UNIVERSITY of STRATHCLYDE
CENTRE FOR ENERGY POLICY

SNZR
Scottish Net Zero Roadmap

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# Policy Brief

## Scottish Net Zero Roadmap

## Emerging Societal, Economic and Policy Opportunities and Challenges


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### Introduction

- The Scottish Net Zero Roadmap (SNZR) project is part of a Government funded challenge to develop net zero industrial clusters by 2040. The aim is to develop a roadmap to show how the industrial cluster along Scotland's East Coast can be decarbonised.

- Six decarbonisation scenarios (described in the appendix and noted below) have been set out in the SNZR project and will be used to establish a series of costed net zero pathways for the range of sites within the Scottish industrial cluster.

The scenarios include:

1. Infrastructure Led
2. Soft Start
3. Regional $H_2$ Network
4. National $H_2$
5. Renewables Push
6. $CO_2$ Shipping

- In this briefing we explore the **emerging societal, economic and policy opportunities and challenges** across the scenarios that the SNZR project is currently considering. In doing so, we draw on the Centre for Energy Policy's (CEP) policy expertise in public policy-facing economic research alongside the early outputs emerging from the SNZR roadmap and a policy review process (see Appendix A).[1] The briefing has also been informed by engagement with project partners, steering group members and a number of targeted bi-lateral meetings. Supporting the summary briefing an assessment of each of the six scenarios can be found in the Appendix B.

- A key takeaway message from our analysis emerges around **the need to consider how activities set out in the roadmap deliver against a range of societal outcomes**, such as those set out in the Scottish Government's National Performance Framework,[2] if the route to industrial transition is to be socially and politically, as well as technically feasible. Here, the roadmap can act as a strategic tool and catalyst to enable discussions around the most sustainable and equitable pathway for the industrial sector and broader societal transition to net zero emissions.

> We explore the key and emerging societal, economic and policy opportunities and challenges of key elements of each of the six scenarios. This is drawn from CEP's expertise and foundation of public policy-facing economic research and engagment with key stakeholders"

# Emerging findings

## Societal challenges and opportunities

### Regional economic and social impacts

- Across the range of scenarios presented, both regionally and nationally focussed solutions have been identified. Whilst regional solutions may provide the most efficient technical delivery (particularly where existing infrastructure is utilised or repurposed), questions arise around fairness, and whether regionally focussed solutions will bring solely regional economic benefits and/or whether tensions may arise across the Scottish Government's 'Just Transition'[3] and the UK Government's 'levelling up'[4] agendas. **Crucially, where firms in critical employment, income generation and supply chains within a region are required to bear the direct cost burden of decarbonisation, the challenges of passing on those costs could trigger processes that involve negative economic and societal outcomes for workers and communities in that region.** This issue should be a major consideration for those tasked with the delivery of a 'Just Transition'.

### Transitory and sustained job creation

- Although further research is required to identify the employment potential associated with different scenarios set out in the roadmap, and the extent to which associated job creation will be transitory (linked to project delivery) or more sustained, **it is clear that all scenarios indicate the potential for job creation associated directly and indirectly with additional industrial activity.** Scenarios reliant on CCS and blue hydrogen production could facilitate the utilisation of workers employed in the oil and gas industry and associated supply chains on an on-going basis where new service activities such as the transport and storage of $CO_2$ creates opportunities in meeting new needs in the transitioning economy over sustained timeframes.[5] On the other hand, **scenarios reliant on renewable electricity generation and green hydrogen production may create jobs in what could be considered new and emerging components of the existing electricity sector,** noting that sustained job creation in renewable activity has proved challenging to date.[6] Here, the growth of the offshore renewables could lead to new supply chain development that has the potential to represent a blend of the employment structures currently associated with the electricity and oil and gas sectors. Depending on which pathway emerges, this may have implications for the skills and training required for new and transitioning workers, an issue recognised by the Green Jobs Taskforce.[7]

