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Incentivising bioenergy with carbon capture and storage (BECCS) responsibly: Comparing stakeholder policy preferences in the United Kingdom and Sweden

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ABSTRACT

Bioenergy with carbon capture and storage (BECCS) plays a central role in scenario pathways that limit global warming in line with the objectives of the Paris Agreement. Yet deliberate policy efforts to incentivise BECCS—whether through amending existing climate policies or introducing entirely new ones—remain rare. In this paper, we contend that BECCS must be incentivised responsibly, through policy-making processes which account for diverse and geographically varying societal values and interests. More specifically, we make the case for responsible incentivisation by undertaking a comparative analysis of stakeholder attitudes to four idealised policy scenarios for BECCS, including representatives of government, business, nongovernmental and academic communities, in the UK and Sweden. The scenarios were: business as usual; international policy reform; national BECCS policy; and national policy for negative emissions technologies. Based on our findings, we recommend that policymakers 1) recognise the need to develop new incentives and make enabling reforms to existing policy instruments; 2) consider the risk of mitigation deterrence in their real world (and not abstracted) contexts; 3) employ multi-instrument approaches to incentivisation that do not overly rely on carbon pricing or 4) force a choice between technology specific or technology neutral policies; and 5) attend to the diversity of stakeholder and wider public perspectives that will ultimately determine the success—or failure—of their policy designs.

1. Introduction

There is a growing ambition to re-orient climate change policies around 'net zero' greenhouse gas emissions targets. Commitments to balance the overall quantity of emissions added to, and emissions removed from, the atmosphere have already been enshrined in law in the United Kingdom (UK), Sweden, France and Norway, and are under consideration in many other countries. Net zero targets theoretically allow for residual emissions from hard-to-abate sectors like agriculture, aviation and shipping, so long as they are offset in other sectors by negative emissions, i.e. the removal of carbon dioxide (CO_2) from the atmosphere. There are many different prospective negative emissions technologies (NETs), spanning those that remove CO_2 via biological activity (e.g. forestation) or chemical processes (e.g. direct air capture) (Minx et al., 2018).

Bioenergy with carbon capture and storage (BECCS) is a photosynthesis-based NET that involves the combustion of biomass—derived either from dedicated crops and trees, or from agricultural or forestry residues or organic wastes—to generate energy, as well as the subsequent point source capture, transport and long-term storage of the released CO_2 in deep geological formations. BECCS is a particularly policy relevant method owing to the central role it has played in the scenario pathways set out by the Intergovernmental Panel on Climate Change (IPCC) to limit global warming to no more than 2 °C or even 1.5

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°C, in line with the Paris Agreement. The bioenergy component of BECCS is a mature technology, while carbon capture and storage (CCS) is currently undergoing demonstration trials in several countries (Royal Society and Royal Academy of Engineering, 2018).

In light of its importance in climate scenarios, there are now mounting calls to incentivise BECCS research, development, demonstration and deployment (RDD&D), through amendments to existing climate policies or altogether new ones. These include providing clearer frameworks for licensing sub-soil access for CO_2 storage (Cox and Edwards, 2019), as well as rules to operationalize the market mechanism under the Paris Agreement. For example, this could include ensuring robust accounting of negative emissions or implementing safeguards for sustainable development (Honegger and Reiner, 2018). Others, meanwhile, are pressing for new RDD&D funding streams targeting either specific aspects of BECCS—such as new bio-feedstocks—or for NETs in general (Lomax et al., 2015; Burns and Nicholson, 2017; Cox and Edwards, 2019), while still others advocate renewable energy certificates or negative emission refund schemes (Pour et al., 2018).

Despite these calls, BECCS has remained a low priority to date for state and non-state climate policy actors around the world (Fridahl, 2017). This is reflected in the current climate policy landscape, where few BECCS-specific policies exist.[1] Moreover, even where climate policies potentially relevant to BECCS do exist, national policy systems often contain regulatory uncertainties, or even explicit legal barriers, that act to disincentivise BECCS deployment. Two prominent exceptions to this rule can be found, however, in the UK and Swedish contexts. Both of these countries have recently enshrined in law a target for achieving net zero emissions (by 2045 in Sweden and by 2050 in the UK). The UK has also recently committed funds for low carbon innovation between 2015 and 2021 through the Clean Growth Strategy and the Industrial Strategy Challenge Fund, while in Sweden the so-called Industrial Leap Fund has been required, since 2019, to dedicate a share of its funding to negative process-related industrial emissions. Most strikingly of all, both countries have BECCS demonstration pilot projects in operation, including at Drax power station in the UK and at Stockholm Exergi's Värtan combined heat and power plant in Sweden.

Despite these apparent similarities however, the UK and Sweden present starkly different contexts within which to develop BECCS policy. Sweden, for example, has eight times as much forest cover as the UK, as well as twice the available land area, but a population almost seven times smaller. According to International Energy Agency (2018) statistics, biomass currently accounts for just 6% of the UK's total primary energy supply, while in Sweden the equivalent figure is 25%. Correspondingly, there are relatively few biogenic point sources of CO_2 in the UK energy sector, and many in Sweden. Yet it is not Sweden, but the UK, which possesses significant domestic capacity for CO_2 storage, including in the North Sea.

