbon Fuels
    - European Marine Energy Centre
    - Scottish Enterprise
    - Glasgow University
- Heavy Duty Vehicles
    - Scottish Enterprise
- Forestry
    - Forestry and Land Scotland
    - CONFOR
    - John Clegg Consulting
    - Scottish Forestry
- Sustainable Building Materials
    - BE-ST
- Renewable Heat
    - Scottish Renewables
    - Nesta
- Professional Services
    - Skills Development Scotland
    - Scottish Engineering / Institute of Civil Engineers
- Sustainable Financial Services
    - SNIB
    - Baillie Gifford
    - Scottish Financial Enterprise
    - Global Ethical Finance
    - Lloyds Bank

Step-by-step methodology

Step 1 - Categorisation of the NZ&CA Economy

The scoping and mapping phases of the project included the identification of which sectors currently, and could in future, constitue Scotland's NZ&CA economy. This involved a wide ranging literature review and resulted in the development of a long list of sectors and subsectors. The term 'sector' is used here to reflect both market opportunities, technologies and traditional sectors. It should not be confused with standard sectoral definitions as outlined in official statistics.

The various categorisations are presented below and include consideration of how the cateogorisation is done within standard industry codes, Scotland's National Strategy for Economic Transformation (NSET), the Climate Change Plan, the Climate Emergency Skills Action Plan (CESAP), alongside the Low Carbon and Renewable Energy Economy (LCREE) data set.

This process allowed for the development of a long list of sectors to be further considered. This long list is shown in Figure 1.

Figure 1 - Long-list categorisation of the Scottish Net Zero and Climate Adaptation Economy.

UK Standard Industry Classification (SIC)

- Agriculture, forestry and fishing
- Mining and Quarrying Industries
- Manufacturing
- Electricity & Gas Supply
- Water Supply & Waste Management
- Construction
- Distribution, Hotels and Catering
- Transport, Storage and Communication
- Business Services and Finance
- Government, and Other Services

Climate Emergency Skills Action Plan (CESAP) priority areas

- Energy transition
- Construction
- Transport
- Manufacturing
- Agriculture and land use management

National Strategy for Economic Transformation (NSET) opportunity areas

- Renewable energy
- The hydrogen economy
- The decarbonisation of transport
- Space
- The "blue economy"
- Sustainable farming & forestry
- Financial services and fintech
- Industrial biotechnology
- Emerging technologies such as photonics and quantum technologies
- Digital technology
- Life sciences
- Food and drink innovation
- Creative industries and tourism

Climate Change Plan

- Electricity
- Buildings
- Transport
- Industry
- Waste and the circular economy
- Land use, land use change and forestry
- Agriculture
- Negative emissions technologies

Low Carbon and Renewable Energy Economy (LCREE) categorisation, as per the Office for National Statistics

- Offshore wind
- Onshore wind
- Solar
- Hydropower
- Other renewable electricity
- Bioenergy
- Alternative fuels
- Renewable heat
- Renewable combined heat and power
- Energy efficient lighting
- Energy efficient products
- Energy monitoring, saving or control systems
- Low carbon consultancy, advisory and offsetting services

Step 2 – Shortlisting of sectors

After rationalising the mappings into a long list of sectors, we carried out a shortlisting process, using a framework to document the decision-making process. This decision tree approach (see appendix) has been data driven where possible and considers, at a high level, the breadth / scalability of the opportunity for Scotland (e.g., job creation, export opportunity, enabling a just transition, a combination?). Next, the framework considers capabilities in the Scottish supply chain, particularly export capability.

This drew on, where appropriate, work carried out by Scottish Enterprise who assessed sectors' supply chain capabilities, largely using professional judgement and knowledge of specific businesses active in different sub-sectors. Assessments made by Scottish Enterprise give roughly equal weight to two factors – the capability of the Scottish sub-sector along its entire local supply chain, and its sub-sector export capabilities. They cover supply chain involvement in design and consultancy, capital, equipment and construction, operations and maintenance, local fuel supply, and the ability to leverage knowhow/resources of parts of the Scottish economy e.g., offshore oil and gas. Whilst this analysis was necessarily high level, it provided a systematic way to engage with a broad range of sectors and make choices about where to focus resource.

Next, the level of interdependencies with other sectors was considered. There was then the opportunity to have a final check for other impacts (e.g., grid balancing, driving innovation etc) which included consideration of what the horizon scanning told us about the longer-term trends or opportunities in the sectors. For a summary of the questions informing the decision tree approach, see Figure 2.

How broad is the economic NZ&CA opportunity in the sector?	This step considered the 'nature of the opportunity' and whether it might result in higher GVA, employment, turnover, business count, salaries, exports and imports. This was to ensure the sectors could yield economic potential at scale. The assessment results in "High" or "Low/Uncertain".
What is the Scottish supply chain capability?	This step uses Scottish Enterprise analysis* for available sectors, as well as a qualitative check of the depth of the Scottish supply chain (existing professional knowledge). For sectors with no SE metric (0-10), qualitative professional judgement is applied.
What is Scotland's export capability?	This step uses Scottish Enterprise analysis* for available sectors. For sectors with no SE metric (0-10), qualitative professional judgement is applied.
What is the level of interdependencies with other sectors?	This step ensures interdependencies with other sectors is included in the decision making process- i.e. is the sector/ subsector a key enabler for another?
Consequential impacts/ other qualitative checks	This final step in the decision tree considers any additional qualitative information that might be relevant to the decision. For instance grid balancing impacts, energy security, innovation.

Figure 2 - Overview of the questions informing the decision tree framework used.

While the framework provided some structure to the shortlisting of sectors to take into the SWOT, it cannot be viewed a providing clear 'In' or 'Out' categorisation. Rather, it should be viewed as a supporting and documenting exercise for the shortlisting process that included professional judgement.

Following this approach several sectors were identified. It is important to note that the following list does not represent a prioritisation of sectors, nor does it intentionally discount sectors. Rather, it intends to facilitate a comparable analysis of sectors to understand the scale of economic opportunities in certain parts of the Scottish economy. The following sectors were selected for further analysis.

Table 2 presents the shortlisted sectors alongside their definitions and NZ&CA opportunity areas covered according to the Scotland's National Strategy for Economic Transformation (2023). They are also categorised by type: infrastructure; goods and products; and services.