### Jobs transition

- This latter point is a key one for further investigation. With a large existing workforce with the skills and expertise to work in an offshore environment,[8] Scotland could be well placed to lead the industrial transition required to support the marine sector's role in future energy and economic system development, setting an international example across almost all decarbonisation actions set out in the roadmap. However, **challenges may still exist around retraining and maintaining desirable options for workers**, who have traditionally had the ability to be highly mobile in working internationally, in securing jobs of desirable quality and rates of pay. While increasing real wages for the UK workforce is a clear aim of Government, this introduces potential tensions and trade-offs given that, certainly in the absence of productivity gains, wage pressures could have cost and price implications across the transitioning economy. This may be a particular displacement concern where different growing sectors within the industrial and energy landscape, such as offshore wind and nuclear power generation, could create a significant demand for workers with similar skills and expertise as those needed to facilitate industrial decarbonisation activities. **Ensuring the sufficient supply of appropriately skilled labour across all scenarios should be a key focus for devolved and national Government.**

> Firstly and most importantly, where firms are supported to decarbonise at existing locations, their current economic contribution will be safeguarded. This has important implications for the existing supply chains and that they support in the wider economy.

### Societal acceptance

- Given the scale of the industrial decarbonisation challenge, and the need for Government funding to support key activities in a number of the scenarios, it is crucial that societal acceptance is identified as a key component in delivering the challenge of industrial decarbonisation. **Here an industrial strategy that takes account of and considers important social narratives that recognises the priorities and needs of people in different communities and regions could play an important role in facilitating decarbonisation in a complex political landscape.** Ultimately, policymakers should also ensure that the actions taken forward are supported locally, regionally and nationally, particularly where this involves deployment of new industrial infrastructure. This will require close collaboration and planning between project developers, local authorities, national decision makers and third party groups such as local development trusts and community groups.

## Economic challenges and opportunities

### Competitiveness challenges

- Across each of the scenarios, key economic challenges emerge that centre around the need for industries to directly and/or indirectly absorb the additional costs of decarbonisation. **No matter what decarbonisation option is adopted, the challenge with any 'polluter pays' type approach is always that industry will attempt to pass these costs onto consumers.** Where consumers have no choice but to absorb impacts on a wide range of consumer prices across the economy, this could affect demand patterns for other goods and services, and the risk of creating a new complex set of potential 'carbon poverty' issues. Where consumers can act to reduce their demands for more expensively produced goods and services, industries bearing decarbonisation costs risk losing competitiveness in both domestic and international markets. This basic economic thinking can become very real for firms operating in competitive international markets, particularly where process industries export outputs into complex global supply chains and the ability to pass on additional costs via prices may be limited. This brings risks of emissions, jobs, and investment leakage.[9] **In short, any loss in international competitiveness brings a risk of offshoring.**[10] In addition to simply shifting the location of emissions, leakage or offshoring risks losing a proportion or ultimately all of the sustained economic contribution that these industries provide to the Scottish and UK economies.

- The UK Government, who are largely responsible for industrial policy in Scotland, recognises this challenge, and, indeed is in the process of implementing subsidy schemes that give transitional support to firms to cover the additional costs associated with the adoption of CCS.[11] Similarly, where fuel switching may involve, at least initially, exposure to the impacts of what may be higher energy supply costs, refinement of existing mechanisms such as 'contracts for difference' (CfD) may come into play. **Importantly, however, a firm's ability to engage with the regulatory process and source the upfront capital needed to cover the costs of additional equipment and infrastructure, which may or may not be provided through UK or Scottish Government capital programmes, may vary significantly.** Ultimately, reduced or no Government support will be needed in situations where i) markets emerge for green products, ii) international competitors move to decarbonise and face the same costs and/ or iii) early mover UK firms can develop some competitive advantage in operating new technologies and processes.

### Opportunities for exporting services

- The scenarios presented in SNZR also set out a number of key economic opportunities. Firstly, and most importantly, **where firms are supported to decarbonise at existing locations, their existing local, regional and national economic contribution can be safeguarded.** This has important implications for the existing supply chains and those that they support in the wider economy. Secondly, across all scenarios, opportunities exist to attract new industry and export

*The net zero principles can be used as a reference against different decarbonisation pathways.*


1. **Understanding who really pays, how and when,** and what gains can be used to balance this is fundamental

2. We need to find pathways that allow us to sustain and **grow our prosperity in an equitable way**

3. Finding options and pathways that can deliver **near term economic returns** is crucial – especially in a post-Covid economic environment

4. **'Offshoring' is not the answe**r if it only shifts emissions, jobs and GDP overseas