Against this backdrop, the current paper aims to comparatively analyse how stakeholders' policy preferences for BECCS are shaped by their understandings of the contextually-specific technological constraints, political climates, and societal expectations which apply in each country. More specifically, the paper compares the findings of two one-day deliberative scenario workshops, one held in London, the other in Stockholm, at which diverse groups of stakeholders were asked to deliberate four idealised policy scenarios mapping alternative near-term pathways for the development of BECCS policy.

Previous research engaging stakeholders has suggested that a lack of policy incentives and political prioritization are broadly perceived as the main barriers to BECCS deployment (Fridahl and Lehtveer, 2018), and highlighted a preference for measures designed to intervene in market processes, for instance by affecting the price of carbon CO_2, or by directing additional government investment into research funding (Bellamy and Healey, 2018). Yet very little research to date has sought to examine how stakeholder perceptions of diverse policy incentives for BECCS might be influenced by an awareness of the varying technological, political and indeed social contexts within which those policies must ultimately be developed and deployed. That such contexts are consequential to governance processes has been highlighted by research engaging publics, where societal attitudes to distinct kinds of policy instrument have been shown to significantly affect attitudes towards BECCS as a technology itself (Bellamy et al., 2019).

By foregrounding the distinctive national contexts within which policy stakeholders in the UK and Sweden must operate, the paper aims to contribute to more nuanced understandings of the principles that should undergird efforts to incentivise BECCS in a responsible manner (Bellamy, 2018). Indeed, building on cognate concepts of responsible innovation (Owen et al., 2013), responsible development (Waller et al., 2020) responsible assessment (Beck and Mahony, 2018) and governance "from the ground up" (Bellamy and Geden, 2019), the paper argues that the responsible incentivisation of BECCS will require relevant governance institutions and practices to engage not only with technical questions of policy design, as if BECCS were already a fixed technology. Instead, these institutions and practices must be attentive to the evolving and cosmopolitan geographies of knowledge-making through which the potentials and pitfalls of BECCS—not just in technical or environmental terms, but also in respect of their broader implications for human needs, justice and ethics (Hulme, 2010; Forster et al., 2020)—are worked out in particular, situated real-world contexts.

2. Method

We convened two deliberative scenarios workshops with stakeholders to consider four idealised policy scenarios for the incentivisation of BECCS. One was held in London and the other was held in Stockholm. Both took place in March 2019, and recruited participants representing a

Table 1
Stakeholder codes and occupations.

Code	Occupation
UK1G	Senior climate policy expert in a government department
UK2G	Senior climate change expert for a non-departmental public body
UK3B	Head of sustainability at an electrical power generation company
UK4B	Senior policy analyst for a renewable energy industry trade group
UK5B	Senior technology analyst for a greenhouse gas removal research programme
UK6N	Director of a public interest research group
UK7A	Climate scientist at a university
SE1G	Member of Parliament and party spokesperson on climate change
SE2G	Member of Parliament and party spokesperson on climate change
SE3G	Member of Parliament and party spokesperson on climate change
SE4G	Special adviser on climate change for one of the parties in Parliament
SE5G	Senior government official on carbon storage
SE6G	Senior government official on bioenergy
SE7G	Senior government official on CCS in the industry sector
SE8B	Senior climate policy expert for a large conglomeration of businesses
SE9B	Head of R&D at an electrical power generation company
SE10N	Climate change reporter for a national newspaper
SE11A	Senior climate policy expert at a large environmental research institution

Acronyms: UK = stakeholder in the UK workshop; SE = stakeholder in the SE workshop; G = government representative; B = business representative; N = nongovernmental organisation representative; A = academia representative.

[1] There are, however, a number of existing policies that are—or could potentially become—BECCS-relevant (Fridahl and Bellamy, 2018). At the international scale, these include the 2006 amendment to the 1996 London Protocol that allows sub-seabed disposal of CO_2, revised accounting guidelines from the IPCC in 2006 on reporting negative emissions in the power sector, and the 2011 inclusion of CCS in the 1997 Kyoto Protocol's Clean Development Mechanism. At the level of the European Union (EU) meanwhile, these potentially relevant policy tools include, for example, the landmark 2003 Emissions Trading System (ETS) and the 2009 CCS Directive, as well as various recent infrastructural, research and innovation funds.

diversity of perspectives from government organisations, businesses, academia, and other non-governmental organisations (Table 1). While the stakeholders were convened in the two cities, they were not all from them and represented the four sectors beyond the metropolitan centres. Each workshop began with an overview of BECCS technology and a survey of the (limited) climate policy landscape as it pertains to incentives for BECCS at national, EU and UN levels (see Fridahl and Bellamy, 2018).

Prior to the workshop, participants were provided with four idealised policy scenarios for BECCS (see Table 2 for abridged descriptions; see supplementary material for full descriptions). At each workshop, stakeholders reviewed these scenarios in turn before engaging in facilitated, but unstructured discussions on the perceived relative strengths and weaknesses of each. By coupling a focus on the four scenarios with an unstructured discussion format we were able to avoid placing constraints on stakeholder responses to the scenarios and to gain more complete, in-depth, and contextual understandings of their perspectives (Zhang and Wildemuth, 2017).

