A new Scottish CO_2 TRANSPORT & STORAGE sector

Supporting decarbonisation, jobs and value across the UK economy

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As the lead academic partner on the Scotland's Net Zero Infrastructure (SNZI) programme, CEP leads work around understanding the transitionary and longer-term economic impacts and job preservation and creation opportunities as Scotland transitions away from oil and gas to low carbon fuels like hydrogen and CO2 removal technologies such as Carbon Capture Utilisation and Storage (CCUS).

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CONTENTS

Foreword

Decarbonising industry is a critical pillar of efforts to meet legally enshrined Net Zero targets by 2045 in Scotland and 2050 across the wider UK. To achieve this, the UK Government has aims to capture and store 20-30 mega tonnes of CO_2 ($MtCO_2$) by 2030. In order to do this, in the way set out in the 2023 Carbon Capture Utilisation and Storage (CCUS) vision, the UK Government's intention is to deliver four CCUS clusters within this timeframe and establish a globally competitive CCUS market by 2035.

Achieving this represents both a technological challenge and a wider public policy one. Identifying economically and politically feasible pathways to CCUS deployment around which consensus across Governments, industry, communities and others can build is critical. Crucially, there are opportunities to support and transition existing jobs and gross value-added (GVA, or GDP), as well as to create new jobs, including for new industry activity around sequestering CO2 emissions back to a range of geological formations, including the offshore reservoirs we've taken fossil fuels from. Thus, it is important that pathways are identified and exploited to ensure the benefits and costs of establishing CCUS in the UK are distributed in ways that support sustainable and more equitable prosperity in the UK.

The Centre for Energy Policy's (CEP) work as the lead academic partner in the Scotland's Net Zero Infrastructure (SNZI) programme has sought to contribute to identifying and shaping how a CO2 transport and storage (T&S) sector can be deployed and invested in ways that are both feasible and deliver value. Given the evolving nature of CCUS systems and sectors across the UK, we explore what the 'size of the prize' might look like based on investment in Scottish and other UK regional T&S sectors to develop the necessary capacity to sequester all potential emissions.

Our research has found that there are potentially positive UK-wide impacts, including economic growth and jobs, of a new Scottish CO2 Management industry in the form of a nascent T&S sector in the economy, linked to the Acorn T&S project and servicing the Scottish industrial cluster, but presenting new export opportunities for the UK economy. However, the 'size of the prize' aside from the level of activity (emissions sequestered) will be determined by action on issues such as labour market participation and skills shortages as well as decisions on how to develop export markets and around future levels of coordination and competition between the clusters.

We believe the insights and analysis presented in this report complement the wider work being done within the Scottish cluster to capture the economic potential of the cluster and can inform ongoing decision-making at devolved and national levels accelerating progress towards industrial decarbonisation. Moreover, our research can contribute to efforts that ensure that the UK leverages its competitive advantage around CCUS while at the same time enabling a transition that is both just and sustainable.

Professor Karen Turner
Director, Centre for Energy Policy,
University of Strathclyde

Executive summary

As lead academic partner on the Scotland's Net Zero Infrastructure (SNZI) programme, the Centre for Energy Policy (CEP) at the University of Strathclyde has investigated the potential UK-wide gross value-added (GVA, or GDP) and employment impacts of a new Scottish CO_2 Management industry emerging around the Acorn T&S project, which will transport and store CO_2 for the Scottish industry cluster. This research complements separate work undertaken by the Acorn project and Biggar Economics on capturing the economic potential of the wider Scottish Cluster including in its scope the proposed emitters (or industrial customers) as well as the T&S industry.

CEP has developed a peer reviewed economy-wide scenario simulation framework to analyse the wider economy outcomes of a nascent T&S sector emerging via Acorn T&S as part of the UK regional cluster approach to deploying CCUS as an industrial decarbonisation solution. This is important work, given that the cluster approach is integral to supporting the UK Government's ambition (as outlined most recently in the UK Government's CCUS Vision as well as in the Powering Up Britain and Industrial Decarbonisation Strategy documents) to deploy CCUS in four industrial clusters and capture and store 20-30 MtCO2 by 2030 and achieve a globally competitive market by 2035. It is hoped that the outcome will be one where the clusters secure a competitive advantage in international markets, decarbonise supply chains, foster innovation and drive environmental, social, and economic benefits. CEP's research as part of the SNZI programme offers important insights and analysis on the opportunities, challenges and trade-offs that will need to be understood and addressed to accelerate progress towards these objectives, both at the Scottish- and UK-levels.

Key findings

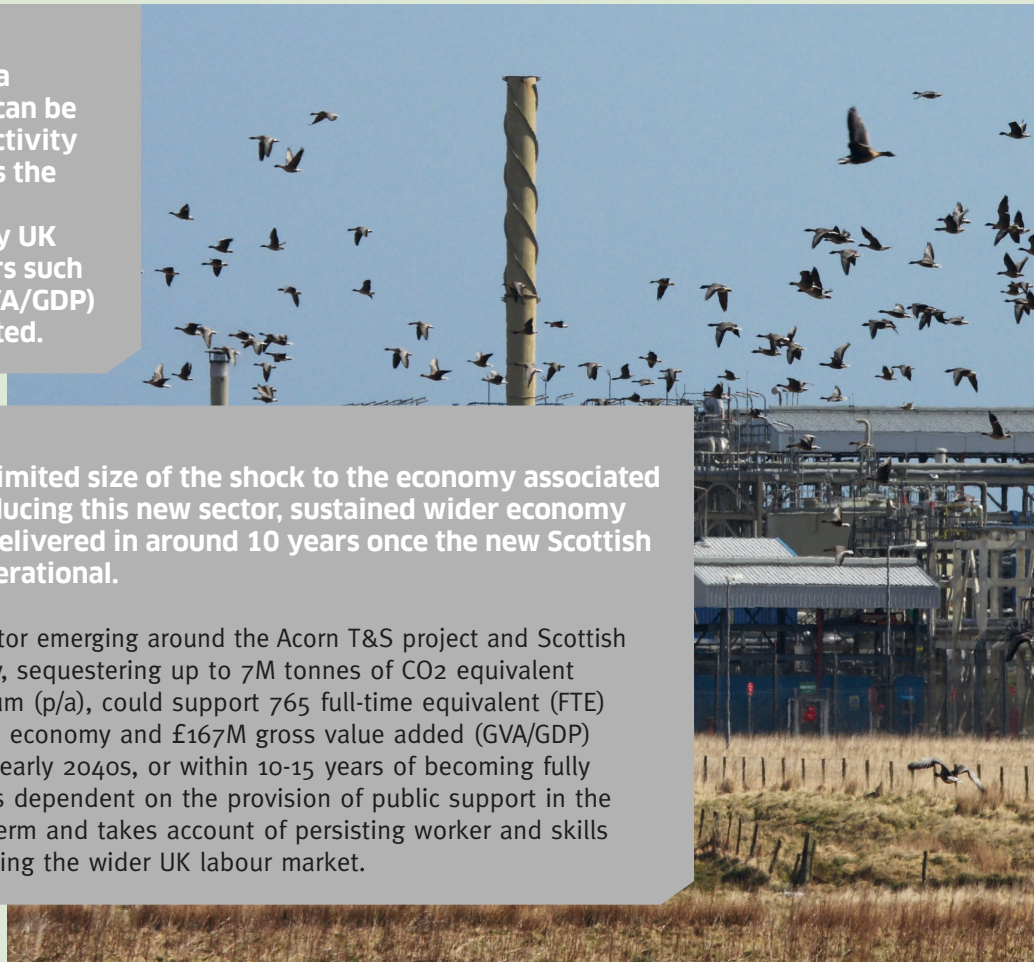
We draw eight key findings from our research around the potential sustained gains, export opportunities, worker and skills shortages, and the importance of understanding key characteristics of nascent sectors, such as the capital intensity that governs how much economic output and value any investment will enable.

Ahead of full information emerging across nascent CCUS systems and sectors in the UK, and until the policy position fully embeds, we focus on the 'size of the prize' if the Scottish and other regional T&S sectors in the UK are invested and supported to develop capacity sufficient to sequester all potential emissions. This also allows comparability of economy-wide impacts across all four Track 1 and 2 systems now identified, and consideration of the implications of resource competition as the wider UK T&S sector emerges. Crucially, this is in a manner enabled by independent academic research on the SNZI programme that can be reported in the public domain, but naturally differing from the approach to economic impact analyses being taken by each individual cluster project in reporting emerging deployment plans.

Findings 1-6 have proven robust throughout a series of applied studies conducted during the three-year lifetime of the SNZI programme as data and information to inform our economy-wide scenario simulation framework have improved and evolved. **Findings 7** and **8** have emerged in the final stages of our SNZI work, where we have comparative analysis across the Track 1 and 2 T&S systems now emerging, and are informed by **Findings 1-6**, which hold in Track 1 and 2 cases.

KEY FINDING

1 The introduction of a Scottish T&S sector can be expected to boost activity income generation across the UK, thereby delivering sustained net gains in key UK macroeconomic indicators such as gross value-added (GVA/GDP) and employment supported.



KEY FINDING

2 Given the limited size of the shock to the economy associated with introducing this new sector, sustained wider economy gains are delivered in around 10 years once the new Scottish T&S sector is operational.

A Scottish T&S sector emerging around the Acorn T&S project and Scottish east coast industry, sequestering up to 7M tonnes of CO2 equivalent (MtCO2e) per annum (p/a), could support 765 full-time equivalent (FTE) jobs across the UK economy and £167M gross value added (GVA/GDP) per annum by the early 2040s, or within 10-15 years of becoming fully operational. This is dependent on the provision of public support in the short to medium term and takes account of persisting worker and skills shortages challenging the wider UK labour market.

KEY FINDING

3 Extending the production capacity of the Scottish T&S sector with a view to exploiting an export base in providing sequestration services (via shipping) to capturing industries elsewhere, either in the UK or overseas, will increase the magnitude of macroeconomic gains.

KEY FINDING

4 The net impact on the public purse is improved if an overseas export base can be exploited even where the economic expansion triggered is very similar.

Expanding the Scottish T&S sector's sequestration capacity by just over 40% (to 10MtCO2e), involving shipping to sequester emissions from elsewhere in the UK and/or through development of an overseas export base could further increase jobs and GDP gains. The number of jobs supported across the wider UK economy by Scottish T&S could increase by 62% (up to 1,236 FTE jobs) and supported GVA by 56% (to £261M p/a). Again, this takes into account persisting worker and skills shortages challenging the broader UK labour market. The magnitude of jobs and GVA supported by an expanded Scottish T&S sector will likely be similar regardless of where emissions are shipped from. However, exploiting an overseas export base would substantially limit the erosion of potentially just over £150M p/a in government revenue generation associated with the wider economy expansion (£55M of which is attributable to overseas export activity) by additional public spending requirements.

KEY FINDING

5 An absence of policy action supporting upskilling and labour market participation could significantly limit the magnitude of wider economy gains and employment supported.

Action to address the type of skills challenges frequently identified by industry and/or encourage greater participation in the UK labour force could lead to substantially greater economic benefits. Here we consider a scenario where the Scottish T&S sector sequesters emissions from the Scottish cluster and elsewhere in the UK and/or through development of an overseas export base. We find that supported employment and GVA outcomes could rise to just under 5,000 FTE jobs and GVA of approaching £500M if worker and/or skills shortages were fully addressed.

Key findings

KEY FINDING

6 In all cases, the economic value of a Scottish T&S sector and the magnitude of wider economy impacts triggered depends crucially on the capital intensity of the emerging industry.

Comparison of the results reported in this report with previous SNZI outputs reveals that if the capital intensity of a new sector is underestimated (as it initially was), the economic output it can produce, and extent of any wider economy expansion is likely to be overestimated, and vice versa.

KEY FINDING

8 Larger investment requirements in the Scottish case deliver a more than proportionate share of the value of new UK CO_2 T&S sector activity and associated employment, GVA and government revenue gains, albeit associated with more Consumer Price Index (CPI) pressure, particularly given the persisting labour supply constraints in in the UK.

With relatively geographically dispersed emissions sources, the Scottish T&S sector sequesters a smaller share (14%) of the total emissions sequestered by all four T&S systems (i.e., the currently planned UK CO2 T&S sector as a whole). On the other hand, this is associated with a relatively large share of both the investment requirement (18%) and the wider economic benefits (19%). This extends across key metrics such as GVA (GDP as measured by income), employment, boosted household spending and the additional government revenues that help offset the direct public spending requirement, albeit with greater expansionary power in the Scottish case, slightly aggravating the nominal cost pressures therein.

KEY FINDING

7 The planned simultaneous staged introduction of Track 1 and 2 CCUS projects, involving what are effectively four regional subsectors of a nascent UK T&S sector, is likely to exacerbate resource competition across all sectors. It will, thereby, constrain wider economy gains in the early stages, despite a slight boost in near term jobs gains.

While focused on the emerging Scottish T&S sector, this report extends to comparative analysis of the potential outcome of other regional T&S sectors emerging linked to the Track 1 and Track 2 CCUS projects, combining to constitute a nascent UK T&S sector. Comparing the results of simply adding across scenario simulations for each Track 1 and 2 case with one where the staged investment and deployment of all four is simultaneously simulated reveals that, even if the regional T&S subsectors do not compete directly with each other, wage cost impacts act to constrain the wider economic expansion. The impact is limited here and eases over time, due to the relatively small supply-side shock generated by nascent T&S activity. However, this is a key generic finding, pointing to challenges for the wider net zero transition, which will involve many new activities emerging in a constrained economic landscape. Multiple net zero projects or activities coming online at the same time in the presence of resource constraints, including but not limited to access to an appropriately skilled workforce, could lead to additional costs accruing both to projects and the wider economy (including the public budget). As such, it is essential that Governments and industry work closely together in both the specific CCUS context and across the wider net zero landscape to understand the dynamics and potential impacts. This is in turn can inform effective project sequencing and related workforce planning in order to mitigate the risks and impacts of congestion.

KEY FINDING

9 If UK public finances, emerging internal and/or external markets in T&S services can bear the higher costs of sequestering to Scottish North Sea stores, increasing the capacity of the UK T&S sector through extensions to the Track 2 T&S systems, and associated regional T&S subsectors, is likely to deliver proportionately greater gains in supported GVA, employment and associated government revenues.

The impact of expanding Scottish T&S capacity to enable shipping (within the UK and/or overseas) on the wider economy benefits delivered per physical unit of emissions sequestered may become an important consideration. This is one regard in which Scottish T&S may be considered appealing. In a scenario where there is additional capacity for shipping, the wider economy benefits grow more in the Scottish case compared to Viking, regardless of where emissions are shipped in from. The GVA, employment and consequent additional government revenue impacts of introducing Scottish T&S all increase by between 55% and 62%. For Viking, the gains from increasing capacity through shipping are also substantial, with the increase in GVA, employment and revenue impacts in the range of 36% to 41% compared to a case where only own cluster emissions are serviced.

Recommendations

Based on the conclusions and future directions set out in Sections 6 and 7 we have arrived at the following three recommendations for policy and industry action:

RECOMMENDATION

1 Policy actors and industry should use the evidence and insight emerging here on the cost/value proposition and potential wider public policy trade-offs in considering how new T&S sector activity around UK CCUS, and the new regional economic activity therein, can deliver a range of potential wider economy gains.

RECOMMENDATION

2 There is an urgent need to review and make decisions on how competition and/or coordination between nascent T&S economic sectors (at home and abroad) will operate. Crucially, this is not limited to 'product' competition (i.e. T&S services) but to resource competition, which is more complex, impacting all sectors of the economy and potentially constituting an example of potential wider 'net zero congestion'. In this regard, it is important to also make decisions regarding the extent of government leadership required to ensure that the new UK T&S sector and other CCUS-related industries maximise domestic GVA, employment and revenue gains in a constrained economic landscape while delivering competitive decarbonisation for the UK industry.

RECOMMENDATION

3 Evidence generated through this research should be continuously revisited and updated as better data on T&S and other nascent sector activity associated with CCUS emerges. Here, it is also recommended that the scope of economy-wide scenario simulation modelling be extended to consider both the funding of CO_2 T&S activity going forward and to incorporate a wider range of CCUS activities and different routes by which they may emerge.