5. Net Zero is a **societal and public policy challenge** more than it is a technological one

$CO_2$ from other nations, services for greenhouse gas removals, exporting expertise and services for floating offshore wind, and exporting hydrogen are key examples. **Here, interest in such UK services, such as geologically storing non-domestic $CO_2$ through infrastructure proposed at the key industrial clusters, is already quickly developing and is driven by, what is regarded to be, a strong regulatory framework and subsidy scheme in the UK.**

- Servicing some extent of external (export) demand for industrial services also reduces domestic funding requirement in deploying and operating new low carbon activities, thereby reducing the extent to which Government needs to draw on public budgets and/or transfer costs to UK households or clustered Scottish industry in supporting such activity. Ultimately this can improve wider economy outcomes associated with developing costly new infrastructure.[12] Opportunities for emerging economic opportunities should continue to be an important consideration for the roadmap and for policymakers more generally.

## Policy challenges and opportunities

### Supportive policy frameworks

- The UK is playing a leading role internationally in designing policy to support industrial decarbonisation. As discussed earlier in this briefing, current policy is centred around /focusses on the design of business models to support the commercialisation of CCUS and hydrogen production. If designed and implemented effectively, these could support the decarbonisation of the UKs industrial base. Additionally, if suitable policy frameworks are established, Scotland and the UK could be well placed to attract new industries which could further contribute to the Scottish and UK economies. **That is, there is a potential to 'onshore' new activity where Scotland and the wider UK can become a more carbon efficient and generally productive (and commercially viable) location in a 'net zero world'.** However, some challenges still exist around how the support for industries to decarbonise will be funded, and for how long, ahead of international markets for green products or an effective carbon price emerging. Supporting industries at dispersed sites, outside of the recognised industrial clusters and where connection to core infrastructure may be difficult (e.g. for $CO_2$ transport and storage) also presents a particular policy challenge which is not unique to Scotland.

- It is also clear that some activities in the roadmap, such as $CO_2$ shipping, $CO_2$ utilisation and hydrogen transport have less well developed policy frameworks and may not progress until a time when commercially viable options come forward. Similarly, it is also less clear how policy frameworks and business models to support industrial firms to fuel switch will materialise over the short to medium term. **Ultimately this less developed policy landscape may mean that other options with more developed policies (such as CCS) may emerge first.** However, for industrial processes that could utilise alternative fuels (e.g. hydrogen), the ability to ultimately utilise green hydrogen in process equipment means that interest in this option is growing. Having said that, the availability of technology (such as hydrogen turbines), and more generally how quickly hydrogen supply (both blue and green) can support demand (both industrial and residential) will be crucial in determining what decarbonisation option is most commercially and technically feasible.

### Government coordination

- As industrial policy is largely reserved to the UK Government, the decarbonisation of industrial sites in Scotland will be largely supported by policy decisions made by the UK Department for Business, Energy and Industrial Strategy (BEIS). Decisions such as the phasing of CCUS clusters,[13] where the Scottish Cluster was not selected for Phase 1, but has been assigned to an accelerated Phase 2 timescale, will play a critical role in how the industrial landscape in Scotland evolves. Here some concerns have been raised around the impact that any delay in supporting the Scottish Cluster in Phase 1 could have on the UKs ability to meet carbon reduction targets[14] alongside challenges around supply chain capacity and competitiveness of Scottish industrial sites within the UK.

- **It is clear that a collaborative approach between Scottish and UK Governments will be essential to effectively delivering industrial decarbonisation.** Although industrial policy is reserved, the Scottish Government are also supporting industrial decarbonisation through a number of capital funds. For example, the £315m Scottish Industrial Energy Transformation Fund (SIETF)[15] is designed to incentivise investment in existing energy intensive sectors to support fuel switching and energy efficiency especially, and to attract the manufacturing industries of the future. It is also clear that Government action alone cannot deliver industrial decarbonisation. Industries themselves will have to play a leading role in developing and delivering emerging technologies, financing projects, and attracting the required labour.

**A whole systems-based approach**

- A strategic whole systems-based approach (i.e., encompassing both energy and economic systems) will be needed to consider how policy decisions across different sectors will interact and influence outcomes nationally. **Across the scenarios presented in the roadmap, it is apparent that policy decisions in linked but separate sectors of the economy may be an important factor in how the industrial landscape in Scotland ultimately develops.** The decarbonisation of heat in residential homes is a key example. Here, the picture for the supply and demand for hydrogen across the economy will vary hugely depending on whether, to what extent, and over what timeframes hydrogen may play a role in servicing domestic heating requirements.