The policy scenarios were designed by the research team to capture a range of hypothetically plausible near-term trajectories for BECCS-relevant policies until 2023. Although 2023 represents a short timeframe for large-scale infrastructure, it was chosen to make it easier for stakeholders to relate to the scenarios as individual actors, and moreover to counteract the tendency for integrated assessment modelling exercises to promote a focus on medium to long-term, rather than shorter-term action. While urgent action is arguably required if NETs are to contribute meaningfully to climate targets, however, it is also unlikely that any of the scenarios (except business as usual) can be realized in the short timeframe suggested. The scenarios should therefore be viewed as constructs designed to accentuate differences between possible development routes by presenting hypothetical courses of action within a condensed time-frame, rather than as realistic proposals for policy development. Key factors bearing on the design of these scenarios included whether policy reform would: (1) evolve to make space for BECCS and/or NETs alongside emissions reductions; (2) be driven at the international or national level; (3) be technology-specific or technology-neutral; (4) be based on newly created instruments or on reforms to existing policies; (5) be cost-neutral to government budgets or allow large public expenditure; and (6) primarily rely upon regulatory, economic or informational instruments (Bemelmans-Videc et al., 2010; Lehmann and Gawel, 2013).

Stakeholder deliberations on the four scenarios were audio recorded and fully transcribed. We then conducted thematic analyses using established procedures for inductive, semantic and constructionist analysis, where the authors familiarised themselves with the data, generated initial codes, searched for themes, reviewed themes, defined and named themes, and reported them (Braun and Clarke, 2006). In the next section we report on the stakeholder attitudes elicited in relation to each policy scenario in turn. We then discuss the study's main findings in relation to emerging academic literatures on responsible incentivisation for BECCS, in the context of broader policy and political processes linked to NETs and climate change itself.

Table 2
Abridged idealised policy scenarios (see supplementary material for full descriptions).

Scenario	Description
1. Business as usual	Climate policy continued to focus primarily on mitigation and no specific policies were created to incentivise BECCS nationally or in the EU
2. International policy reform	A range of existing international climate policies were reformed to incentivise BECCS, including LULUCF accounting under the UNFCCC, the EU ETS and its various funding schemes, and the IMO's CO_2 export ban
3. National BECCS policy	Technology-specific policies were created to incentivise BECCS nationally, including procurements, feed-in-tariffs and quota obligations
4. National NETs policy	Technology neutral policies were created to incentivise NETs nationally, including standards for permanency of stored carbon combined with tax credits and reversed dedicated auctions

Acronyms: BECCS = bioenergy with carbon capture and storage; EU = European Union; UNFCCC = United Nations Framework Convention on Climate Change; ETS = Emissions Trading System; IMO = International Maritime Organisation; LULUCF = land use, land-use change and forestry; NETs = negative emissions technologies.

3. Findings

Table 3 summarises the themes derived from the stakeholder deliberations, including issues of emphasis that were common to both workshops and issues that were emphasised in one workshop only. In the remainder of this section we describe the findings in relation to each of the four scenarios in detail.

3.1. Scenario one: business as usual

The British discussion of scenario one focussed on scrutinising where current and near-term UK climate policy was thought to stand in relation to the scenario. Some stakeholders in the UK (UKG1, UK3B) noted that while there were no existing policies aimed specifically at BECCS, there were policies emerging in related areas that could potentially incentivise BECCS indirectly, such as those concerning bioenergy strategy and carbon capture, usage and storage (CCUS). It was emphasised, however, that:

> "We don't necessarily have something that looks at BECCS as a technology brought together. It's not clear that BECCS is being welcomed into that policy framework" (UK2G).

Under these current policies (or lack thereof), the development of the CCUS infrastructure alone was seen to require much longer than the five-year timeframe considered by the scenarios.

Accordingly, the stakeholders agreed that without policies to incentivise BECCS, the technology would simply not materialise in the UK:

> "You won't get BECCS under this scenario because of the cost of BECCS relative to counterfactual technologies, which will provide you with energy and carbon reduction. The cost of BECCS is that much higher and in the power sector, the way it works, bioenergy combustion is already counted as zero so there is no further incentive to capture that carbon" (UK1G).

Nevertheless, scenario one was deemed to have at least one advantage over the others, where "the opportunity in this scenario is the strength to try and focus on the emission reductions" and not risk BECCS being "used as an excuse to not reduce emissions" (UK6N). This was, however, conveyed under the caveat that emissions reductions alone would not be enough to reach net zero emissions, nor would they attend to residual emissions in sectors more difficult to decarbonise, like agriculture.

The Swedish discussion, similarly, expressed agreement that business as usual would not incentivize BECCS in Sweden (SE1G, SE2G, SE3G, SE5G, SE9B, SE11A). However, four qualifications were raised.

First, it was noted that some existing policies already targeted BECCS (SE1G, SE3G, SE4G). BECCS strategy development was mentioned, as was an appropriation for BECCS in the investment fund 'Industriklivet':

> "Proponents of business as usual simply have to surrender to the fact that investment support for BECCS is already agreed" (SE3G).

Second, as in the UK, some stakeholders noted that BECCS cannot be seen in isolation and that existing fossil fuel CCS policies could incentivise BECCS indirectly (SE7G, SE9B, SE11A). Yet it was also noted that

Table 3
Common and different themes emphasised by British and Swedish stakeholders in relation to the four scenarios.

