The economic opportunity for a large scale CO_2 management industry in Scotland

Karen Turner, Julia Race and Graeme Sweeney, Centre for Energy Policy, University of Strathclyde

SUMMARY

This paper outlines the need to extend the 'CCUS' debate, from its current focus in technology and cost reduction, to consider instead the value that may be unlocked, sustained and created across the economy through development of a world leading large scale CO_2 management industry. The proposition is development of a Scottish industry that builds on our existing strengths to enable decarbonisation of intractable sectors like high value manufacturing (HVM) and domestic heating, while also providing new export opportunities as European nations respond to the ambitions of the Paris Agreement. It is an opportunity that can be realised through the continued transition of unabated oil and gas towards zero emission energy systems, exploiting the already strong supply chain links within the Scottish economy, and, crucially, providing sustained, secure and attractive career opportunities to existing and new Scottish workforce entrants.

The core foundations of the opportunity for Scotland *do* lie in CCUS, with world class offshore geological sites with large CO_2 storage potential in the Scottish continental shelf *and* the presence of existing skills, knowledge, capacity and infrastructure to deliver CO_2 transport and storage services. It would utilise existing onshore and offshore energy supply industry, pipeline infrastructure and associated extensive supply chain links, and provide attractive upskilling and reskilling opportunities for existing workers in the sector and appealing career prospects in a low carbon industry context for the next generation. This is crucial in delivery of Scotland's ambitions for a 'Just Transition'. In short, establishing a large scale CO_2 management industry would mean an alternative and new use for the capacity, infrastructure and workforce traditionally associated with Scotland's oil and gas industry. The shift in this capacity has already begun through the offshore renewables sector. ***Our initial estimates suggest that by 2030 anywhere between 7,000 and 45,000 UK jobs could ultimately be associated with Scotland securing 40% of the carbon storage element of a European CO_2 management market. By 2050 this could rise to between 22,000 and 105,000 jobs, and more as the industry extends to low carbon fuel supply.***

Building this strength would meet the need for Scottish industry to decarbonise without simply off-shoring our CO_2 emissions, jobs and GDP. Attention needs to focus on high value manufacturing (HVM) activity including petrochemicals, chemicals and the wider manufacturing industry at Grangemouth and beyond. We need to develop systems to manage CO_2 emissions from industrial processes here in Scotland, including the production and distribution of low carbon fuel in the form of cost effective hydrogen. In doing so, we have the opportunity to develop Scotland's ability to attract and host international industry in high value clusters that offer CO_2 management capability, and a strong export base for both low carbon products and technology.

Meeting Scotland's industrial decarbonisation needs would combine with the opportunity for Scotland to become an early mover in a European, and potentially global, large scale CO_2 management industry. The need for a global CO_2 management industry involving CCUS is driven by the ambitions of the Paris Agreement. Individual countries are developing their own responses, and the timeframes emerging are ambitious (e.g. the UK Chancellor's 2019 Spring Statement regarding constraints on the type of boilers that can be installed in new homes by 2025).

The key long term driver of a CO_2 management industry involving CCUS in Scotland and the wider UK is likely to be the need to decarbonise 'hard to treat' industrial and domestic heat with the continued use of our gas infrastructure. The Scottish CO_2 management industry could involve production and distribution of hydrogen at scale. Scotland has very significant potential to deploy 'blue hydrogen' for early rapid decarbonisation of heat – and a share of transport - through the 2030s / 40s, together with building up 'green hydrogen' at scale in the longer term.

The economic opportunity for a large scale CO_2 management industry in Scotland

Karen Turner, Julia Race and Graeme Sweeney, Centre for Energy Policy, University of Strathclyde

Context

There is a real need to shift the debate around decarbonisation solutions like carbon capture, utilisation and storage (CCUS) away from what has been a dominant focus on technology and cost reduction. Instead, we need to consider **whether different solutions may unlock, sustain and even create new value in a whole economy and societal system**. In particular, **can they contribute to what is becoming commonly referred to as the Just Transition?**[1] This paper focuses attention on whether **development of CCUS infrastructure in the context of a large scale CO_2 management industry in Scotland** can be understood in this way.