## A need to focus on outcomes – a theory of change approach

- The SNZR project is focussed on understanding a range of decarbonisation pathways for Scotland's industrial base. **However, it is crucially important for decision makers to reflect on what kind of destination might be desirable and acceptable across society – i.e., what are the outcomes and consequences for people's lives?** Thus, while it is entirely appropriate for the SNZR project to focus on identifying technical solutions to reduce emissions, especially in its early stages, **it is important going forward that the roadmap and the decision makers that use it as a tool, consider how activities set out will impact a wide range of economic and societal outcomes.** For example, Scotland's National Performance Framework (NPF)[16] presents national outcomes under 11 key themes.

These include:

| | |
|---|---|
| ■ children and young people | ■ environment |
| ■ communities | ■ health |
| ■ culture | ■ human rights |
| ■ economy | ■ international |
| ■ education | ■ poverty |
| ■ fair work and business | |

- Understanding the impact on a wide range of outcomes impacting citizens and stakeholder groups concerned with each and all of these themes will be crucial for **delivering a sustainable and equitable transition to a mid-century society that meets net zero emissions obligations**, whilst also addressing a range of other challenges.

- Here, we suggest a theory of change approach should be adopted by decision makers. This involves describing the desired outcomes and working backwards to understand what activities and actions are needed to get there in **an affordable, feasible and socially acceptable way**, and to identify future research and cross-sector collaborations in ways that effectively address the complex challenges involved. This outcome-based approach around industrial policy is being adopted by both the Scottish and UK Governments. For example the National Planning Framework 4 (NPF4)[17] presents the goal of delivering 'Green Industrial Green Transition Zones' and under their 'Clean Growth' Grand Challenge,[18] BEIS have set a mission to establish the world's first net zero carbon industrial cluster by 2040 and at least one low-carbon cluster by 2030. However, we suggest that these industrially focussed outcomes could also be broadened to consider wider societal outcomes such as those described in the NPF.

> It is crucially important for decision makers to reflect on what kind of destination might be desirable and acceptable across society – i.e., what are the outcomes and consequences for people's lives?

## References

1 A slide deck supporting this review process is available on request from CEP and is summasired in Appendix A (cep@strath.ac.uk).
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4 Levelling Up the United Kingdom. https://www.gov.uk/government/publications/levelling-up-the-united-kingdom
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## Appendix A - High-level policy review

A high level policy review was undertaken to understand the level of policy support present for each key decarbonisation activity. A gap analysis was undertaken and each decarbonisation activity given a Red (R) Amber (A) Green (G) status. As can be seen in Table 1 below, Hydrogen production, $CO_2$ capture, $CO_2$ storage, $CO_2$ transport, fuel switching and energy effiency were given amber status - meaning policy support was in a design/implementation phase but had not yet materialised into delivery/action. Hydrogen transport, $CO_2$ utilisation and GHG removals were given a red status as policy support was yet to be in the design/implementation phase, with any Government support currrently focused on more targeted R&D activity.

Table 1 - Gap analysis of policy support for key decarbonisation activites

| Key Decarbonisation Activity | Supporting Policy | Gap / Status | Status (RAG) |
|---|---|---|---|
| Hydrogen production | 1,2,3,4,5,12,14,16 | Policy frameworks in design/consideration to support commercialisation | |
| Hydrogen transport | 9,12,14,16 | Limited policy support for hydrogen transport. Limited support may be incorporated in gas network company business plans | |
| Co2 capture | 1,6,5,8,10,11,14,15 | Policy frameworks in design/consideration to support commercialisation | |
| Co2 storage | 1,5,7,8,10,11,14,15 | Policy frameworks in design/consideration to support commercialisation | |
| Co2 transport | 1,5,7,8,10,11,14,15 | Limited policy support/frameworks for CO2 shipping and associated infrastructure | |
| Co2 utilisation | 1,5,8,14,15 | Little policy support for CO2 utilisation – likely to be commercially driven | |
| GHG removals | 1,13 | Policy support focussed on R&D and not yet commercial deployment | |
| Fuel switching | 1,10,12,13,14 | Policy development in early stages and reliant on increased supply of hydrogen or electricity | |
| Energy efficiency | 1,10,14 | Policy frameworks in early stages – likely to be commercially driven | |