	Common themes	Different themes
Scenario one: Business as usual	• BECCS could be indirectly incentivised through policies in related areas • The lack of direct incentives means that BECCS would not materialise • Not incentivising BECCS would refocus efforts on emissions reductions	• Businesses piloting BECCS have increased awareness of it among policymakers (SE) • Some (though limited) direct incentives for BECCS exist (SE)
Scenario two: International policy reform	• A stabilised price on tradable EUAs of £40/480 SEK /tCO_2 in 2023 is considered too low, too soon	• Other industries may lobby against removal of EUAs corresponding to those claimed by BECCS operators (UK) • An increase in the price of EUAs to 480 SEK would increase capital available to the Swedish Innovation Fund (SE) • EU ETS reforms should be combined with a price floor or other national policy to avoid EUA price volatility (SE) • EU funding and policy reforms are seen as slow (SE) • Recognising the Norwegian Aurora CO_2 transport and storage initiative as a Project of Common Interest to the EU would render BECCS more viable (SE)
Scenario three: National BECCS policy	• Technology specific policy excludes the possibility for synergies between BECCS and fossil CCS	• Concern over propriety of biomass production systems and supply chains, including imports (UK) • Strong sustainability clauses could help avoid negative environmental impacts from imported biomass (UK) • Scale, spatial configuration and environmental impacts of infrastructure key but overlooked elements for successful national policy on BECCS (UK) • Preference for contracts for difference scheme (UK)
Scenario four: National policy for NETs	• Long term strategies and collaborations are needed • Fixed payment tax credits of £45/540 SEK are deemed too low to stimulate investment	• Even if incentives remain neutral, MRV requirements would favour some NETs over others (UK) • Technology neutral approach avoids political risk of "picking winners" (SE) • Reflects that different technologies will be needed for different industries (SE) • Technology neutral tax may not recognise need for incentives at different stages, e.g. BECCS may suffer because it is comparatively immature (SE)
Scenario non-specific		• Large potential storage capacity in the North Sea and onshore saline aquifers (UK) • Concern over crude accounting methods for emissions from direct and indirect land use change and forestry from different biofuel feedstocks (UK) • Domestic supply of biomass could be improved (UK) • Usage of biomass will continue regardless of whether BECCS is implemented (SE)
	• A longer timeframe than five years would be needed to incentivise BECCS	

although "the potential synergies with CCS are large, the full potential is not reflected in current policy" (SE7G).

Third, while current policies include few incentives for BECCS, several stakeholders noted recent shifts in awareness of BECCS among policymakers, in part pushed by Swedish industry (SE1G, SE3G, SE5G, SE7G, SE9B).

Fourth, it was also noted that BECCS policies should not be used as an excuse to postpone emissions reductions. Incentivization of BECCS should go hand in hand with unceasing pressure to mitigate fossil emissions (SE5G, SE11A).

Like the UK stakeholders, the Swedish stakeholders raised the need for long-term and stable policy. Yet, unlike in the UK, the next five years were seen as crucial for the longer timeframe. The lack of policy incentives was seen as the key deployment barrier. One stakeholder noted:

> "If one wants to reach the Swedish policy objectives and to have a couple of BECCS units in place in 2040, then businesses have to start expanding to large scale by 2030, something that requires decisions in a couple of years' time. In this perspective, 2040 is today" (SE9B).

3.2. Scenario two: international policy reform

The British discussion of scenario two proceeded under the knowledge that, if the UK were to leave the EU without an agreement (a possibility at the time the workshop was held), a carbon tax would replace the function of the EU ETS. The stakeholders focussed on two main subjects: the price and availability of tradeable European Union Allowances (EUAs) and the need for effective accounting rules for emissions arising from land-use change and forestry.

The stabilised price on tradable EUAs of £40 per tonne of CO_2 in 2023 assumed in the scenario was deemed by several stakeholders to be both too low and too early (UK2G, UK3B, UK6N, UK7A):

> "I don't think it will stabilise at 2023, I hope it doesn't. I think it's going to have to continue to rise right out to the end of the century" (UK3B).

The automatic removal of a corresponding amount of EUAs available in future auctions for every new EUA claimed by a BECCS operator raised a question for some stakeholders (UK1G, UK2G, UK4B) about its relative merits and pitfalls:

> "If in the scenario where you are also removing a corresponding EUA and the BECCS operator gets the credit for that then you've kind of doubled their money haven't you? But if it's just that they're claiming an EUA in either case there might be second order issues like other emitting industries might lobby that it's not a great idea to remove credits out of the system which it makes it harder for the BECCS operator" (UK1G).

The second main area of discussion centred on the presently 'crude' (UK2G) accounting of emissions from LULUCF, in particular those arising from indirect land-use change:

> "What I mean is the impact that you have if you decide to burn somebody else's wood from some other country" (UK6N).

At the same time, it was noted that the impacts of, and by extension the much-needed accounting for, land-use change would vary with different biomass feedstocks. The stakeholders also noted that while Norway may develop CO_2 storage infrastructure, and that the UK may utilise that in the near-term, the UK itself has a great deal of potential storage capacity in the North Sea and in onshore saline aquifers (UK1G, UK3B, UK4B, UK6N).