Table 2: Shortlisted Sectors for SWOT Analysis

Type of sector	Sector group	Subsector (where relevant)	Full definition	NSET opportunity area covered
Infrastructure	Wind	Onshore wind	The production of electricity from offshore wind. Includes all value chain stages, including the operation and maintenance of the infrastructure for producing electricity from offshore wind, and the businesses supplying all goods and services involved in the development and deployment of offshore wind. Renewable energy	Renewable energy
Infrastructure	Wind	Offshore wind	The production of electricity from onshore wind. Includes all value chain stages, including the operation and maintenance of the infrastructure for producing electricity from onshore wind, and the businesses supplying all goods and services involved in the development and deployment of onshore wind.	Renewable energy; the 'blue economy' (included as an NSET opportunity area rather than a full sector analysis)
Infrastructure	Hydrogen	N/A	The hydrogen sector includes blue and green hydrogen production, distribution, storage, and usage. Grey hydrogen is not included. Data often refers solely to green hydrogen, where this is the case, this is noted in the text	Renewable energy; the hydrogen economy; the decarbonisation of transport
Infrastructure	Renewable Heat	N/A	Scotland's renewable heat sector can be described as a collection of multiple niche markets. Heat pumps and heat networks are the focus of this SWOT given their prioritisation in multiple key documents.	Renewable energy
Infrastructure	Wave and Tidal	N/A	The production of electricity from wave and/or tidal sources. Includes all value chain stages, including the operation and maintenance of the infrastructure for producing electricity from wave and/or tidal sources.	Renewable energy; the "blue economy"
Infrastructure	Carbon Capture, Use and Storage	N/A	CCUS involves carbon capture from emitters and from the atmosphere, as well as storage, transport, and utilisation.	Emerging technologies such as photonics and quantum technologies(?)
Goods / products	Sustainable Transport	Low Carbon Fuels	The economic impact of the production of LCFs, including their production facilities and infrastructure. LCFs include biological and non-biological synthetic fuels of gaseous (biogas, blue and green hydrogen, and synthetic methane) and liquid (liquid biofuels, ammonia, and synthetic liquid hydrocarbon fuels) nature. Aviation LCFs are known as Sustainable Aviation Fuels (SAFs).	Renewable energy; the decarbonisation of transport

Type of sector	Sector group	Subsector (where relevant)	Full definition	NSET opportunity area covered
Goods / products	Sustainable Transport	Heavy Duty Vehicles	The economic impact of the design and manufacture of HDVs and their associated charging and refuelling infrastructure. Covers all large land vehicles excluding trains, from on-road heavy goods vehicles (HGVs), buses and coaches to off-road construction and agricultural vehicles. Supply chain data is provided where available.	Renewable energy; the decarbonisation of transport
Goods / products	Sustainable Building Materials	N/A	Sustainable building materials includes the production and manufacturing of new low-carbon materials to replace high-carbon products (including low carbon cement, bricks, insulation materials), the production and manufacturing of timber products, and the improved recycling of existing materials.	N/A
Goods / products	Forestry	N/A	The cultivation, conservation, and management of forests for timber production, biodiversity conservation, forest tourism, and provision of ecosystem services (including carbon sequestration for carbon credits). Includes activities from forest planning and management to the extraction of timber through logging and initial processing stages like sawmilling or chipping. The further processing of wood into final consumer goods, typically categorised under manufacturing or construction, is mentioned for context only and is mostly covered in the sustainable building materials SWOT.	Sustainable farming & forestry
Services	Sustainable services		The professional services sector spans the Scottish economy both horizontally across sectors and vertically along value chains. It includes engineering, planning and digital skills, and well as consulting and advisory services (financial services are analysed in their own SWOT). There may be overlaps with other parts of the NZ&CA economy.	Covers all NSET opportunities

Type of sector	Sector group	Subsector (where relevant)	Full definition	NSET opportunity area covered
Services	Sustainable services		Sustainable financial services in Scotland include asset management, consultation on sustainable finance frameworks and investments, and related professional services. The sector comprises traditional banks, insurance, life and pensions businesses, and wealth management, all headquartered in the UK. Quantitative data are for the financial sector as a whole, which may overestimate the size of the sector today.	N/A

Step 3 - SWOT analysis

The SWOT analyses were undertaken via research and stakeholder engagement. The stakeholders consulted have been listed above, and sources are provided in the SWOTs and Endnotes.

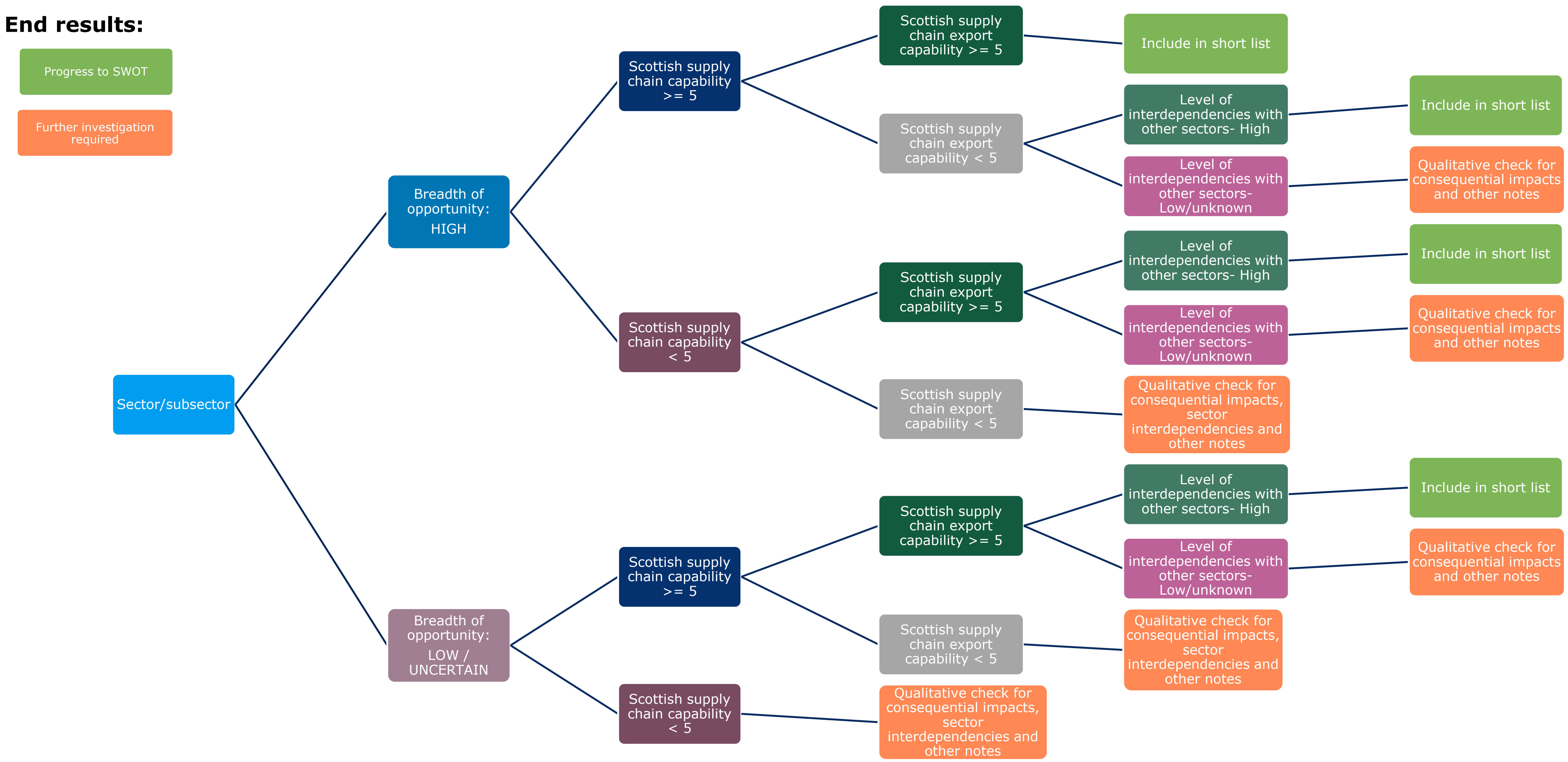
The sliders accompanying the SWOT analysis are derived from an internal and comparative assessment of sectoral performance across various aspects. In certain domains, such as Demand and Policy Support, the analysis leans on qualitative measures, relying on professional judgment and insights extracted from the SWOT analysis. Meanwhile, in areas like GVA and Jobs, the evaluation adopts a quantitative approach, comparing present and future Gross Value Added (GVA) and Full-Time Equivalents (FTEs) both within and across sectors.

