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Who wants North Sea CCS, and why? Assessing differences in opinion between oil and gas industry respondents and wider energy and environmental stakeholders.

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Abstract

Whilst Scotland and the wider UK is making good progress with research and development towards deployment of offshore carbon capture and storage, there is increasing divergence in opinion on the necessity of CCS for meeting climate change targets. Oil and gas operators appear optimistic about the technical feasibility of CCS; whereas civil society and NGOs are increasingly vocal in their scepticism towards the necessity of CCS in a net-zero society. Given that operators' expertise may be required to support offshore CO_2 storage given their subsea experience, and that civil society is important in shaping government and public opinion, this divergence may be a challenge to offshore CCS deployment in the UK and elsewhere. The purpose of this paper is to evaluate the grounds on which oil and gas operators' views on CCS differ from a wider range of stakeholders, through a survey and in-depth interviews. Our results show that people with more knowledge of CCS are more likely to support its deployment, and that strong belief in anthropogenic climate change is lower – albeit rising – among oil and gas respondents. Our results also show concern that the net-zero transition may have negative effects for carbon-intensive regions, and that storage expertise is the UK's strongest skill set for CCS deployment. We suggest that across a range of stakeholders, the value of CCS is thus most likely to lie in specific applications (e.g. hydrogen) and/or very specific localities (e.g. places with existing subsurface knowledge and skills), rather than widespread deployment as a mitigation technology.

Keywords

Carbon capture and storage; just transition; North Sea; offshore CCS; oil and gas

Highlights

- Offshore CCS research & development making good progress in Scotland and wider UK;
- Yet differing views between oil and gas developers and civil society on CCS;
- Survey and interview research explores differences between stakeholders;
- Respondents more familiar with CCS tend to see it as more necessary for mitigation;
- CCS most likely to find stakeholder support for specific and/or localised uses.

Acknowledgements

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1. Introduction

Whilst the UK, and in particular Scotland, is making some of the strongest progress globally in the research, development and deployment of offshore CCS, the technology is at a crossroads. On one hand, initiatives such as STEMM-CCS (Dean et al, 2020) and the Acorn project (Alcalde et al., 2019) demonstrate ability to move offshore CCS on the UK Continental Shelf towards larger-scale deployment through research and development approaches which link developers, researchers and regulators. On the other hand, there is increasingly vocal scepticism to CCS from NGOs and civil society organisations, Friends of the Earth Scotland calling the technology a 'false solution' (Friends of the Earth Scotland, 2019) due to the lack of deployment and its perceived role in perpetuating a fossil fuel economy. As CCS deployment is likely to require collaboration with oil and gas operators due their practical experience of subsurface operations offshore, and as NGOs and civil society organisations can have significant influence over the public and by extent political figures through high-profile campaigning, these diverging positions have the potential to present a significant problem for CCS deployment. The purpose of this paper is therefore to understand stakeholder views on the necessity and required focus of CCS research and development efforts, with a focus on the North Sea and the north-east of Scotland as a region globally where offshore CCS deployment is making comparatively good progress.

2. Background and context

2.1. CCS in Scotland and the wider UK: the current situation

As above, Scotland as a devolved part of the UK is making comparatively good progress towards offshore CCS deployment, as demonstrated by the Acorn Project and the hosting in Scottish waters of advanced CCS-related R&D activity such as the STEMM-CCS experimental work, which seeks to exemplify a methodology for developing environmental and ecological baselines to aid monitoring of CO_2 storage sites in the marine environment (https://www.stemm-ccs.eu/). CCS in the Scottish and UK offshore context comes against a much wider backdrop of policy pressures aimed at ensuring the net-zero transition is both technically viable and socially appropriate. For instance, as well as declaring a 'climate emergency' in spring 2019, the Scottish Government established a Just Transition Commission tasked with advising on how a net-zero economy may be developed that is fair for all. The interim report of the Just Transition Commission (2020) highlights the regional industry collaboration in north-east Scotland for CCS as a good example of how industry may work together to identify its contribution to a just transition. Similarly, the Scottish Government's post-COVID-19 Advisory Group on Economic Recovery (Scottish Government, 2020) identifies CCS technologies as having a potential role in contributing to a 'wellbeing economy' that prioritises equality, diversity and the provision of fair and decent work.

Oil and Gas UK – the UK's representative body for the oil and gas industry – has highlighted the importance of CCS technologies, and its commitment to supporting the development and deployment of such technologies, if the UK and Scotland are to meet their climate change obligations (Oil and Gas UK, 2020). At a regional level, Opportunity North East, a private sector organisation under the leadership of Sir Ian Wood driving the diversification of north-east Scotland's economy, has co-funded the creation of North East Carbon Capture Usage and Storage (NECCUS) to accelerate and promote a Scottish CCS cluster (Opportunity North East, n.d.). By contrast, civil society organisations have shown increasing scepticism towards the potential of CCS to contribute to a climate change response in either Scotland or the wider UK. Concerns centre around a lack of trust in the oil and gas sectors to deploy CCS given their track record on decarbonisation to date and the funding that has already gone into CCS to limited output (Friends of the Earth Scotland, 2020); and the (mis)use of CCS projections by the oil and gas industries to offset and justify new exploration (Greenpeace UK, 2020). A high-profile survey of North Sea oil workers undertaken by a collaboration of civil society organisations (Platform/Friends of the Earth Scotland/Greenpeace, 2020) likewise noted a mixed and lukewarm response to CCS as a possible transition strategy for North Sea workers, with some sceptical of the technology's viability and others seeing its use confined to niche areas such as hydrogen production.

2.2. Scholarly background

Whilst much – but not all – social science research on CCS has concerned itself with public acceptance of the technology and risk communication strategies to allay public fears over issues such as leakage and seismicity, a growing body of scholarship believes that important discussions over the ethical, moral and justice dimensions of CCS and associated technologies have been marginalised in CCS-focused research and in practice (e.g. Mabon et al, 2015; Markusson et al., 2020). Kuch (2017) argues that an over-emphasis on educating publics about the risks of CCS technologies diverts attention from the need to engage all sectors of society in the process of determining technically appropriate yet societally acceptable energy futures; and indeed that the oil and gas sector's claims that their expertise in subsurface operations makes them well suited to CCS projects needs to be opened up to critical scrutiny. Stephens (2014) believes that investment in CCS infrastructure through public funds risks society being 'locked-in' to a fossil fuel economy, and may divert time and resources away from social and technological innovations which may yield faster decarbonisation returns. Mabon & Shackley (2015) find that stakeholders and publics, especially those with more egalitarian viewpoints, cite the extractive industries' track record to date in being able to change course in response to environmental and societal pressures as grounds for scepticism as to whether industry will indeed have the will to deliver CCS to scale and on time. Even under more pragmatic framings which seek to position CCS as part of a just or managed transition for workers in oil and gas industries, Swennenhuis et al (2020) find across Scotland, the Netherlands and Norway that support for CCS among civil society stakeholders is conditional on more evidence that CCS will actually produce jobs appropriate to local industries, and on strong policy and regulatory steer to ensure that CCS deployment primarily serves society and not the profits of fossil fuel industries. Janipour et al (2021) propose, based on research in the Netherlands, that the tension between CCS supporting a just transition and CCS contributing to carbon lock-in may be balanced through policy instruments that keep CCS as an intermediate option with clear phase-out timeframes, and by matching investment in CCS with support for investments in non-fossil fuel climate-neutral options.

