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A net-zero storyline for success? News media analysis of the social legitimacy of bioenergy with carbon capture and storage in the United Kingdom

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ABSTRACT

Bioenergy with carbon capture and storage (BECCS) features in global scale assessments of climate mitigation, but with limited exploration of how and where the technology could be deployed. BECCS is unlikely to perform a major role in national strategies whilst key aspects of deployment and public concerns are unaddressed, as happened with fracking. Since public understanding of the technology is limited, there is a crucial role for the news media in facilitating greater public discussion and understanding of BECCS. Here, a news media analysis of both national and regional newspapers explores the 'storylines' which frame the public debate on BECCS in the UK, and the coalitions of actors involved in presenting them. Several storylines present a positive framing of BECCS as *Necessary* and an *Opportunity*, particularly in regional newspapers of Yorkshire and the Humber where Drax's biomass power station is located. The *Anchor for transition* storyline describes the regional socio-economic opportunity of Drax's proposed BECCS project. However, this pro-BECCS coalition is undermined by other storylines that frame BECCS as *Dangerous* and *Overhyped*. To achieve discursive dominance, facilitating social acceptance and legitimacy for the technology, the positive framing of BECCS will require disarming storylines labelling BECCS as *Worse than coal*, *No silver bullet*, an *Environmental disaster*, and a *Distraction*. Our results suggest storyline resonance varies according to context, with notable differences between the public discourse at national and regional level; the *Anchor for transition* storyline resonates in an industrial community facing the socio-economic challenges of decarbonisation.

1. Introduction

BECCS is included in the majority of Intergovernmental Panel on Climate Change (IPCC) scenarios consistent with the Paris Agreement temperature goal, with median global BECCS deployment of around 3–7 Gt CO_2 removal needed per year by 2050 to achieve the 2°C and 1.5°C warming limits respectively, extending to 6–15 Gt CO_2 per year by 2100 [1]. To put this in context, delivering on the 2050 target would require 380–700 million hectares of land globally for dedicated bioenergy cropping [2], an area 1–2 times the size of India [3]. Whilst some policymakers favour using BECCS to meet net-zero targets, few commercial operations exist globally [4] and key questions remain unanswered relating to costs, scalability, public acceptance, and environmental impacts [5–7]. There is a risk that developed countries with ambitious BECCS policies, such as the UK, will import biomass feedstock from developing countries, where bioenergy expansion could increase land degradation and desertification, trigger biodiversity losses, increase food prices, and adversely affect food security for up to 150 million people [7–9]. Potential losses of vertebrate biodiversity [10,11] and negative impacts on global water availability have also been suggested [12]. However, the nature of impacts will depend upon scale, location, and management of BECCS; careful integration of non-food bioenergy crops with existing agricultural and marginal landscapes could avoid some, if not all, of the negative consequences, and enable improvements to the local environment, such as for biodiversity, soil health, and flood risk mitigation [13–16].

The political fate of BECCS will be determined by decision-making at the national and community scales, where public attitudes will be

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important in whether and how the technology is deployed. Public awareness is currently low, even in nations where policymakers are actively considering BECCS and other negative emission technologies (NETs): in 2019 just 5.7 % of people in the UK and 9.6 % in the US were familiar with NETs including BECCS [17]. There is already early evidence of friction between policymakers' ambitions and the public response: the UK government's plan to achieve a net-zero economy relies heavily on the use of BECCS [18], whilst the recent UK Climate Assembly found limited support for the technology's use [19]. Although there is some evidence that the public see BECCS slightly more favourably than direct air carbon capture and storage (DACCS) [17,19,20], it also receives less support than NETs considered more 'natural', including afforestation, habitat restoration, and wood use in construction [19,20].