The jobs and GVA projections presented in the SWOT analyses were created via scenario analyses where possible. Scottish Enterprise generated economic impact and carbon reduction scenarios over the period 2020-2050 for a range of low carbon transition technologies including renewable electricity generation, low carbon heat, low carbon transport, hydrogen and enabling technologies such as carbon capture and storage. These projections focus on the direct economic impacts arising from the delivery of Scotland's projected domestic transition and assume that existing relationships between key variables (such as turnover per head and GVA as a % of turnover) remain unchanged as sectors expand. As such, the projections do not account fully for potential increases in exports or Scottish content or for development of economies of scale or other dynamic shifts that may arise from improved technologies and processes.

Baseline data was sourced from the Office for National Statistics (ONS) Low Carbon and Renewable Energy Economy (LCREE). The future scenarios were from Scottish Power and Scottish and Southern Energy "Future Energy Scenarios" data (High case - Leading the Way and Low case - Falling Short). Scenarios for Scotland's largest industries supplemented this using NECCUS - Local Hydrogen Scenario (High case) and Soft Start (Low case) data. Economic data sources include the Fraser of Allander Institute's "The Economic Impact of Scotland's Renewable Energy Sector" study (2022), Scottish Annual Business Statistics and Department for Energy Security and Net Zero data for technology cost projections out to 2050.

For each technology, a "Low" and "High" deployment scenario has been projected in 5-year intervals over the period 2020-2050. These market forecasts were used to estimate future levels of Scottish investment, turnover, GVA, exports, jobs and emission reductions. Only the high deployment scenario is used in this analysis as presented in each SWOT analysis. For further detail on the scenario analysis developed by Scottish Enterprise, see endnote 5.

Figure 3 - The full decision tree.



Appendix B
SWOT abbreviations

SWOT abbreviations

BERD	Business enterprise research and development
CAPEX	Capital Expenditures
CCS	Carbon capture and storage
CCUS	Carbon capture, utilisation and storage
CESAP	Climate Emergency Skills Action Plan
CfD	Contracts for Difference
CITB	Construction Industry Training Board
CO2	Carbon dioxide
EGSS	Environmental Goods and Services Sector (from the ONS)
ESG	Environmental, social and governance
EU	European Union
ETS	Emissions Trading Scheme
FTE	Full-time equivalent
GDP	Gross domestic product
GVA	Gross value added
GW	Gigawatt
H2	Hydrogen
HDV	Heavy duty vehicles
HERD	Higher education research and development
HGV	Heavy Goods Vehicle
INTOG	Innovation and Targeted Oil & Gas
LCF	Low-carbon fuel
LCREE	Low carbon and renewable energy economy
LEVC	London Electric Vehicle Company
LNG	Liquefied Natural Gas
NBS	Nature-based solutions
NETs	Negative emissions' technologies
NSET	National Strategy for Economic Transformation
NZ&CA	Net Zero and Climate Adaptation
OECD	Organisation for Economic Co-operation and Development
OEM	Original equipment manufacturers
ONS	Office for National Statistics
R&D	Research and development
RD&I	Research, Development and Innovation
SABS	Scottish Annual Business Statistics
SAF	Sustainable aviation fuel
SATE	Sustainable aviation testing environment
SIC	UK Standard Industry Classification
SIM	Strategic investment model
SME	Small and medium-sized enterprises
STEM	Science, technology, engineering, and mathematics
SWOT	Strengths, weaknesses, opportunities and threats
TCO	Total Cost Ownership
TRL	Technology Readiness Level

Appendix C
End notes

Presented here are Endnotes which support the SWOT analyses. These Endnotes provide data sources and wider perspectives linked to statements made in the SWOT analyses, as appropriate. The links are correct as of January 2024.

- Onshore Wind
- Offshore Wind
- Wave and Tidal
- Hydrogen
- Carbon Capture, Utilisation and Storage (CCUS)
- Low Carbon Fuels (LCFs)
- Low Carbon Heavy Duty Vehicles (HDVs)
- Forestry
- Sustainable Building Materials
- Renewable Heat
- Professional Services
- Sustainable Financial Servics