The Swedish discussion focused less on LULUCF accounting rules and more on EU mitigation policy. As in the British discussion, a stabilised price on tradable EUAs of 480 SEK (£40) in 2023 was deemed to be both too low and too early:

> "480 SEK is far too low, but there are opportunities on short and mid-term to start the operation of BECCS in Sweden and let the EU ETS finance upscaling, as the EUA price increases over time" (SE11A).

Many other stakeholders agreed that EU ETS finance for BECCS offered mid- and long-term potential. As the marginal abatement cost increases over time, they argued that BECCS ought to become competitive (SE2G, SE7G). EUA price volatility, however, was deemed a "nightmare" (SE11A) for investors. The preferred option would be to combine EU ETS reform with, for example, a price floor or other national policy (SE1G, SE11A).

It was also noted that an increase in the price of EUAs would, in turn, strengthen the capitalization of the European Innovation Fund. Part of this funding, they argued, could be used to finance BECCS (SE2G, SE4G, SE7G). Others hesitated, arguing that engaging with EU funding is both painfully slow and administratively burdensome. It was deemed more appropriate for large infrastructure projects, such as transport and storage, than for financing capture units (SE5G, SE9B). As suggested in the scenario, seeking approval for the Norwegian Aurora CO_2 transport and storage initiative as a Project of Common Interest to the EU[2], and thus granting access to funding from the Connecting Europe Facility, was raised as one potential avenue for making BECCS more commercially viable (SE9B).

It was also noted that EU policy reform is slow and sometimes unpredictable, and that to actually realise this scenario would require a stepwise enlargement of international cooperation among willing front-runners (SE1G, SE9B). One actor noted that "while negative emissions are mentioned in the proposed new EU climate strategy, it doesn't exactly feel like it's pushing for radical change" (SE1G).

3.3. Scenario three: national BECCS policy

The British discussion proceeded under the assumption that a national BECCS policy should be based principally on 'contracts for difference', whereby government would guarantee a higher price for producers selling energy derived from BECCS facilities. This approach would be consistent with existing policy; as one stakeholder put it, "the way the UK electricity market works is you have contracts for difference to incentivise things" (UK1G).

Three sets of questions were raised, however, about implementing such a policy in practice. The first concerned how to incentivise appropriate biomass production systems and supply chains, and particularly the question of balancing imported and domestic feedstocks. Several stakeholders (UK7A, UK1G, UK3B) were uncertain about how existing carbon accounting methodologies (whereby emissions generated by biomass combustion are accounted for in the land-use sector of the country where that biomass was grown, and *not* in the energy sector of the country where it is consumed) might be adapted to allocate credit for negative emissions from BECCS.

> "If you add CCS into the [bioenergy] equation, I'm still not 100 % sure whether the UK gets the credit" (UK1G).

Some stakeholders asserted that any potential environmental degradation associated with imported biomass could be avoided by "strong sustainability clauses" (UK3B); indeed, this was seen as a strength of existing UK bioenergy governance:

> "You know it has to meet the British regulations and you go out and you check. And I would say that's what we do with sustainability" (UK3B).

Others, by contrast, maintained that "just because we import loads of things doesn't make it acceptable" (UK6N). Despite these divisions, all stakeholders *were* agreed that the UK should be doing more to expand its domestic biomass supply.

A second set of questions raised by stakeholders concerned how a national BECCS policy scenario might constrain the design, construction and governance of CO_2 transport and storage infrastructure. Some stakeholders (UK6N, UK5B, UK3B, UK1G) were concerned that insufficient attention had been given even to basic questions about the scale, spatial configuration, and indeed the potential environmental impacts of infrastructure building likely to be associated with a national BECCS policy.

Others, meanwhile, raised questions about how liability and responsibility for CO_2 transport and storage infrastructures would be allocated, with analogies being drawn to the roles of the *National Grid* role in UK electricity distribution, and *Network Rail* in maintaining the UK's railway infrastructure (UK3B, UK6N). More practically, some stakeholders suggested that new CO_2 transport and storage infrastructure might need to be 'clustered', to help capture emissions from large-scale electricity generation facilities *and* smaller-scale facilities such as anaerobic digestion plants:

> "We would want the capacity for those smaller capturers of CO_2 to feed into a larger network around hubs" (UK2G).

Finally, a third set of questions centred on trade-offs and synergies between a technology-specific BECCS policy, and wider national efforts to mitigate climate change. For example, some stakeholders suggested that infrastructure built under a technology-specific BECCS policy should be designed to capture CO_2 generated from *non*-biogenic sources as well:

> "If there is an action plan for the CCUS more broadly and it's not specifically limiting itself to, or defining itself as a BECCS specific policy, then we might want to make sure that fossil CCS' CO_2 can also get onto the system" (UK2G).

Other stakeholders, meanwhile, worried that a well-intentioned national policy based on specific quota obligations for CO_2 captured and stored from biogenic sources could in fact be detrimental to BECCS development, unless it were extended to apply to all sources of CO_2:

> "The way this is phrased, for the UK context, might actually stunt BECCS and GGRs [greenhouse gas removals] as a whole. You might want the obligation on all sources, biogenic and fossil" (UK1G).

The Swedish discussion was largely based on three assumptions. First, the usage of biomass in Sweden will continue regardless of whether BECCS is implemented or not. The already existing pulp and paper industry and the heat and power sector were noted to have a large BECCS potential (SE11A, SE7G, SE6G). In respect to this, two stakeholders raised concern over the issue of responsibility for fulfilling the Swedish net-zero target (SE4G, SE9B):

[2] This proposal was approved after the workshop.