SECTION

1 Introduction

The CEP at the University of Strathclyde joined the SNZI programme in 2021 to lead work around understanding the longer-term economic impacts, particularly job preservation and creation opportunities, as Scotland and the wider UK economy transitions away from oil and gas. Our specific focus has been on exploring the case of a Scottish CO_2 Management industry emerging around the Acorn T&S project servicing a Scottish cluster.[1,2] A broader CO_2 Management industry would involve a range of businesses, including developers of the necessary infrastructure, operators of the T&S system, as well as all the businesses in their supply chains that enable the development and operation of this industry. In many cases, the development and operation of the industry will require specialised workers, drawing to some extent from the experience and skills developed in the UK Oil and Gas (O&G) extraction industry, but there is also the potential for extensive requirements for less-specialised construction workers. It should also be noted that despite the range of skills that will likely be required, not all will be essential over all timeframes, nor will all the employment opportunities be sustained long-term.

Therein, we have devoted attention to investigating the value proposition for the UK economy of exploiting wider economic value opportunities associated with investing and deploying a new Scottish CO2 T&S sector (a regional subsector of UK T&S) that shares key characteristics with existing oil and gas supply chains but reverses the direction of carbon flows, from extracting hydrocarbons to sequestering CO2 generated pre- or post-combustion.

Understanding the 'size of the prize' associated with a Scottish T&S sector

Our aim is to understand the 'size of the prize' in terms of the supported GVA and jobs that may ultimately be associated with a Scottish T&S sector with the capacity to sequester all emissions generated in the identified Scottish industry cluster and the long-term economic adjustment of the UK economy in response to its introduction. Our scenario analyses suggest the economy may fully adjust to the rollout of such a new activity by 2042 if the government guarantees demand for the economic output of the T&S sector by effectively purchasing the output (e.g., by full subsidy of users). We recognise that the recently published UK Government CCUS Vision talks about realising a 'self-sustaining CCUS market' by 2035, which may imply results of the scenario analyses presented here should only be reported to that year.[3] Moreover, it is not clear that all potential emitters will make use of the services of the T&S sector within the timeframes studied here.

However, at the time of undertaking this research there remained some uncertainty around the rollout, while the policy position, as established by the CCUS Business Models, indicated the potential for government support over the T&S costs beyond 2035. Thus, we modelled scenarios where all potential emissions are sequestered and where the UK Government continues to cover the T&S costs into the early 2040s, noting that the wider economic adjustment is almost entirely achieved by 2035. Thus, the resulting analysis should be viewed as providing a useful insight into the potential green industry opportunity linked to a Scottish CO2 T&S sector, and how sustained support could reap further potential benefits.

Our research complements work done within the Scottish Cluster by the Acorn project and

Biggar Economics to assess the economic impacts of planned and emerging cluster activity.[4] Yet it is worth noting that while our analysis has focused exclusively on the T&S sector element, the Scottish Cluster's economic impact assessment also includes the proposed emitters (or industrial customers) in its scope. Furthermore, the Cluster's analyses were based on data provided by emitters and submitted to the Department of Energy Security and Net Zero (DESNZ) as part of Track 2 of the CCUS cluster sequencing process in July 2023.

This is important in accounting for the divergence in our results around GVA and jobs. Another key difference is that we have modelled how current labour supply constraints might impact jobs, GVA and the long-term economic adjustment of the sector. More generally, and crucially, the more top-down 'size of the prize' approach adopted in the independent research reported here (based on peer-reviewed methods) permits comparability with results generated using a consistent methodology for the other Track 1 and 2 regional T&S sectors (ultimately reflecting a nascent UK-wide T&S sector).

About this report

This report presents the most recent results available from our economy-wide scenario simulations for the introduction of a Scottish T&S sector, updated not only with continually improving benchmark data from the Office for National Statistics (ONS) but on scenarios in the wake of the July 2023 Track 2 decision for the Acorn T&S system including the Acorn T&S project.[5] Findings are considered in the context of comparable scenario simulations for regional T&S sectors emerging around the two Track 1 T&S systems (East Coast and HyNet) and the other Track 2 T&S System (Viking). We also extend to consider the potential impacts and implications if both Track 2 T&S sectors were to implement their plans to expand their infrastructure to exploit additional geological storage capacity. This would enable the nascent UK T&S sector emerging through four regional subsectors to play a role in decarbonising other industry clusters in the UK that do not have access to proximate CCUS networks or export their services to industries overseas.

Key insights emerge in terms of the cost versus value trade-off where Scottish T&S may involve higher investment, operational and public funding costs in large part due to the dispersed geographical nature of emissions sources and the location of North Sea stores. However, this enables a Scottish T&S sector that delivers higher than average wider economy gains in terms of employment, GVA and additional government revenues per physical unit of CO_2 sequestered.

The report is structured as follows. In **Section 2** we provide a non-technical introduction to the economy-wide scenario simulation framework developed through the SNZI programme. **Section 3** then sets out the Scottish and other UK regional T&S sector pictures emerging and used to inform our economy-wide modelling work. Our key findings are set out in **Section 4**, followed by a presentation of the most recent results emerging for the Scottish case. In **Section 5**, we then go on to consider these results and their implications in the context of comparable findings for regional T&S subsections of the UK-wide sector emerging around the other Track 1 and 2 clusters. Finally, **Sections 6** and **7** offer some conclusions and consideration of emerging policy implications as well as recommendations for action. ■

1 https://www.theacornproject.uk/projects
2 https://www.thescottishcluster.co.uk/
3 https://www.gov.uk/government/publications/carbon-capture-usage-and-storage-a-vision-to-establish-a-competitive-market
4 Scottish Cluster (2024, forthcoming) Capturing the Economic Potential: Maximising the Positive Economic Impact of the Scottish Cluster Industrial Decarbonisation Strategy
5 https://www.gov.uk/government/publications/cluster-sequencing-for-carbon-capture-usage-and-storage-ccus-track-2#:~:text=Track%2D2%20aims%20to%20establish,to%20deliver%20Track%2D2%20objectives

SECTION

2 Developing the economy-wide scenario simulation framework

Here, we use a Computable General Equilibrium (CGE) scenario simulation framework to investigate the potential economy-wide impacts of introducing a new UK CO_2 T&S sector. In the SNZI programme, our specific focus is the Scottish T&S sector emerging around the Acorn T&S project as part of Track 2 of the T&S system sequencing process, but with comparative analysis for the other Track 1 & 2 cases.

2.1 What is CGE?

CGE models are large-scale numerical models that combine economic theory and real economic data to simulate the macroeconomic, sectoral and distributional impacts of policy actions and other shocks/disturbances to the economy. This often includes the dynamics of how different sectors and markets adjust year-by-year over extended time frames.

CGE modellers work by fitting real economic data – generally building on national input-output accounting data on the composition of activity between production sectors and final consumers – to a set of equations. The aim is to capture impacts on the structure of the economy and the response of agents (firms, households, government) to changes in prices, incomes and activity levels triggered by a given policy action or economic disturbance.

It is this whole economy perspective, capturing both demand- and supply-side behaviour in ways that are grounded in economic theory, which enables CGE model users to understand the potentially extensive – and often unanticipated – economy-wide impacts of shocks using economic intuition, with the magnitude of gross and net impacts on price and quantity variables quantified using real data.

The main strength of CGE models lies in their flexibility, where they can be adapted to simulate a wide range of policy actions and economic disturbances, and to examine the impacts of making different assumptions regarding how the economy, and different markets and agents therein, function and respond.

For this reason, CGE models are used by a range of research and policy organisations, including the World Bank, the European Commission, HM Treasury and the Scottish Government.

2.2 The UKENVI model applied to the introduction of a new UK CO_2 T&S sector via regional subsectors

Given the focus of CEP's work on the SNZI programme on understanding and quantifying the impacts of the new CO2 T&S sector, projected to build out around the Scottish Acorn T&S project as part of the UK's industrial strategy activity on CCUS clustering, we adopt the UKENVI CGE model of the UK economy. The model uses a UK social accounting matrix (SAM), incorporates the (at the time) most recently available (2018) UK input-output (IO) tables[6] alongside other relevant national accounting data published by the Office for National Statistics (ONS).[7] The model covers all the UK's existing production sectors aggregated into 33 broad sectors, identifying key industries likely to be involved in and/or directly or indirectly impacted by the supply and demand of CCUS activity.[8]

We simulate the introduction of a 34th sector, which is a nascent UK CO2 T&S sector, using peer-reviewed methods[9] and incorporating scenario and key modelling assumptions (see below) that draw on the outcomes of expert stakeholder consultations[10] during the SNZI programme. The scenario development for introducing this new sector involves consideration of the upfront investment and operational stages of the nascent T&S sector, with a focus on the Scottish T&S sector linked to the Acorn T&S[11] servicing the Scottish cluster through Track 2 of the UK Government's cluster sequencing initiative. However, with the now peer-reviewed modelling approach developed for investigating the national impacts of regional T&S sector emergence, we can extend here to run comparable simulations for the two Track 1 projects (HyNet and East Coast) and the other Track 2 project (Viking), and simultaneous simulation of all four regional sub-sectors constituting the nascent UK T&S sector.

2.3 Our scenarios

Our scenario simulation analysis is based on modelling the following scenarios:

SCENARIO 1

DOMESTIC SEQUESTRATION ONLY:

Scenario 1A

The Scottish T&S sector engages in domestic transportation of captured CO2. This scenario (as with all others) is then considered in turn for each of the Track 1 T&S sectors (labelled by the cluster names of Hynet and East Coast in line with the T&S systems involved) and the Track 2 T&S sector (labelled as Viking). In all cases, **Scenario 1** involves sequestration from own cluster industries via pipelines – i.e., without shipping (introduced in **Scenario 2**) in the presence of labour market constraints (relaxed in all **B scenarios**). **Scenario 1A** is also the case where we compare 'additive' and 'simultaneous' approaches to simulating the comparative and UK-wide impacts of the staged investment and deployment of all four regional T&S sectors associated with Track 1 and Track 2 developments in the UK.

Scenario 1B

As in **scenario 1A** but relaxing labour supply constraints in each regional T&S sector case. That is, domestic transportation of captured CO2 from Track 1 and 2 cluster industries via pipelines without shipping in the absence of labour market constraints.

SCENARIO 2

INTRODUCING SHIPPING OF EMISSIONS BY TRACK 2 T&S SECTORS, CONSIDERING DOMESTIC (REST OF UK, RUK) AND OVERSEAS (REST OF WORLD, ROW) CASES RESPECTIVELY:

Scenario 2A (RUK)

Domestic transportation of captured CO2 from Track 1 and 2 cluster sectors via pipelines **plus** sequestration of emissions from other UK clusters (regional industry clusters that are not included in Track 1 or 2) via shipping by Track 2 T&S sectors only, in the presence of labour market constraints.

Scenario 2B (RUK)

As **Scenario 2A (RUK)** but in the absence of labour market constraints.

Scenario 2A (ROW)

Domestic transportation of captured CO2 from Track 1 and 2 cluster industries via pipelines **plus** exports of T&S services (shipping in CO2 captured overseas) by Track 2 T&S sectors only, in the presence of labour market constraints.

Scenario 2B (ROW)

As in **Scenario 2A (ROW)** but in the absence of labour market constraints.

6 The 2018 UK analytical IO tables used to inform the core structural database of our economy-wide UKENVI model can be found at https://www.ons.gov.uk/economy/nationalaccounts/supplyandusetables/datasets/ukinputoutputanalyticaltablesindustrybyindustry, noting that IO tables tend to be published with a lag of around 4 years

7 The SAM where we incorporate the CO2 T&S sector is available here: https://doi.org/10.15129/67521ce7-3184-47bf-8d63-4764ae5d1951

8 See Appendix A for a list of the sectors in our model and their corresponding SIC codes

9 For CGE model developments conducted as part of the SNZI programme, with a focus on the Scottish side of a new UK T&S sector, see Turner et al. (2021a), published open access in the Sage journal Local Economy at https://doi.org/10.1177/02690942211055687, and Turner at al (2023a) also published open access in Local Economy at https://doi.org/10.1177/02690942231203932. For corresponding work considering a wider UK T&S sector see Turner et al. (2022a), published open access in the Elsevier journal Ecological Economics at https://doi.org/10.1016/j.ecolecon.2022.107547

10 For example, see the CEP Policy Brief by Turner et al. (2022b) at https://doi.org/10.17868/strath.00083228.

11 The Acorn project is a joint venture between different companies. Our focus is specifically on Acorn T&S, which focusses on reusing oil and gas infrastructure to transport and store captured CO2. More information is available via https://www.theacornproject.uk/

2.4 Key assumptions

- We assume that the structure of the nascent UK T&S sector, and the regional subsectors therein, shares the upstream supply chain of the UK's existing O&G sector but servicing a new market for CO2 sequestration.
- Until such a time as the users of a UK T&S sector (and the regional subsectors therein) may be expected to pay the full costs of providing T&S services and that the capacity of the new T&S sector is fully utilised, we assume that the UK Government effectively demands all the output of the nascent T&S sector(s).[12]
- However, we introduce additional scenarios (all cases labelled 2 above) to consider the potential of exporting T&S services (i.e., 'importing' captured CO2), in line with the plans of the Acorn and Viking T&S systems to expand their capacity to service other (non-Track 1 or 2) UK and/or overseas industries, where the latter constitutes development of a T&S export base.
- In these **Scenario 2** cases, we refine our T&S supply chain assumptions for Acorn and Viking T&S sectors so that a portion of the capital requirements shifts to the international maritime transportation industry (shipping services). The main implication is a reduction in the capital intensity of these two regional subsectors and the wider UK T&S sector relative to entirely domestic sequestration cases.
- We assume that the national labour supply is fixed, with some flexibility in the form of an initial unemployment pool from which all UK producers can source additional workers. We consider two main labour market conditions: the central case (**A scenarios**) allows for a real wage bargaining response as labour demand rises (negatively correlated with the unemployment rate), while a comparator (**B scenarios**) assumes a fixed real wage case, motivated by the need to understand the importance of wage bargaining in the labour market.[13]
- All our scenario simulations involve focusing on the investment and deployment of regional T&S sectors in isolation. That is, we abstract from any other changes or disturbances that may impact in the timeframe studied. This is important in understanding the causality and 'moving parts' in the economy driving outcomes. However, it also implies that any expansionary effects need to be considered in terms of supported activity, given that net outcomes for the economy in the timeframes studied will ultimately involve a much wider set of drivers and changes.
- Herein, we also conduct comparable scenario simulations introducing each regional T&S sector in isolation and one where we simultaneously simulate the staged introduction of all four. This is important in considering how a greater extent of increased competition for resources – with focus on the labour market – may impact costs and prices across the economy and thereby further constrain the economic expansion. ■

12 We do consider alternative assumptions, including a full 'industry pays' approach in the Turner et al. (2022a) paper available at https://doi.org/10.1016/j.ecolecon.2022.107547

13 The sensitivity of the previous round of our SNZI programme results to a wider range of wage determination assumptions are considered in our peer reviewed Turner et al. (2023a) paper at https://doi.org/10.1177/02690942231203932, and for earlier UK-wide results in the Turner et al. (2023e) CEP policy brief at https://doi.org/10.17868/strath.00086068

SECTION 3

The Scottish and wider UK CO_2 T&S sector picture

During the programme, we have been updating the structure of the Scottish and the other UK regional T&S sectors as new data and insights from stakeholders emerge. However, as highlighted in the introduction we had to make some decisions about the scope of our research due to the evolving nature of the CCUS rollout and associated uncertainty. We focused primarily on the T&S component of the Acorn and Viking T&S systems. Thus, our assumptions on the structure of the Scottish T&S sector have evolved to reflect material that emerged following the conclusion of the Track 2 selection and the publication of relevant material such as the 2023 'Scottish Net Zero Roadmap' (SNZR) report[14] and updating of ONS data on the structure and interdependence of UK industries.

Firstly, the O&G industry used as a benchmark sector for CO2 T&S activity in Scotland is now separately identified in the 2018 UK IO tables. The key implication of this development is that the T&S sector used here is more capital and less labour-intensive than what we considered in previous work we have published under the SNZI programme.[15] Secondly, it is now assumed that the Scottish T&S system goes beyond industrial capture to include sequestration of emissions from the Peterhead combined cycle gas turbine (CCGT) and an additional 3MtCO2 emission shipped in via the Peterhead Port from elsewhere in the UK or from overseas. The key implication of this latter update is an increase in the level of investments. Other updates include the timing of the investment will now take place in three years starting from 2027 instead of the four years previously assumed when the Track 2 decision and timing were unknown.[16]

3.1 The Scottish Cluster

Based on the updated information and data, the Scottish Cluster T&S network now requires £498.79M of new capital (a small increase relative to our previous estimates[17]), to sequester 7MtCO2e (a significant increase in our estimated Scottish cluster emissions, now including the Peterhead CCGT power plant). We note that we only consider the capital that would be necessary to transport and store captured CO2. Any additional capital associated with capturing CO2, for instance, is outwith the scope of this project and therefore has not been included here.