Onshore Wind

1. LCREE, 2024, https://www.ons.gov.uk/economy/environmentalaccounts/datasets/lowcarbonandrenewableenergyeconomyfirstestimatesdataset.
2. Ramboll calculation, scaling Fraser of Allander Institute GVA figures which use 2021 LCREE data (https://fraserofallander.org/wp-content/uploads/2023/12/The-Economic-Impact-of-Scotlands-Renewable-Energy-Sector.pdf) against 2022 LCREE figures (https://www.ons.gov.uk/economy/environmentalaccounts/datasets/lowcarbonandrenewableenergyeconomyfirstestimatesdataset). Equation for 2022 GVA as follows = (2021 GVA / 2021 LCREE Turnover) x (2022 LCREE Turnover)
3. Scenario-based projections developed by Scottish Enterprise (2024). https://scottish-enterprise.com/media/e5vlpm4u/the-economic-impact-of-scotlands-energy-transition.pdf.
4. https://www.renewableuk.com/news/596321/New-poll-shows-majority-of-Scottish-voters-support-building-more-onshore-wind.htm; https://www.renewableuk.com/news/583064/Poll-shows-majority-of-people-in-Scotland-want-planning-system-to-enable-more-onshore-wind-farms-.htm#:~:text=Support%20is%20even%20higher%20among,than%20doubling%20our%20current%20capacity.
5. https://www.scottishrenewables.com/our-industry/statistics calculation using chart 5.
6. https://www.theccc.org.uk/wp-content/uploads/2020/12/Sector-summary-Electricity-generation.pdf.
7. https://www.gov.scot/binaries/content/documents/govscot/publications/strategy-plan/2023/09/onshore-wind-sector-deal-scotland/documents/onshore-wind-sector-deal-scotland/onshore-wind-sector-deal-scotland/govscot%3Adocument/onshore-wind-sector-deal-scotland.pdf.
8. Scottish Government's recent "Onshore wind: policy statement 2022" (https://www.gov.scot/publications/onshore-wind-policy-statement-2022/documents/) reaffirms its commitment to the development of 20GW of operational Scottish onshore wind by 2030.
9. https://www.renewableuk.com/news/596321/New-poll-shows-majority-of-Scottish-voters-support-building-more-onshore-wind.htm; https://www.renewableuk.com/news/583064/Poll-shows-majority-of-people-in-Scotland-want-planning-system-to-enable-more-onshore-wind-farms-.htm#:~:text=Support%20is%20even%20higher%20among,than%20doubling%20our%20current%20capacity.
10. https://www.data.gov.uk/dataset/a5b0ed13-c960-49ce-b1f6-3a6bbe0db1b7/renewable-energy-planning-database-repd; https://www.gov.scot/publications/onshore-wind-policy-statement-2022/documents/.
11. https://www.climatexchange.org.uk/media/5974/cxc-assessment-of-the-structure-conduct-and-performance-of-scotland-s-onshore-wind-offshore-wind-and-hydrogen-sectors-nov-2023.pdf.
12. https://www.scottishrenewables.com/our-industry/statistics.
13. https://www.gov.scot/binaries/content/documents/govscot/publications/strategy-plan/2023/09/onshore-wind-sector-deal-scotland/documents/onshore-wind-sector-deal-scotland/onshore-wind-sector-deal-scotland/govscot%3Adocument/onshore-wind-sector-deal-scotland.pdf.
14. The 4.5GW of consented but not yet built projects also includes 3.2GW of projects which rely on turbines of 150m – turbines which are increasingly rare as 180m turbines become the minimum size available on the global market. https://www.scottishrenewables.com/assets/000/002/108/Scottish_Renewables_Final_Response_Onshore_Wind_Policy_Statement_Refresh_2021_Consultative_Draft_28.01.22_original.pdf?1643622916.
15. The increasing size of turbines is associated with a number of technical and regulatory issues, notably related to grid connection but also including issues such as obtaining sufficient traffic and policing support for the transport of abnormal loads and the issue of "oversail", where land access rights are required when turbine components pass over the land at the side of a road, leading to expensive and time consuming negotiations with landowners (https://www.gov.scot/publications/onshore-wind-strategic-leadership-group-minutes-15-march-2023/).
16. https://www.zerowastescotland.org.uk/resources/future-onshore-wind-decommissioning-scotland.
17. https://www.gov.scot/publications/onshore-wind-sector-deal-scotland/pages/8/.
18. One regulatory bottleneck example from the past includes the exclusion of onshore wind from the CFD scheme from 2015, as the UK Government prioritised other, more nascent sectors for investment. This exclusion was temporary, however, and results from September 2021's bidding round revealed that nine projects totalling approximately 1GW of new onshore wind projects were successful, with all nine located in Scotland https://windeurope.org/newsroom/press-releases/repowering-europes-wind-farms-is-a-win-win-win/.
19. https://www.scottishrenewables.com/assets/000/002/108/Scottish_Renewables_Final_Response_Onshore_Wind_Policy_Statement_Refresh_2021_Consultative_Draft_28.01.22_original.pdf?1643622916.

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27. https://www.ons.gov.uk/economy/environmentalaccounts/datasets/lowcarbonandrenewableenergyeconomyfirstestimatesdataset
28. https://www.zerowastescotland.org.uk/resources/future-onshore-wind-decommissioning-scotland.
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30. See https://www.climatexchange.org.uk/research/projects/economic-analysis-of-scotland-s-wind-and-hydrogen-sectors/. Vivid Economics also highlight the potential for the export of components (https://www.vivideconomics.com/casestudy/benefits-of-onshore-wind-to-the-uk/#:~:text=Our%20new%20report%2C%20Quantifying%20the,a%20%C2%A3360m%20export%20industry.).
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Hydrogen

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135. NZTC (2023) Hydrogen Backbone Link - Connecting Scotland to Europe. Available at: https://www.netzerotc.com/reports/hydrogen-backbone-link-report/ (Accessed 28 September 2023).

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137. Net Zero Technology Centre (2023) Hydrogen Backbone Link, Aberdeen: Net Zero Technology Centre. Available at: https://www.netzerotc.com/reports/hydrogen-backbone-link-report/ (Accessed: 29 September 2023).

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142. The Aberdeen Hydrogen Hub (n.d.) Hydrogen in Scotland: skills and qualifications gap analysis. Aberdeen. Available at: https://assets.ctfassets.net/ttigp4bhhbqp/36JUUOlkbBPC3az26MsUX6/370eee4c2e57f5c75a7305f2cd16ae3c/Hydrogen_in_Scotland_-_Skill___Qualifications_gap_analysis_booklet.pdf (Accessed 28 September 2023).

143. Robert Gordon University (2021) UK Offshore Energy Workforce Transferability Review. Available at: http://www.rgueti.com/wp-content/uploads/2021/05/workforce-transferability-report.pdf (Accessed 28 September 2023).

144. Analysis by Scottish Enterprise. Robert Gordon University (2021) UK Offshore Energy Workforce Transferability Review. Available at: http://www.rgueti.com/wp-content/uploads/2021/05/workforce-transferability-report.pdf (Accessed 28 September 2023).

145. Hydrasun Hydrogen Skills Academy launches energy transition training solutions (2023) Available at: https://www.nof.co.uk/news/2023/october/hydrasun-hydrogen-skills-academy-launches-energy-transition-training-solutions/ (Accessed 24 November 2023).

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Carbon Capture, Utilisation and Storage (CCUS)

148. https://www.gov.uk/government/publications/participating-in-the-uk-ets/participating-in-the-uk-ets

149. https://www.gov.scot/binaries/content/documents/govscot/publications/strategy-plan/2023/01/draft-energy-strategy-transition-plan/documents/draft-energy-strategy-transition-plan/draft-energy-strategy-transition-plan/govscot%3Adocument/draft-energy-strategy-transition-plan.pdf p.185

150. https://www.gov.scot/binaries/content/documents/govscot/publications/progress-report/2023/05/climate-change-monitoring-report-2023/documents/climate-change-plan-monitoring-reports-2023/climate-change-plan-monitoring-reports-2023/govscot%3Adocument/climate-change-plan-monitoring-reports-2023.pdf page 155 and 9

151. https://www.gov.scot/policies/oil-and-gas/carbon-capture-utilisation-and-storage/ 2023-11-08

152. https://www.gov.scot/binaries/content/documents/govscot/publications/strategy-plan/2023/01/draft-energy-strategy-transition-plan/documents/draft-energy-strategy-transition-plan/draft-energy-strategy-transition-plan/govscot%3Adocument/draft-energy-strategy-transition-plan.pdf p.146