The decarbonisation ambitions of the Paris Agreement will require large scale CO_2 management. CCUS has been identified by the International Energy Agency (IEA) and the United Nations Intergovernmental Panel on Climate Change (IPCC) as necessary for **between 12% and 20% of emissions reduction**.[2] This share will **necessarily rise** if the target for global warming shifts from 2 degrees to **1.5 degrees Celsius.**[3] The UK Government's November 2018 **CCUS Action Plan** concurs with this view.[4] It also identifies the opportunity for the UK to become a global leader in delivering and deploying CCUS technology, while emphasising the **role of CCUS in delivering credible routes to decarbonisation of high value regional industry clusters**. But the deeper and broader decarbonisation challenge, and the pace required, is reflected in other areas of UK policy discussion. For example, the Chancellor's Spring Statement 2019 sets out 2025 and 2030 targets for **low carbon heating and 'greening of the gas grid'**. [5] Demands such as these, and the responses of other European nations to the Paris agreement, reflect the need for a structured and integrated response through large scale CO_2 management.

The Scottish Government has stated its support for the Paris Agreement and promotes Scotland's role as a world leader on climate change.[6] The **2018 Scottish Climate Change Bill** raised Scotland's ambitions in direct response to the Paris Agreement, and proposes a **90% reduction in all greenhouse gas emissions by 2050**.[7] This will mean achieving **net-zero emissions** of carbon dioxide, CO_2, by the same date. In other words, Scotland aims to be **carbon-neutral by 2050**. The establishment of the **Just Transition Commission** in early 2019 reflects the fact that the Scottish Government's ambitions require that **climate and economic plans and policies must complement one another, including the need to both sustain existing and create new high quality jobs**.[8] Its focus on CCUS as part of the solution is reflected in the role taken in various UK Government fora and initiatives, such as the 2018 Cost Challenge Taskforce[9], support of the EU-funded Acorn CCUS project at St Fergus (near Peterhead) [10], and research funding via Scottish Carbon Capture and Storage.[11]

It is **not only the need for large scale CO_2 management in the form of CCUS to contribute to the decarbonisation of domestic of heat and high value manufacturing (HVM) that are important for Scotland**. Given the distinct characteristics and (linked) capacity of both our economy and offshore energy industry and geology, there is a real opportunity not only to deliver the **transport and storage elements** of a full CCUS service system domestically, but also for **Scotland to become an early mover in the global industry for large scale CO_2 management, where CCUS could also potentially enable low, or even zero, carbon fuel supply**. That is, **exploiting the capability and capacity of our already heavily integrated onshore and offshore renewables** and fuel supply industry is crucial, not only to the decarbonisation of the Scottish economy, but also to the 'just'

nature of the transition through **unlocking and realising opportunities for a sustained industry contribution, evolution and growth**.

The nature and extent of the opportunity will, of course, be affected by a range of factors. These include the cost of alternative climate initiatives, along with the economies of scale and learning that could be achieved both in the relatively near term and throughout the low carbon transition over coming decades. The industrial opportunities presented by investment in a large scale CO_2 management system and infrastructure must also be considered in the context of potentially both **enabling a continued but greener market for UK gas** *and* **more fully exploiting our offshore wind resources through clean full-scale production, transport, storage and use of low or even zero carbon gas** in the form of hydrogen.

Scotland's opportunity

The quite unique nature of the opportunity for a large scale CO_2 management industry in Scotland is grounded in the nature and scope of opportunities for operators in a number of areas. We can consider these in the context of (i) the **competitive decarbonisation needs that may be served by the industry**, and (ii) **Scotland's capacity to deliver and become a leading international player in the new large scale CO_2 management industry**.

(i) The need for large scale CO_2 management in Scotland, the UK and Europe

The Scottish process industry needs to decarbonise without simply offshoring CO_2 emissions, jobs and GDP

Industrial decarbonisation is a pressing problem for Scotland. It is a challenge facing all industrialised nations, particularly where **climate policy actions may trigger offshoring not only of CO_2 generation but investment, jobs and GDP**. [12] Scotland's manufacturing base has already seen a significant decline. Some of the most dramatic drops in our carbon emissions have been a result of, for example, the decline of the steel industry.[13] **Crucially, that decline has essentially taken the form of the steel industry being offshored. But we still use steel.** Much of the industry has moved to China, taking its emissions with it and even increasing them, not least through the transportation requirements of importing steel to Scotland. China now burns more coal than the rest of the world combined. With cheap energy from coal and cheap labour, they manufacture a large proportion of UK and other products which are imported.