BECCS combines two technologies - carbon capture and storage (CCS) and bioenergy - and they each face public support challenges. The safety of CO_2 transport and storage is consistently raised as a public concern [21,22], frequently compared to radioactive waste disposal [23], and people living close to CO_2 storage sites perceive risks more acutely [24,25]. In their study of public perception of CCS across five countries, Whitmarsh *et al* [26] found nationality to be the leading determinant of support, followed by proximity to the project, with the greatest public backing in the UK, where CO_2 storage options exist offshore. Lowest support for CCS was found in the Netherlands, at least partly owing to historical public backlash to a proposed CCS project. Support for carbon capture projects is strongest in locations with historical connection to heavy and fossil fuel industries, where the technology could be integrated with the local economy [26–28]. Biomass feedstock supply is also controversial, with negative public attitudes concerning sustainability and the impact on biodiversity and forests [29], and the risk to food security of using agricultural land for bioenergy crops [23,30]. Imported forest biomass is used by Drax, the UK's largest power station, which transitioned from burning coal and plans to operate the world's largest BECCS facility. The company has faced sustained opposition from environmental activists and NGOs critical of their biomass imports and of BECCS technology [31].

Whilst it is a responsibility of national government to take decisions on climate policy, it is community-level knowledge that can help identify how NETs such as BECCS would be best integrated in a specific context [32]; local resistance to renewables is not necessarily to the technologies *per se*, but the "place-blind ways" in which they are sometimes deployed [33]. Wüstenhagen *et al* [34] distinguish social acceptance at the broad socio-political level from social acceptance at the community level, which is influenced by local factors including distributional justice (cost and benefits), and trust between local stakeholders. To address these challenges, companies in the fossil fuel industry have sought ongoing community and stakeholder support of the necessity of resource extraction in a process known as a 'social license to operate' [35].

To establish a social license to operate for energy projects such as BECCS requires: i. addressing the specific project context; ii. building relationships with stakeholders; iii. communicating with local people the benefits and impacts of the project; iv. understanding sustainability as a dominant concern within communities; and v. an adaptable approach when engaging with the community [35]. Recent energy technologies have both succeeded and failed to achieve a social license to operate based on these principles: in Poland, stakeholders and local politicians were fully engaged in the process of a successfully introduced fracking industry, whereas top-down approaches in Belarus and the UK both led to public backlash [36,37]. The local context is key to a social license to operate: "The legitimacy of a project hinges on whether people think a project will create more benefits than problems. And people's perceptions emerge from a combination of local economics, demographics and social values" [38]. To serve communities where NETs including BECCS are deployed, it is important to look beyond CO_2 removal to local needs and ecological conditions [5,32]. Recent regional studies have begun to explore the environmental, social, and economic aspects of BECCS deployment, including co-benefits beyond CO_2 removal, mostly limited to the UK and US [15,33,39–42].

The news media is an important source of information on energy technology [43], and performs a key role in agenda-setting and influencing public attitudes regarding new technologies [44,45], with an incentive to engage with critical viewpoints [46]. News media can also be used as a tool of persuasion by different actors, and has previously undermined or affirmed the legitimacy and deployment of new energy technology, such as oil sands in Canada [47]. A newspaper analysis considering the public discourse of BECCS in its early stages of discussion found very limited information, with some evidence suggesting positive perceptions for the technology's role in combating climate change [48]. In a more recent study, focused on the narratives of BECCS used by expert scientists in peer-review literature and opinion pieces, Haikola *et al* [49] point to criticism of BECCS for being the product of political feasibility rather than environmental necessity, although a 'reluctant acceptance' of the technology was also found. Updating their first study, Haikola *et al* [50] argue that the IPCC's reliance of BECCS in mitigation scenarios has narrowed public debate on the full range of decarbonisation options available, including deep mitigation and 'degrowth' pathways, despite a lack of expert narratives supporting large-scale BECCS deployment. Distinguishing between large-scale and limited deployment of BECCS, they find emergence of expert support for the necessity of the latter, reflecting the reality of carbon budgets and the inadequacy of alternative mitigation tools.