14 The 2023 SNZR report is available at https://snzr.co.uk/
15 This is up to and including the Turner et al. (2023b) CEP policy brief published at https://doi.org/10.17868/strath.00084117
16 The previous assumption on timing is reflected in outputs such as the peer reviewed paper by Turner et al. (2021a), published open access in the Sage journal Local Economy at https://doi.org/10.1177/02690942211055687, and the CEP policy brief by Alabi et al. (2021) at https://doi.org/10.17868/78261
17 Also see the peer reviewed paper by Calvillo et al. (2022) published open access in the Elsevier International Journal of Greenhouse Gas Control at https://doi.org/10.1016/j.ijggc.2022.103695 for information on our methods for estimating investment in regional T&S capacity

TABLE

1 Scottish regional cluster emissions sources and interventions/impacts of linked CO_2 Transport and Storage capacity

Key T&S sector investment and operational characteristics	SCOTTISH T&S SECTOR: Domestic transportation via pipelines **without shipping**	SCOTTISH T&S SECTOR: Domestic transportation via pipelines **and exports via shipping**
Total capital stock created (£M)	499	746
Pre-operation investment* (£M)	582	871
Ongoing additional annual investment (£M)	75	112
Total output/demand serviced (£M)	173	306
Demand serviced outside own cluster (£M)	0	134
International shipping services imports (£M)	0.2	31.9
Direct employment (FTE)	75	133
Gross value added (GVA/GDP) (£M)	109	167
Total emissions serviced (Mt, millions of tonnes of CO_2)	**7**	**10**

*Evenly distributed over the investment period

This capital requirement implies a £581.7M pre-operation investment between 2027-2029, with £74.82M ongoing investment after 2030 when the cluster becomes operational.[18] The corresponding value of output and, thus, required demand for Scottish is £17.69M, which we assume here is guaranteed by the UK Government (likely through subsidy of T&S users). See the first column of **Table 1**.

If the Acorn T&S system expands to service other clusters in the rest of the UK (RUK), or overseas/the rest of the world (ROW), the sequestered emissions reach 10MtCO2e, 3MtCO2e of which are shipped to Peterhead port from outside Scotland. For simplicity, we have considered that the RUK emissions are shipped from the Solent cluster in Southampton, whereas the ROW emissions are coming from the port of Hamburg in Germany.

We use these illustrative examples to calculate the marine transportation costs. In that case, the total new capital required is £746.26M, with the additional £247.47M involving the development of port facilities and the expansion of storage to service the shipped emissions. In this case, £870.52M pre-operation investment in 2027-2029 and £111.94M ongoing investment thereafter are needed.[19]

There are also investment requirements in the international marine transportation sector, which is assumed to provide shipping services, but the impacts of external investments are not modelled here. The total demand rises to £306.18M, with the value of exports being £133.5M, covered (at least initially) by the UK Government if from elsewhere in the UK and by external actors if from overseas. See the second data column of **Table 1**.

3.2 The other regional T&S sectors

3.2.1 Viking T&S sector

The other Track 2 T&S system enabling a further regional subsector of UK T&S, Viking, presents similarities with the Scottish case. As in the case of the Scottish T&S system, Viking has a plan to export its T&S services to RUK or ROW industries. In addition, the development phase of the cluster starts after the Track 1 T&S systems become operational and the network investment takes place in the same three-year period as the Scottish system.

Note that there are some unique characteristics in the case of the Viking cluster and linked T&S system that affect our modelling approach. The industries in the wider area covered by the cluster emit a total of approximately 16MtCO2e. Given the lack of clarity on what industries/emissions will be connected to the Viking T&S system at this stage, we calculate the initial (own cluster) capacity with a capability to transport the entire 16MtCO2e.

However, Viking's published plans[20] indicate the development of a 15MtCO2e storage, but this may incorporate the stated plan to ship 3MtCO2e from outside the cluster rather than devote the full capacity to own cluster emissions. Thus, our non-

18 We make a simplifying assumption that the first injection and the full operation of the T&S network happen in the same year. In practice the operation of the T&S system may take place in a more staged way, but this would lead to limited differences in our quantitative results, and the dynamics thereof

19 We make a further simplifying assumption in relation to shipping, in assuming that shipping and the full operation of the pipelines servicing the Scottish Cluster industries happen simultaneously

20 The plans of the Viking cluster are detailed in the "Transforming the Humber into a net zero SuperPlace" publication available via https://vikingccs.co.uk/assets/images/Viking-CCS-Transforming-the-Humber-into-a-net-zero-SuperPlace-web.pdf

shipping scenario involves sequestering only 12MtCO2e, despite the network being built for a larger volume of emissions. The main implication is that the investment required per MtCO2e of emissions may be artificially inflated. On the other hand, as our results show, Viking still has the lowest emissions sequestration cost amongst the clusters and linked regional T&S sectors we consider. Nonetheless, going forward, it will be important to revisit our analyses once more information emerge on the specific industries connecting to the network, and/or if a given regional T&S sector seeks to expand its storage.

In **Table 2**, Viking requires £587.28M new capital to sequester the minimum level of 12MtCO2e emissions. The pre-operation investment for the initial own cluster only case is estimated to be £685.06M in 2027-2029, with an annual ongoing investment of £88.09M from 2030. This supports an output value of £203.31M, where, again, we assume the corresponding demand is entirely guaranteed by the UK Government. See the first data column of **Table 2**.

As noted above, Viking joins the Acorn T&S system in planning to export its services to other UK or overseas users, similarly up to a volume of 3MtCO2e. Again, for simplicity (and comparability), we assume the same routes as in the Scottish T&S sector linked to the Acorn system, with RUK emissions coming from Southampton on the south coast of England and ROW emissions being shipped from Hamburg in Germany.

Consequently, the total emissions actually serviced by Viking T&S increase to 15MtCO2e, and this uses the full planned storage capacity. Nonetheless, an additional £190.46M of capital stock, associated with enabling the shipping of emissions, taking the total requirement this requires a higher total – £777.74M – of new capital creation. A pre-operation investment of £907.24M and ongoing of £116.66M is required to support a demand worth £311.9M. The value of shipped CO2 is £108.59M – again who pays depends on the scenario. Here, the South Humber T&S system, now covered by Viking, delivers the regional T&S sector with the most significant differences to previous CEP work.[21]

3.2.2 Track 1 T&S sectors – East Coast & Hynet

The investment enabling the two Track 1 T&S sectors begins earlier, we assume over the 4 years to 2026, with these two regional elements of the UK T&S sector entering the Operational Phase in 2027. Unlike the Scottish and Viking T&S sectors, the Track 1 CCUS rollout T&S systems do not currently report any plans to export T&S services and their full capacity will be used to sequester their own emissions. Thus, in **Table 3**, we provide our projection of the industry picture corresponding to the domestic elements of the Scottish and Viking cases reported in the first data columns of **Tables 1** and **2**.[22]

TABLE 2 Viking regional cluster emissions sources and interventions/impacts of linked CO_2 Transport and Storage capacity

Key T&S sector investment and operational characteristics	VIKING T&S SECTOR: Domestic transportation via pipelines **without shipping**	VIKING T&S SECTOR: Domestic transportation via pipelines **and exports via shipping**
Total capital stock created (£M)	587	778
Pre-operation investment* (£M)	685	907
Ongoing additional annual investment (£M)	88	117
Total output/demand serviced (£M)	203	312
Demand serviced outside own cluster (£M)	0	109
International shipping services imports (£M)	0.2	28.0
Direct employment (FTE)	88	136
Value added (GVA/GDP) (£M)	128	174
Total emissions serviced (Mt, millions of tonnes of CO_2)	**12**	**15**

*Evenly distributed over the investment period

21 In previous estimations – e.g., the work reported in the Turner et al. (2023c) CEP policy brief at https://doi.org/10.17868/strath.00085736 – we have assumed that the activity in the North East of England outside of what has become the Track 1 East Coast T&S system would cover all the South Humber region up to Leeds. Plans for the Viking activity now identified as a Track 2 indicate a narrower geographical focus, leading to smaller network length requirements but with a less than proportionate decrease in sequestered emissions – see https://vikingccs.co.uk/assets/images/Viking-CCS-Transforming-the-Humber-into-a-net-zero-SuperPlace-web.pdf

22 Note that the development of the Track 2 T&S systems begins in 2027, by which point the Track 1 T&S systems are operational. Thus, the ongoing additional annual investments for Track 1 will begin while the pre-operational investment is taking place in Track 2.

Rolling out the East Coast T&S sector requires the creation of £1,161.68M of new capital to sequester 22MtCO2e emissions in the wider Teesside and North Humber region. Here, a total pre-operation investment of £1,458.47M is necessary to introduce the new capital, spread evenly over the 2023-2026 period. The East Coast T&S sector becomes operational in 2027, and thereafter, the ongoing additional investment required is £174.25M pa. The value of output and thus required demand for East Coast T&S services is £402.16M, again assumed to be guaranteed by the UK Government.

The Hynet T&S sector requires £437.06M new capital for its 8.59MtCO2e emissions in the Merseyside region. Here, the pre-operation investment is £548.73M, again spread over the 2023-2026 period, with this regional T&S sector becoming operational in 2027. The ongoing investment requirements are £65.56M, supporting an output and estimated demand of £151.31M, guaranteed by the UK Government.

As in **Tables 1-2**, **Table 3** also includes estimates of the direct employment and gross value added (GVA/GDP) contribution of each of the regional T&S systems and for the UK industry as a whole.[23] However, in order to understand the full potential contribution of introducing a new UK T&S sector via the regional cluster approach we use the information presented in **Tables 1-3** to inform economy-wide scenario simulations in our UKENVI CGE model. This is the focus of the remainder of the report, starting with the Scottish T&S sector – the focus of the SNZI programme – in **Section 4**.

TABLE

3 UK regional cluster emissions sources and interventions/impacts of linked CO_2 Transport and Storage capacity (own cluster emissions only)

Key T&S sector investment and operational characteristics	TRACK 1		TRACK 2		UK-WIDE
	East Coast cluster	Hynet cluster	Scottish cluster	Viking cluster	All clusters
Total capital stock created (£M)	1,162	437	499	587	2,685
Pre-operation investment* (£M)	1,458	549	582	685	3,274
Ongoing additional annual investment (£M)	174	66	75	88	403
Total output/demand serviced (£M)	402	151	173	203	929
International shipping services imports (£M)	0.2	0.2	0.2	0.2	0.2
Direct employment (FTE)	175	66	75	88	404
Value added (GVA/GDP) (£M)	254	96	109	128	587
Total emissions serviced (Mt, millions of tonnes of CO_2)	**22**	**9**	**7**	**12**	**50**

*Evenly distributed over the investment period

23 The UK picture in Table 3 sums across the four regional T&S system cases. If the four are introduced in the same scenario simulation, there may be some marginal differences due to price and other responses in different markets across the UK economy. We are currently re-running our estimates of the total UK-wide impacts with all four cluster cases included in the same scenario for a separate project funded by the Industrial Decarbonisation Research Centre (IDRIC) – see https://www.strath.ac.uk/humanities/centreforenergypolicy/ourprojects/idric/ – to update on the estimates presented in the Turner et al. (2023c) CEP policy brief – https://doi.org/10.17868/strath.00085736- https://doi.org/10.17868/strath.00085736. This policy brief was produced as part of a recent project funded by the UK Carbon Capture and Storage Research Centre (UKCCSR) – see https://www.strath.ac.uk/humanities/centreforenergypolicy/ourprojects/ukccsrc22/

SECTION

4 The economy-wide impacts of introducing a Scottish CO_2 T&S sector emerging around the Acorn T&S Project

4.1 Key findings

During the SNZI programme, we have produced a series of peer-reviewed papers and policy briefs developing methods and reporting results from economy-wide scenario simulations exploring the potential UK-wide economic impacts of introducing a Scottish T&S sector to service Scottish cluster demand[24] and/or to service sequestration demand elsewhere in the UK or overseas[25]. As outlined above, data, information and stakeholder insights to inform our UKENVI model and the scenarios have evolved throughout the 3-year duration of the programme, not least as the policy landscape around CCUS in Scotland and the wider UK has shifted. Nonetheless, six recurring key findings persist, enabling some fundamental insights (that we also find apply in other UK T&S system contexts) to emerge from our research:

KEY FINDING

1 The introduction of a Scottish T&S sector can be expected to boost activity income generation across the UK, thereby delivering sustained net gains in key UK macroeconomic indicators such as gross value-added (GVA/GDP) and employment supported.

As would be expected, this requires that capture industries do not lose competitiveness in international markets.[26] While the expansionary process triggered by first investing and then operating new T&S sector activity can be expected to deliver net gains in public revenues, avoiding competitiveness loss is likely to require at least transitory government support and/or guarantee of demand for T&S services.

KEY FINDING

2 Given the limited size of the shock to the economy associated with introducing this new sector, sustained wider economy gains are delivered in around 10 years once the new Scottish T&S sector is operational.

Initial infrastructure development activity is likely to trigger the delivery of transitory gains across the economy, including additional government revenues in the timeframe before public support of operational T&S is required.

24 See the peer reviewed paper by Turner et al. (2021a) published open access in the Sage journal Local Economy at https://doi.org/10.1177/02690942211055687, and the CEP policy brief by Alabi et al. (2021) at https://doi.org/10.17868/78261

25 See the peer reviewed paper by Turner et al. (2023a) also published open access in the Sage journal Local Economy at https://doi.org/10.1177/02690942231203932, and the series of CEP policy briefs by Turner et al published in 2022 (https://doi.org/10.17868/79716) and 2023 (https://doi.org/10.17868/strath.00084117 and https://doi.org/10.17868/strath.00086569)

26 Also see the peer reviewed paper by Turner et al. (2021b), published open access in the Elsevier journal Ecological Economics at https://doi.org/10.1016/j.ecolecon.2021.106978, and an earlier CEP policy brief by Turner et al. (2020) at https://strathprints.strath.ac.uk/72094/

SECTION 4 CONTINUED

KEY FINDING

3 Extending the production capacity of the Scottish T&S sector with a view to exploiting an export base in providing sequestration services (via shipping) to capturing industries elsewhere, either in the UK or overseas, will increase the magnitude of macroeconomic gains.

However, further boosts to the GVA/GDP and total UK employment supported are less than proportionate to those associated with the initial pipeline-based domestic T&S sector activity. This is due to some leakage of value via (what we assume is) international shipping activity. Moreover, the increased activity adds further wage-cost (and associated CPI) pressure for as long as labour supply constraints persist.

"Limiting real wage growth will dampen additional government revenue generation, given the importance of income taxes to the UK public purse"

KEY FINDING

4 The net impact on the public purse is improved if an overseas export base can be exploited even where the economic expansion triggered is very similar.

This is because there is no additional public spending requirement in supporting further UK usage of the Scottish T&S sector, but where consideration of such an outcome needs to be set in the context of the impacts of sequestering UK emissions via the other Track 1 and 2 regional T&S sectors.

KEY FINDING

5 An absence of policy action supporting upskilling and labour market participation could significantly limit the magnitude of wider economy gains and employment supported.

This is despite the limited size of the shock to the economy, with constraints on the supply of workers (and associated skills shortages) and consequent wage-competition driving price-driven displacement of activity, including employment, in other sectors of the economy. It also triggers some upward pressure on the CPI. On the other hand, limiting real wage growth will dampen additional government revenue generation, given the importance of income taxes to the UK public purse.

KEY FINDING

6 In all cases, the economic value of a Scottish T&S sector and the magnitude of wider economy impacts triggered depends crucially on the capital intensity of the emerging industry.

The key point here is the more capital-intensive an industry is, the smaller the industry capacity and upstream supply chain requirements resulting from any given monetary investment in creating infrastructure.