This is not the right approach. If the low carbon transition is to be a just one, we need to retain and grow jobs and GDP whilst meeting climate targets in the long term. This will always be a preferable outcome to job offshoring/GDP loss and not meeting targets in the short and long term.

In terms of what is important for the immediate future and transition of the Scottish economy to 2050 ambitions, **a particular focus of attention must be high value manufacturing (HVM) activity in primary, secondary and tertiary petrochemicals and chemicals manufacturing industries**. While the 'low hanging fruit' of changing behaviour in our use of things like plastic bags and cutlery is an easy challenge, for the foreseeable future we will all continue to consume products that depend on these industries in our everyday lives. **A just outcome for Scotland or the world as a whole will not be delivered by permitting a decline of these industries on our shores.** For example, in 2014 the combined petrochemicals, petroleum and wider chemicals industry[14] directly employed around 7,600 people in full-time equivalent (FTE) terms. This grew to a total of around **14,000 Scottish FTE jobs** if we consider those employed in supply chains to support not only industry production but workers spending their wages in towns and cities across Scotland.[15] **We need to develop systems to manage CO_2 emissions from industrial processes *here in* Scotland**, including the potential to **recycle CO_2 through the utilisation element of CCUS**.

We have the opportunity to develop Scotland's ability to attract and host international industry in high value clusters that offer CO_2 management capability

Scotland has a strong start in terms of industrial CO_2 emissions that need to be managed, particularly (but not exclusively) in terms of the growing presence of Grangemouth cluster just outside of Falkirk in the eastern central belt. The Grangemouth site may be best known for its historic role as Scotland's only crude oil refinery and the supply of (now 70% of[16]) the fuel to Scotland's filling stations as well as Northern Ireland and the north of England. But the Grangemouth Vision 2025 (compiled by Chemical Sciences Scotland, Scottish Enterprise and Falkirk Council[17]) focuses on the **role and future of the chemical science and manufacture production and jobs** located at the 1, 700 acre site. It states the aim of **establishing Grangemouth as a major European focus of activity in the chemical sciences sector**.

This type of vision is important, not least in relation to the anticipated shift away from use of cars run on petrol and diesel, which could in turn free up capacity at the Grangemouth site for growth and development of high value manufacturing (HVM) in the primary, secondary and tertiary petrochemical and chemical manufacturing industries. Potential growth in activity is not just about the total number of firms, jobs and CO_2 to be managed at Grangemouth and other Scottish industrial clusters. Rather, the type of approach set out in the Grangemouth Vision 2025 offers opportunities to strengthen the growth of the cluster as it increasingly encompasses a **full chain and lifecycle of activities from R&D, through design, production, logistics and services, to end of life management**.

Crucially, the adoption of an industrial strategy focussed on inward investment in manufacturing activity increasingly locates responsibility for a sustainable and just approach to managing CO2, jobs and GDP embedded in low carbon products *within Scotland.* Where these activities are located within Scotland, responsibility for CO_2 management then **falls under the jurisdiction of the Scottish Government and its ambitious Climate Change Plan**. This, in turn, will increase the reach and impact of supporting initiatives such as the Scottish Just Transition Commission.

Scotland's existing investment and planning for carbon capture in thermal power generation

The Scottish base for a large scale CO_2 management industry is broader. Not only do we already have an **existing onshore pipeline that can be used to transport CO_2 from Grangemouth to the coastal St Fergus gas processing plant in North East Scotland**, where the Acorn CCS project is already underway, there is already existing investment and planning for carbon capture at the nearby thermal electricity plant at Peterhead. **The continued operation of the Peterhead power plant, but with decarbonised gas power generation, is not only important for the continued security and resilience of Scottish electricity supply, but also for the direct and indirect jobs it supports in the region.[18]** The Peterhead power plant has already been a key element of various CCUS FEED (front end engineering design) projects.