153. https://www.scottish-enterprise.com/media/4319/ccus-economic-impact-assessment-report.pdf

154. https://www.gov.scot/binaries/content/documents/govscot/publications/strategy-plan/2023/01/draft-energy-strategy-transition-plan/documents/draft-energy-strategy-transition-plan/draft-energy-strategy-transition-plan/govscot%3Adocument/draft-energy-strategy-transition-plan.pdf p.14
155. https://www.scottish-enterprise.com/media/4319/ccus-economic-impact-assessment-report.pdf p.1
156. https://www.gov.scot/binaries/content/documents/govscot/publications/strategy-plan/2023/01/draft-energy-strategy-transition-plan/documents/draft-energy-strategy-transition-plan/draft-energy-strategy-transition-plan/govscot%3Adocument/draft-energy-strategy-transition-plan.pdf p.121
157. Stakeholder interview.
158. https://www.iea.org/reports/putting-co2-to-use 2023-11-08
159. https://www.gov.scot/binaries/content/documents/govscot/publications/strategy-plan/2023/01/draft-energy-strategy-transition-plan/documents/draft-energy-strategy-transition-plan/draft-energy-strategy-transition-plan/govscot%3Adocument/draft-energy-strategy-transition-plan.pdf p.167
160. https://www.scottish-enterprise.com/media/4319/ccus-economic-impact-assessment-report.pdf p.77
161. https://www.scottish-enterprise.com/media/4319/ccus-economic-impact-assessment-report.pdf p.77
162. https://www.energy-system-and-just-transition-independent-analysis.co.uk/summary-report.pdf
163. Interview EMEC. And https://www.gov.scot/binaries/content/documents/govscot/publications/strategy-plan/2020/10/shaping-scotlands-economy-scotlands-inward-investment-plan/documents/scotlands-inward-investment-plan-shaping-scotlands-economy/scotlands-inward-investment-plan-shaping-scotlands-economy/govscot%3Adocument/scotlands-inward-investment-plan-shaping-scotlands-economy.pdf p.49
164. https://www.gov.scot/binaries/content/documents/govscot/publications/research-and-analysis/2022/10/building-new-scotland-stronger-economy-independence/documents/building-new-scotland-stronger-economy-independence/building-new-scotland-stronger-economy-independence/govscot%3Adocument/building-new-scotland-stronger-economy-independence.pdf p.78.
165. https://storegga.earth/news/2021/news/scottish-cluster-expected-to-deliver-20-600-jobs-in-the-next-decade 2023-11-09
166. https://www.scottish-enterprise.com/media/4319/ccus-economic-impact-assessment-report.pdf
167. https://www.gov.scot/policies/oil-and-gas/carbon-capture-utilisation-and-storage/ 2023-11-08
168. https://www.scottish-enterprise.com/media/4319/ccus-economic-impact-assessment-report.pdf p.1.
169. https://www.gov.scot/binaries/content/documents/govscot/publications/strategy-plan/2020/10/shaping-scotlands-economy-scotlands-inward-investment-plan/documents/scotlands-inward-investment-plan-shaping-scotlands-economy/scotlands-inward-investment-plan-shaping-scotlands-economy/govscot%3Adocument/scotlands-inward-investment-plan-shaping-scotlands-economy.pdf p.6 (executive summary).

Low Carbon Fuels (LCFs)

170. UK policy – RTFO Scheme, Jet Zero Strategy, SAF Mandate, Advanced Fuels Fund, UK maritime decarbonisation policy, UK Hydrogen Strategy. Scottish policy – Bioenergy Action Plan; Hydrogen Action Plan; Carbon Neutral Islands; Aviation Strategy (consultation). https://www.climatexchange.org.uk/research/projects/low-carbon-transport-fuels-an-evidence-review/
171. The Department for Transport's "Low carbon transport fuels: DfT Science Advisory Council position paper" highlights a number of LCF topics including environmental issues, system issues, security and resilience of supply, infrastructure considerations, and future costs and economics. The paper also recognises the need to develop an evidence base on potential constraints on feedstock supply, competing demands from other energy intensive sectors, and the carbon emissions saved over the whole life cycle of a fuel from production to point of use.
172. https://www.evaluationsonline.org.uk/evaluations/Search.do?ui=basic&action=show&id=816
173. https://www.climatexchange.org.uk/media/5135/cxc-understanding-opportunities-for-developing-a-scottish-co2-utilisation-economy-february-2022.pdf
174. In the long run, power-to-liquid is seen as the main production route for SAF, but the technologies to do so are still relatively immature. https://www.evaluationsonline.org.uk/evaluations/Search.do?ui=basic&action=show&id=816
175. https://www.icao.int/environmental-protection/LTAG/Documents/REPORT%20ON%20THE%20FEASIBILITY%20OF%20A%20LONG-TERM%20ASPIRATIONAL%20GOAL_en.pdf
176. Particular sensitivities are development of green hydrogen and carbon capture infrastructure in Scotland https://www.climatexchange.org.uk/research/projects/low-carbon-transport-fuels-an-evidence-review/
177. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1137149/RTFO_Compliance_Guidance_2023_Final.pdf/.
178. Crop-based biofuels tend to have the highest carbon intensity due to the significant emissions associated with crop cultivation e.g., from fertilizer use, land use change (potentially). Hydrogen, methanol, and drop-in hydrocarbons produced from renewable electricity (i.e., RFNBOs other than ammonia) tend to have the lowest carbon intensity. The carbon intensity of waste-based fuels is largely dependent on the emissions from the conversion process. https://www.climatexchange.org.uk/research/projects/low-carbon-transport-fuels-an-evidence-review/
179. https://www.climatexchange.org.uk/research/projects/low-carbon-transport-fuels-an-evidence-review/
180. Seven LCFs are currently approved for use in the aviation sector, currently certified to be blended with conventional aviation fuel at volumes of up to 50%. The are currently no operational or planned SAF facilities in Scotland and very limited uptake of the fuels. https://www.climatexchange.org.uk/research/projects/low-carbon-transport-fuels-an-evidence-review/

181. This limit has been set due to the lower aromatic content in SAF compared with conventional fuel, which reduces the efficiency of aircraft system sealing materials. There have been several demonstration flights using 100% SAF, but further work needs to be performed before 100% SAF blends can be certified https://www.evaluationsonline.org.uk/evaluations/Search.do?ui=basic&action=show&id=816.

182. Stakeholders consulted noted that synthetic fuels also provide the potential to eliminate limits, due to reduced contamination risk, but the technology required to produce these fuels is not yet operational.