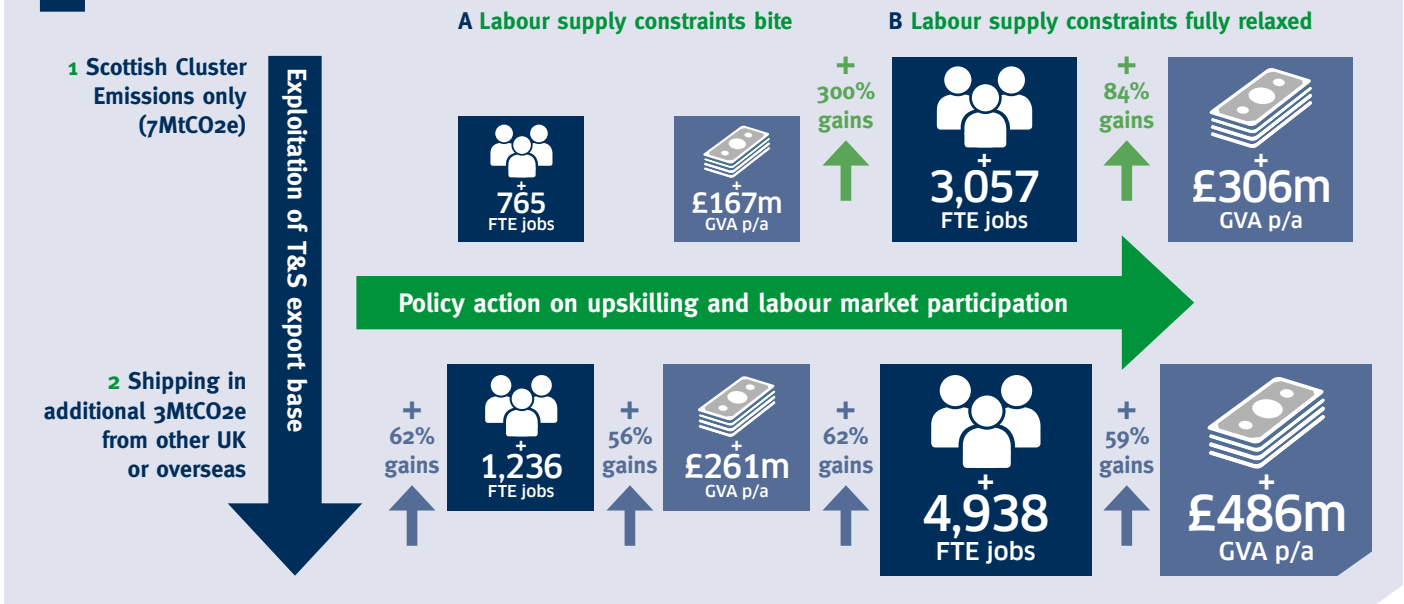
4.2 Latest applied results (following the July 2023 Track 2 announcement)

Findings 1-5 all relate to challenges and/or opportunities that policymakers and/or industry actors can affect or respond to in delivering the Scottish T&S sector. **Finding #6** relates to the importance of developing intelligence on the economic characteristics of a nascent sector like CO_2 T&S. This is one of two points on which the most recent economy-wide scenario simulations reported here[27] differ from results reported in earlier work on the SNZI programme.[28] This is because – as explained in **Section 3** of this report – more recent (albeit not as recent as would be ideal[29]) economy-wide data indicate that the UK O&G industry benchmark we use to specify the structure of the Scottish (and other UK) T&S sector in the UKENVI model is more capital-intensive than estimated in our earlier SNZI programme and other CCUS project work.[30]

Also, as noted above, the second key point of difference in the results reported here from previous SNZI programme outputs is that the information to inform our analysis of how and over what timeframe the Scottish T&S sector may emerge has improved following the UK CCUS Track 2 T&S system announcement in July 2023.[31] In particular, our latest scenario simulations – initially focussed on industrial capture in the Scottish cluster – now include sequestration of emissions from the Peterhead power plant.

The headline outcomes from our latest scenario simulations are reported in **Figure 1** (all values reported in 2018 prices), which summarises the sustained (long-run) impacts on UK GVA/GDP and employment of introducing a Scottish T&S sector that is operational by 2030.

FIGURE 1 UK-wide economic impacts of introducing a Scottish CO_2 Transport & Storage industry via UK CCUS Track 2 – labour supply challenges and export opportunities



27 And in the most recent of our peer-reviewed works published (open access) in the peer-reviewed journal Local Economy: our Turner et al. (2023a) paper published at https://doi.org/10.1177/02690942231203932

28 Including our first paper published in Local Economy: Turner et al., (2021a), available open access at https://doi.org/10.1177/02690942211055687

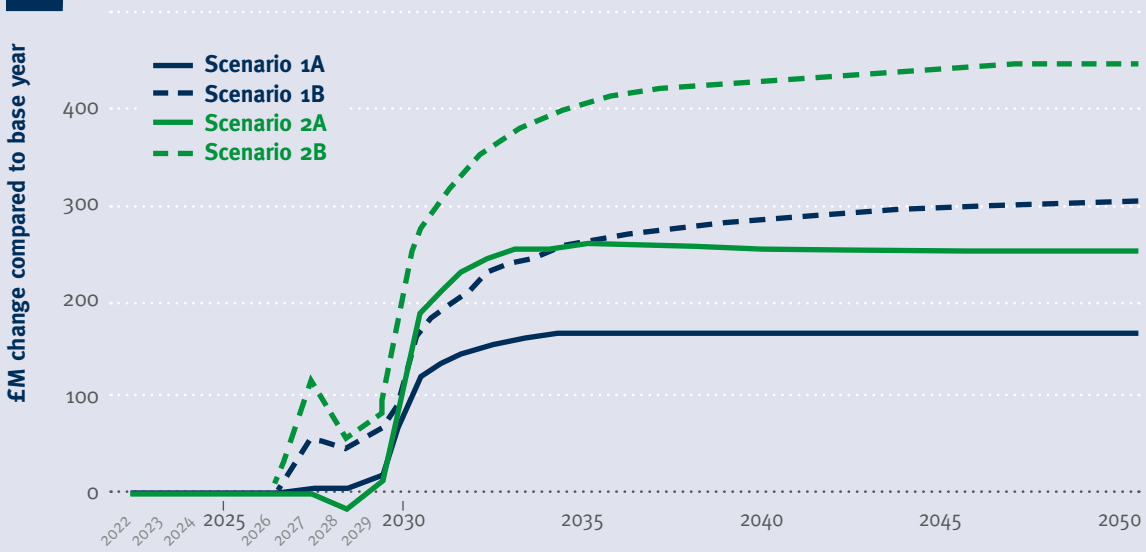
29 As explained earlier, UK IO data are produced with a lag of around 4 years

30 Including the UK T&S work reported in the earlier Turner et al. (2022a) Ecological Economics paper -https://doi.org/10.1016/j.ecolecon.2022.107547 – conducted during our collaboration with the Bellona Foundation in a project funded by the Children's Investment Fund Foundation

31 See https://www.gov.uk/government/publications/cluster-sequencing-for-carbon-capture-usage-and-storage-ccus-track-2/update-to-industry-on-conclusion-of-the-ccus-cluster-sequencing-track-2-expression-of-interest

FIGURE

2 Dynamic adjustment of UK net GVA (GDP) impacts due to the deployment and operation of the Scottish T&S sector



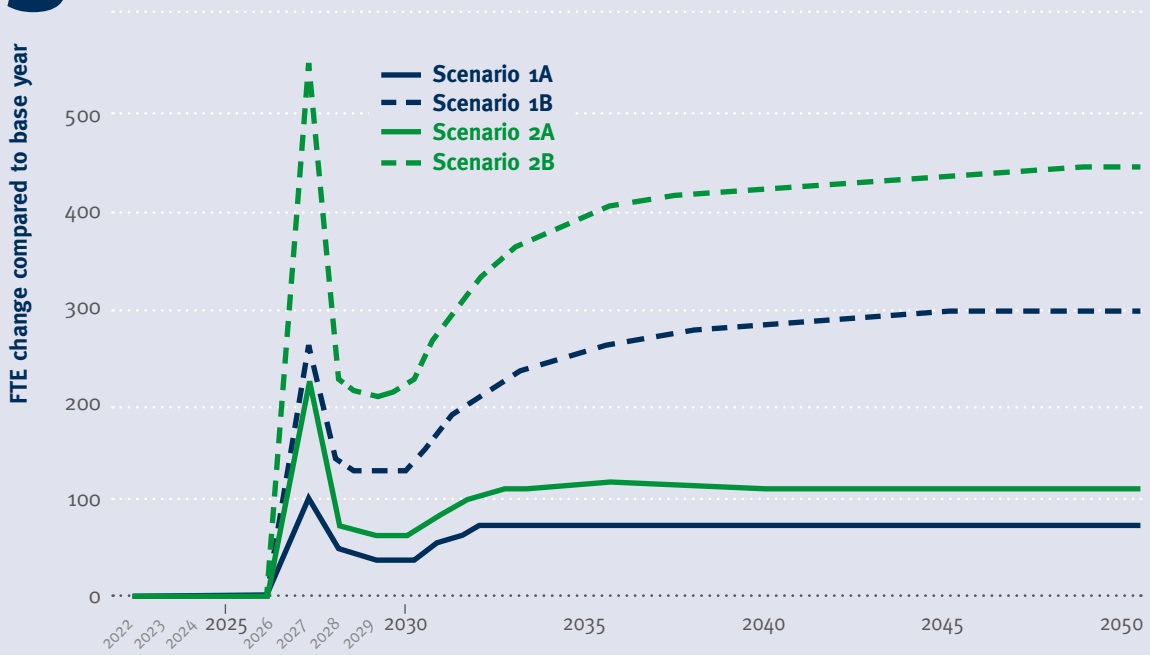
Results are shown for different scenarios regarding whether the persisting UK labour supply constraint 'bites' through wage competition and price pressure (**A** vs. **B**) and whether additional Scottish T&S capacity is created to exploit export opportunities involving shipping of emissions from other UK nations or overseas (**1** vs. **2**).

The adjustment pathways of GVA and employment in each case, including the upfront investment period before the new Scottish T&S sector is operational from 2030, shown in **Figures 2** and **3**, respectively, where the sustained outcomes reported in **Figure 1** are achieved by 2042 in the **A cases** (within the period to 2045 when the government support may end, including the Industrial Carbon Capture, ICC, contract).[32] However, it will take longer (beyond 2045) in the more expansionary **B cases**, with implications in interpreting the sustained **B case** results in **Figure 1** given the 'government guarantees demand' assumption, which is likely to only be appropriate to the mid-2040s at the latest.

Our central (**A**) case – where we assume that persisting UK labour supply constraints trigger wage-cost pressures as labour demand increases with the new Scottish T&S supply chain activity – is on the left hand-side of **Figure 1**. If we start with the case where Scottish T&S only services the 7mtCO2e of emissions generated in the Scottish cluster (now including the Peterhead power station), we see that the 75 full-time equivalent (FTE) direct industry jobs reported for this case in **Section 3** increases tenfold, to 765. This is due to the wider economic expansion

32 In the Industrial Carbon Capture business models summary (BEIS, 2022), (see page 48) it is mentioned that the duration of the Industrial Carbon Capture contract will be 10 years with a possible extension of five years subject to certain conditions being met

FIGURE 3 Dynamic adjustment of total UK net employment impacts due to the deployment and operation of the Scottish T&S sector



that is triggered, and to the greater labour-intensity of indirect supply chain activity supported by the consumption activity induced by employment and other income impacts. The extent of the wider expansion supported is reflected in the sustained uplift in UK GVA with a value of £167M per annum.

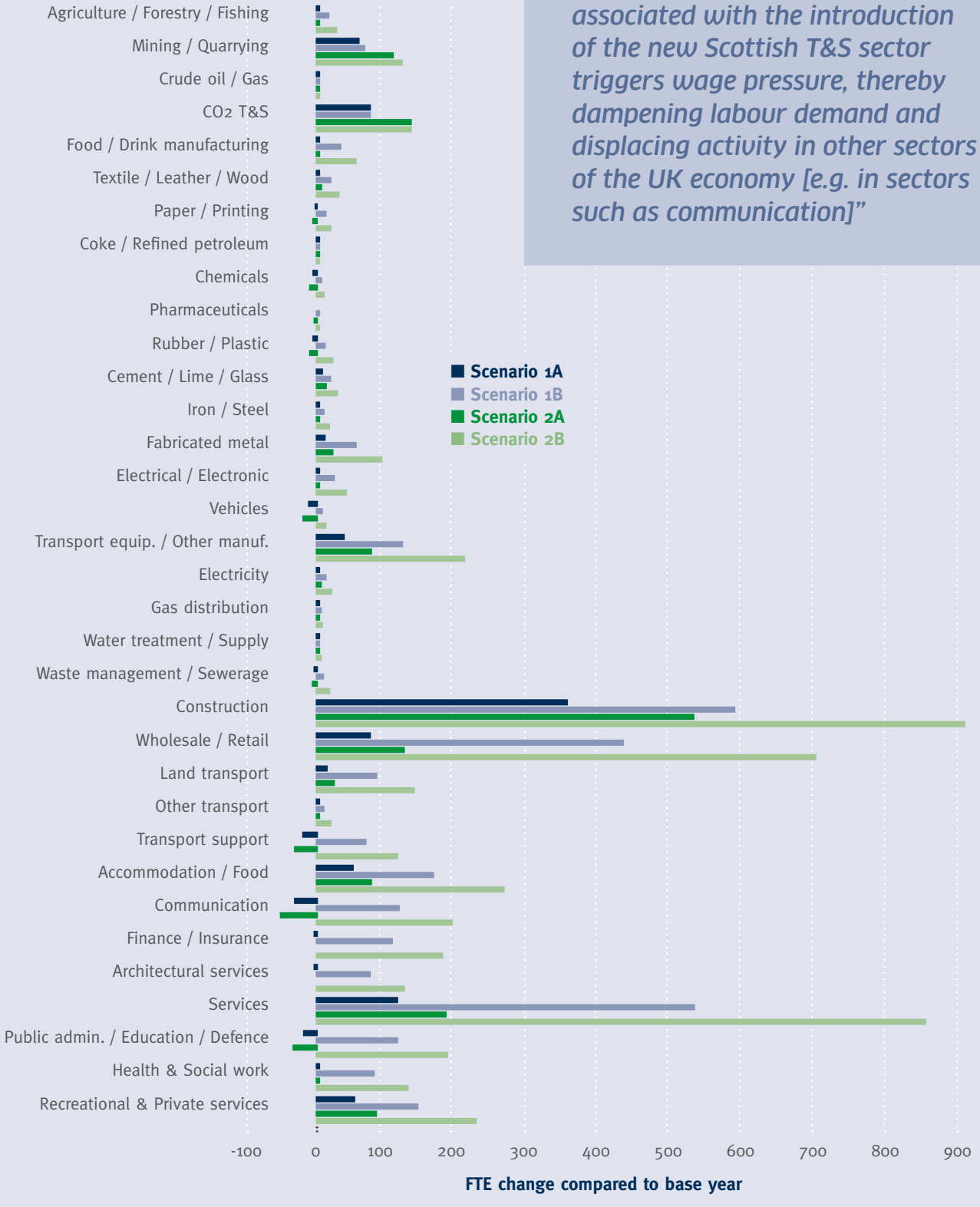
However, that additional labour demand associated with the introduction of the new Scottish T&S sector triggers wage pressure, thereby dampening labour demand and displacing activity in other sectors of the UK economy – see **Figure 4** – is clear if we consider the corresponding **B case**. This effectively shows 'the size of the prize' if constraints in the UK labour market – and, crucially, their impact on wage-cost and price pressure across the economy – could be extensively eased through policy action to support skills, training, and participation in the UK labour force. Our **B cases** represent an extreme where there is no response in real wage bargaining as labour demand increases, similar to what a simple demand-drive multiplier model may estimate but involving a longer dynamic adjustment process that such simpler models do not identify.