3. Methods

3.1. Research Design and Recruitment

The research took a mixed-methods approach, involving quantitative surveying and in-depth interviewing of people whose work involves regular engagement with CCS as an energy transition strategy through, for example, research and development, project development, or policy and regulation. A mixed methods research approach can offer a more comprehensive examination of a problem (Halcomb *et al.* 2015) and the capacity to combine multiple data, reduce intrinsic biases and increase the validity of qualitative analyses (Creswell 2015). Longhofer et al (2012) asserts that knowledge and meaning are constructed in and out of people's interactions and their external world and are built and transferred in a social framework. In a similar vein, this research explores experts' interactions in carbon-intensive regions regarding CCS as an energy transition strategy, using interview responses to provide additional explanatory background to the trends and relations assessed through the quantitative survey research. Data collection for the study followed a parallel design approach (Teddlie and Tashakkori, 2009). The quantitative survey proceeded alongside the qualitative interviews, with the latter deepening and expanding on central areas of examination. There are of course limitations to this sampling approach, which are discussed in Section 3.5. below.

The target respondents for both the survey and the interviews were people with theoretical and practical expertise in CCS, on the grounds that their work is connected with CCS deployment. This may be enabling CCS (development, policy, regulation) or advocating for a more cautious approach (NGOs, lobbying etc). It is acknowledged in the CCS literature that, when only a small number of projects are in existence and/or the technology is not well known across society, understanding the views of key stakeholders and opinion shapers (both for and against CCS) may be of more value in gauging societal ‘support’ for CCS than soliciting the views of the general public (Littlecott, 2012; Malone et al, 2010; Reiner, 2015). Accordingly, sampling was targeted towards those who would be able to offer an informed and in-depth judgement on CCS and its role in energy transitions.

To encompass a breadth of perspectives, but also to ensure that responses were focused towards those who had a professional engagement with CCS, the *survey* was disseminated across a breadth of channels including email listservs, social media (via accounts with follower bases predominately with an interest in CCS), and professional networking sites; as well as asking personal contacts of the lead researcher to share the survey through their own channels. Recruitment approaches of this nature have been utilised elsewhere in the literature for expert surveys, where a relatively small sample of people with specific experiences and knowledges is required (e.g. Guzzini et al, 2020; McKellar et al, 2017).

Interview respondents were recruited through a combination of self-selection sampling, whereby individuals were approached either by email or social media platforms to participate in the study; and snowball sampling, where respondents were asked to identify additional potential participants, and so on. However, to mitigate the risk of the pool of respondents reflecting only a narrow range of perspectives and experiences around CCS, since respondents are more likely to recommend other participants with similar characteristics to themselves (Creswell 2015), early contact was made with target groups who were under-represented in the sample and unrelated to existing interviewees (i.e. those outside of the oil and gas and power sectors). Doing so is especially important for CCS, where it has long been understood that there is a closely-connected community of practitioners and researchers who may be resistant to outside perspectives on the technology (Stephens et al, 2011). Identification of respondents who may be more distant from the developer and policy sectors engaging closely with CCS deployment proceeded through internet-based searching for relevant organisations and contacts by sector (i.e. academia, oil and gas, renewables, NGOs). This approach was coherent with the researchers’ purpose to reach out to knowledgeable professionals that were interested in the research topic, considered it significant and had time to participate. Again, focused sampling of this nature has been utilised to gain richer insights in other energy-related research (e.g. Bertheau et al, 2020; Sanderink & Nasiritousi, 2020).

3.2. Survey

The survey element of the study was designed to collect data about stakeholder’s views and perception on: (1) climate change and CCS as an energy transition strategy; (2) opportunities and barriers for CCS; (3) government and private industry role for CCS development; and (4) CCS in carbon-intensive emerging economies.

Google Forms, a survey administration app, was used to design the questionnaire, collect and partially analyse the data. It was selected because of its intuitive user interface. Both open-ended and closed questions where included. Within the closed questions category, four types were used: list, category, ranking and matrix. Open questions asked participants to elaborate on specific previous closed questions. Additionally, a free text option was included for participants to share any additional views they might have about CCS.

Following a pilot phase, a self-administered online survey was electronically conducted. The researcher distributed it through email and publicised it on a range of social media platforms (i.e. Twitter and LinkedIn). The survey was open from the 1st of August to the 9th of September 2018. During this period, 100 people participated in the survey, 20% of which were from research/academia, 71% from the private sector, 6% from NGOs or international organisations, and 3% from government. The 71% of private sector responses were made up of 44% from the oil and gas sector, 8% from renewables, 6% from electric power, 3% from heavy industry, and 10% identifying as 'other' private sector. 19% of respondents reported their expertise as being in economics or business; 49% in engineering; 9% in environment; 14% in geosciences; 1% in legal; 6% in policy; 1% in social issues; and 1% identifying as 'other.' The survey was analysed using Microsoft Excel with each question then being graphically represented. The qualitative information given in free-text comments was coded according to key areas of enquiry which arose from the literature review, survey questions and answers. When open-ended answers are quoted in the text, they are given the prefix *S* followed by the number of the survey respondent in order to maintain anonymity.

3.3. Semi-Structured (In-depth) Interviews

Creswell *et al.* (2018) advise in favour of mixed-methods study design, linking surveys with other methods. This study hence complements survey results with semi-structured (in-depth) interviews to explore and understand societal views of CCS as an energy transition strategy for carbon-intensive regions. The use of semi-structured (in-depth) interviews offered the opportunity to investigate responses in detail by asking participants to expand on their answers.

As Table 1 shows, 23 interviews were conducted, participants come from different types of organisations, countries and professional backgrounds. In order to achieve the research aim, that is, to understand societal views of CCS as an energy transition strategy for carbon-intensive regions, it was considered pertinent to capture a wide range of perspectives through selecting a diverse group of actors to obtain a holistic view of CCS technologies. The author selected participants from academia, research centres, private and public listed companies involved in the energy sector in general, as well as from the oil and gas and CCS subsectors in particular.

Considering concerns over CCS by some environmental NGOs, the author made an effort to include NGO perspectives around the technology. Additionally, the oil and gas industry is said to have a crucial role in the CCS deployment technology due to its technical knowledge and expertise. For this reason, participants were selected to understand the opportunities and challenges associated with CO_2 transport and storage in particular. More broadly, CCS is considered as an integral part of the production of blue hydrogen (i.e. hydrogen created from fossil fuel sources, where the CO_2 emitted is stored and captured); therefore, professionals employed in energy companies with an interest in this area were also included. Finally, academia and research centres have an essential role in helping to move the technology forward not only through innovation and cost reduction but also by contributing knowledge across a broad range of legal, commercial and social issues. In addition to the seventeen participants based in the UK, six interviews were conducted with participants from the Netherlands, Belgium, Norway, France, Venezuela and Mexico; who offered a global perspective on CCS, as well as for Europe and emerging economy countries. Interviews took place in July, August and September 2018, followed a semi-structured approach and were transcribed by the researcher with the assistance of a transcribing software. Transcripts were coded into manageable code categories. Using content analysis, the author analysed the occurrence, implications and associations of certain concepts, words or themes (Halcomb *et al.* 2015). When interview responses are quoted in the text, they are given the prefix *I* followed by the interview number, as per Table 1.