The need to decarbonise heat with potential continued use of gas infrastructure

The **St Fergus Acorn project**[19] is also important in terms of exploiting opportunities open to Scotland in determining how we will continue to meet our energy needs through the zero carbon transition. The project involves **repurposing an existing CO_2 capture plant at St Fergus's gas processing plant**. Decarbonisation of heat is challenging given our current dependence on gas and existing gas distribution infrastructure to deliver our heating needs (around 80% of Scottish households rely on gas powered heating systems - and those who don't often rely on more expensive and more polluting fuels such as coal or heating oil[20]). **Even as electrification and other solutions emerge and grow, we will need to find ways to decarbonise the use of natural gas for some time**. Moreover, this needs to be done in an affordable way: while a series of targets have

been set to reduce fuel poverty in Scotland, it remains a major problem (where those without access to the gas grid often more likely to be in fuel poverty[21]). **A crucial point is that low, or zero, carbon gas solutions could play an important role in taking the pressure off the electricity system, and specifically the growing reliance on renewables, in supplying heat at affordable prices to consumers.** This combines with the importance of sustaining and growing high quality jobs (the source of wage income and tax revenue that ultimately enables household consumption of all types of goods and services) to put **the needs of the Scottish population** at the heart of considering just why and how an efficient and productive Scottish CO_2 management industry has a key role to play in the low carbon transition. Taking this wider perspective reflects that fact that **the beneficiaries of Scottish activity in developing CO_2 management industry activity from a CCUS base are not limited to emitting firms with a need for CO_2 abatement**.

Scotland is already a **major player in the UK gas distribution industry**, currently accounting for one-third of all UK gas imports and processing, and directly employing over 6,000 people on a full-time equivalent basis. It offers the best UK location to start production of low or even zero carbon gas. This involves the production of hydrogen. **Hydrogen can either be blended with natural gas in the distribution system, which reduces CO_2 emissions at the point of use, or can be distributed as a zero carbon fuel**. **Hydrogen can be produced in two ways and Scotland has significant potential in both cases.** The first is to decarbonise the natural gas we currently use before it is distributed (through a process called steam methane reforming). This is called blue hydrogen, involving steam methane reform (SMR) and CCUS. The second is to convert excess renewable power generated, for example, from offshore wind farms into hydrogen (through a process called electrolysis). This is called green hydrogen. **Scotland has the potential to be able to repurpose our existing pipeline infrastructure to transport hydrogen** (this will require regulatory changes to enable a higher blend of hydrogen in distribution and transmission networks).

Capacity to deliver large scale CO_2 management in Scotland

Skills, capacity and infrastructure to deliver CO_2 transport and storage services

A recurring theme in the above discussion of Scotland's need for large scale CO_2 management is how **we can utilise our existing onshore and offshore energy supply industry and pipeline infrastructure**. We have these because of our historical reliance on gas to serve our heating needs and 45 years as an oil and gas producing and exporting nation. On the face of it, this history may be regarded as posing a real challenge for decarbonisation. In fact, **Scotland's history in oil and gas is the foundation for the economic opportunity for a large scale Scottish *CO_2 management industry.***

There are two key elements of the Scottish opportunity here. First **Scotland has an extensive network of existing onshore and offshore pipelines and infrastructure**. As the oil and gas industry matures, there is extensive discussion around the costs and potential (albeit transitory) economic opportunities associated with decommissioning. **Establishing a large scale CO_2 management industry would mean an alternative and new use for this capacity and infrastructure** (as well as a potentially more effective use of resources required for decommissioning) through and potentially beyond the low carbon transition.

Second, a **wealth of transferable skills, knowledge and capacity required for delivery of large scale CO_2 management** using CCUS technologies already exist in Scotland's on and offshore evolving oil and gas industry and supply chain. The onshore industry is most commonly associated with servicing the oil and gas industry but in fact services what is an increasingly integrated offshore energy production industry, including offshore renewables. This point is crucial in

understanding the need and potential nature of the **delivery of a just transition** to a zero carbon Scottish economy.

Recent research at the University of Strathclyde's Centre for Energy Policy (CEP), supported by the Crown Estate Scotland, focuses on the contribution of the onshore support industry to the Scottish economy, particularly in terms of both industry and supply chain jobs.[22] It shows that the onshore support industry currently employs around 26 thousand people on a full-time equivalent (FTE) basis. When jobs in the wider supply chain, and those supported by spending of worker incomes, are taken into account, in 2014 the total number of **Scottish FTE jobs supported by the onshore industry was over forty-four thousand**. A large share of spending on industry output comes from the offshore sector. For every £1million of spending on the services and activity of 'mining support' industry output, **around 11 FTE jobs are required throughout the Scottish economy** to meet industry, supply chain and other spending needs. **If this level of 'jobs per pound' could be retained in servicing a large scale CO_2 management industry**, it would represent a relatively strong level of performance in terms of what has commonly been referred to as the creation of, or transition to, 'green jobs'.