SECTION 4 CONTINUED

FIGURE

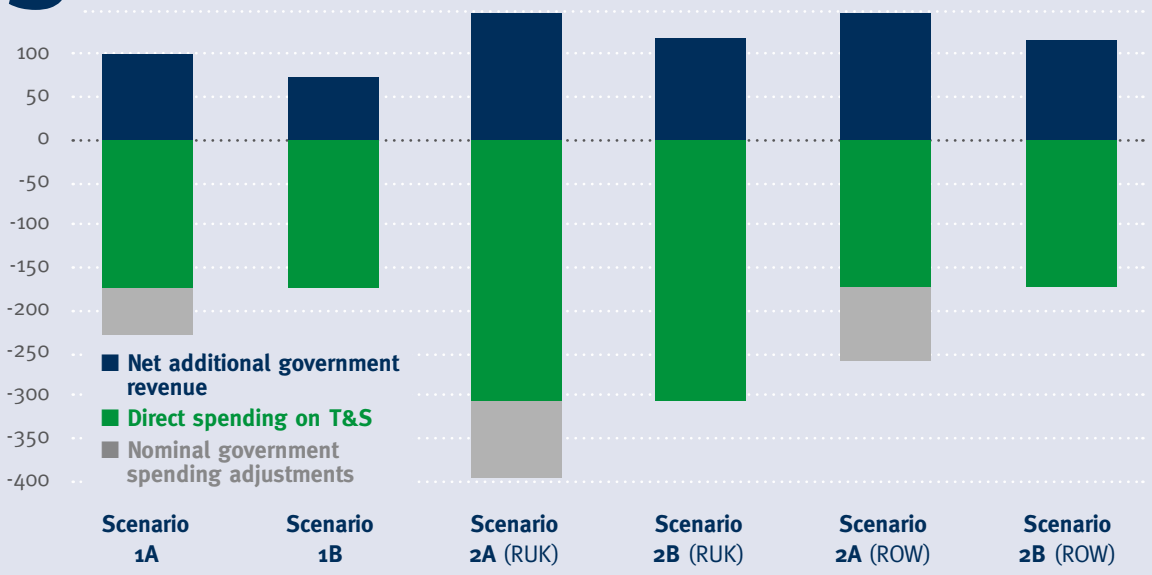
4 Sustained sectoral employment impacts due to the operation of the Scottish T&S sector

"...additional labour demand [e.g. in sectors such as construction] associated with the introduction of the new Scottish T&S sector triggers wage pressure, thereby dampening labour demand and displacing activity in other sectors of the UK economy [e.g. in sectors such as communication]"



FIGURE

5 Sustained impacts on UK public budget (£M) of introducing Scottish T&S, varying labour market assumptions (A vs. B) and export destination



The shift from **Scenario 1** to **Scenario 2** is more discreet and achievable, here, we further scale the investment and rollout of the Scottish T&S sector to service an additional 3MtCO2e shipped in via the Peterhead Port from elsewhere in the UK or from overseas. The impacts on GVA, employment and other sectoral and macroeconomic activity variables are almost identical whether we run our scenarios assuming the sequestration needs in question are located elsewhere in the UK or overseas.

However, there is a key difference in terms of the public support requirement. If the Scottish T&S sector is servicing sequestration requirements elsewhere in the UK, we assume this will imply that the UK Government must subsidise users, effectively guaranteeing demand for the additional Scottish T&S output. In moving from Scenario 1 to 2, this increases the size of the green element of the bars in **Figure 5** that represents the 'direct spending on T&S' element of the (deficit) impact on the UK public budget.

Where an overseas export base is exploited, this additional public spending requirement drops out and the increased revenues associated with the bigger Scenario 2 expansion (blue element of the bars in **Figure 5**) offset more of the deficit impact on the public budget.

There are a couple of other noteworthy points in considering **Figure 5**. First, while the **B scenarios** all involve a greater expansion in activity and employment, the government revenue gains are smaller. This is the trade-off in expanding employment without real wage growth: the increase in income tax is limited to expanding the tax base.

The second point to note is that any increase in the consumer price index (CPI) – see **Table 4** in **Section 5** – resulting from the constrained expansion will have further negative impacts on the public finances (and vice versa). Of course, this is assuming that the UK Government is committed to maintaining real spending levels on good and service, transfers, and benefits. If not, the negative grey bar elements would disappear from **Figure 2**.

This section of the report has updated on all our previously published estimates of the wider UK economy impacts of introducing the Scottish T&S sector, using the most recently available model and scenario information, and the industry picture set out in **Section 3**. No doubt there will be need for further updates as the policy and industry landscape, and data/evidence base, further evolve.

However, the other key development in our final year working on the SNZI programme is to set the findings reported above in the context of the wider UK picture on the unfolding T&S system sequencing process. This motivates setting the results reported so far alongside those for other clusters and the wider UK, and developing a set of reporting metrics that allow for valuable and informative comparisons. This is the focus of **Section 5**. ■

SECTION

5 Comparative analysis of the economy-wide impacts of introducing the Scottish T&S sector as part of a wider UK CCUS rollout

5.1 Own cluster emissions only

The last stage of our research on the SNZI programme involved running comparable economy-wide scenario simulations for each of the other Track 1 and Track 2 regional T&S subsectors.

In **Section 3**, we have explained our assumptions regarding the investment and operation of regional T&S sector activity emerging around the East Coast, Hynet and Viking cases. In **Table 4** we report the sustained outcomes, again all achieved by around 2040 under the assumption of the UK Government guaranteeing demand for the full capacity created during this timeframe (13 years after the Track 1 T&S systems become operational, 10 years for Track 2), focusing on the case (labelled **A** in **Section 4**) where the UK's persisting labour supply constraints bite. See **Tables B.2** and **B.3** in **Appendix B** for corresponding **Scenario 1B** case results, where the labour supply constraint or, more specifically, the wage-cost impacts thereof are relaxed.

5.1.1 UK-wide outcomes

The final column of **Table 4** provides the aggregate picture for the wider UK T&S sector, focusing on the case where the regional subsector associated with each cluster only sequesters local cluster emissions.[33] Here, it is important to note that the UK outcomes reported in **Table 4** and **Figure 8** (as well as below in **Table 5** for scenarios involving shipping of emissions from outwith the Track 1 and 2 clusters) are an additive picture across separate simulations for each regional T&S subsector case. We have also simulated the introduction of the UK T&S sector via the staged introduction of all four regional subsectors (i.e., running the four individual scenarios in a single simulation).

33 See Footnote 16 above – the UK outcomes reported in Table 4 and Figure 6 (as well as below in Table 5) are an additive picture across separate simulations for each regional T&S subsector case. Going forward, it will be appropriate to simulate all T&S system cases simultaneously in line with how the UK cluster sequencing process involves different T&S system and economic sector activities emerging alongside one another and between Track 1 and 2. This may reveal additional economic adjustment processes that cause the national picture to deviate, perhaps very slightly, from the additive picture reported here

TABLE

4 Sustained macroeconomic impacts of introducing a UK T&S sector via the Track 1 and Track 2 regional subsectors (domestic emissions only)

	TRACK 1		TRACK 2		UK-WIDE	
	East Coast	Hynet	Scottish	Viking		
Capacity for emmissions sequestration	22MtCO2e	9MtCO2e	7MtCO2e	12MtCO2e	50MtCO2e	56MtCO2e
Public spending requirements (£M), composed of:	**534**	**201**	**229**	**270**	**1,235**	**1,539**
Direct spending on T&S (£M)	402	151	173	203	929	1,172
Nominal adjustments to meet real spending commitments (£M)	132	50	57	67	305	367
Additional government revenues generated (£M)	226	85	97	114	522	629
Net public spending requirement (£M)	308	116	132	156	713	910
Gross value added, GVA, or GDP (£M)	389	146	167	196	898	1,066
Gross value added, GVA, or GDP (% change)	0.020	0.008	0.009	0.010	0.047	0.056
Employment (FTE)	1,781	671	765	901	4,117	4,961
Employment (% change)	0.006	0.002	0.003	0.003	0.014	0.017
Unemployment (% change)	-0.141	-0.053	-0.061	-0.071	-0.327	-0.394
Average nominal wage (% change)	0.030	0.011	0.013	0.015	0.070	0.085
Average real wage (% change)	0.016	0.006	0.007	0.008	0.037	0.045
CPI – index to 1 (% change)	0.014	0.005	0.006	0.007	0.033	0.040
Exports (£M)	-155	-58	-67	-78	-359	-432
Imports (£M)	215	81	93	109	498	650
Real household consumption (£M)	287	108	123	145	662	789
Total investment (£M)	**248**	**93**	**107**	**125**	**573**	**674**

This is motivated by the need to understand how the resource competition associated with more extensive nascent sector activity, occurring in the same broad timeframes, may exacerbate cost and price pressures, and the impacts thereof, beyond a simple summation of component elements. To our knowledge, it also constitutes a first test of how the potentially crowded net-zero space could be associated with an accumulation of pressures on constrained resources. The outcomes for UK T&S (likely to be one of the smaller nascent sector activities emerging through the net zero transition) are reflected in **Figures 6** and **7**, where we compare our core 'additive' and the additional 'simultaneous' case, where we show how key macroeconomic variables adjust to the 2040 outcomes we focus on.

"...a first test of how the potentially crowded net-zero space could be associated with an accumulation of pressures on constrained resources"

FIGURE

6 Dynamic adjustment of UK real wage, nominal wage and CPI impacts due to the deployment and operation of the UK T&S sector (additive and simultaneous simulation results)

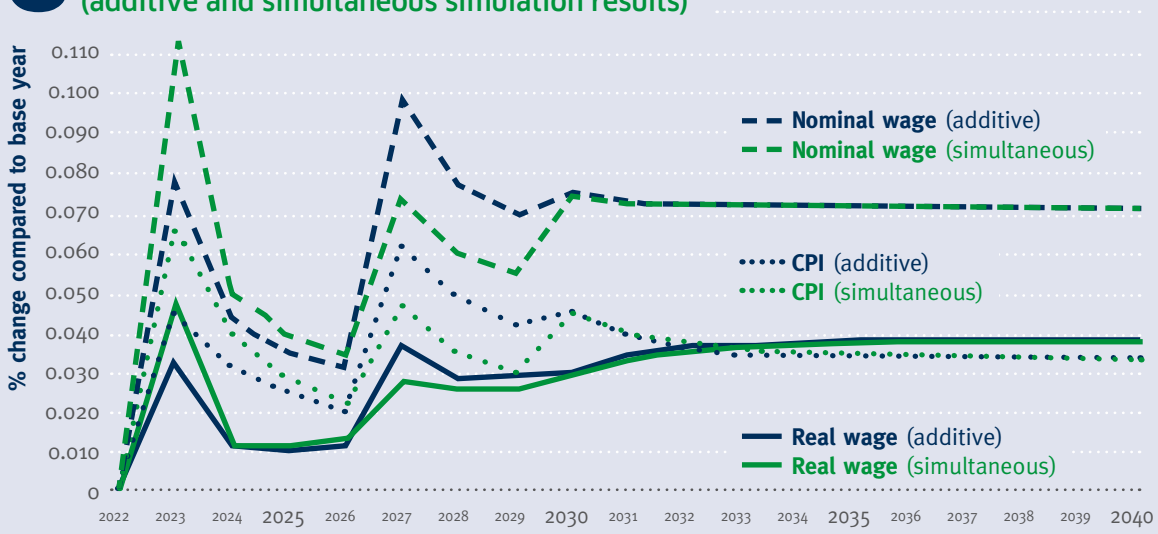


Figure 6 reports the dynamic real wage response as the four regional T&S subsectors are first invested in and then become operational. Note that the initial spike, as investment in the two Track 1 cases begins, is greater in the simultaneous case, which triggers greater nominal wage impacts for producers and CPI impacts for consumers. In **Figure 7**, while the larger transitory real wage increase induces a more substantial gain in employment, the cost-price effects cause a temporary slump in gross value added (GDP) in the simultaneous simulation case.

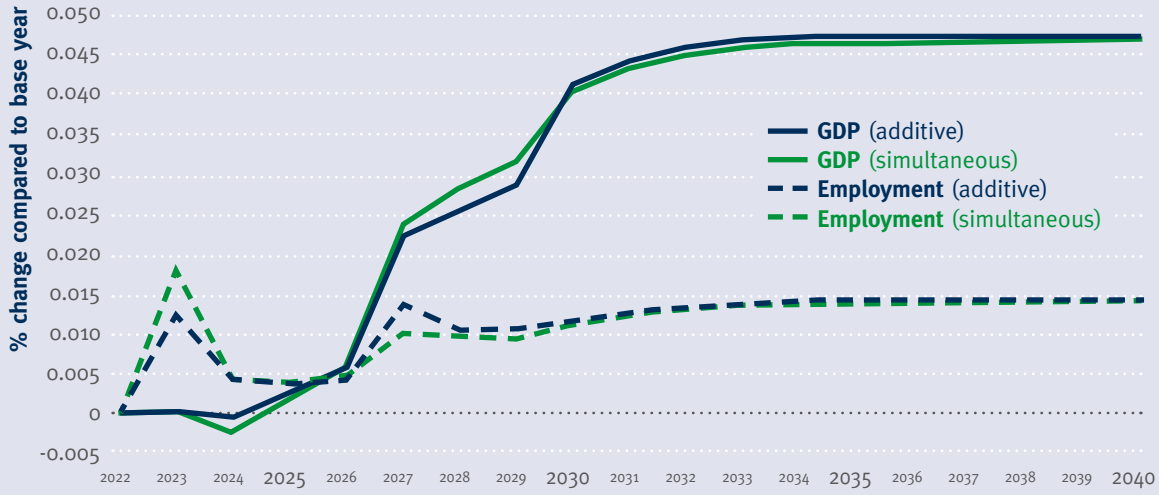
By the time investment begins in the two Track 2 regional T&S systems in 2027, the slightly faster expansion in activity across the economy in the additive case causes the labour supply constraint to 'bite' a bit more so that the real wage driven cost-price pressure becomes greater than in the simultaneous simulation case. This causes the respective GDP and employment transition paths to begin to merge so that, by the time the economy adjusts to the 2040 period that we focus on here, there is little difference between the two cases (translating to around 5 FTE jobs and less than £M in annual GDP). For this reason, we focus our comparison of 2040 outcomes on the additive results reported in **Table 4** and continue with that approach in considering the impact of shipping in the two Track 2 cases. (**Section 5.2**).

Nonetheless, the results reported here are important for policymakers to consider. In terms of the nascent T&S sector case we focus on here, it suggests that even if the regional T&S subsectors do not compete directly with each other (which we constrain them from doing here with the exogenous introduction of T&S activity), the impact of albeit staged simultaneous investment and deployment will have significant wage-drive cost price impacts that are likely to constrain the wider economic expansion. This underpins **Key Finding 7** for the work reported here. However, arguably, while the impact is relatively small for T&S on its own, the kind of dynamics highlighted here are likely to become more important if a greater number of net-zero activities, including the rollout of other nascent sectors, must happen in the same/similar timeframes.[34]

34 In another current project, funded by the UKRI Industrial Decarbonisation Research Centre (IDRIC), also as part of the ISCF IDC, we are exploring the regional level impacts of taking an additive or simultaneous scenario simulation approach

FIGURE

7 Dynamic adjustment of UK GDP and net employment impacts due to the deployment and operation of the UK T&S sector (additive and simultaneous simulation results)



KEY FINDING

7 **The planned simultaneous staged introduction of Track 1 and 2 CCUS projects, involving what are effectively four regional subsectors of a nascent UK T&S sector, is likely to exacerbate resource competition across all sectors. It will, thereby, constrain wider economy gains in the early stages, despite a slight boost in near term jobs gains.**

5.1.2 Comparison of outcomes across the Track 1 and 2 regional T&S subsectors

We can conclude that the first three key findings reported in **Section 4.1** for Scotland apply to all Track 1 and 2 regional T&S subsectors. Even with worker and skills shortages persisting throughout the UK labour market, the picture is broadly one of new regional T&S sector activity delivering sustained net gains in key UK macroeconomic indicators such as GVA/GDP and employment supported. The sustained positive picture emerges relatively quickly, within 10 years or so, even in the case of the relatively large Track 1 East Coast cluster (which we assume becomes operational in 2027).

While we focus here on the currently more realistic labour supply constrained case, we can confirm that the economy-wide gains associated with all the T&S system cases, and for the UK-wide T&S sector, could be substantially larger if action is taken on upskilling and labour market participation. (See **Appendix B**)[35] Similarly, the progression of our work through different database iterations shows that **Finding #6** remains key in investigating nascent T&S sector activity: if the capital intensity of a new sector is underestimated, the economic output it can produce and the extent of any wider economy expansion is likely to be overestimated, and vice versa.