Table 1: Summary of interviewees

Code	Position of research participants	Professional expertise	Type of organisation	Country	Interview Approach
I001	Executive	Communications	CCS research centre	UK	Face-Face Interview
I002	Director	Business and Management	Oil and gas research centre	UK	Face-Face Group interview
I003	Research Assistant	Social sciences	Academia	UK	Face-Face Interview
I004	Junior Researcher	Chemistry	Academia	Netherlands	Skype Interview
I005	Policy Officer	Policy	CCS research centre	UK	Face-Face Interview
I006	Senior Lecturer	Engineering	Academia	UK	Face-Face Interview
I007	Managerial	Business and Management	Energy (private sector)	UK	Face-Face Group interview
I008	Director	Business and Management	Oil and gas (private sector)	UK	Face-Face Group interview
I009	Executive	Engineering	Oil and gas research centre	UK	Face-Face Interview
I010	Managerial	Business and Management	Oil and gas (private sector)	UK	Face-Face Interview
I011	Director	Geosciences	Private Energy	UK	Face-Face Interview
I012	Professor	Legal	Academia	UK	Face-Face Interview
I013	Advisor	Communications	CCS research centre	Belgium	Skype Interview
I014	Policy Manager	Economics and Management	ENGO	Norway	Skype Interview
I015	Director	Business and Management	Energy (private sector)	UK	Skype Interview
I016	Director	Legal	Academia	UK	Face-Face Group interview
I017	Consultant	Geosciences	Oil and gas (private sector)	France	Skype Interview

I018	Consultant	Physics	Oil and gas (private sector)	UK	Face-Face Interview
I019	Consultant	Engineering	Energy (private sector)	UK	Skype Group interview
I020	PhD candidate	Geosciences	Academia	Mexico	Skype interview
I021	Operations Officer	Business and Management	Energy (private sector)	UK	Skype interview
I022	Researcher	Social sciences	Academia	UK	Face-Face Interview
I023	Researcher	Legal	Academia	Venezuela	Face-Face Group interview

3.4. Ethical considerations

In terms of research ethics, the initial contact provided precise details concerning the study, stated aim and objectives, anonymity, protection of data and voluntary participation. During interviews, research participants were asked to read and sign a consent form, certifying they comprehended the nature of the research and their role within it. Completion of the survey was considered as approval for inclusion. No financial incentive was offered; however, it was felt that it was appropriate to offer a summary of the survey results once the research study was finished to those who voluntary expressed their interest.

3.5. Limitations

As outlined in Section 3.1., sampling was targeted towards those with a professional engagement in CCS, yet was also cognisant of the need to look beyond a closed CCS community and ensure that more cautious or critical perspectives were included. In this regard, the study was able to recruit an appropriately informed sample covering a range of perspectives. Nonetheless, it is still the case that a large proportion of respondents came from the oil and gas sectors, or from research organisations with the aim of supporting CCS deployment. Moreover, reflecting broader research into stakeholder engagement in marine contexts (Esteves et al, 2012; Vanclay, 2012), it is worth remembering that stakeholders' interest in or concern towards a project can change over time, and that stakeholders may thus become more engaged and vocal as projects come to fruition. It may hence be the case that new stakeholders, or new opinions, emerge if offshore CCS projects move towards deployment in the UK. Further research may thus wish to track the evolution of stakeholder concerns over time – especially as CCS rationales shift to connect with industrial sources and hydrogen production and storage.

4. Findings

4.1 Necessity of CCS in the energy transition

Respondents were asked to assess their level of awareness about CCS technology. This was considered useful to obtain insights on how their level of knowledge might influence their perception about the necessity for CCS. A positive relation was observed between the level of awareness and the perception of necessity; that is to say, the more participants feel they know about CCS, the more they view it as a necessary strategy in the energy transition. Respondents rating their level of awareness as 'Excellent' on average scored the necessity of CCS as 4.7 out of 5. For 'Good', the average score was 4.4; for 'Somewhat Aware' 4.2.; 'Poor' 3.8; and 'Never heard of it' 3.3. In response to the question of how necessary each of the strategies are, the vast majority of respondents think that renewables have the highest level of necessity, with 78% of respondents rating renewables as 'very necessary.' Comparably, CCS was considered less necessary than all the other strategies, with 64% of respondents assessing CCS as 'very necessary' compared to 76% for energy efficiency and 73% for behaviour change.

The in-depth interview quotes likewise show interviewees describing CCS as an important component of the energy transition. The magnitude of the required emission reductions and the relatively short time scale available to do so were identified as central elements for CCS necessity:

> *"I think it is a crucial technology, at least if we want to stay within the bounds that we have set ourselves in the Paris Agreement. Anyone who has been following this topic knows that 1.5 degrees is going to be impossible, 2 degrees is already going to be a huge challenge, and we are simply not moving fast enough. In that sense, CCS is crucial." (I014, NGO)*

> *"If we're going to solve the problem, in the time scale that we have, then CCS seems to me to be indispensable." (I012, academia)*

However, in contrast to arguments over the necessity of CCS to meet climate obligations in the time available and with infrastructural constraints, other respondents were less positive about the desirability or necessity of the technology:

> *"This is all too little, too late unless we dramatically increase [CCS] roll-out immediately." (S019, academia)*

> *"I think CCS is a nasty idea. It's not practical, it's incredibly costly, and that money could be used somewhere else." (I016, academia)*

4.2 Applications for CCS technology

Whilst many respondents believed in the necessity of CCS technologies as part of an energy transition, a key issue was divergence among respondents about where is CCS required. Industrial applications were viewed as being the most important. 60 percent of respondents considered that "Decarbonising heavy industrial sources" (e.g. cement, iron and steel, oil refining) should be the main application for CCS; compared to, for example, 53% for decarbonising coal or gas power; 23% for enhanced oil recovery; 19% for hydrogen production; and 11% for bioenergy CCS.

One research participant mentioned that, in their opinion, there is a change of discourse regarding the use of CCS from electricity to industrial applications.