183. The IATA stated that in 2021 airlines "purchased every drop of the 125m litres of SAF that was available" despite its price being at least 2 to 4 times higher than that of conventional aviation fuel. This industry demand comes even though there is little SAF currently supplied into any of Scotland's airports, although stakeholders signalled a desire to transition towards it. https://www.evaluationsonline.org.uk/evaluations/Search.do?ui=basic&action=show&id=816

184. https://www.evaluationsonline.org.uk/evaluations/Search.do?ui=basic&action=show&id=816

185. https://www.gov.uk/government/consultations/mandating-the-use-of-sustainable-aviation-fuels-in-the-uk

186. In particular, stakeholders concern surrounding UK Government commitment to the Contracts for Difference (CfD) approach, and the consequential lack of incentives for any industry not currently mandated to adopt SAF to do so. https://www.evaluationsonline.org.uk/evaluations/Search.do?ui=basic&action=show&id=816

187. Building a 500kt p.a. plant is estimated to cost £500m-£1bn and take around five years to complete. https://www.evaluationsonline.org.uk/evaluations/Search.do?ui=basic&action=show&id=816

188. Many feedstocks needed to produce LCFs for transport can also be used to decarbonise heat/power generation, creating both domestic and international competition. For example, lignocellulosic feedstocks are essential to Scotland's bioenergy carbon capture and storage (BECCS) ambitions and residual waste is used extensively in energy from waste facilities. For synthetic LCFs, the competition is for green renewable electricity. https://www.climatexchange.org.uk/research/projects/low-carbon-transport-fuels-an-evidence-review/

189. DfT have recently closed a consultation on the subject, and the ReFuelEU Maritime proposal is under consideration in the European parliament. https://www.climatexchange.org.uk/research/projects/low-carbon-transport-fuels-an-evidence-review/

190. The International Maritime Organisation (IMO) has set concrete emissions reductions targets to 2030 and 2050. These legislation and policy drivers define a clear requirement for decarbonisation and are already influencing sector behaviour. CO2 emission reduction is becoming a key factor in the selection of new vessel power systems, with clear evidence of a transition to alternative, greener fuels in new ship orders. https://www.evaluationsonline.org.uk/evaluations/Search.do?ui=basic&action=show&id=817

191. To add to their first, operational, methanol-powered vessel, Maersk have announced an extra 24 methanol-powered vessels on order for delivery between 2024 and 2027 https://www.maersk.com/news/articles/2023/09/08/equinor-and-maersk-partner-to-supply-first-methanol-enabled-container-vessel

192. https://www.climatexchange.org.uk/research/projects/low-carbon-transport-fuels-an-evidence-review/

193. https://www.climatexchange.org.uk/media/5135/cxc-understanding-opportunities-for-developing-a-scottish-co2-utilisation-economy-february-2022.pdf

194. Stakeholders also raised the potential for Scotland's existing infrastructure to grow in significance in the coming decades, as climate change impacts open potential northern trade routes.

195. A point made by multiple stakeholders consulted.

196. SAF production is already happening, elsewhere in the globe, and will continue to grow, however the window of opportunity to be part of this is narrowing – if action is not taken soon, it will be too late, others will capture the market, leaving Scotland in the role of buyer, which will inevitably drive up the cost of aviation. https://www.evaluationsonline.org.uk/evaluations/Search.do?ui=basic&action=show&id=816

197. Scenario-based projections developed by Scottish Enterprise (2024). https://scottish-enterprise.com/media/e5vlpm4u/the-economic-impact-of-scotlands-energy-transition.pdf.

198. https://www.evaluationsonline.org.uk/evaluations/Search.do?ui=basic&action=show&id=816

199. European and UK policy drivers are expected to create distinct markets for synthetic fuels including those derived from CO2. The ReFuelEU initiative contains a notable proposal for renewable fuels of non-biological origin to account for 5% of aviation fuel by 2035 and 28% by 2050, representing a large export opportunity for Scotland. https://www.climatexchange.org.uk/media/5135/cxc-understanding-opportunities-for-developing-a-scottish-co2-utilisation-economy-february-2022.pdf

200. https://www.climatexchange.org.uk/media/5135/cxc-understanding-opportunities-for-developing-a-scottish-co2-utilisation-economy-february-2022.pdf

201. https://www.climatexchange.org.uk/media/5135/cxc-understanding-opportunities-for-developing-a-scottish-co2-utilisation-economy-february-2022.pdf

202. Scenario-based projections developed by Scottish Enterprise (2024). https://scottish-enterprise.com/media/e5vlpm4u/the-economic-impact-of-scotlands-energy-transition.pdf.

203. Biofuel supply chain management in the circular economy transition: An inclusive knowledge map of the field (2022). Available at: https://www.sciencedirect.com/science/article/abs/pii/S0045653522004611

204. LCF data within the Office for National Statistics' Low Carbon and Renewable Energy Economy database is staggered across "Alternative Fuels" and "Bioenergy", the latter of which is heavily influenced by the use of solid biomass used to generate heat or electricity and thus not relevant for LCFs.

205. Chemical-based goods include basic chemicals – e.g., organics / inorganics, fertilisers, industrial gases, plastic, rubber and man-made fibres (much of which is reliant on North Sea oil); pharmaceutical/fine chemicals; and speciality chemicals e.g., specialist organics / inorganics, additives, pesticides, paints and dyes. Source – Scenario-based projections developed by Scottish Enterprise (2024). https://scottish-enterprise.com/media/e5vlpm4u/the-economic-impact-of-scotlands-energy-transition.pdf.

206. https://assets.publishing.service.gov.uk/media/620ce902d3bf7f4f04b2b51e/low-carbon-fuels-strategy-call-for-ideas.pdf;https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/932933/renewable-fuel-statistics-2019-final-report.pdf.

207. Scenario-based projections developed by Scottish Enterprise (2024). https://scottish-enterprise.com/media/e5vlpm4u/the-economic-impact-of-scotlands-energy-transition.pdf.

208. Scenario-based projections developed by Scottish Enterprise (2024). https://scottish-enterprise.com/media/e5vlpm4u/the-economic-impact-of-scotlands-energy-transition.pdf.

209. https://fraserofallander.org/publications/the-economic-impact-of-scotlands-renewable-energy-sector-2022-update/

210. Scenario-based projections developed by Scottish Enterprise (2024). https://scottish-enterprise.com/media/e5vlpm4u/the-economic-impact-of-scotlands-energy-transition.pdf.

211. https://www.evaluationsonline.org.uk/evaluations/Search.do?ui=basic&action=show&id=816

212. https://iuk.ktn-uk.org/transport/aviation/

213. https://www.evaluationsonline.org.uk/evaluations/Search.do?ui=basic&action=show&id=816

214. These are expected to be high-skilled jobs, with opportunities to develop new expertise in Scotland. CO2 utilisation has potential to support rural and island communities, and expertise from the petroleum and refining sector could be repurposed for synthetic fuel production, protecting at-risk skills. https://www.climatexchange.org.uk/media/5135/cxc-understanding-opportunities-for-developing-a-scottish-co2-utilisation-economy-february-2022.pdf

215. Scenario-based projections developed by Scottish Enterprise (2024). https://scottish-enterprise.com/media/e5vlpm4u/the-economic-impact-of-scotlands-energy-transition.pdf.