Table 2 - Supporting reference list

| Tag | Policy | Published |
|---|---|---|
| 1 | Industrial Decarbonisation Strategy | BEIS, March 2021 |
| 2 | Design of a business model for low carbon hydrogen (consultation) | BEIS, August 2021 |
| 3 | Hydrogen Strategy | BEIS, August 2021 |
| 4 | Hydrogen Policy Statement | SG, December 2020 |
| 5 | Ten Point Plan for a green industrial revolution | UK Gov, November 2020 |
| 6 | CCUS Business Models (update) – Carbon Capture | BEIS, May 2021 |
| 7 | CCUS Business Models (update) – Transport and Storage | BEIS, May 2021 |
| 8 | Cluster Sequencing for CCUS (phase 2 update) | BEIS, May 2021 |
| 9 | Scotland's electricity and gas networks: vision to 2030 | SG, March 2019 |
| 10 | Securing a green recovery on a path to net zero: climate change plan 2018–2032 - update | SG, December 2020 |
| 11 | Scotland Energy Strategy Position Statement | SG, March 2021 |
| 12 | Draft Hydrogen Action Plan | SG, November 2021 |
| 13 | Net Zero Review | HMT, October 2021 |
| 14 | Net Zero Strategy: Build Back Greener | BEIS, October 2021 |
| 15 | CCUS Economics Impacts Study | SG, November 2021 |
| 16 | Business Models for Low Carbon Hydrogen Production | BEIS, August 2020 |

## Appendix B - Scenario assessment

## Scenario 1: Existing Infrastructure Led

This scenario serves as a 'base' considering current policies and trends. Its main focus is on using and repurposing existing infrastructure, 'an approach that focuses on making maximum "early" impact on today's emissions'.

- This scenario focuses on the prompt delivery of CCS and other energy infrastructure projects in Scotland.
- It focuses on the repurposing of gas feeder pipelines for transmission of energy and emission carriers, and an early deployment of large blue hydrogen production sites at St. Fergus and Grangemouth.
- It assumes that these are taken to completion at pace, permitting appropriate industrial sites to decarbonise when these emissions mitigation options become viable. The largest emitters are addressed roughly in size order, with St. Fergus, Grangemouth and Fife resolved, via particular exploitation of CCUS to remove fossil fuel combustion and process emissions.
- Following this early period, green hydrogen is assumed to be deployed utilising the existing offshore wind build out from the Fife coast.

| Opportunities | Challenges |
|---|---|
| **Social**<br>• Shifting towards hydrogen can help reduce building heating emissions in population centres near the clusters.<br>• Transitioning through the production and use of blue hydrogen and CCS transport and storage will help to safeguard industrial jobs that otherwise may be lost.<br>**Economic**<br>• Reusing existing infrastructure can reduce capex requirements<br>• New economic activity due to the creation of the hydrogen and CCS sectors, plus a change in activity for the current oil and gas, and the construction sector for the repurposing of infrastructure.<br>• Early development could kick-start these new industries, creating demand for hydrogen and CCS, and producing skill and expertise, which can be exported and help develop competitive advantage in operationalising low carbon solutions.<br>**Policy**<br>• Regional, bottom-up focus for developments and policies, potentially bringing social and economic benefits to local communities.<br>• The production of blue hydrogen creates an important case for the implementation of CCS at these clusters, which in turn will facilitate and encourage industrial decarbonisation. | **Social**<br>• The extent of hydrogen fuel switching for heat (in %) and the cost of blue (and green) hydrogen, and thus the impact to the consumer, is unclear.<br>• Policies need to ensure that jobs are created and filled in local areas and to the benefit of local areas, this will be crucial to social acceptance of CCUS.<br>**Economic**<br>• High % of hydrogen for heat would need changes in boilers/appliances and also potentially to existing gas infrastructure.<br>• The focus on CCS makes the role of energy efficiency more limited for industrial decarbonisation.<br>• Relying on existing infrastructure could limit long term growth of the CCS and hydrogen industries, which in turn, may hinder the transition of jobs from the oil and gas sectors.<br>**Policy**<br>• Early action will require policy support/government subsidies in regional clusters to avoid competitiveness loss and to allow learning-by-doing for first mover activities<br>• Regional focus will require 'buy-in' from local government and communities. Policy support need to ensure this. |

## Scenario 2: Soft start

Overall, this is a very similar scenario to the 'Infrastructure led' one, but with a slightly different time scale. CCS takes longer to develop and implement, therefore other sectors receive an earlier boost. The clusters rely on other forms of fuel switching and energy efficiency to compensate the delay of CCS.