35 Please see the CEP Policy Brief at https://doi.org/10.17868/strath.00086068 for previous UK-wide analysis, prior to our data and scenario updates following the announcement of the Track 2 T&S systems in July 2023

SECTION 5 CONTINUED

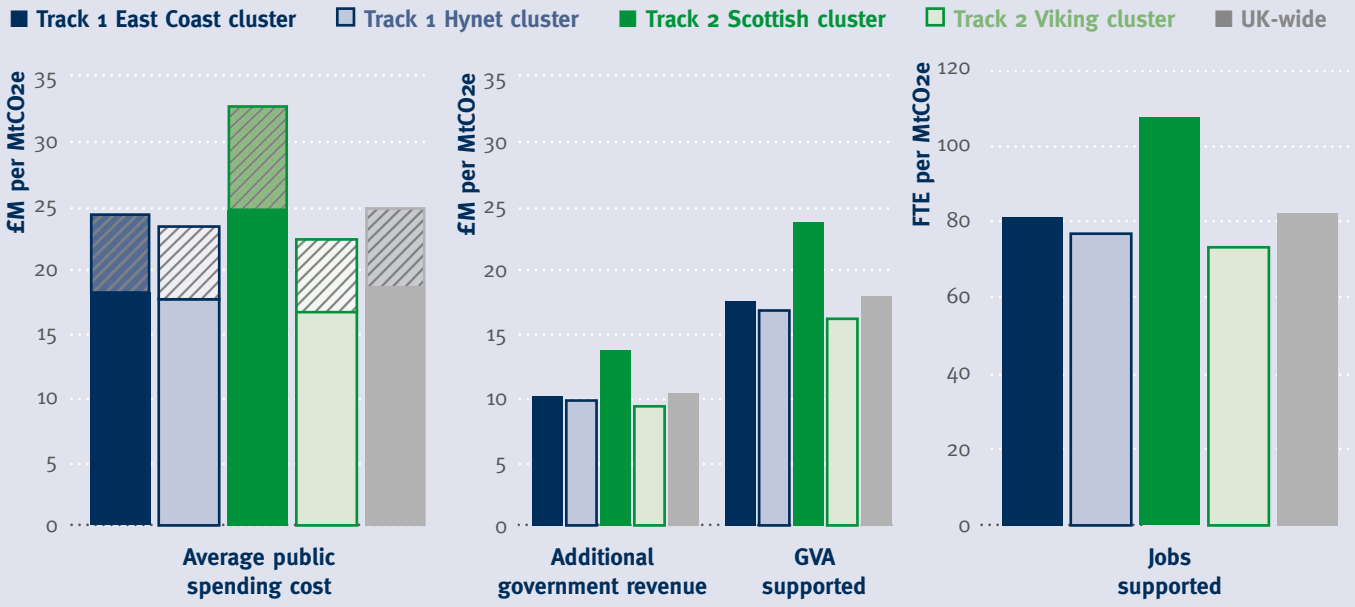
The comparative picture emerging in **Table 4** needs to be taken in the context of the scale of activity in each Track 1 and Track 2 case. For example, the most significant wider economy gains are observed for the East Coast T&S sector, which receives 45% of the initial investment (**Table 3**) and requires 43% of the annual government demand guarantee once operational, i.e., £402M each year, inflating to £534M if CPI impacts are considered (**Table 4**). Corresponding to the latter, it delivers 43% of the total employment, GVA/GDP and associated additional government revenue gains (given that we have assumed a common UK O&G industry benchmark for all supply chain activity to support the output effectively 'demanded' across the clusters). It sequesters 44% of the total emissions sequestered by the UK T&S as a whole.

The other Track 1 regional T&S sector, Hynet, sequesters 18% of total emissions, requiring 17% of the upfront investment and 16% of the annual public spending to guarantee demand (both direct and the CPI-adjusted variant in the top row of **Table 4**). This is associated with 16% of the employment, GVA/GDP, and additional government revenue gains. Here, Hynet shares some characteristics with Viking in terms of having greater sequestration capacity linked to geographically proximate emissions generation, with Viking accounting for 24% of the transport and storage of emissions but only requiring 21% of the upfront investment and 22% of the public spending requirement. However, this also means it only delivers 22% of the GVA, government revenue and employment benefits.

These characteristics are reflected in the comparative metrics reported in **Figure 8**, where, on the left, we see that the average costs to the public purse of sequestering one MtCO2e via

FIGURE

8 Comparative headline metrics of public spending costs and wider economy gains per $MtCO_2e$ sequestered for the different Track 1 & 2 T&S sectors (scenario 1A – own cluster emissions only)



new T&S sector activity are relatively high in the case of the Scottish T&S sector. This metric is calculated as the direct public spending divided by the emissions sequestered, in the solid element of each bar unadjusted for the CPI increase associated with the expansion – i.e., £173m for the 7MtCO2e for the Scottish case in **Table 4**. The value increases – as shown in the dashed element of each bar – if we include the nominal spending adjustments (on all government purchases) caused by the rise in the CPI triggered by introducing new T&S activity. This represents £57M in the Scottish case (associated with just a 0.006% increase in the CPI), taking the total public spending requirement in the top row of **Table 4** to £229M for that Track 2 regional T&S sector.

However, the relatively big CPI driven dashed element (even for what looks like a very marginal increase in that central price index) reflects that the outcome of the wider economy activity stimulated by the Scottish T&S in the supply constrained economic environment is also markedly higher than average. This dynamic is reflected in the middle and right-hand frames of **Figure 8** in terms of the above average additional government revenues, GVA/GDP and employment supported per physical unit of emissions (MtCO2e) sequestered by Scottish T&S.

This is where the Scottish cluster and the linked regional T&S sector is quite distinct. With relatively geographically dispersed emissions sources – spreading up from Grangemouth in the eastern central belt of Scotland, through Mossmorran, via a feeder pipeline, to the Peterhead powerplant, linking to the offshore pipeline network at St Fergus – the Scottish T&S sector sequesters a smaller share of emissions (14%). On the other hand, this is associated with a relatively large share of both the investment requirement (18%) and of the wider economic benefits (19%), extending across key metrics such as GVA (GDP), employment, boosted household spending and the additional government revenues that help offset the direct public spending requirement, albeit aggravating the nominal cost pressures therein.

Thus, another key finding for the SNZI programme and nascent T&S sector linked to the Scottish cluster emerges.

The more geographically concentrated T&S systems in the North of England can sequester emissions at lower average (and marginal) cost to the public purse per physical unit. However:

KEY FINDING

8 **Larger investment requirements in the Scottish case deliver a more than proportionate share of the value of the new UK T&S sectoral activity and associated employment, GVA and government revenue gains, albeit associated with more CPI pressure, particularly given the persisting labour supply constraints in the UK.**

5.2 Shipping potential of Track 2 T&S sectors

The next question is whether similar findings emerge if we consider the additional sequestration capacity identified (so far) for T&S activity associated with the Scottish cluster and the other Track 2 T&S system, Viking. This could equate to potential for the associated regional T&S subsectors to sequester more emissions from UK industry clusters outside the Track 1 and Track 2 core, and/or develop an overseas T&S export base.

According to the data available at the time of the study, both the Acorn T&S system and Viking have plans in place to each service an additional 3MtCO2e of emissions in addition to the requirements of the industries in the local cluster. As set out in **Section 3**, this will involve further investment, including a shift to international shipping rather than domestic

TABLE

5 Additional sustained macroeconomic impacts in the UK of extending capacity of the Track 2 T&S sectors to ship emissions from elsewhere in the UK or overseas

	SCOTTISH T&S SECTOR			
	Shipping additional 3MtCO2e to Scottish stores from elsewhere in the UK		Shipping additional 3MtCO2e to Scottish stores from overseas	
	Additional impacts	Total impacts with 10MtCO2e capacity	Additional impacts	Total impacts with 10MtCO2e capacity
Public spending requirements (£M), composed of:	**168**	**398**	**31**	**260**
Direct spending on T&S (£M)	134	306	0	173
Nominal adjustments to meet real spending commitments (£M)	35	92	31	88
Additional government revenues generated (£M)	59	156	55	152
Net public spending requirement (£M)	109	241	-24	109
Gross value added, GVA, or GDP (£M)	94	261	91	258
Gross value added, GVA, or GDP (% change)	0.005	0.014	0.005	0.013
Employment (FTE)	471	1,236	439	1,204
Employment (% change)	0.002	0.004	0.001	0.004
Unemployment (% change)	-0.037	-0.098	-0.035	-0.096
Average nominal wage (% change)	0.008	0.021	0.007	0.021
Average real wage (% change)	0.004	0.011	0.004	0.011
CPI – index to 1 (% change)	0.004	0.010	0.004	0.010
Exports (£M)	-41	-108	92	25
Imports (£M)	83	176	78	171
Real household consumption (£M)	71	194	64	187
Total investment (£M)	**57**	**163**	**55**	**162**

pipeline transport in bringing emissions to North Sea stores. Here, our estimates for both the Scottish and Viking T&S sectors assume an average journey based on the distance from the Southampton industry cluster for other UK or Hamburg in Germany for overseas emissions.

Thus, as in the domestic case in **Section 5.1**, Viking again has a cost advantage in terms of relatively shorter distances for transport to offshore stores. However, for both Track 2 T&S sectors, the average cost of shipping in emissions is higher than sequestering own cluster emissions, while there is leakage of wider economy value due to the reliance on international shipping services rather than domestic network activity.

Nonetheless, the results in **Table 5** –

VIKING T&S SECTOR				UK-WIDE T&S SECTOR (INCLUDING ENTIRELY DOMESTIC TRACK 1 & 2 T&S SECTORS)	
Shipping additional 3MtCO2e to Viking stores from elsewhere in the UK		Shipping additional 3MtCO2e to Viking stores from overseas		(with shipping within UK for Scottish cluster and Viking)	(with overseas shipping for Scottish cluster and Viking)
Additional impacts	**Total impacts with 15MtCO2e capacity**	**Additional impacts**	**Total impacts with 15MtCO2e capacity**	**Total impacts with 56MtCO2e capacity**	**Total impacts with 56MtCO2e capacity**
136	**406**	**25**	**295**	**1,539**	**1,290**
109	312	0	203	1,172	929
28	94	25	91	367	361
47	161	43	158	629	620
89	245	-19	137	910	670
74	270	72	268	1,066	1,061
0.004	0.014	0.004	0.014	0.056	0.055
374	1,274	348	1,249	4,961	4,904
0.001	0.004	0.001	0.004	0.017	0.017
-0.030	-0.101	-0.028	-0.099	-0.394	-0.389
0.006	0.022	0.006	0.021	0.085	0.084
0.003	0.011	0.003	0.011	0.045	0.044
0.003	0.010	0.003	0.010	0.040	0.040
-33	-111	76	-3	-432	-191
68	177	65	174	650	641
56	201	50	195	789	776
44	**170**	**43**	**168**	**674**	**672**

reporting both the additional impacts relative to **Table 4** for the Scottish and Viking cases, distinguishing between shipping from other UK industry or overseas, and the adjusted picture for both and UK-wide under **Scenario 2A**[36] – demonstrate that the **Key Findings 4** and **5** set out in **Section 4.1**, for the Acorn-linked Scottish T&S sector, also apply in the case of Viking. That is, our scenario simulation results suggest that extending the capacity of either Track 2 element of the UK T&S sector to sequester emissions from elsewhere in the UK or overseas will increase the magnitude of macroeconomic gains, even with national labour supply constraints biting.

However, where the additional emissions are sequestered from within the UK, the direct public spending requirement in guaranteeing demand for the additional 6MtCO2e being sequestered from UK industry increases from £929M in the final column of **Table 4** to £1.17BN in the penultimate column of **Table 5**. This increase of £242M per annum is exacerbated by an additional £62M (i.e., from £305M in **Table 4** to £367M in **Table 5**) to maintain the real value of all government spending.

36 The corresponding 2B scenario results – with labour supply constraints relaxed are presented in Table B.4 in Appendix B

On the other hand, where an overseas export base is exploited, the £56M increase in nominal spending adjustments (i.e., from the £305M value in the final column of **Table 4** to the £361M result in the final column of **Table 5**) is the only additional public spending requirement that erodes an additional £98M in revenue gains.[37]

However, the additional revenue gain is limited due to the additional boosts to UK GVA and employment (and associated income) being less than proportionate to those associated with the initial pipeline-based domestic T&S sector activity. This is due to the leakage effect of relying on international shipping. Moreover, the greater CPI pressure is driven by further wage-cost pressure for as long as labour supply constraints persist.

Regarding the picture across the two Track 2 regional T&S sectors, the average cost to the public purse of sequestration remains lower for Viking when shipping capacity is added. Consider the Acorn and Viking outcomes for average public spending cost per MtCO2e in **Figure 9** relative to the no shipping case in the left-hand frame of Figure 8. Here, the direct public spending requirements (including CPI impacts on nominal spending in the dashed element of each bar) per MtCO2e reported for each of the Track 2 T&S sectors in **Figure 8** increase by 21% and 20% (from £33Mand £22M to £40M and £27M) in the Scottish and Viking cases respectively where shipping involves additional UK emissions.

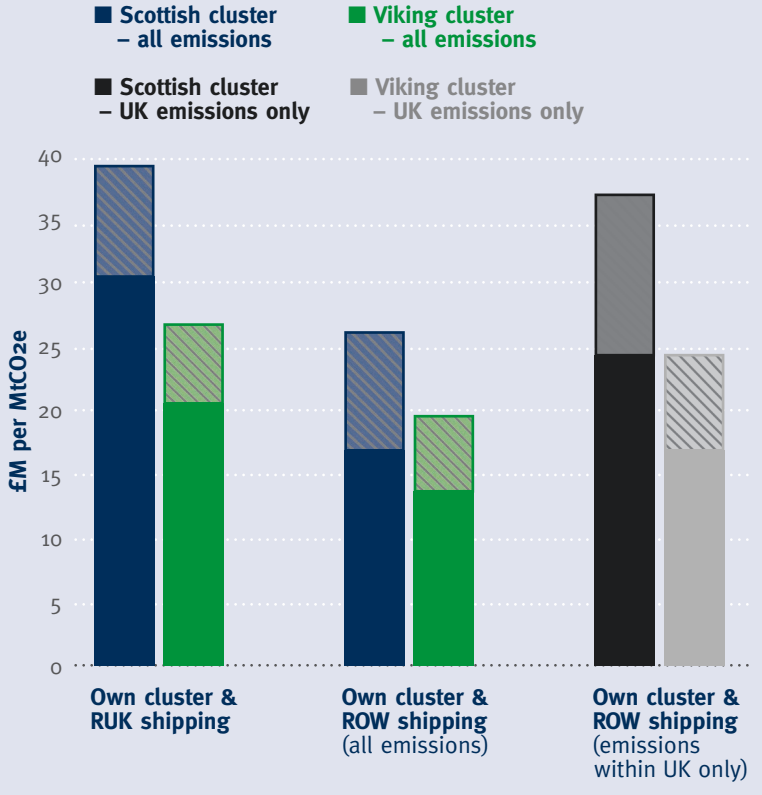
On the other hand, if emissions are shipped from overseas (middle frame of **Figure 9**), the average cost per MtCO2e falls for the UK Government, being spread over a larger amount of sequestration, and is lower for Viking, with its lower shipping and sequestration costs relative to Scottish T&S. However, part of this (3MtCO2e in each of the Acorn and Viking cases) relates to emissions reductions that are paid for by the overseas users of UK T&S services but do not count towards UK net-zero targets.

In the right-hand frame of **Figure 9**, we reset the metric in terms of only shipping emissions generated within the UK (and darken the shading to distinguish from the middle frame). The impact for both the Scottish and Viking T&S sector cases is limited to the larger CPI impacts on wider nominal government spending requirements when the constrained economy grows more with exploitation of the new export base. That is, the solid bars in the right-hand frame of **Figure 9** are the same as for the Scottish and Viking cases in **Figure 8**, but the dashed elements increase, more so in the Scottish case because of the greater wider economy expansion with exports per MtCO2e.

The question is whether the public spending and other costs that would be reflected in effective or actual output prices for either of these clusters would make shipping a viable prospect. Here, the impact of shipping on the wider

FIGURE

9 Comparative headline metrics of public spending per MtCO2e sequestration for Acorn and Viking T&S sectors with shipping (scenario 2A)



37 As noted previously – see Footnotes 16 and 27 – the UK level picture reported in Tables 4 and 5 is an additive one, across the four regional T&S subsectors, each simulated separately. If we simulate all of the regional T&S sector scenarios simultaneously, there may be impacts across markets, prices and sectors that cause variations in some or all timeframes from an additive picture. Moreover, when we introduce shipping – with a different capital intensity and input mix – this may trigger further variations. We are currently exploring these issues in a project funded by IDRIC

economy benefits delivered per physical unit of emissions sequestered may become an important consideration. In this regard the Scottish T&S may be considered appealing.

That is, comparing the results in **Tables 4** and **5**, we find that, with additional capacity for shipping, the wider economy benefits grow more in the Scottish case compared to Viking regardless of where emissions are shipped in from. The GVA, employment and consequent additional government revenue impacts of introducing Scottish T&S all increase between 55% and 62% when moving from **Table 4** to **Table 5** (slightly less when exporting overseas due to price and international competitiveness impacts). For Viking, the gains from increasing capacity through shipping are also substantial, with the increase in GVA, employment and revenue impacts moving between **Tables 4** and **5** in the 36% to 41% range.