> "I know that the forest industry is afraid that they will have to pay for negative emissions as a result of the oil and fossil industry not being able to meet their climate commitments" (SE9B).

A technology-specific policy rewarding BECCS, as suggested by scenario three, could help alleviate this concern. Together with the realization that there are many potential benefits with synergies between BECCS and CCS (SE3G), a solution raised was to include CCS in the same incentive structure as that proposed for BECCS (SE4G, SE7G):

> "I don't believe that BECCS will be able to be realized on its own. Instead one has to look at the synergies that exist between CCS and BECCS" (SE7G).

Another stakeholder (SE11A) stressed that there may be a need to clearly distinguish between the two, to avoid giving incentives for the continued use of fossil fuels (SE11A).

Second, it was noted that storage of CO_2 in Sweden is at best a long-term alternative, even if this process was led by a state company. The need for multilateral cooperation was stressed, noting that the so-called Helsinki Convention currently prohibited sub-seabed storage in the Baltic Sea. Long-term benefits of developing national storage were noted to include less reliance on Norwegian storage and the potential to sell storage capacity to Finland (SE5G). At the same time, however, the competency required to build and operate offshore storage was noted to not currently exist in Sweden (SE9B, SE7G). Consequently, in the near-term, the option to ship CO_2 to Norway was seen as most appropriate (SE5G, SE9B, SE7G).

Third, the stakeholders agreed that business as usual would provide insufficient support to BECCS, and that EU ETS reforms would take too long. They therefore also agreed that some kind of national regulation or incentive was required. The signal from the industry was noted as being clear that it would not happen by itself (SE1G, SE9B, SE11A).

3.4. Scenario four: national policy for NETs

The British discussion of scenario four began by questioning the adequacy of some of its components. The time horizon of 100 years permanence for tax-incentivized CO_2 capture and storage was considered too modest, in light of studies suggesting minimal leakage (1%) in geological storage up to three thousand years.

Once again, an important strand of the discussion focused on the challenge of measuring the quantity and durability of carbon capture, and on the relevance of developing appropriate monitoring, reporting and verification (MRV) instruments. Even if the policy incentive remained neutral, the technical difficulty and economic cost of MRV would necessarily favour some technologies over others.

Some stakeholders imagined a situation in which the scenario effectively resulted in immediate support for technologies for which robust accounting metrics already existed, combined with "a commitment to widen that, as you understand more and can bring more monitoring in of enhanced weathering or other options that you want to do" (UK1G).

The discussion of scenario 4 also focused on whether the proposed incentives would be sufficient to encourage substantial private investment in BECCS; some thought a tax credit would not be sufficient. It was noted that "a tax [credit] is hard to invest a lot of money against" (UK3B), and that "a tax [credit] is a lot less bankable" (UK4B). This, in contrast to contracts for difference, which offer the guarantee of a long-term commitment from the government.

> "You might have a tax credit, but if you are required to make arrangements for your own transport, demonstrating performance of maybe one thousand, two thousand years, and also to arrange monitoring for compliance, some people might actually be put off" (UK5B).

Stakeholders, however, mentioned the tax credits recently introduced in the United States to incentivize carbon capture, storage and reuse (amendments to the Section 45Q of the Internal Revenue Code), which appear to be having an impact with a comparable range of monetary benefits ($50 [£40] per tonne of CO_2 stored and $35 [£28] per tonne of CO_2 re-utilized).

Finally, stakeholders questioned whether the scenario incorporated enough incentives for radical technological innovation.

> "Noticeably absent [in this scenario] is any kind of innovation… It's just a kind of classic valley of death between some ideas and playing the markets" (UK1G).

The Swedish discussion of this scenario had some stakeholders arguing that negative emissions are needed regardless of the technology used (SE4G, S11A). However, the difficulties involved in evaluating NETs against each other were raised (SE2G, SE6G). It would require, one stakeholder noted, "knowledge of opportunity costs, for example of investing in afforestation or biochar, compared to BECCS" (SE2G). A more technology neutral approach was, nonetheless, seen as a possibility in order to avoid the risk of politicians picking winners.

Financial incentives were discussed as fundamental for NETs deployment. Specific to BECCS, however, the prices in scenario four were seen as too low. Part of the discussion also focused on the difficulty of understanding the difference between incentives such as tax credits, reversed auctions, and guaranteed prices, and the need to openly discuss all alternatives regarding policy instruments as well as NETs (SE2G, SE11A).

> "Should we build up an alternative system, financing large-scale afforestation, biochar; these alternatives must be discussed. I think that it is also important for acceptance" (SE2G).

The group discussed the possibility of having a "palette of solutions for negative emissions" (SE6G). BECCS was seen to be among a few alternatives available right now, but in the long-term other technologies would be needed too:

> "It is important not to lock into one type of negative emissions technology. We have to keep many paths open" (SE6G).

The need for sharing knowledge and infrastructure was also noted. The lack of funding for developing collaboration platforms was a concern; an addition that could improve the viability of scenario four (SE1G, SE5G, SE7G, SE9B, SE10 N).