- This scenario follows a similar overall strategic direction to the Infrastructure Led scenario. However, progress on major $H_2$ projects and existing pipeline (feeder) repurposing in particular is slower.
- To compensate as emissions targets become more onerous and carbon costs increase, a more site-oriented strategy develops, with individual sites essentially incentivised to invest in cost-effective interventions, such as efficiency measures and Net Zero compliant fuel-switches (potentially including a greater role for bioenergy and an earlier start for green hydrogen).
- The late availability of pipeline $CO_2$ removal options necessitates some degree of interim shipping / rail solutions. In this scenario, green hydrogen production is in the two main locations along the Scottish East Coast with existing and future offshore wind build out – Fife and the North Aberdeenshire coast.

| Opportunities | Challenges |
|---|---|
| **Social**<br>• Potential for job creation in new emerging sectors such as hydrogen production from offshore wind and energy efficiency<br>**Economic**<br>• In this scenario, green hydrogen and biofuels will have a stronger presence earlier. Also energy efficiency measures will be implemented, boosting these sectors.<br>• Skill and expertise from the green hydrogen can be exported and help develop competitive advantage in operationalising low carbon solutions.<br>• Alternative $CO_2$ transport would create new economic activity (shipping, rail) with long term potential for the shipping and $CO_2$ import sectors.<br>**Policy**<br>• $CO_2$ shipping could complement the CCS industries when available, allowing for the import of $CO_2$ from other sites in the UK and overseas for management and storage, creating further value to the economy. | **Social**<br>• The site-focused approach could mean that the 'benefits' of using new technologies and fuels may only apply to the clusters and it will take longer to extend to other areas.<br>• The delay in CCS deployment could put supply chains and jobs associated with the oil and gas industry at risk.<br>**Economic**<br>• The delay in CCS and repurposing infrastructure could lead to reduce activity in the construction and oil and gas sectors. Some jobs in these sectors could be at risk.<br>• The interim $CO_2$ transport options, in the form of shipping and/or rail, would potentially involve extra cost, and brings the risk of long-term redundant assets. However, it could also enable the $CO_2$ shipping and storage sector for imports.<br>**Policy**<br>• The delay on CCS and blue hydrogen comes with an increased activity on energy efficiency, renewables (offshore wind), green hydrogen and biofuels. Therefore, retraining programmes and policies will be key to allow for jobs to be transferred across sectors.<br>• Emerging policy frameworks are not as clear on how $CO_2$ shipping will be supported, regulated and enabled. |

## Scenario 3: Regional $H_2$ Network

This scenario expands from the 'infrastructure led' one, still repurposing existing infrastructure, with a stronger focus on developing a larger hydrogen industry within the region.

- In this scenario hydrogen strategies are planned and developed at a regional level at the 3 larger sub clusters within the study area: St. Fergus, Grangemouth, Fife.
- The aim is that hydrogen production and demand will be largely temporally balanced within each region. This leads to an increased focus on how each sub-cluster can achieve Net Zero in its own way and utilising local opportunities and resources (more circularity).
- Industrial fuel switches are oriented towards hydrogen due to ready availability of fuel via local distribution networks. There is some degree of shipping of hydrogen out of the region, but this is focused at St Fergus. The sub-cluster nature of hydrogen deployment creates greater opportunity for $CO_2$ capture beyond core process emissions and the potential need for greater shipping of $CO_2$ into large storage locations.