216. https://www.ons.gov.uk/economy/environmentalaccounts/datasets/lowcarbonandrenewableenergyeconomyfirstestimatesdataset.

217. Scenario-based projections developed by Scottish Enterprise (2024). https://scottish-enterprise.com/media/e5vlpm4u/the-economic-impact-of-scotlands-energy-transition.pdf.

218. https://assets.publishing.service.gov.uk/media/620ce902d3bf7f4f04b2b51e/low-carbon-fuels-strategy-call-for-ideas.pdf

219. https://www.e4tech.com/uploads/files/final-report-aviation-abdc-feasibility-study-issue-v1-0.pdf

220. Synthetic plants produce 210kt and 440kt of synthetic crude and methanol, respectively. Additional job creation would be expected in the manufacture and construction of key equipment, as well as in the operational jobs related to the utilities used by the facility (electricity and green hydrogen production). https://www.climatexchange.org.uk/media/5135/cxc-understanding-opportunities-for-developing-a-scottish-co2-utilisation-economy-february-2022.pdf

221. Synthetic plants produce 210kt and 440kt of synthetic crude and methanol, respectively. Additional job creation would be expected in the manufacture and construction of key equipment, as well as in the operational jobs related to the utilities used by the facility (electricity and green hydrogen production). https://www.climatexchange.org.uk/media/5135/cxc-understanding-opportunities-for-developing-a-scottish-co2-utilisation-economy-february-2022.pdf

222. Research opportunities include microbial design, selection and characterisation; microbial growth technologies; catalyst and electrode developments; energy efficiency and process optimisation; and production application development. https://www.climatexchange.org.uk/media/5135/cxc-understanding-opportunities-for-developing-a-scottish-co2-utilisation-economy-february-2022.pdf

223. https://www.gov.uk/government/publications/low-carbon-transport-fuels-dft-science-advisory-council-position-paper/low-carbon-transport-fuels-dft-science-advisory-council-position-paper#:~:text=Summary%20of%20SAC%20recommendations,-Successful%20decarbonisation%20of&text=Low%20carbon%20fuels%20offer%20notable,with%20little%20or%20no%20modification

224. https://www.gov.uk/government/consultations/mandating-the-use-of-sustainable-aviation-fuels-in-the-uk

225. https://www.evaluationsonline.org.uk/evaluations/Search.do?ui=basic&action=show&id=816

226. Stakeholder interviews. Also, see https://www.climatexchange.org.uk/media/5135/cxc-understanding-opportunities-for-developing-a-scottish-co2-utilisation-economy-february-2022.pdf

Low Carbon Heavy Duty Vehicles (HDVs)

227. Off-road HDVs are particularly diverse. They are typically split into two major categories (agricultural including tractors, loaders, combine harvesters, sprayers and other specialised products, and construction including excavators, cranes, pile drivers, loaders, dumpers, compactors, spreaders and planers) https://www.scottish-enterprise.com/media/4062/zehdv_market-intelligence-mining-lowcvp-2.pdf.

228. https://www.gov.scot/publications/transition-transport-sector-discussion-paper/documents/ .

229. In particular, note the Zero Emission Truck Taskforce (ZETT), which comprises leaders across road haulage and logistics operators, manufacturing, energy, and finance sectors to identify the hurdles and opportunities offered by the transition to zero emission trucks https://www.gov.scot/publications/transition-transport-sector-discussion-paper/documents/.

230. The Bus Decarbonisation Taskforce has also been set up, bringing together senior leaders from bus, energy, and finance sectors in Scotland https://www.transport.gov.scot/our-approach/mission-zero-for-transport/.

231. Examples of funding, from Scottish Government directly or through Transport Scotland, include: over £113m to support the roll-out of zero-emission buses; over £85m through the Low Carbon Transport Loan to help people and businesses make the switch to ultra-low emission vehicles; £65m to grow Scotland's accessible public electric vehicle charging network (ChargePlace Scotland); over £60m in 3500 vehicles across the public sector fleet; and £7m in two new transport innovation projects focusing on decarbonising HDVs (one based at the LOCATE facility at the Michelin Scotland Innovation Parc in Dundee, the other at the Power Networks Demonstration Centre (part of the University of Strathclyde) https://www.transport.gov.scot/our-approach/mission-zero-for-transport/.

232. Other funding examples provided in recent years, from zero emission charging systems to the feasibility of lithium-sulphur flow batteries, include: £28m for zero emission HDVs in 2022 https://www.transport.gov.scot/news/28-million-for-zero-emission-heavy-duty-vehicles/, https://www.scottish-enterprise-mediacentre.com/news/gbp-28-million-for-zero-emission-heavy-duty-vehicles; £7m for zero emission mobility innovations in 2021 https://www.strath.ac.uk/whystrathclyde/news/2021/7millionforzeroemissionmobilityinnovations/; £720k to help decarbonise heavy transport in 2021 https://www.deadlinenews.co.uk/2021/12/14/720k-to-help-decarbonise-scottish-heavy-transport/; £560k in 2023 to support the decarbonisation of HDVs https://www.scottishconstructionnow.com/articles/specialist-funding-to-help-decarbonise-heavy-duty-vehicles.

233. Examples of this niche manufacturing is highlighted through Scottish companies' manufacturing of buses, refuse collection vehicles, earth moving vehicles, emergency vehicles, and marine vessels. Scotland is also noted to be at the forefront of the demonstration and deployment of electric and hydrogen technologies and infrastructure. https://www.gov.scot/publications/transition-transport-sector-discussion-paper/documents/.

234. https://www.transport.gov.scot/publication/meeting-setting-the-task-zero-emission-truck-taskforce-4-may-2022/industry-overview-and-swot-analysis/.

235. https://www.transport.gov.scot/publication/skills-for-low-carbon-heavy-duty-vehicles-hdvs/.

236. Almost all HGVs registered in Scotland are still powered by conventional (ICE) powertrains, with only 20 ULEV HGVs registered by the end on 2021, constituting less than 0.1% of the total https://www.transport.gov.scot/publication/meeting-trials-and-supply-chain-zero-emission-truck-taskforce-23-june-2022/impacts-on-the-supply-chain/.

237. Low carbon, in this instance, including battery electric, fuel cell electric, direct hydrogen combustion (both dual fuel with diesel and pure hydrogen), biomethane and pantograph systems (which provides power via fixed overhead cables similar to the operation of electric trams and trains). https://www.transport.gov.scot/media/50464/skills-for-low-carbon-hdvs-pdf.pdf

238. https://www.transport.gov.scot/publication/skills-for-low-carbon-heavy-duty-vehicles-hdvs/.

239. https://www.transport.gov.scot/publication/meeting-setting-the-task-zero-emission-truck-taskforce-4-may-2022/industry-overview-and-swot-analysis/.

240. https://www.transport.gov.scot/publication/skills-for-low-carbon-heavy-duty-vehicles-hdvs/.