> *"If you asked people 5 years ago, CCS for electricity would have got a high priority. Now we're talking more about CCS for industrial applications, steel, petrochemicals, which are not so easy to decarbonize." (I022, academia)*

Notably, and perhaps reflecting the fast-moving energy policy and technological innovation landscape, only 19% of respondents overall identified hydrogen as a key use for CCS technologies. However, some respondents did see the potential for CCS to support the hydrogen economy:

> *"Hydrogen is a key technology which is coming, and it connects to CCS." (I009, academia/oil and gas)*

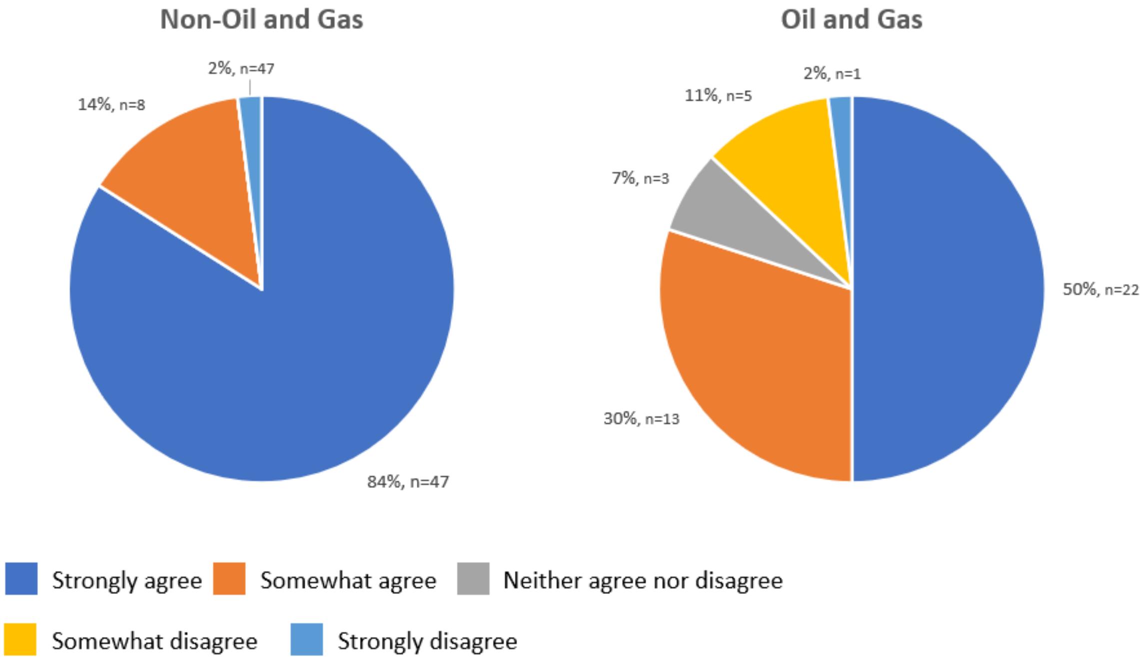
> *"Fossil energy with CCS only makes somewhat sense for blue hydrogen production." (S020)*

4.3 CCS and climate change mitigation

Underpinning respondents' views on CCS, 84 percent of non-oil and gas sector respondents "strongly agree" that climate change is the result of anthropogenic (i.e. human) interference (see Figure 1). This percentage decreased among those who belong to the oil and gas sector (50%), although respondents suggested this was changing:

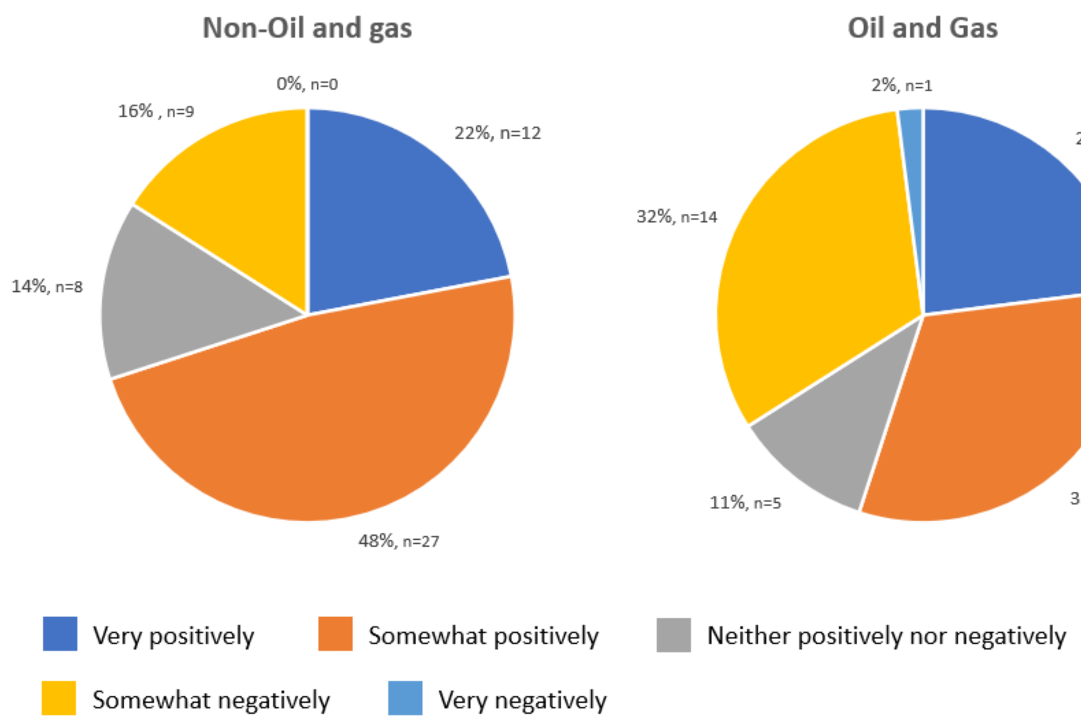
> *"I would say slowly waking up, that's the best way to describe it. A lot of people used to dismiss it and say: 'You're solving a problem that doesn't exist'. In the last six months, the oil and gas industry has suddenly woken up. Now they talk about the concept of net-zero emissions." (I009, oil and gas)*

Figure 1: extent to which respondents agreed or disagreed that climate change is the result of anthropogenic (i.e. human) interference



The majority of non-oil and gas respondents (70%) either strongly or somewhat viewed the energy transition as a positive factor for regions in the UK dependent on carbon-intensive industries, indicating that they see it as an opportunity. The percentage of respondents who either strongly or somewhat see the energy transition in carbon-intensive regions in the UK positively, however, decreased among who are part of the oil and gas sector (55%). More than one-third of the oil and gas respondents (34%) think the energy transition will have a strong or somewhat negative effect, suggesting that it could be perceived as a threat to the regional economy and jobs (Figure 2).

Figure 2: how respondents think energy transition will most likely affect regions of the UK which rely on carbon-intensive industries (e.g. north-east Scotland/north-east England)?