Questions of the future competition for biomass resources were also triggered by the technology neutral scenario:

> "Everyone wants to use the biomass in different ways, it is not obvious where the biogenic emissions will be localized in the future Swedish economy" (SE3G).

However, a further developed bio-economy was also discussed as a possibility for BECCS. The heat and power sector, it was mentioned, could utilise "an increasing share of breadcrumbs falling off the [bio-economy] table" (SE9B), i.e. to burn an expected increasing amount of waste generated from a growing bio-economy.

The timing of financial incentives and when they would be paid out was identified as an important factor in the incentivization of different types of NETs. Focusing solely on technology neutral, results-based payments for negative emissions may result in under-utilization of Sweden's large potential for BECCS simply because it is currently a less mature solution (SE11A). Concerns about long-term financing were also raised, and in particular whether enough funding would be available to run operations with BECCS once they were set up (SEG2, SE9B).

4. Discussion

Our findings indicate that the successful and competitive deployment of BECCS is unlikely to occur in either the British or Swedish

context without the creation of new incentives and enabling reforms in policy frameworks. This incompatibility with the business as usual scenario is well aligned with emerging literature on the topic (Fridahl, 2019; Levihn et al., 2019).

While new and reformed incentives are required, however, it was the view of all stakeholders that these should be designed carefully so as not to detract from ongoing fossil emissions reductions. This reaffirms concerns that the deployment (or even consideration) of BECCS and other NETs might carry a 'mitigation deterrence' risk (Markusson et al., 2018; Anderson and Peters, 2016). While this risk is yet to be borne out, policy measures may be taken now to minimize it, for example by developing separate targets and accounting metrics for emissions reductions and negative emissions (McLaren et al., 2019). Nevertheless, the stakeholders were all alert to the importance of avoiding trade-offs between near-term emissions reductions and the promotion of future negative emissions. This suggests that concerns about mitigation deterrence, while implicit within the century-long, global technology-cost optimization scenarios produced by integrated assessment models (IAMs), may in fact be less applicable to the real-world opportunities and constraints within which policy actors make decisions in the shorter-term. Indeed, deliberative exercises such as this one may even help to counteract the tendency—embedded in IAMs and other dominant forms of assessment—to obscure near-term opportunities for radical change while projecting ambitious transformations, including the large-scale deployment of NETs, into the long-term future (Beck and Mahony, 2018).

Economic instruments were a particular focus of concern among our stakeholders. In particular, pricing levels (both of tradeable EUAs in the international policy reform scenario and of fixed payment tax credits in the national policy for NETs scenario) were deemed too low to stimulate investment in BECCS. This contrasts with earlier, more optimistic stakeholder views that considered a price of $50 per tonne of CO_2 sequestered sufficient to stimulate investment (Bellamy and Healey, 2018). Indeed, more recent cost estimates have indicated that a price of £40 to £50 would be highly unlikely to cover the full capital and operational cost of BECCS (Levihn et al., 2019). An appropriate carbon price mechanism might instead be achieved through hybrid trading schemes with price-like features, such as an auction reserve price (Fankhauser et al., 2010). Even if such a mechanism could be established, however, it should not be regarded as a 'fix-all' measure; focussing on wider co-benefits would provide greater scope for incentivisation through multiple policy angles (Cox and Edwards, 2019). For BECCS, this might include funding for local demonstration projects using local wastes and residues or a single, definitive international biomass certification scheme (ibid).

At a more general level, consideration of the technology specific and technology neutral scenarios revealed a *dilemma of incentives* for BECCS. A technology specific policy would incentivise BECCS, but disadvantage other NETs as well as fossil CCS, thereby reducing scope for synergies between these domains. On the other hand, a technology neutral policy could incentivise other NETs and fossil CCS, but disadvantage BECCS as a comparatively immature approach. A multi-instrument approach will very likely be needed to help overcome this dilemma.

While our findings draw attention to a number of common themes among British and Swedish stakeholders, they also highlight important relative differences. These include not only clear geographical contrasts – for example between the two countries' CO_2 storage capacities and biomass supplies – but also differing societal contexts that shape prevailing public policy preferences and stakeholder concerns. For example, British stakeholders showed particularly strong support for a 'contracts for difference' scheme in relation to the national BECCS policy scenario. Interestingly, this contrasts with recent research showing public opposition to this form of policy incentive for BECCS in the UK (Bellamy et al., 2019), thereby stressing the importance of attending to differences in perspective *within* countries as well as *between* them.

Compared to the Swedish stakeholders, the British stakeholders raised more vocal concerns about sustainability and accounting methods, stressing the need to attend to emissions arising from indirect land-use change. This resonates with earlier calls for a single, definitive international biomass certification scheme, which would also need to address concerns about sustainability (Cox and Edwards, 2019). On the other hand, Swedish stakeholders seemed more concerned by the slow pace of EU policy reforms, echoing wider scepticism about the speed of formal regulatory adjustments to the EU ETS (Geden et al., 2018). While potentially beneficial, such reforms are, however, not essential pre-requisites for BECCS, which is more likely to emerge through the 'bottom up' actions of individual countries, cities and companies (Bellamy and Geden, 2019). All of these findings reinforce the importance of tailoring policy incentives for NETs to the situated socio-economic and political contexts within which they are developed and deliberated (Buck, 2018; see also Bellamy and Palmer, 2019).