It is important to note that these are not straightforward proportionate 'multiplier' impacts – for example, based on the per $MtCO_2e$ metrics in **Table 6** – with the Scottish T&S capacity growing by 43% (from 7 to 10$MtCO_2e$) and Viking by 30% (from 12 to 15 $MtCO_2e$). This is partly due to the change in supply chain requirements (including reduced capital intensity with reduced reliance on pipelines and greater reliance on imported shipping).

This outcome is also due, on the one hand, to the wider economy response as the greater wider economy expansion taking place in the presence of the same labour supply constraints. However, the greater increase in labour demand is therefore associated with largely proportionate increase in real wage rates which help partly offset the CPI impacts in on household spending. On the other hand, rising labour costs will have implications for the competitiveness of all sectors of the economy, including the emerging T&S sector and associated CCUS projects.

This all allows us to identify a ninth and final key finding:

KEY FINDING

9 If UK public finances, emerging internal and/or external markets in T&S services can bear the higher costs of sequestering to Scottish North Sea stores, increasing the capacity of the UK T&S sector through extensions to the Track 2 T&S systems, and associated regional T&S subsectors, is likely to deliver proportionately greater gains in supported GVA, employment and associated government revenues.

However, in expanding capacity in this way, it becomes increasingly important to investigate and understand the impacts of associated shifts in the T&S supply chains and the implications of labour market responses and supply constraints in underpinning key trade-offs between rising real wages and cost-of-living/doing business impacts, including on CCUS projects going forward. ■

SECTION

6 Emerging conclusions and policy implications

Our results demonstrate that nascent sector activity in CO_2 T&S emerging around the CCUS networks being developed in the UK around the Track 1 and 2 clusters have the potential to deliver substantial economic benefits (Key Finding 1). This is reflected in specific simulated results such as levels of GVA (GDP), employment and government revenues supported in different timeframes and potentially sustained when the economy has fully adjusted, which takes around 10-15 years (Key Finding 2).

Here, dependent on provision of public support in the short- to medium-term, we find that **a Scottish T&S sector emerging around the Acorn T&S system and Scottish East Coast industry, sequestering 7M tonnes of CO2 equivalent (MtCO2e) per annum, could support 765 FTE jobs across the UK economy. This is associated with supporting £167M gross value added (GVA or GDP) per annum by the early 2040s, or within 10-15 years of becoming fully operational.**

Where supply constraints in the UK labour market persist and/or there is insufficient action on skills and labour market participation, there is a likelihood of some extent of displacement of activity in some sectors and wage-cost driven price increase affecting all sectors of the economy. This will limit the magnitude of activity supported and of any potential wider economy expansion triggered by investment in new regional T&S sector activity. For example, our results show that **if action is taken to address the type of skills challenges frequently identified by industry and/or encourage greater participation in the UK labour force, economic benefits could be substantially greater, increasing the jobs and GVA gains supported to, respectively just over 3,000 full-time equivalents across the UK and just over £300M per annum.** However, such an outcome would involve limited real wage growth which will limit the extent of income tax accruing from an increased tax base. (**Key Finding 3**).

Such a trade-off regarding the extent of activity supported set against impacts on the tax base is an important one for policymakers to consider. This is particularly so in the timeframes considered here, where substantial public support is likely to be required and planned by the UK Government – possibly throughout the period to the early 2040s considered here – in a form that we assume here effectively guarantees demand for T&S capacity created through interventions such as subsidising T&S users.

Generally, policymakers face a real challenge in considering the trade-offs in terms of the costs versus the benefits of enabling greater expansion of new T&S sector activity. A crucial case in point is the potential benefits achievable – in terms of both delivering greater reductions in damaging CO2 emissions and increasing the economic benefits of new sector activity – if greater geological storage potential associated with the Track 2 T&S systems is exploited through shipping of emissions from elsewhere in the UK or from overseas (**Key Finding 4**). Our findings show that the potential economic benefits are similar regardless of where emissions are shipped from, but the costs to the public purse are not (**Key Finding 5**).

Our specific focus on the SNZI programme on a T&S sector emerging around the Scottish cluster and Acorn T&S project exemplifies this point and should inform policy thinking around how nascent UK regional T&S sector capacity may be planned to ensure efficient utilisation of that capacity and the most competitive decarbonisation pathways for UK industry, within and beyond the Track 1 and 2 clusters.

That is, **we find that the number of FTE jobs supported across the wider UK economy by a Scottish T&S sector is likely to increase by 62% (from 765 to up to 1,236 – see Figure 1) and supported GVA by 56% (from £167M per annum to £261M) if the sector's sequestration capacity were to increase by just over 40%, from 7MtCO2e for Scottish cluster emissions to 10MtCO2e,**

through development of an internal UK and/or overseas export base. This is assuming that no action is taken on relaxing labour supply constraints or addressing skills challenges: if action were forthcoming, the employment and GVA supported emergence of a Scottish T&S sector servicing both Scottish industry and other UK or overseas decarbonisation requirements could rise to almost 5,000 jobs and close to a £500M per annum contribution to GDP.

However, if emissions are shipped from elsewhere in the UK, with the implication that the UK Government effectively guarantees demand for the additional 3MtCO2e in Scottish T&S capacity, we estimate that the public spending requirement (including CPI impacts on nominal spending commitments) will increase by 74%. On the other hand, if an overseas export-base is developed, the additional public spending requirement is limited to nominal adjustments to real government spending due to the CPI impacts of introducing the new industry activity. Our findings (across Tables 4-5) suggest that this CPI pressure would imply a 14% increase in required wider public spending relative to a potential 56% increase in additional government revenues, proportionate to greater employment gains (underlying the importance of income tax) if an overseas rather than internal UK shipping base is developed for Scottish T&S.

Of course, all the quantitative results reported here are dependent on the information available to inform our economy-wide model and the scenarios we put into it. Comparison with our earlier SNZI programme outputs shows that with such an infrastructure-intensive nascent sector as CO2 T&S, the magnitude of GVA, employment, revenue, CPI and other numerical results are crucially dependent on understanding the capital intensity of the new industry (**Key Finding 6**). Moreover, noting that our analysis benchmarks T&S on the existing UK oil and gas industry and its supply chains, there is a need to consider the extent to which current high-value jobs and skilled workers can be transitioned to nascent sectors like T&S and whether there are implications not only in terms of things like wage rates but also for the local communities where labour may move to and from.

Thus, there are key policy implications not only in terms of the need to engage in workforce planning at regional and national levels, alongside attention to skills and workforce participation, but to support the development of information and datasets that enable systematic and policy-facing analyses of the role that nascent regional and national sectors like T&S may play in the transitioning economy.

Nonetheless, even with the immature information sets available at the time of this study, the qualitative insights are robust. Moreover, our analysis produces some key insights in terms of the cost versus value propositions that emerge in considering the potential contributions of CCUS systems and linked nascent T&S sector activity emerging in different parts of the country. Crucially, the approach adopted allows us not only to compare potential wider economy outcomes across each of the regional T&S subsectors linked to the Track 1 and Track 2 CCUS developments, but to consider how the simultaneous (but staged) introduction of several (even similar) new activities may impact in a supply-constrained economy. Here, even with even UK-wide T&S potentially being small relative to what will need done in terms of new activities and nascent sectors in the net zero space, we do find that emergence of regional T&S subsectors is likely to exacerbate resource competition across all sectors. Thus, our analysis suggests something of a congestion effect that constrains wider economy gains in the early stages, even where we abstract from direct production and resource competition (**Key Finding 7**).

With our project focusing on the Scottish case, our results suggest that the T&S sector emerging around the relatively geographically dispersed Scottish cluster may involve greater levels of investment per physical unit of emissions sequestered than other emerging regional T&S subsectors. However, there is something of a positive value trade off in that the higher average costs reflect a proportionately greater level of economic activity. Thus, the GVA, employment and revenue outcomes per unit of sequestration activity are likely to be above the UK average when regional T&S activity associated with the other three planned T&S systems is considered and compared (**Key Finding 8**).

However, such value propositions need to be set in the context of the costs to domestic actors, including the industry actors who will need to bear the costs of T&S and other CCUS requirements going forward, and whether emerging international

SECTION 6 CONTINUED

markets in T&S will bear prices implied by the costs of sequestration in regional networks such as the Scottish one.

Thus, our finding that increasing UK T&S capacity via shipping of CO_2 emissions from elsewhere in the UK or overseas via the Track 2 Scottish and Viking regional T&S sectors is likely to deliver proportionately greater gains in supported GVA, employment and associated government revenues must be qualified. This is regarding whether emerging internal and/or external markets in T&S services can bear the costs of sequestering to North Sea stores (**Key Finding 9**). Moreover, any further expansion will exacerbate trade-offs between the benefits of rising real wages and income from employment and the impacts of persisting labour supply constraints on the costs-of-living and doing-business, including deploying and operating the CCUS project itself.

This, in turn, emphasises the need for Government leadership and planning in prioritising the objectives of the CCUS rollout set in the context of prevailing and evolving economic conditions and constraints and how they can be improved and/or mitigated, particularly in terms of easing congestion effects. Moreover, this is not limited to the needs of the Track 1 and 2 industry clusters. Going forward, others, such as the South Wales cluster and the Solent cluster (which we focus on in calculating domestic shipping costs), may need to rely on using the storage services of other UK clusters or overseas providers, given that they do not have any neighbouring storage sites that could be accessed via pipelines. Any plans regarding an extension to direct air capture (which would likely involve less and/or different onshore supply chain activity) would introduce further trade-offs in terms of the benefits such a presumably commercial opportunity may present.

Generally, from an industrial decarbonisation perspective, the question arising is how the cost and value propositions for UK actors compare in terms of, for example, using Scottish or Viking T&S sector services or importing T&S services from an international competitor, such as Norway.

This should give rise to some important considerations. On the one hand, if the emerging Scottish and/or Viking regional T&S sectors are competitive in international markets, the UK could maintain the benefits of exporting T&S services abroad. However, if other UK industry clusters require T&S capacity, an outcome of a free-market approach may be that some actors will potentially rely on (for them) more expensive international T&S services, thereby increasing overall domestic industrial decarbonisation costs and risking competitiveness. On the other hand, if the Scottish and/or Viking regional T&S sectors are not competitive in the international marketplace, the UK risks losing the potential wider economy benefits like losing out on a new export base and importing services required to meet industrial decarbonisation targets.

Thus, in addition to better understanding the cost/value proposition, there is an urgent need to review and make decisions on how competition between T&S networks (at home and abroad) will operate and the extent of government leadership required to ensure that new UK T&S and other CCUS-related industries maximise domestic GVA, employment and revenue gains while delivering competitive decarbonisation for UK industry. ■

RECOMMENDATION

1 Policy actors and industry should use the evidence and insight emerging here on the cost/value proposition and potential wider public policy trade-offs in considering how new T&S sector activity around UK CCUS, and the new regional economic activity therein, can deliver a range of potential wider economy gains.

RECOMMENDATION

2 There is an urgent need to review and make decisions on how competition and/or coordination between nascent T&S economic sectors (at home and abroad) will operate. Crucially, this is not limited to 'product' competition (i.e. T&S services) but to resource competition, which is more complex, impacting all sectors of the economy and potentially constituting an example of potential wider 'net zero congestion'. In this regard, it is important to also make decisions regarding the extent of government leadership required to ensure that the new UK T&S sector and other CCUS-related industries maximise domestic GVA, employment and revenue gains in a constrained economic landscape while delivering competitive decarbonisation for the UK industry.

SECTION 7

Future research directions

Throughout this report, we have highlighted that there are limitations in relation to the available information on what a UK T&S sector, and regional subsectors linked to the Track 1 and 2 T&S systems therein, may look like. We have also highlighted how different model and scenario assumptions can lead to qualitative and quantitative differences in results and demonstrated that the usefulness of simple multiplier calculations is limited in the context of labour supply and other constraints. Thus, one fundamental research need going forward is for work of the kind reported here to be updated on an ongoing basis as more data, insight to inform scenarios and modelling assumptions, as well as the policy landscape, become available through the development of the Track 1 & 2 regional T&S subsectors and beyond.

For Scotland, this will involve continued engagement between the research and the Acorn project communities to ensure that the type of sophisticated theory-consistent economy-wide modelling capacity developed through SNZI can be further leveraged and used to fully understand how deep decarbonisation can contribute to sustainable economies, not only at the national level studied here, but also the Scottish economy, and regions therein. However, the work carried out through SNZI reported here also provides useful foundations at a wider UK level and a broader focus on UK CCUS.

Thus, it would also be useful to extend the scope of the analyses presented here, which focused specifically on the impacts of investing, deploying, and expanding T&S activity. For example, it will also be useful to incorporate the capture element to consider the broader rollout of CCUS in the UK economy, extending on CEP work focusing on the implications of additional capital requirements for capture firms.[38]

However, this is not as straightforward as expanding the scenarios of this report to include the implications of carbon capture. For instance, across the different clusters, plans exist to substitute fossil fuels with low carbon alternatives, such as blue hydrogen. Such a development would have implications on both the decarbonisation cost of the participating industries, emerging supply chains, and the network requirements to transport captured CO_2. All these factors would need to be considered in terms of how they affect the structure of industries in the economy-wide database and how they are modelled as part of the wider development of CCUS.

Here, an important issue to consider is how different and combined CCUS services may emerge and evolve over time. For example, might T&S ultimately – at least in some areas – become a new industry offering that incorporates a range of aspects of CCUS, including capture, thereby reducing the additional capital investment and maintenance requirements within capture firms? If such a wider CCUS sector were to emerge, there are key considerations in terms of what its supply chain may look like, who are the potential users and at what cost, and how other potential activities, including but not limited to direct air capture, would affect the picture. These considerations have potential implications for UK T&S and the wider regional and national economies, which require further analyses.

38 See work for Scotland reported in the 2021b open access peer reviewed paper by Turner et al. (2021b) published in Ecological Economics at https://doi.org/10.1016/j.ecolecon.2021.106978 and a later UK-wide peer reviewed study by Turner et al. (2022d) published by Climate Policy at https://doi.org/10.1080/14693062.2022.2110031

Across all these areas, there is a need to further examine and consider just how CCUS will be 'paid for' going forward. Here, we have assumed that, while upfront investment may be forthcoming from private sector sources, the emergence of a decarbonisation-focussed nascent sector like CO2 T&S requires that the government act to guarantee demand for its output if that investment is to be de-risked and, thus, forthcoming. Previously, within the SNZI programme and other projects, we have begun to consider the economy-wide implications of different 'who pays' scenarios.[39] This research strand should be revisited as and when information on potential approaches and relevant domestic and international market conditions emerges and firms up.

Finally, the attention within the study has been on emissions generated by industries within specific industrial clusters (and potential oversizing in terms of broad coverage in the absence of information on what industry actors will be identified as capturers in Track 1 and 2). This is motivated by industries linked to the Track 1 and 2 effectively being the frontrunners in CCUS deployment and the ones receiving government support in using T&S services (equating, at least initially, to the government demand guarantee assumed above).

However, a significant number of dispersed, off-cluster production sites across multiple sectors will also need to decarbonise their production if the UK were to meet its net-zero goals. It is therefore essential to study the different decarbonisation options, including CCUS, potentially with road transportation, for off-cluster industry activity, and to identify how different potential plans of action may impact at sectoral, local, regional, and national economy levels.

Thus, we arrive at our third and final recommendation (see box, left), linked to the first two recommendations reported at the end of **Section 6**. ■

RECOMMENDATION

3 Evidence generated through this research should be continuously revisited and updated as better data on T&S and other nascent sector activity associated with CCUS emerges. Here, it is also recommended that the scope of economy-wide scenario simulation modelling be extended to consider both the funding of CO2 T&S activity going forward and to incorporate a wider range of CCUS activities and different routes by which they may emerge.