4.4 Key Influencing Factors for CCS in Carbon-Intensive Regions in the UK

The above responses indicate a landscape where (a) there remains recognition of the value of CCS in decarbonising industrial sectors; (b) there is lower but increasing awareness of the urgency of climate action within the oil and gas sectors; and (c) there is a slightly more pessimistic view within the oil and gas sector of how the energy transition will affect carbon-intensive regions. Against this backdrop, respondents saw CCS as providing potential to balance climate change obligations with the continued prevalence of the oil and gas industries:

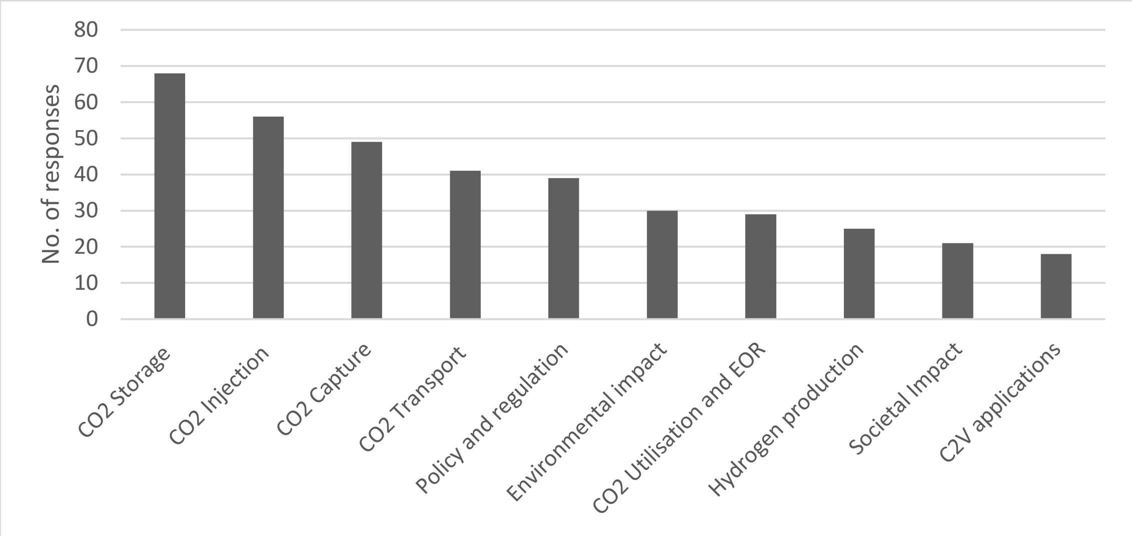
> *"Pulling on the expertise of Aberdeen, there's a lot of geoscience expertise there as part of the petroleum sector." (I001, academia)*

> *"If you think about Aberdeen, CCS would potentially be a new business that could thrive here, because you have most of the skills necessary to make it happen." (I018, oil and gas)*

> *"We have the North Sea on our doorstep and we have a great understanding of the reservoirs where you can dispose the CO2 in. I think that's the main thing." (I009, academia/oil and gas)*

Regarding UK's knowledge and expertise, research participants identified CO_2 storage as the main area where the value of UK's expertise lies (see Figure 3).

Figure 3: Respondents' perception on UK's CCS knowledge and expertise

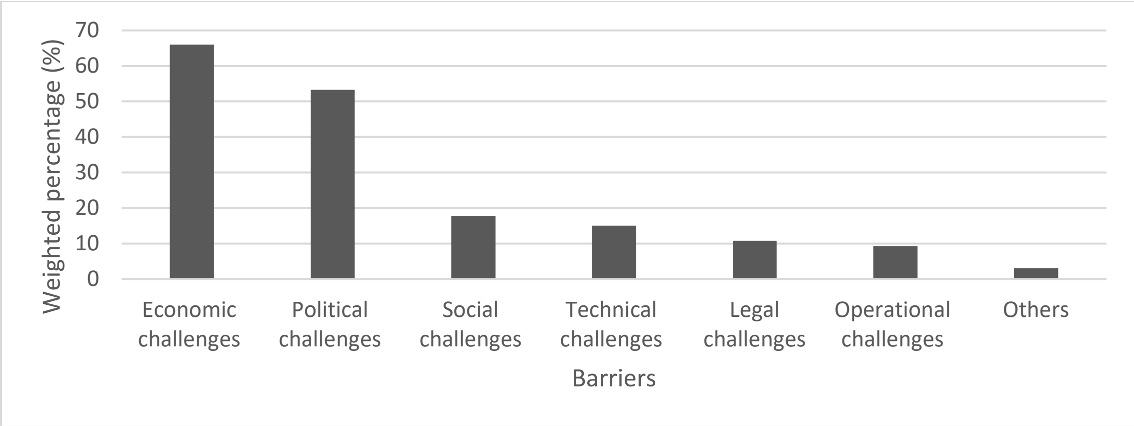


Research participants believed that these strengths position the UK above other potential sites in Europe. Additionally, one research participant highlighted public acceptance as a key asset for carbon-intensive regions in the UK:

> *"If we look at regional societal issues about CCS, countries that have an oil and gas history are generally more positive." (I014, NGO)*

On the other hand, some of the research participants were sceptical about the likelihood that the UK would benefit from these opportunities, pointing out several barriers and challenges. Overall, there was agreement between the research participants about the two main barriers for CCS. Economic and political challenges ranked close first and second, respectively; while social challenges were placed third (Figure 4).

Figure 4: Respondents' perception of main barriers to UK CCS deployment



The open-ended responses from the survey and the interviews reveal interesting insights as to what exactly respondents feel the barriers to CCS deployment are. These include economics around carbon pricing and infrastructure:

> *"The price of carbon is a key challenge. Joe Public does not want a price on carbon or the additional trickle-down costs, which essentially lower our standard of living." (S016, oil and gas)*

> *"CCS is not economically viable unless it can be used for other purposes." (S023, renewable energy)*

A perceived lack of political will or consensus:

> *"Politically, it is difficult because the problem is a global scale 50-year time horizon problem and politicians' time horizon is four-years" (I009, academia/oil and gas)*

> *"That's three failures we've had now, three government failures. First of all, I'd like to see them honour their commitments." (I018, oil and gas)*

And a lack of public interest, plus NGOs with vocal skepticism towards CCS:

> *"My wish answer would be - how do you convince the general populace of a technology solution that no one likes?" (I014, NGO)*

> *"You cannot ever expect to inform the entire public about why cement production requires CCS, changing the public's opinion normally needs to go through trusted institutions." (I014, NGO)*

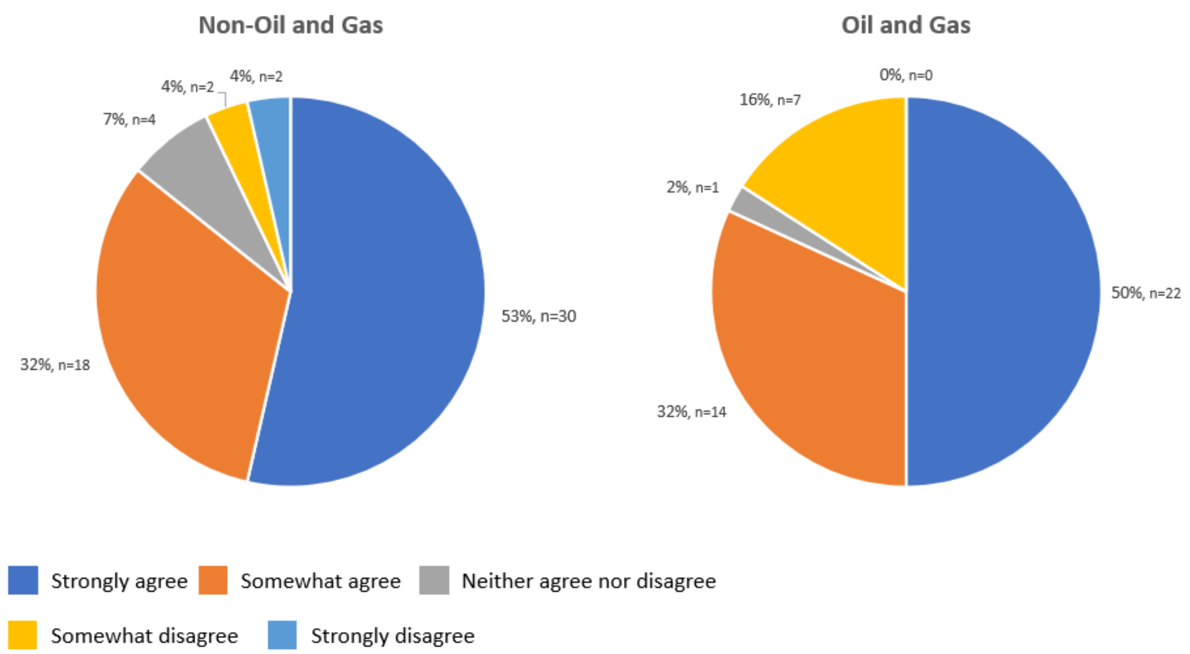
"[Names another ENGO] doesn't really like CCS. They think it is a way of perpetuating the oil and gas industry. So, what we have constantly been trying to do is stressing that it's not about that, it's about transition." (I001, academia)