This is crucially important in terms of the types of jobs currently associated with the oil and gas industry that could be sustained through the introduction of a large scale CO_2 management industry, and, thus, for the justness of the transition. Developing a new low carbon industry that builds from the strong foundations set over the last 45 years in the oil and gas industry has a number of key benefits. Not only does it mean developing new uses for the capacity that we have already invested heavily in, it provides new opportunities to exploit and share supply chain and other resources, to reduce costs and improve industry productivity and energy efficiency. But crucially, it will generate valuable new opportunities for the workforce. **A large scale CO_2 management industry will provide attractive upskilling and reskilling opportunities for existing workers in the sector and appealing career prospects for the next generation of workers throughout the industry itself and its extensive Scottish supply chains**.

The offshore side of the industry is not so straightforward to consider for two reasons. First, in national accounting terms the Scottish offshore sector is not formally part of the Scottish economy, treated instead as an extra-UK Continental Shelf region.[23] Second, any current accounting in terms of jobs and other measures of economic value generation related to industry sales must be considered in terms of exactly what is being produced and sold. That is, while the same skills and engineering that are currently used in the oil and gas extraction industry may be employed in CO_2 management, **the output that generates revenues is very different**. Producing sufficient output to generate £1million in revenues from transporting, injecting and monitoring CO_2 in geological stores in the North Sea is likely to require complementary but varying types and levels of skills, worker hours and use of equipment compared to generating £1million from extracting oil and gas. On the other hand, as the CO_2 management industry builds out from a CCUS base, other revenue streams will emerge (for example, from low carbon gas). **As technology develops, and a greater emphasis on recycling, reusing and sharing resources across different low carbon activities, productivity will improve.**

Generally, this is an important issue to explore: **just how do we unlock and realise future monetary value from our offshore capacity and infrastructure in the context of a large scale CO_2 management industry that can evolve to incorporate a range of low carbon activities?** In the US in particular, the starting point for CCUS has been enhanced oil recovery (EOR), which has triggered strong economic 'multiplier effects'.[24] There is potential for EOR to play a role in a Scottish and UK context.[25] However, the longer term future of a large scale CO_2 management

industry could not be solely linked to either this potential use of captured CO_2 or to it being part of the process of injecting CO_2 into storage sites.

Storage facilities for CO_2 in the North Sea

The **existence of world class offshore geological sites with large CO_2 storage potential in the Scottish continental shelf** add to the existing onshore foundations on which to build a Scottish CO_2 management industry. This storage capacity would permit a Scottish CO_2 management industry to **service the needs not only of Scottish, UK and international process industry firms operating within Scotland**, but also to **export CO_2 management services to other countries that may be able to capture CO_2 but have insufficient or no storage capacity**. An obvious first target market for Scotland in this regard is the rest of the UK, where there is clear policy and industry focus on the need to decarbonise a larger number of regional industrial clusters but with more limited storage capacity than Scotland.

The challenge, then, is how the availability of this storage capacity, and the infrastructure, knowledge and skills to utilise it, can provide the **foundation for new markets, activities and high quality employment opportunities under the umbrella of large scale CO_2 management**. This needs to be addressed on the basis of properly considering the **nature and extent of the value ultimately accruing to Scottish households, private and public sectors that could be unlocked and/or generated over different timeframes** through the development of a CO_2 management industry that builds from a CCUS base. A fundamental point is that CCUS can potentially enable the Scottish economy and society to continue to do what it has been doing, coupled with enabling us to move to doing things differently building on the base we have already invested in. Thus, discussion around CCUS must shift to consider **how an integrated CO_2 management industry could ultimately develop in a wider economy context, what costs and returns can be socialised in different ways, along with what role(s) of Scottish and UK governments may adopt to enable the unlocking of sustained value flows in a cost effective way**.

Potential to enter a European market for CO_2 management

Another opportunity to be explored is **whether the prospects for a domestic CO_2 management industry could be strengthened and sustained by entering international markets**. In this respect, Scotland's capacity is enhanced by the deep water port at Peterhead. This is one of the UK's most versatile ports. It can operate without becoming congested in all types of weather and, with berthing facilities at depths of up to 14 metres, it already serves a broad range of industries including oil and gas, along with renewables, fishing and leisure/tourism industries. Thus, it **provides capacity for a Scottish large scale CO_2 management industry to export its services beyond UK shores**, bringing in overseas CO_2 for Scottish storage by ship, while the domestic side of the industry would utilise the pipeline infrastructure.