At the same time, however, there is a clear need to connect national and multilateral policies. Uniform UN regulation may, at first sight, be challenging from the perspective of responsible incentivization for BECCS and other NETs. For a long time, UN regulation prohibiting export and sub-seabed storage of CO_2 was also a real challenge for countries that sought to develop BECCS incentive structures. In recent years, however, several of the multilateral regulative barriers to carbon storage have been dismantled. The 2006 amendment to the London Protocol to the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter, and the 2007 amendments to the Convention for the Protection of the Marine Environment of the North-East Atlantic (the OSPAR Convention), for example, have facilitated sub-seabed CO_2 storage. Since 2019, members to the London Protocol can also provisionally apply regulation allowing the export of CO_2 for sub-seabed storage (IMO, 2019).

While the dismantling of legal barriers to CO_2 transport and storage has progressed considerably, multilateral cooperation on BECCS is still undeveloped. As noted by the UK stakeholders, common accounting rules is one area where multilateral cooperation is key. Common MRV rules for negative emissions will be crucial for enhancing transparency and enabling international cooperation on implementation. The IPCC has already developed accounting guidelines for LULUCF and BECCS (IPCC, 2006, 2019). There is still, however, much room for further clarification on how LULUCF guidelines are to be applied (UNFCCC, 2019). As the global response to climate change is progressing under the Paris Agreement and the countries' nationally determined contributions evolve to include economy-wide targets, more and more countries are expected to move towards stricter accounting (Sato and Nojiri, 2019). Enhanced MRV rules for LULUCF would greatly enhance clarity on emissions and uptakes of biomass growth and harvest at aggregate levels. This, in turn, would improve the possibilities for assessing the systemic effects of technologies such as BECCS.

Thus, MRV rules serve as a foundation for increased transparency, yet not necessarily for incentivization as such. The Paris Agreement therefore does not limit the possibility for responsible incentivization of BECCS in national (such as the UK and Sweden) or supranational settings (such as the EU).

5. Conclusions and recommendations

While our study has examined stakeholder preferences around four idealised policy scenarios for BECCS in the UK and Sweden only, it has nonetheless highlighted how varying stakeholder responses to these scenarios can be traced to the specific, situated socio-economic and political contexts within which decisions must be taken, and justified, in each of these two national jurisdictions. Given the likelihood that BECCS, and indeed other NETs, may be governed to a significant extent "from the ground up" (Bellamy and Geden, 2019), it is important not to see BECCS as a fixed technology, to be promoted or adopted in a ready-made fashion, but instead to see its particular configuration as emerging always in the context of geographically-varying societal values

and constraints. Incentivising BECCS responsibly requires the establishment of processes that can illuminate and arbitrate among these diverse societal values, interests and knowledge claims. The uncertainties, ambiguities and contestations that surround the potential promises and pitfalls of BECCS—and indeed of other NETs—should compel us to act as 'honest brokers' (Pielke, 2007), by opening up the scope of available options for policymakers and clarifying as wide a range of feasible pathways as possible through the use of alternative scenarios. Policymakers themselves face the obligation of grappling head on with ambiguity and dissensus. We suggest they can do so by embracing 'clumsy' policy designs that are open to learning from multiple perspectives on BECCS, as opposed to presuming any single one as correct in advance (Verweij and Thompson, 2006).

In this paper we have opened up the range of options available to policymakers by developing a variety of alternative scenarios and subjecting them to deliberation among a diverse range of stakeholder perspectives. This revealed a number of commonalities and differences in perspective between the two countries. It is nevertheless possible to draw several conclusions. First, a business as usual scenario is inconsistent with ambitions to develop and deploy BECCS. Second, any policy incentives to stimulate BECCS should not detract from emissions reductions. Third, economic incentives that focus on carbon pricing will be insufficient. Fourth, a dilemma exists with respect to the pursuit of either technology specific and technology neutral policies. Fifth, each national context raises different geographical and policy preferences and concerns. In turn, we therefore recommend that policymakers: 1) recognise the need to develop new incentives and make enabling reforms to existing policy instruments; 2) consider the risk of mitigation deterrence in their real world (not abstracted) contexts; 3) employ multi-instrument approaches to incentivisation that do not overly rely on carbon pricing or 4) force a choice between technology specific or technology neutral policies; and 5) attend to the diversity of stakeholder and wider public perspectives that will ultimately determine the success—or failure—of their policy designs.

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CRediT authorship contribution statement

Rob Bellamy: Conceptualization, Methodology, Formal analysis, Investigation, Data curation, Writing - original draft, Writing - review & editing, Visualization. **Mathias Fridahl:** Conceptualization, Methodology, Formal analysis, Investigation, Writing - original draft, Writing - review & editing. **Javier Lezaun:** Conceptualization, Methodology, Formal analysis, Investigation, Writing - original draft, Writing - review & editing. **James Palmer:** Conceptualization, Methodology, Formal analysis, Investigation, Writing - original draft, Writing - review & editing. **Emily Rodriguez:** Methodology, Investigation, Writing - review & editing. **Adrian Lefvert:** Methodology, Investigation, Writing - review & editing. **Anders Hansson:** Methodology, Investigation, Writing - review & editing. **Stefan Grönkvist:** Investigation, Writing - review & editing, Methodology. **Simon Haikola:** Methodology, Investigation, Writing - review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary material

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