By contrast, most respondents agree that legal, technical and operational challenges were not critical. For example, when asked about technical barriers, the confident reply from one respondent was "Work the problem like we always do in oil and gas." (S038, oil and gas).

4.5. The role of government

In response to the question "to which extent do you agree or disagree that the government should subsidise the industry to develop CCS?", 85% of non-oil and gas respondents either "agree" or "strongly agree" that the government should subsidise the industry (Figure 5). Similarly, the vast majority of respondents from the oil and gas sector (82%) either strongly or somewhat believed that government subsidies are necessary (Figure 5).

Figure 5: extent to which respondents agree or disagree that the government should subsidise the industry to develop CCS



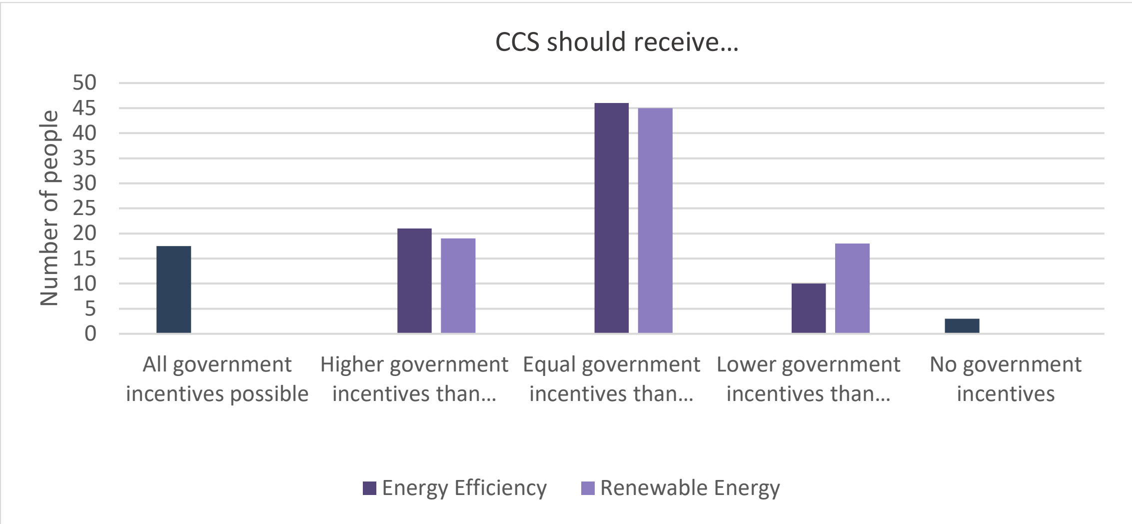
Most research participants believed that CCS deployment in the UK will not happen without government funding. However, whilst the survey responses suggest that government support for CCS research, development and deployment is perceived as necessary by operators, respondents expressed scepticism about this happening under current economic and political conditions, and also cautioned against the over-enthusiasm industry had been guilty of in the past:

> *"They won't put money into it because they can't afford it, their focus is entirely on Brexit, let alone on doing things like CCS." (I015, energy)*

> *"At the moment it looks as if we're really pushing ahead quite aggressively. Let's see what the next few years bring, we're good at talking a good game, but we don't always deliver." (I012, academia)*

As shown in Figure 6, most participants believe that CCS should have at least equal incentives to other low-carbon strategies.

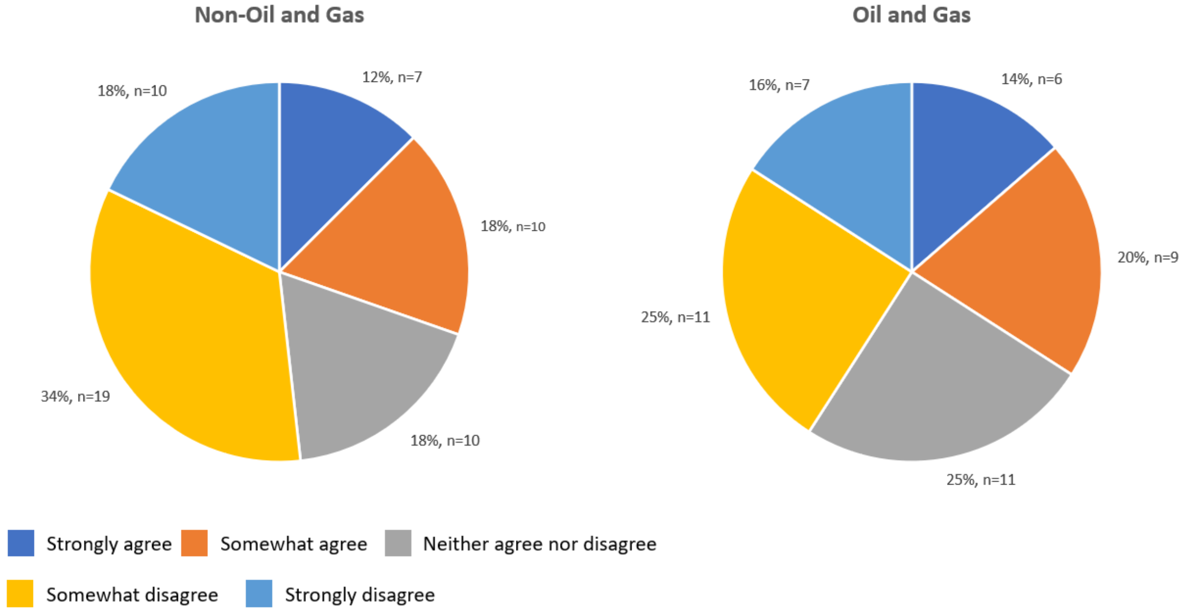
Figure 6: level of subsidy participants believe CCS ought to receive



4.6. The role of the private sector

As shown in Figure 7, over half of non-oil and gas respondents (52%) either strongly or somewhat oppose the idea that the private sector should be left alone to develop CCS. In contrast, just under one-third of non-oil and gas respondents (30%) either strongly or somewhat believed that the industry should be the one responsible for the projects, not the government. Expectations from participants in the oil and gas sector did not change notably from the non-oil and gas respondents (Figure 7).