Other potential **early movers, and potential collaborators, in developing the international CO_2 management industry and market are Norway and the Netherlands**. It is important to note that the emergence of international markets in CO_2 management would **require amendment of the London Protocol** (a convention applying to marine pollution). For this and other reasons, a market does not yet exist so that, while other nations are also exploring their potential role, **Scotland still has the opportunity to become an early mover**. In terms of the potential storage capacity available, Norway is likely to be the other key player (and potential collaborator) in developing a European industry and market. Germany is an example of a nation with limited potential for offshore storage but with strong industrial supply chain linkages to the Netherlands in general and the CCUS feasibility project at the port of Rotterdam in particular. Of course, the UK, and indeed Scotland, could elect to import CO2 management services provided by another country. Such a

decision would require consideration of **balance of trade impacts**. A 2017 study by Summit Power[26] found that **shipping UK CO_2 abroad would be likely to result in a potential £100bn deficit in the UK Balance of Trade (BoT) between 2020 and 2060 and increased emissions reduction costs**. On the other hand, the study estimated **positive cumulative impacts on the UK BoT if UK CO_2 management services were exported**.

So just how much CO_2 could be managed in a European market and what could this mean in terms of industry and UK supply chain jobs?

In 2018, a study conducted for Norway by SINTEF[27] presents the information in Table 1 regarding the volume of CO_2 that may be managed in a European market. SINTEF use IEA and IPCC scenarios, where the size of the European market is estimated for low, moderate and high scenarios for CCS activity across Europe in 2030 and 2050 (low represents a case with no CO_2 management in power sectors or from hydrogen production from natural gas).

Table 1. Estimated scale of activity in European CO_2 Management Industry under different scenarios for 2030 and 2050[28]

	2030	2050
	CO_2 volume (Mtonnes/year)	CO_2 volume (tonnes/year)
Low CCS	50	170
Moderate CCS	130	320
High CCS	390	1087

What might this mean in terms of jobs? The SINTEF report estimates the direct employment required for the storage element of CCS under the assumption that Norway could capture 40% of the European market as reported on the left side of Table 2. Scotland has a similar North Sea profile to Norway in terms of potential offshore geological storage capacity. Thus, a reasonable assumption at this stage is that Scotland could secure a similar market share and direct employment profile in storage activity.

Table 2. Jobs associated with a 40% share of the European market for CO_2 storage under different scenarios for 2030 and 2050[29,30]

	Potential direct employment in CO_2 storage (40% market share)		Total direct and indirect UK supply chain jobs	
	2030	2050	2030	2050
Low CCS	757	2,204	7,638	22,239
Moderate CCS	1,724	3,589	17,396	36,214
High CCS	4,530	10,358	45,709	104,516

So what level of total (direct *and* full supply chain) employment across the Scottish and UK economies may be supported if a 40% share of the European CO_2 management market and associated jobs are located in Scotland's off-shore sector? Indirect jobs will include upstream CO_2 transport activity, but also indirect supply chain activity across many sectors of the UK economy. If we assume that the upstream supply chain (including transport activity) for *CO_2 injection* is similar to that for *oil and gas extraction in the UK*, we can estimate the total jobs by applying the employment multiplier for the UK offshore extraction industry. This has a value 10.09 total UK jobs per direct industry job.[31] Doing so gives the results reported on the right of Table 2.

This tells us that, if Scotland could take 40% of the carbon storage element European large scale CO_2 management market by 2030, anywhere between 7,600 and 45,000 UK jobs could ultimately be associated with this activity. **By 2050 this could rise to between 22,000 and 105,000 jobs**. Note that these estimates are deliberately conservative with a focus on jobs supported by CO_2 storage and (indirectly) transport activity. As noted in other studies, such as the Summit Power report of 2017[32], when the potential to sustain and/or create a wider range of jobs - particularly in the industries emitting CO_2 and/or those playing a role in producing and distributing hydrogen – is taken into account, the number of jobs that could be associated with the emergence and evolution of a large scale CO_2 management industry would grow.

Additional Opportunities Arising From Large Scale CO_2 Management

This paper has focussed on the core and larger foundations for a large scale CO_2 management industry in Scotland. But development of such an industry brings the **opportunity for additional players to benefit from economies of scale and infrastructure**. This can potentially allow industries such as farming, forestry, distilling and biotechnology to participate in developing economically viable pathways to managing emissions. These pathways are developed through negative emissions and bio-conversions.