241. In HDV and off-road segments, product development and replacement cycles typically span 8-10 years due to lower volumes necessitating longer production periods for investment payback, and high durability and reliability requirements leading to lengthy pre-manufacture testing. Manufacturers are risk-averse due to costs associated with product failures and warranty repairs, and reputational risks. New suppliers must offer clear advantages in cost, reliability, durability, customer experience, and compliance with legislation. https://www.scottish-enterprise.com/media/4062/zehdv_market-intelligence-mining-lowcvp-2.pdf.

242. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1097246/impact-assessment-bus-end-of-sales.pdf

243. https://www.transport.gov.scot/media/52921/total-costs-of-ownership.pdf

244. 'Stranded assets' refers to assets that lose value due to changes associated with the energy transition (e.g., an alternative technology becomes more competitive, impacting the value of companies' assets associated with "the wrong" technology). https://www.transport.gov.scot/publication/meeting-setting-the-task-zero-emission-truck-taskforce-4-may-2022/industry-overview-and-swot-analysis/.

245. https://www.transport.gov.scot/publication/meeting-setting-the-task-zero-emission-truck-taskforce-4-may-2022/industry-overview-and-swot-analysis/.

246. Around 90% of licence holders have ten vehicles or less registered on their licence and 8% have between 11 and 50 vehicles registered. Based on this same data, it is estimated that around 2% of licence holders operate over 35% of vehicles https://www.transport.gov.scot/publication/meeting-setting-the-task-zero-emission-truck-taskforce-4-may-2022/industry-overview-and-swot-analysis/.

247. Current OEMs and production in Scotland: Emergency One in Cumnock (all electric fire engine); Farid Hillend in Dunfermline (a wide range of specialised waste and refuse collection and handling vehicles from 7.5T to 32T); Volvo (Rokbak) in Cumnock (large rigid and articulated haulers, typically for mining and heavy construction industries) https://www.scottish-enterprise.com/media/4062/zehdv_market-intelligence-mining-lowcvp-2.pdf.

248. The Transition Paper for Transport identifies Scottish sector strengths in battery and energy storage, on-road HDVs, greener railways and hydrogen-powered vehicles. It also notes that Scotland is well placed to attract inward investment from companies seeking to grow in these sectors. https://www.gov.scot/publications/transition-transport-sector-discussion-paper/documents/.

249. Alexander Dennis Ltd has been at the forefront of innovation in zero emission buses, leading the market in the development in double decker battery and hydrogen powered vehicles with specialised international partners https://www.sdi.co.uk/business-in-scotland/find-your-industry/energy-industries/low-carbon-transport.

250. https://www.transport.gov.scot/publication/meeting-trials-and-supply-chain-zero-emission-truck-taskforce-23-june-2022/impacts-on-the-supply-chain/.

251. Current supply chain companies and production in Scotland: AMTE Power in Thurso (Li-ion battery cell manufacturer); Artemis Intelligent Power in Edinburgh (digital displacement efficiency hydraulic pumps & valves); Bosch Rexroth in Glenrothes (UK's largest supplier, produces a wide range of hydraulics, electric drives and industrial power solutions, major supplier to construction and agricultural machinery sector); Clas-Sic Silicon Carbide in Lochgelly (power electronics) https://www.scottish-enterprise.com/media/4062/zehdv_market-intelligence-mining-lowcvp-2.pdf.

252. https://www.transport.gov.scot/publication/meeting-trials-and-supply-chain-zero-emission-truck-taskforce-23-june-2022/impacts-on-the-supply-chain/.

253. High volume manufacturing capability may be important for supply chain firms as OEMs increase production. Scottish firms currently only have low to medium volume capabilities. Companies surveyed also highlighted the need for capital investment to fund manufacturing facilities https://www.transport.gov.scot/publication/meeting-trials-and-supply-chain-zero-emission-truck-taskforce-23-june-2022/impacts-on-the-supply-chain/.

254. A recent survey of Scottish companies found that, while main companies are unaware of the relevant supply capabilities in Scotland, growing demand for a more developed supply chain for zero emission HDVs represents an opportunity for Scotland to increase its market share in the future https://www.transport.gov.scot/publication/meeting-trials-and-supply-chain-zero-emission-truck-taskforce-23-june-2022/impacts-on-the-supply-chain/ .

255. There are opportunities for the UK to establish competitiveness in manufacturing if it secures production incentives, demand for zero emission vehicles and alignment with the European Single Market and EU emissions regulations. Related growth opportunities in the supply chain include production of chemical inputs for batteries and software platforms for mobility services https://www.lse.ac.uk/granthaminstitute/publication/seizing-sustainable-growth-opportunities-from-zero-emission-passenger-vehicles-in-the-uk/.
256. New technologies are forecasted to account for more than two-thirds of required emissions reductions by 2045 https://www.transport.gov.scot/publication/meeting-setting-the-task-zero-emission-truck-taskforce-4-may-2022/industry-overview-and-swot-analysis/
257. https://foe.scot/resource/report-on-the-move/.
258. Transport Scotland suggest that supply chain pressure is delivering uptake of low carbon HDVs, especially for food and drink retailers. https://www.transport.gov.scot/publication/skills-for-low-carbon-heavy-duty-vehicles-hdvs/
259. https://www.transport.gov.scot/publication/meeting-setting-the-task-zero-emission-truck-taskforce-4-may-2022/industry-overview-and-swot-analysis/.
260. In the medium term (2020-2040+) significant CO2 savings of 85-90% are possible using low carbon fuels such as biomethane and biodiesel, operating in largely conventional ICE powertrains. Both fuels are undergoing rapid growth, especially in on-road HGVs, but to achieve zero emissions, the primary choices are either battery electric or hydrogen fuel cells. https://www.scottish-enterprise.com/media/4062/zehdv_market-intelligence-mining-lowcvp-2.pdf.
261. For example, a JCB "backhoe" excavator diesel fuel tank holds 150L and weighs about 150kg when full. Current HDV battery technology requires a battery weighing over 3 tonnes, approximately 20x the mass of the diesel tank and 10x the volume. Larger machines such as the Volvo dump trucks built in Motherwell have diesel tanks up to 500L, so the issue is even more acute. Hydrogen represents a lighter alternative, however a 150L diesel engine equivalent would still require 600kg of high-pressure cylinders https://www.scottish-enterprise.com/media/4062/zehdv_market-intelligence-mining-lowcvp-2.pdf.
262. Heavy vehicles on the road towards the circular economy: Analysis and comparison with the automotive industry - ScienceDirect.
263. https://www.transport.gov.scot/publication/meeting-trials-and-supply-chain-zero-emission-truck-taskforce-23-june-2022/impacts-on-the-supply-chain/.
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265. The four UK-based commercial vehicle manufacturers (Dennis Eagle, London Electric Vehicle Company (LEVC), Leyland Trucks and Vauxhall) exported almost 60% of their production, with almost all of this going to the EU https://www.transport.gov.scot/media/52214/impacts-on-the-supply-chain.pdf.
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