Figure 7: extent to which respondents agree or disagree that the private sector should be left to develop CCS, not the government



Nonetheless, most participants believed that the oil and gas industry has a crucial function in CCS deployment:

> *"The oil and gas industry are the ones with all of the expertise, knowledge and the skills, also data, a lot of the data about the storage sites. So, storage is going to be where their role is. Storage is where they can make money." (I005, academia)*

In contrast, some respondents expressed concern about the CCS status being affected by its association with the oil and gas sector, perceiving that this could hinder the much-needed collaboration between government, industry and society.

> *"In regions where you do not have that expertise in the oil and gas sector, you will find a disconnect between the people and the companies that will be implementing CCS. There is only the perception of oil and gas as the evil polluter, and they are basically the enemy. So, working with or seeing the enemy as being part of the solution is simply impossible because there is simply no trust." (I014, NGO)*

Another respondent stated that carbon-intensive regions that have historically benefited economically from the oil and gas sector will generally be more supportive and recognize the industry as part of the solution; but that historical relations with oil and gas operators will vary from case to case:

"This familiarity with the industry may have a good or bad influence depending on past experience." (I020, academia)

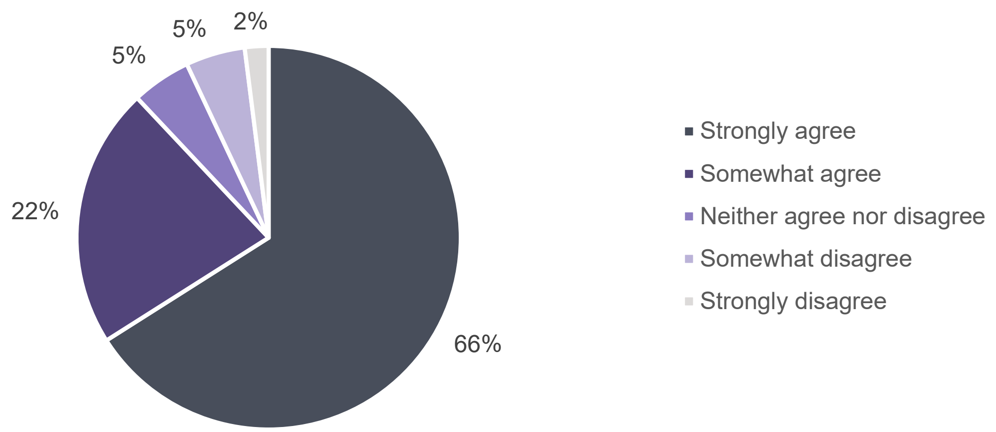
However, it was clear from responses that the industrial sector is increasingly willing to collaborate with the government in CCS deployment:

"Before the industry used to say - the government will pay, we're just going to help develop; that's not the case anymore, I think the industry now says - if we can have a little bit of funding to help out, that will be good." (I017, oil and gas)

4.7. Variations in Emerging Economies

In response to the question "to which extent do you agree or disagree that CCS is an important component of the low-carbon transition in fossil fuel-intensive emerging economies?", over 80 percent of respondents either "agree" or "strongly agree" that there is a place for CCS in emerging economies, such as Mexico (Figure 8).

Figure 8: extent to which respondents agree or disagree that CCS is an important component of the low-carbon transition in fossil fuel-intensive emerging economies



On one hand, emerging economy contexts have been identified as a setting in which operators in more economically developed nations may be able to provide CCS expertise to balance energy demand from fossil fuel-powered energy infrastructure with climate change obligations (Castrejon et al, 2018). Our results would suggest respondents agreed with this assertion. However, one respondent stated that the argument for carrying out CCS in emerging economies does not only come from within the country, but also rests on the international CCS community's need to run demonstration projects in new locations other than where they already exist. Such an approach is vital to verify the benefits and shortcomings of this technology under a wide range of variables.

> *"There are very few projects in humid or warm areas. The intention in Mexico was to do some demonstration projects that allowed us to collect information for both Mexico and the world." (I020, academia)*

This response indicates that there may be limitations to what can be directly applied based on knowledge gleaned in more temperate contexts. Furthermore, other respondents also questioned the necessity or propriety of importing CCS into emerging economy contexts:

> *"On the question for developing CCS on fossil energy in emerging economies, renewables will always be cheaper, barring a major grid stability incentive, it is a waste of money in my opinion." (S020, NGO)*

> *"In terms of using carbon hydrocarbons to generate electricity, it [CCS] prolongs an industry that is inherently dying." (I016, academia)*

> *"Emerging economies can jump directly to the energy carriers of the future (renewables, hydrogen) and have CCS as a supporting tool for its industry (through either CCS route or blue hydrogen)." (I014, NGO)*

In addition to repeated mentions of Asian emerging economies among research participants, Mexico appeared from the responses as a country with the potential to carry out CCS projects. This is in no small part due to its long-standing oil and gas activities, and the centrality of this carbon-intensive industry to Mexico's socio-economic development imperatives. Although a significant potential was recognized from Mexico's established oil and gas sector in carbon-intensive regions, several concerns were raised, most significantly: (a) lack of a specific regulation for CCS; (b) complex social dynamics with the state-owned petroleum company (PEMEX); (c) lack of analysis of CCS for heavy industry; and (d) the falling price of renewables. One respondent gave an example from a carbon-intensive city in Mexico – Coatzacoalcos - where an expectation of receiving cash payments might affect CCS projects; and again questioned the necessity or viability of CCS given rapid renewables deployment:

> *"In Coatzacoalcos, they immediately ask you - how much money is the community going to receive?" (I020, academia)*

"The prices that we have from renewables - solar and wind- in Mexico, leave any other [technology] out of the competition." (I020, academia)

5. Discussion

Our first discussion point concerns the relation between knowledge of and attitudes towards CCS, and respondents' familiarity and/or sectoral affiliation. It is notable that respondents who were most likely to view CCS as highly necessary were those with the most self-reported familiarity of the technology. In other words, the people most likely to see CCS as necessary were those working on CCS on a regular basis. This is in contrast to ideas in science and technology studies such as the 'certainty trough' (MacKenzie, 1998), which indicates that the more familiar experts are with a topic, the more aware they are of the intricacies and uncertainties around it and the less likely they are to make judgements with certainty. Rather, what our responses point towards is the existence of a self-sustaining epistemic community around CCS (Stephens et al, 2011), whereby a community of experts and practitioners working closely on CCS create and perpetuate narratives about how necessary CCS is to meet climate change goals (Mabon et al., 2015). Indeed, our open-ended findings in particular show how respondents working on CCS issues continually re-position the technology as being necessary for different aspects of decarbonisation as the climate change mitigation narrative unfolds and new technologies emerge, moving from decarbonisation of coal- and gas power to industrial applications, and now on to 'just transition' uses, deployment in hydrogen production, and deployment in emerging economy contexts as a means of balancing economic, social and environmental imperatives.