| Opportunities | Challenges |
|---|---|
| **Social**<br>• Shifting towards hydrogen in regions near the cluster can help reduce heating and public transport emissions, also improving air quality.<br>• The use of hydrogen for residential heat is potentially less disruptive than electrification.<br>**Economic**<br>• Economic activity by creating hydrogen networks at demand centres near clusters. Potential for job creation and transfer for the oil and gas, and construction sectors.<br>• Production of green hydrogen at a quicker pace, boosting the offshore wind sector and the economic activity around its supply chains.<br>• The shipping of (blue) hydrogen will kick-start the shipping industry, also allowing for $CO_2$ shipping and related export services.<br>**Policy**<br>• The production and use of blue hydrogen creates an important case for the creation of CCS at scale, facilitating industrial decarbonisation<br>• Alignment with the 'green growth' and 'levelling up' agendas, promoting regional development. | **Social**<br>• This scenario suggests the creation of dedicated hydrogen pipeline networks, so population centres will be using 100% hydrogen, requiring changes in boilers/appliances.<br>• The localised approach on hydrogen use could create discrepancies in cost for different consumers. Those near the clusters may have to pay more for their heating than those lacking access to hydrogen.<br>**Economic**<br>• The cost of blue (and green) hydrogen, in addition to new network and appliances costs, is likely to be greater than the status quo and the electrification alternative, and thus, impacting the consumers ability to pay for essential services.<br>**Policy**<br>• A large-scale appliance replacement programme will be needed to enable the use of hydrogen for heating.<br>• Retraining programmes and policies will be key to allow for jobs to be transferred across sectors. |

## Scenario 4: National $H_2$

This scenario is a larger more ambitious version of the 'regional $H_2$' one, with an even stronger focus on developing a very large hydrogen industry to meet all types of demands.

- In this scenario, Scotland contributes substantially to an overall UK hydrogen-focused switching strategy incentivised by government that covers use of $H_2$ in other sectors such as power, transport, homes and commerce.
- Scotland's existing fossil infrastructure alongside onshore and offshore wind development delivers both blue and green hydrogen production and distribution relatively early, with industry and non-industry migrating to hydrogen solutions as appropriate.
- The scenario is highly interconnected, both to England via hydrogen pipelines (used to balance hydrogen supply and demand) and potentially to Europe via ships. Local supply of $H_2$ can greatly exceed local use.

| Opportunities | Challenges |
|---|---|
| **Social**<br>• Repurposing infrastructure would boost activity on the oil and gas and construction sectors, allowing for a more gradual jobs and activity transition to the hydrogen and CCS industries.<br>• The use of hydrogen for residential heat is potentially less disruptive than electrification.<br>**Economic**<br>• Production of green hydrogen to complement blue H2, boosting the offshore wind sector and related supply chains.<br>• New economic activity due to the creation of hydrogen and CCS sectors, also allowing for job transitions from oil and gas sector.<br>• $CO_2$ shipping could complement the CCS industries when available, allowing for the importation of $CO_2$ from other sites in the UK and overseas for management and storage, creating further value to the economy.<br>**Policy**<br>• National, more integrated focus for developments and policies, potentially creating greater overall impact.<br>• The increased demand for blue hydrogen would need the creation of CCS at scale, serving not only the cluster demand but the increasing production of blue hydrogen for residential heating across the UK.<br>• Alignment with the 'green growth' and 'levelling up' agendas | **Social**<br>• This scenario suggests a very large extent of use for residential hydrogen. So some populations centres will be using 100% hydrogen, and this would need changes in boilers/appliances.<br>• Hydrogen use could create discrepancies in cost for different consumers. Those with access to hydrogen may pay more for their heating than those lacking access.<br>**Economic**<br>• This scenario will need the creation of dedicated hydrogen pipeline networks and 'transmission' networks to balance production and demand between regions. This will require larger investments, which will translate to higher costs to consumers.<br>• The cost of blue (and green) hydrogen, in addition to new network and appliances costs, needs investigation, so we can assess the impact to the consumer.<br>**Policy**<br>• A large-scale appliance replacement programme will be needed to enable the use of hydrogen for heating.<br>• Retraining programmes and policies will be key to allow for jobs to be transferred across sectors.<br>• Policies to capitalise on IP and skills creation on the shipping, CCS and hydrogen sectors will be required. |

## Scenario 5: Renewables Push

This scenario also follows a national strategy but focusing more on renewables than in CCS deployment.