The question of negative emissions is an important one. Scotland's ambition is to become **a zero or carbon neutral economy by 2050. This will require the deployment of negative emissions technologies (NET's)** to offset residual emissions from harder to decarbonise sectors of the Scottish economy. One of the most promising and scalable technologies is bio-energy with CCS (BECCS). The Committee on Climate Change has identified **BECCS as one of the most effective ways of making use of limited biomass resources**[33] for the production of power and heat as well as green fuels and chemicals via gasification. It has been suggested that **Scotland has the potential to deliver up to 8.8 million tonnes of CO_2 per year of negative CO_2 emissions using BECCS based on domestic biomass energy crop sources.**[34]

There is also significant potential to **leverage existing Scottish expertise in applied biotechnology to develop advanced bio-conversion pathways to products that deliver added value to the economy**. These might involve bacterial, yeasts, or enzymatic conversions, many of which could potentially include the use of low-carbon hydrogen as a co-feedstock and energy source.

Institutions and infrastructure to support the birth and development of a new large scale CO_2 management industry in Scotland

A key challenge that must be overcome if a Scottish large scale CO_2 management industry is to emerge is building the confidence of all the players involved. Any new industry faces challenges in terms of **reducing risk and uncertainty for both suppliers and users**. The CCUS foundation of a Scottish CO_2 management industry is particularly challenged given that the core output delivered is a global common resource (global warming abatement) and the largely new technologies involved. For this reason, the institutional and political context, and the presence of a wider supporting infrastructure is crucial. This is another area where Scotland has particular strengths. We have a **solid body of existing public, private and HEI networks and relationships capable of underpinning an inclusive and collaborative approach** to supporting the birth and development of a new large scale CO_2 management industry in Scotland. Scottish Government support is already very clear, and there is positive movement from Westminster (most recently with the November 2018 CCUS Action Plan). The St Fergus Acorn project already was already listed as a Projects of Common Interest (PCI) listing in November 2017, and a CO_2 storage license is already in place. The Scottish Government's continuing investment in the Scottish Carbon Capture and Storage research initiative also serves to demonstrate understanding of the need to continue to

address challenges around CCUS technologies. However, **actions to enable the roll out and evolution of the industry activity, in a manner that ensures the value generated for Scotland and the wider UK is maximised**, will require cooperative action between both the Holyrood and Westminster Governments. In particular, **building confidence in the operation of the physical infrastructure underpinning a CCUS system requires consideration of how the assets in question may be effectively regulated**.

The next steps in considering the case for a large scale CO_2 management industry in Scotland

What lies at the heart of the narrative presented here is the **need to extend focus in the 'CCUS' debate from the technology and cost reduction focus to date. Instead we need to consider the value that may be unlocked, sustained and created in a whole economy system and how this can be socialised, and the system regulated, in a way that enables different actors to play the roles required to realise that value.** The aim of this paper has been to focus attention on exploring how a large scale economic opportunity may be realised. In this regard we have focussed on the opportunities presented through increased integration of both Scotland offshore energy sector and the associated onshore support industry, and extended Scottish and UK supply chains, in a large scale CO_2 management industry that builds from a CCUS base.

More work needs to be done to fully assess and quantify the potential returns to the Scottish economy of fostering and promoting a large scale CO_2 management industry that can both service our own decarbonisation needs *and* constitute a new export opportunity. The latter would involve transporting, by pipeline and ships, CO_2 that has been captured elsewhere in the UK and Europe to our offshore storage sites, and entering a very, young and innovative market alongside neighbours such as Norway and the Netherlands. Making **an early commitment to a new Scottish industry in large scale CO_2 management**, **where we can build on existing skills, capacity and infrastructure** - currently in the form of our traditional off and onshore oil and gas industry and associated supply chain – but continuing to shift this capacity to enable and service a zero carbon economy, **seems entirely consistent with Scotland's ambitions for a 'just transition'**.

---

[1] International Labour Organisation (ILO), 2015. Guidelines for a just transition towards environmentally sustainable economies and societies for all.