Whilst the above may point to a relatively small community of CCS practitioners and researchers working to try to stay relevant in the face of rapidly deploying renewables and increasing scepticism from civil society over CCS, what was also notable was the increasing reflexivity of oil and gas industry respondents. There was a marked difference between oil and gas respondents and non-oil and gas respondents on anthropogenic climate change, with fewer oil and gas respondents agreeing climate change was caused by humans. Yet the open-ended responses pointed to increasing acceptance within the sector of the need to take climate change seriously and enact meaningful responses, and also of the need for industry to rein in some of the excessive optimism it has displayed in the past with regard to being able to develop and deploy technologies. Similarly, oil and gas respondents were slightly more likely to view it as being the responsibility of the private sector to put CCS into practice.

These responses are interesting, because they point to a rising acknowledgement within the oil and gas sector – whose technical expertise has previously been positioned by the industry itself as being somehow necessary for CCS deployment (Kuch, 2017) – of the need for actions that are compatible with climate change imperatives. Reflecting the findings of the Platform/Friends of the Earth/Greenpeace (2020) report into transitions for North Sea oil workers, under a backdrop of increasing calls for urgent climate action and a rapid move away from fossil fuel-related activities, it may hence be the case that oil and gas sectors are beginning to see CCS as the only way in which their offshore and subsurface activities can remain relevant in the face of a social and political climate favouring rapid emissions reduction and renewable energy technologies. This reflects our finding that respondents rate storage and injection – two activities closely linked to offshore oil and gas – as the UK's two leading areas of CCS expertise. However, reflecting Kuch (2017) on the imperative to critically scrutinise industry claims to having the necessary 'expertise' to implement CCS, positive claims that industry can 'work the problem' were offset in our results against an acknowledgement that industry has in the past been over-optimistic about the practicalities of deploying CCS. One may hence question whether industry rhetoric of having the subsurface knowledge and expertise for CCS due to their experience of oil and gas operations reflects the reality of subsurface CO_2 storage, where potential storage sites must be tested and monitored over several years before a conclusion can be made about suitability.

At the same time, though, our findings also indicate significant scepticism among respondents from outside of oil and gas as to the necessity or economic viability of CCS outside of very specific applications such as hydrogen production. Such concerns centre on the economics of CCS, the rate of deployment, and a general lack of enthusiasm for CCS from policymakers and the electorate. This reflects scholarly work questioning the necessity of CCS investment within a rapidly-shifting landscape (Stephens, 2014), and civil society scepticism of CCS investment (especially from public funds) as sustaining fossil fuel operators rather than making meaningful contributions to emissions reduction or a just transition for a carbon-intensive workforce (Friends of the Earth Scotland, 2020; Greenpeace UK, 2020). In sum, reflecting the existing scholarly and policy literature, our findings point to a critical divergence between industry on one hand, which positions CCS technologies as critical to handle the tougher aspects of decarbonisation such as industrial emissions and hydrogen production whilst helping to transition oil and gas jobs (e.g. One North East, n.d); and civil society on the other, which sees an ever-diminishing role for CCS and for the companies that operate it.

Our second, briefer, discussion point relates to where CCS happens. Respondents from the oil and gas sector were notably more pessimistic about how the energy transition would affect carbon-intensive regions within the UK; and a majority of participants thought that CCS would be an important part of meeting climate change obligations for emerging economies where fossil fuels form a large part of the economy (such as Mexico). Previous research has indicated that there is interest in CCS from local and regional governments as part of a just transition for regions reliant on carbon-intensive activity, *but* that support is very dependent on the local context and that more evidence is required of how exactly CCS may provide jobs for those working in industries such as oil and gas and petrochemical refining (Swennenhuis et al., 2020). Similarly, previous research has noted the importance of CCS for emerging economies such as Mexico and Vietnam, where oil and gas revenues make a notable contribution to national economies and socio-economic development imperatives, but that economic and policy for support for deployment is necessary to achieve these goals (e.g. Castrejón et al, 2018; Nguyen-Trinh & Ha-Duong, 2015). Again, however, any enthusiasm for global CCS based on expertise garnered in well-established oil and gas producing regions needs to be tempered with the acknowledgement (as raised by our respondents) that CCS applications in emerging economy contexts may face issues relating to higher water consumption and different climatic or geological characteristics, for which less data may exist (Davids et al., 2020; Pérez Sánchez et al, 2019).

At a high level, our findings are thus consistent with extant research which identifies carbon-intensive regions within more affluent nations, and emerging economies where oil and gas revenues and fossil fuel power retain a prominent position, as two geographical contexts where CCS could help to balance multiple pressures. However, the open-ended responses indicate that where possible, there is a preference among stakeholders to use CCS only as a last resort when other decarbonisation options are unavailable, and that for emerging economies in particular it is preferable to develop energy transition pathways that jump straight to renewable energy sources. Reflecting the findings of Swennenhuis et al (2020), our results show that the role of CCS in a just transition is likely to be highly place-specific, and may only make sense in settings such as north-east Scotland with very specific infrastructural arrangements and technical skill-sets among the workforce. Moreover, recent events in Scotland such as the failure of the BiFab fabrication yard to gain contracts for manufacture of wind turbine components, with work going overseas (Energy Voice, 2020) serves as a reminder that trade unions and NGOs are becoming increasingly sceptical of claims that net-zero technologies will deliver local employment benefits to carbon-intensive workforces, and that governmental and developer rhetoric on fair and decent work through climate change mitigation needs to be backed up with policy and legislative support to ensure jobs and economic benefits are delivered to communities that need them. Supporting the findings of Janipour et al. (2021), our results thus underline the need for a clear policy framing of CCS as an intermediate technology for specific applications with well-specified timeframes for phase-out, and government support mechanisms for CCS that do not divert from non-fossil options or become perceived as ‘subsiding’ extractive industries, if there is to be broad stakeholder consensus on targeted CCS deployment.

6. Conclusion

Whilst Scotland and the UK is making comparatively strong progress in the research and development of offshore CCS as a climate change mitigation technology, there appears to be increasing divergence in public discourse on the extent to which CCS is a necessary part of the net-zero transition. Understanding why there is divergence between more positive operators and developers on one hand, and increasingly critical or sceptical voices from academia and civil society on the other, is critical to identify whether there are feasible and acceptable pathways to CCS deployment that can balance these competing pressures. Our results show that belief in the necessity of CCS tends to be higher among those working closely with the technology, who may have personal and professional interest in seeing CCS come to fruition, whereas across a wider range of respondents there is a preference for deployment of renewable technologies wherever possible. Across our qualitative and quantitative responses, the picture that emerges is one where CCS is both desirable and feasible under very specific circumstances, such as hydrogen production or drawing on experience of subsurface operations to support storage in already well-known subsea locations such as the North Sea and Gulf of Mexico. What is not clear from our findings, and what the wider policy discourses increasingly emphasise, are the circumstances (if any) under which civil society organisations may be prepared to support CCS deployment. Further research may hence wish to explore policy, legislative and financing structures which can help the pragmatic climate mitigation benefits of CCS operations to be reconciled with civil society stakeholder concerns.

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