- This scenario focuses on a holistic, strategic promotion of renewables, promoting electrification and green hydrogen early on, although some blue hydrogen (predominantly via known projects) is developed initially.
- This is done mainly via wind generation, but also through successful bioenergy deployment. As with the National $H_2$ scenario, widespread availability of clean hydrogen allows disparate sites to decarbonise at the emitting site rather than extensively using CCS to transport away large volumes of $CO_2$; CCUS infrastructure is still required and largely supports mitigation of large point sources, process emissions and deployment of BECCS rather than continued use of fossil fuels.

| Opportunities | Challenges |
|---|---|
| **Social**<br>• The use of green hydrogen and CCS will help decarbonise industrial clusters, allowing to keep industrial jobs that otherwise may have been lost.<br>• Potential for job transfer from the oil and gas, and construction sectors to the renewables sector.<br>**Economic**<br>• The offshore wind farms in the northeast will see considerable investments and economic growth in the region.<br>• Big push for energy efficiency and electrification (HP installation). Important job creation opportunities in those sectors to be able to keep up with demand.<br>• $CO_2$ shipping could complement the CCS industries when available and power generation using BECCS.<br>**Policy**<br>• National focus for developments and policies to push on renewables, with the potential of greater positive impacts. | **Social**<br>• This scenario suggests a large extent of use electrification and green hydrogen. Where and how the fuel switching will occur is unclear, but it is likely that hydrogen use will focus on industrial process and transport, and less so for residential heat.<br>• The localised approach on hydrogen use could create discrepancies in cost for different consumers. Those near the clusters may have to pay more for their heating than those lacking access to hydrogen.<br>• New jobs and supply chains need to be sourced locally, avoiding off-shoring jobs, to maintain and grow value in the communities.<br>**Economic**<br>• The economic transition to the renewables and low carbon heat sectors needs to take place rapidly to meet targets and demand, this will require large public and private investments, and may create labour constraint issues.<br>• Specialised workforce will be needed, and it is key that those jobs are sourced locally, to ensure community acceptance.<br>**Policy**<br>• Retraining programmes will be required for the large-scale rollout of heat pumps and building retrofitting.<br>• A comprehensive set of policies to support the electrification of services will be required. |

## Scenario 6: $CO_2$ shipping

This scenario focuses on developing a $CO_2$ shipping industry, allowing for $CO_2$ imports. Repurposing of infrastructure is more limited.

- In this scenario, an extensive $CO_2$ shipping solution is used to deal with emerging and persistent challenges to pipeline strategies.
- The investment in port and harbour infrastructure lead to a strategy wherein Scotland maximises the utilisation of its $CO_2$ storage sites by taking in emissions from other UK clusters and from Europe.
- This is further extended by the development of onshore 'bunker' $CO_2$ storage for shipping creates, allowing for smaller emitters to freight $CO_2$ to the dockside. The relative cost of $CO_2$ shipping and relatively high availability of pure $CO_2$ streams also encourages focused application of $CO_2$ utilisation to create useful feedstocks.

| Opportunities | Challenges |
|---|---|
| **Social**<br>• The use of green hydrogen and CCS will help decarbonise industrial clusters, allowing to keep industrial jobs that otherwise may have been lost.<br><br>**Economic**<br>• $CO_2$ shipping will kick-start the shipping industry, also allowing for $CO_2$ imports from other sites in GB and overseas.<br>• Repurposing infrastructure would boost the economic activity of the oil and gas and construction sectors, allowing for a potentially more gradual jobs and activity transition to the hydrogen and CCS industries.<br><br>**Policy**<br>• $CO_2$ shipping allows for the importation of $CO_2$ from other sites in the UK and overseas for management and storage, creating further value to the economy. This will also allow to export hydrogen and skills to other European countries and the world.<br>• Alignment with the 'green growth' and 'levelling up' agendas | **Social**<br>• Fuel switching for residential heat is less of a priority in this scenario, this could potentially delay policy actions in this area.<br>• The localised approach for hydrogen use could create discrepancies in cost for different consumers. Those near the clusters may have to pay more for their heating than those lacking access to hydrogen.<br>• New jobs and supply chains need to be sourced locally, avoiding off-shoring jobs, to maintain and grow value in the communities.<br>**Economic**<br>• The impact on other sectors is unclear (renewables, energy efficiency, etc.)<br>• Specialised workforce will be needed to enable a large-scale $CO_2$ shipping industry. Key that those jobs are sourced locally, to ensure community acceptance.<br><br>**Policy**<br>• Policy and business models to support $CO_2$ shipping are needed.<br>• Policies to capitalise on IP and skills creation on the shipping, CCS and hydrogen sectors will be required. |