[2] IEA (2013). Technology Roadmap Carbon Capture and Storage

[3] IPCC (2019). Mitigation Pathways Compatible with 1.5°C in the Context of Sustainable Development report. This report indicates that most mitigation pathways are heavily reliant on carbon management at a large scale before middle of the century to remove carbon dioxide from the atmosphere by CCUS, BECCS, direct air capture or a combination of all of these technologies

[4] Department for Business, Energy & Industrial Strategy, BEIS (2018). The UK carbon capture usage and storage deployment pathway: an action plan (see pp. 29, 38)

[5] HM Treasury (2019). Spring Statement 2019: Written Ministerial Statement

[6] Scottish Government (2018). Climate Change Policy

[7] Scottish Government (2018). Climate Change Bill

[8] Scottish Government (2019). Just Transition Commission

[9] BEIS (2018). Delivering clean growth: CCUS Cost Challenge Taskforce report

[10] Scottish Government (2018). Oil and Gas Policy, Carbon Capture Utilisation and Storage

[11] Scottish Carbon Capture and Storage http://www.sccs.org.uk/

[12] Zero Emissions Platform (ZEP (2018). Role of CCUS in a below 2 degrees scenario report and Turner, K., Katris, A. and de Vries, F.P. (2018) Beyond Carbon Leakage: Off-Shoring of Employment and GDP in Decarbonizing International Supply Chains. Working paper published by the University of Strathclyde.

[13] Scottish Government (2016). Scottish Greenhouse Gas Emissions 2014 publication

[14] Here we refer to activities classed under 19 and 20 in the 2007 Standard Industrial Classification as accounted for in the Scottish Government's Input-Output Tables.

[15] All data on industry activity levels (including full-time equivalent employment) reported in this paper are drawn or derived from the Scottish Government Input-Output Tables and Multipliers for the accounting year 2014. Full tables

are publicly available at https://www2.gov.scot/Topics/Statistics/Browse/Economy/Input-Output/Downloads/IO1998-2015All

[16] British Broadcasting Company (2019) Grangemouth: 100 years in the oil industry

[17] Peter Brett Associates on behalf of Chemical Sciences Scotland and Scottish Enterprise (2017) Future Grangemouth Vision 2025 Evaluation of Economic Effects report

[18] Gill, S. and Bell, K. (2017) Meeting Scotland's peak demand for electricity, Climate Exchange Report

[19] Pale Blu Dot, Acorn CCS project website

[20] Scottish Government (2018). Scottish house condition survey 2017 key findings

[21] Scottish Government (2016). A Scotland without fuel poverty is a fairer Scotland: report by the Scottish Fuel Poverty Strategic Working Group

[22] Turner, K., Alabi, O., Low, R. & Race, J. (2019). Reframing the Value Case for CCUS: Evidence on the Economic Value Case for CCUS in Scotland and the UK. Report published by the University of Strathclyde.

[23] Scottish Government Input-Output model data sources website

[24] Carbon Utilisation Research Council (2018). Making carbon a commodity – the potential of carbon capture RD&D

[25] SCCS (2015). CO_2 Storage and Enhanced Oil Recovery in the North Sea: Securing a low carbon future for the UK, SCCS Joint Industry Project Report

[26] Carbon Capture and Storage Association (CCSA) (2017). Clean Air, Clean Industry, Clean Growth: How Carbon Capture Will Boost the UK Economy East Coast UK Carbon Capture and Storage Investment Study prepared by Summit Power

[27] SINTEF (2018). Industrial opportunities and employment prospects in large-scale CO_2 management in Norway , Report 2018:0594, ISBN 978-82-14-6865-8

[28] The information in Table 1 is drawn from Figure 5, p.22 of the SINTEF (2018) report[27]

[29] Information in the first two numerical columns of Table 2 extracted from Table B7, p.48 of the SINTEF (2018) report[27]

[30] The SINTEF (2018) report[27] estimates direct employment in each capture, transport (pipeline and shipping) and storage, assuming Norway has European market shares of 10%, 25% and 40% respectively. Here, we consider transport of CO_2 to storage as an upstream activity to storage, in the same way as transport of oil and gas away from offshore sites is upstream to the extraction industry. Thus direct jobs in transport activity should be considered in the context a storage multiplier calculation to avoid double counting is to be avoided.

[31] The Turner et al. (2018) brief can be downloaded at https://strathprints.strath.ac.uk/63554/

[32] See Endnote 26

[33] Committee on Climate Change (2007) Bioenergy Review Report

[34] Alcalde, J, Smith, P., Hazeldine, S. and Bond C.E. (2018) The potential for implementation of Negative Emission Technologies in Scotland, International Journal of Greenhouse Gas Control, 76, pages 85-91