39 See the peer reviewed papers by Turner et al. (2021a, 2022a) published open access by Local Economy – https://doi.org/10.1177/02690942211055687 – and by Ecological Economics – https://doi.org/10.1016/j.ecolecon.2022.107547 – respectively

Publications

- Alabi, O., Katris, A., Turner, K., Race, J., & Stewart, J. (2021). *Could the Introduction of a New CO2 Transport and Storage Industry in Scotland Service Decarbonisation, 'Green Growth' and 'Just Transition' Agendas?*. University of Strathclyde, Glasgow. https://doi.org/10.17868/78261
- Calvillo, C., Race, J., Chang, E., Turner, K., & Katris, A. (2022). Characterisation of UK industrial clusters and techno-economic cost assessment for carbon dioxide transport and storage implementation. *International Journal of Greenhouse Gas Control*, 119, 103695. https://doi.org/10.1016/j.ijggc.2022.103695
- Department for Business, Energy & Industrial Strategy (BEIS) (2022). Carbon Capture, Usage and Storage. Industrial Carbon Capture business models summary, December 2022 update. Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1125226/industrial-carbon-capture-business-model-summary-december-2022.pdf
- Katris, A. (2023). *An updated 2018 UK SAM for CCS deployment with shipping in different industrial clusters*. A Social Accounting Matrix Excel File (dataset). https://doi.org/10.15129/421856e3-3fa9-4d4d-9cbf-d9181dfdafdd
- SNZR. (2023). *A net zero roadmap for travel and tourism*. Collaborative report. Retrieved from: https://www.tmdassets.co.uk/client_assets/NECCUS/SNZR_final.pdf
- Turner, K., Race, J., Katris, A., & Stewart, J. (2020). State Aid or Subsidy Control: Ensuring Prosperity in the Race to Net Zero. University of Strathclyde, Glasgow. https://strathprints.strath.ac.uk/72094/
- Turner, K., Race, J., Alabi, O., Calvillo, C., Katris, A., Stewart, J., & Swales, K. (2021a). Could a new Scottish CO2 transport and storage industry deliver employment multiplier and other wider economy benefits to the UK economy? Local Economy, 36(5), 411-429. https://doi.org/10.1177/02690942211055687
- Turner, K., Race, J., Alabi, O., Katris, A., & Swales, J. K. (2021b). Policy options for funding carbon capture in regional industrial clusters: what are the impacts and trade-offs involved in compensating industry competitiveness loss?. Ecological Economics, 184, 106978. https://doi.org/10.1016/j.ecolecon.2021.106978
- Turner, K., Race, J., Alabi, O., Calvillo, C., Katris, A., & Swales, K. (2022a). Policy trade-offs in introducing a CO2 transport and storage industry to service the UK's regional manufacturing clusters. Ecological Economics, 201, 107547. https://doi.org/10.1016/j.ecolecon.2022.107547
- Turner, K., Katris, A., Alabi, O., & Corbett, H. (2022b). The evolution and wider economy outcomes of a UK CO2 transport and storage industry: the importance of labour requirements, electricity demand and transportation options. University of Strathclyde, Glasgow. https://doi.org/10.17868/strath.00083228
- Turner, K., Alabi, O., Katris, A., Calvillo, C., Stewart, J., & Race, J. (2022c). The importance of building export capacity in a new Scottish CO2 Transport and Storage industry: alleviating domestic funding pressures and securing green growth and jobs transition. University of Strathclyde, Glasgow. https://doi.org/10.17868/79716
- Turner, K., Race, J., Alabi, O., Katris, A., & Swales, K. (2022d). The relationship between a 'polluter pays' approach to carbon capture, regional policy and 'just transition' employment agendas. Climate Policy, 23, 366-378. https://doi.org/10.1080/14693062.2022.2110031
- Turner, K., Katris, A., Karim Zanhouo, A., Calvillo, C., & Race, J. (2023a). The potential importance of exploiting export markets for CO2 transport and storage services in realising the economic value of Scottish CCS. Local Economy, 38, 264-281. https://doi.org/10.1177/02690942231203932
- Turner, K., Katris, A., Karim Zanhouo, A., Corbett, H., & Race, J. (2023b). The potential economic value of increasing Scottish CO2 Transport and Storage capacity to service overseas export demand. University of Strathclyde, Glasgow. https://doi.org/10.17868/strath.00084117
- Turner, K., Katris, A., Calvillo, C., Race, J., & Corbett, H. (2023c). Jobs and UK CCUS: the constrained employment impacts of a new UK CO2 Transport and Storage Industry. University of Strathclyde, Glasgow. https://doi.org/10.17868/strath.00085736
- Turner, K., Katris, A., Calvillo, C., Corbett, H., & Race, J. (2023d). Developing and Export Base for Scottish CCUS: Maximising Returns on Investments and Costs to Public Budget. University of Strathclyde, Glasgow. https://doi.org/10.17868/strath.00086569
- Turner, K., Katris, A., Calvillo, C., Corbett, H., & Race, J. (2023e). The Importance of Early Employment and Government Revenue Gains in Governing the Wider Economy Costs and Benefits of Deploying UK CCUS. University of Strathclyde, Glasgow. https://doi.org/10.17868/strath.00086068
- Viking. (2023). Viking CCS Transforming the Humber into a net zero. Retrieved from: https://vikingccs.co.uk/assets/images/Viking-CCS-Transforming-the-Humber-into-a-net-zero-Super Place-web.pdf

Appendix A

Sectors identified in the UKENVI CGE model

Sector no.	Sector name	SIC code
S1	Agriculture, Forestry & Fishing	01-03
S2	Coal, Mining & Quarrying	05 & 08-09
S3	Crude Oil & Gas	06-07
S4	CO2 Transport & Storage	New sector
S5	Food, Drinks & Tobacco	10-12
S6	Textile, Leather & Wood	13-16
S7	Paper & Printing	17-18
S8	Coke & Refined Petroleum Products	19
S9	Chemicals	20
S10	Pharmaceuticals	21
S11	Rubber & Plastic	22
S12	Cement, Lime & Glass	23
S13	Iron, Steel & Metal	24 & 25.4
S14	Manufacture of Fabricated Metal Products, excluding Weapons & Ammunition	25.1-3 & 25.5-9
S15	Electrical Manufacturing	26-28
S16	Manufacture of Motor Vehicles, Trailers & Semi-Trailers	29
S17	Transport Equipment & Other Manufacturing (incl Repair)	30-33
S18	Electricity	35.1
S19	Gas Distribution	35.2-3
S20	Natural Water Treatment & Supply Services	36
S21	Waste Management & remediation	37-39
S22	Construction – Buildings	41-43
S23	Wholesale & Retail Trade	45-47
S24	Land Transport	49
S25	Other transport	50-51
S26	Transport Support	52-53
S27	Accommodation & Food Service Activities	55-56
S28	Communication	58-63
S29	Financial & Insurance Services	64-66
S30	Architectural Services	71
S31	Services	68-70 & 72-82
S32	Public Administration, Education & Defence	84-85
S33	Health & Social Work	86-88
S34	Recreational & other Private Services	90-98

Appendix B

Key economy-wide results under for alternative scenarios

Table B1 is an expanded version of **Table 4** in the main report, relating to **Scenarios 1A** and **2A**. It shows the implications in the wider UK economy if the Acorn and Viking T&S systems expand their capacity to service CO2 emissions from abroad. See the last data column of **Table B1** which reports the UK-wide results of **Scenario 2A** (ROW). Exporting T&S services brings additional demand to the wider UK T&S sector leading to better GVA, employment and public budget outcomes. However, as pointed out in **Section 5** of the main report, the increase in economy-wide benefits is less than proportionate to the increase in sequestered emissions, as some potential benefits are lost to the international marine transportation sector that we assume provides the shipping of captured CO2.

TABLE

B1 Sustained macroeconomic impacts of introducing a UK T&S industry via the Track 1 and Track 2 clusters (domestic & ROW emissions)

	TRACK 1		TRACK 2		UK-WIDE	UK-WIDE (SCOTTISH & VIKING SHIPPING)
	SCENARIO 1A		SCENARIO 1A		SCENARIO 1A	SCENARIO 2A (ROW)
	East Coast	Hynet	Scottish	Viking		
Capacity for emmissions sequestration	22MtCO2e	9MtCO2e	7MtCO2e	12MtCO2e	50MtCO2e	56MtCO2e
Public spending requirements (£M), composed of:	**534**	**201**	**229**	**270**	**1,235**	**1,290**
Direct spending on T&S (£M)	402	151	173	203	929	929
Nominal adjustments to meet real spending commitments (£M)	132	50	57	67	305	361
Additional government revenues generated (£M)	226	85	97	114	522	620
Net public spending requirement (£M)	308	116	132	156	713	670
Gross value added, GVA, or GDP (£M)	389	146	167	196	898	1,061
Gross value added, GVA, or GDP (% change)	0.020	0.008	0.009	0.010	0.047	0.055
Employment (FTE)	1,781	671	765	901	4,117	4,904
Employment (% change)	0.006	0.002	0.003	0.003	0.014	0.017
Unemployment (% change)	-0.141	-0.053	-0.061	-0.071	-0.327	-0.389
Average nominal wage (% change)	0.030	0.011	0.013	0.015	0.070	0.084
Average real wage (% change)	0.016	0.006	0.007	0.008	0.037	0.044
CPI – index to 1 (% change)	0.014	0.005	0.006	0.007	0.033	0.040
Exports (£M)	-155	-58	-67	-78	-359	-191
Imports (£M)	215	81	93	109	498	641
Real household consumption (£M)	287	108	123	145	662	776
Total investment (£M)	**248**	**93**	**107**	**125**	**573**	**672**

APPENDIX B CONTINUED

Tables B. and **B3** report the **Scenario 1B** and **2B** respectively and correspond to the **Scenario 1A** results in **Table 4** within the main text and **Scenario 1A/2A** results in **Table B1** of this Appendix. As explained in the main text of this report, the difference in moving from **A** to **B** scenarios is that simulations are run under the latter assuming no labour market constraints. Similarly, **Table B4** reports **Scenario 2B** results that are comparable with the **Scenario 2A** results reported in **Table 5** in the main text.

The key result in moving from the **A** to **B** scenarios in all cases is that the magnitude of wider economy benefits grow with only limited pressure on wages and price and the consequent impacts on international competitiveness and the government budget. However, as set out in **Section 4.2**, achieving such outcomes would require action on easing labour supply constraints through action on skills and/or encouraging workers into the UK labour force.

TABLE

B2 Sustained macroeconomic impacts of introducing a UK T&S industry via the Track 1 and Track 2 clusters under a fixed real wage (B scenarios, domestic emissions only)

	TRACK 1		TRACK 2		UK-WIDE	UK-WIDE (SCOTTISH & VIKING SHIPPING)
	SCENARIO 1B		SCENARIO 1B		SCENARIO 1B	SCENARIO 2B (RUK)
	East Coast	Hynet	Scottish	Viking		
Capacity for emmissions sequestration	22MtCO2e	9MtCO2e	7MtCO2e	12MtCO2e	50MtCO2e	56MtCO2e
Public spending requirements (£M), composed of:	**402**	**152**	**173**	**204**	**930**	**1,172**
Direct spending on T&S (£M)	402	151	173	203	929	1,172
Nominal adjustments to meet real spending commitments (£M)	0	0	0	0	1	1
Additional government revenues generated (£M)	174	66	75	88	402	484
Net public spending requirement (£M)	229	86	98	116	529	689
Gross value added, GVA, or GDP (£M)	713	268	306	361	1,649	1,971
Gross value added, GVA, or GDP (% change)	0.037	0.014	0.016	0.019	0.086	0.103
Employment (FTE)	7,116	2,679	3,057	3,599	16,451	19,825
Employment (% change)	0.024	0.009	0.010	0.012	0.056	0.067
Unemployment (% change)	-0.565	-0.213	-0.243	-0.286	-1.305	-1.573
Average nominal wage (% change)	0.000	0.000	0.000	0.000	0.000	0.000
Average real wage (% change)	0.000	0.000	0.000	0.000	0.000	0.000
CPI – index to 1 (% change)	0.000	0.000	0.000	0.000	0.000	0.000
Exports (£M)	0	0	-67	0	0	0
Imports (£M)	178	67	93	90	411	545
Real household consumption (£M)	333	125	123	168	770	919
Total investment (£M)	**351**	**132**	**107**	**178**	**812**	**962**

TABLE

B3 Sustained macroeconomic impacts of introducing a UK T&S industry via the Track 1 and Track 2 clusters under a fixed real wage (B scenarios, domestic & ROW emissions)

	TRACK 1		TRACK 2		UK-WIDE	UK-WIDE (SCOTTISH & VIKING SHIPPING)
	SCENARIO 1B		SCENARIO 1B		SCENARIO 1B	SCENARIO 2B (ROW)
	East Coast	Hynet	Scottish	Viking		
Capacity for emmissions sequestration	22MtCO2e	9MtCO2e	7MtCO2e	12MtCO2e	50MtCO2e	56MtCO2e
Public spending requirements (£M), composed of:	**402**	**152**	**173**	**204**	**930**	**928**
Direct spending on T&S (£M)	402	151	173	203	929	929
Nominal adjustments to meet real spending commitments (£M)	0	0	0	0	1	-2
Additional government revenues generated (£M)	174	66	75	88	402	477
Net public spending requirement (£M)	229	86	98	116	529	451
Gross value added, GVA, or GDP (£M)	713	268	306	361	1,649	1,955
Gross value added, GVA, or GDP (% change)	0.037	0.014	0.016	0.019	0.086	0.102
Employment (FTE)	7,116	2,679	3,057	3,599	16,451	19,597
Employment (% change)	0.024	0.009	0.010	0.012	0.056	0.066
Unemployment (% change)	-0.565	-0.213	-0.243	-0.286	-1.305	-1.555
Average nominal wage (% change)	0.000	0.000	0.000	0.000	0.000	0.000
Average real wage (% change)	0.000	0.000	0.000	0.000	0.000	0.000
CPI – index to 1 (% change)	0.000	0.000	0.000	0.000	0.000	0.000
Exports (£M)	0	0	-67	0	0	236
Imports (£M)	178	67	93	90	411	538
Real household consumption (£M)	333	125	123	168	770	904
Total investment (£M)	**351**	**132**	**107**	**178**	**812**	**957**

APPENDIX B CONTINUED

TABLE

B4 Additional sustained macroeconomic impacts in the UK of extending capacity of the Track 2 clusters to ship emissions from elsewhere in the UK or overseas (fixed real wage)

	SCOTTISH T&S SECTOR			
	SCENARIO 2B (RUK) Shipping additional 3MtCO2e to Scottish stores from elsewhere in the UK		SCENARIO 2B (ROW) Shipping additional 3MtCO2e to Scottish stores from overseas	
	Additional impacts	Total impacts with 10MtCO2e capacity	Additional impacts	Total impacts with 10MtCO2e capacity
Public spending requirements (£M), composed of:	**134**	**306**	**-1**	**172**
Direct spending on T&S (£M)	134	306	0	173
Nominal adjustments to meet real spending commitments (£M)	0	0	-1	-1
Additional government revenues generated (£M)	46	120	42	117
Net public spending requirement (£M)	88	186	-43	55
Gross value added, GVA, or GDP (£M)	180	486	171	478
Gross value added, GVA, or GDP (% change)	0.009	0.025	0.009	0.025
Employment (FTE)	1,881	4,938	1,755	4,812
Employment (% change)	0.006	0.017	0.006	0.016
Unemployment (% change)	-0.149	-0.392	-0.139	-0.382
Average nominal wage (% change)	0.000	0.000	0.000	0.000
Average real wage (% change)	0.000	0.000	0.000	0.000
CPI – index to 1 (% change)	0.000	0.000	0.000	0.000
Exports (£M)	67	0	197	130
Imports (£M)	57	149	53	146
Real household consumption (£M)	103	226	95	218
Total investment (£M)	**128**	**235**	**125**	**232**

VIKING T&S SECTOR				UK-WIDE T&S SECTOR	
SCENARIO 2B (RUK) Shipping additional 3MtCO2e to Viking stores from elsewhere in the UK		SCENARIO 2B (ROW) Shipping additional 3MtCO2e to Viking stores from overseas		SCENARIO 2B (RUK) (with shipping within UK for Scottish cluster and Viking)	SCENARIO 2B (ROW) (with overseas shipping for Scottish cluster and Viking)
Additional impacts	Total impacts with 15MtCO2e capacity	Additional impacts	Total impacts with 15MtCO2e capacity	Total impacts with 56MtCO2e capacity	Total impacts with 56MtCO2e capacity
109	**312**	**-1**	**202**	**1,172**	**928**
109	312	0	203	1,172	929
0	0	-1	-1	1	-2
36	124	33	121	484	477
72	188	-34	81	689	451
142	503	135	496	1,971	1,955
0.007	0.026	0.007	0.026	0.103	0.102
1,493	5,092	1,391	4,990	19,825	19,597
0.005	0.017	0.005	0.017	0.067	0.066
-0.118	-0.404	-0.110	-0.396	-1.573	-1.555
0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000
0.000	0.000	0.000	0.000	0.000	0.000
0	0	106	106	0	236
61	151	57	147	545	538
66	234	59	227	919	904
66	**244**	**63**	**241**	**962**	**957**

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