Storylines, such as a 'reluctant acceptance' of BECCS, are used in the news media as a means of communicating with readers [43–46]. As part of their transfer of information on a topic such as BECCS, newspapers will present language - both their own and that of relevant actors - which represents normative statements and evaluations that shape our views of the world. Discourse analysis is used as an interpretative and constructivist approach to analyse how language socially constructs meaning in communication [52]. The most powerful discursive tool available is argued by political scientist Maarten Hajer to be the storyline, which includes "analogies, historical references, clichés, appeals to collective fears or senses of guilt". It is defined as an "analytical term that unites several established concerns in research in the constructivist tradition" [51]. As they develop in usage, these storylines can become 'tropes' or figures of speech which rationalise an attitude to a particular problem: they sound right [53]. The key function of a storyline is to facilitate consensus and a sense of unity on complex and multi-faceted topics, such as BECCS, from people of diverse political views, beliefs, and values [52,53]. This means that actors who hold different values and might not necessarily agree with one another may still use the same BECCS storyline. Hajer refers to this ability of the storyline to facilitate common understanding between diverse actors on complex issues as the "communicative miracle" [53]. Scholars of this field have explored the 'coalitions' of actors which advance storylines, as well as the factors which give these storylines discursive power, or resonance [54,55].

Discourse analysis of the storylines used in public debate can represent an important indicator of public acceptance of the technology, and conditions for the technology's acceptance [54]. In the absence of a robust level of public understanding of BECCS, such an analysis can be of particular relevance to policymakers and industry considering prospects for a social license to operate the technology. Whilst there have been past attempts to tie the pillars of a social license to operate to news media analyses [56], we instead determined to advance findings from the previous discourse analyses of BECCS [49,50] by exploring the development, discursive power, and policy influence of BECCS storylines, across news media at both the national level and a regional level where a specific project is underway. The UK was a suitable case study here because there is evidence of an active discussion of the potential and development of BECCS in the UK mass media, as well as industry and political ambition for the technology, numerous scientific studies on BECCS potential, and infrastructure supportive of the technology [41].

The objectives of this study were: 1) present the status and contours of the public debate of BECCS, indicated by the storylines identified in mass media and the actors presenting them; 2) evaluate the discursive power of these storylines, at both the national and regional level; and 3) determine to what extent this analysis facilitates understanding of the prospects for social acceptance and policy of BECCS, both in the UK and more broadly.

2. Materials and methods

Whilst in recent years social media has begun to contribute to news sources, we decided to look exclusively at newspapers in our study because their paper or digital formats are still used by around half of UK adults, who see them as more trustworthy, detailed, and helpful than social media [57]. Newspaper companies therefore perform an influential role in the public debate in the UK and are likely to influence news content of non-newspaper sources such as television and social media. We looked at both national and regional newspapers. National media can perform an important role in drawing public attention to an energy technology upstream in its development process, such as BECCS, with social control over the technology lessened by the time it is developed and deployed [58]. Whilst the present public debate on BECCS was expected to be largely abstract, given the very limited deployment of the technology, we also expected coverage of Drax's BECCS project in the Yorkshire and the Humber region. Given the project represents the only advanced proposals for BECCS in the UK, our regional newspaper search was limited to this region. Using the Nexis database, we searched for keywords relating to BECCS in the ten national UK newspapers with the greatest reach, during the 2001–2022 period, with 2001 representing the first known usage of BECCS in the peer-review literature [59]. Our regional newspaper analytic dataset was gathered using the Newsbank database, where we searched for the same BECCS keywords in three major regional newspapers of the Yorkshire and the Humber region (see SI for further details of the methodology). The newspaper article data was structured in a detailed codebook, which was used to record relevant information as the articles were analysed.

There has been some ambiguity in interpreting a definition of Hajer's storyline, with it being seen both as an overarching narrative, combining a number of more specific frames [55], and *vice versa* [54]. Whilst both approaches allow a robust analysis, we adopted an approach similar to Williams and Sovacool [54], determining that under this approach the storyline can more closely reflect the specific words and metaphors used to convey meaning; for example, fracking has been referred to in the UK as a 'bridging', 'stepping stone', or 'lower carbon' technology [54], and together these phrases present the same 'bridge' storyline. To facilitate identification of BECCS storylines, as the articles were read any recurring words, statements, analogies, historical references, and appeals to collective fears were identified as sufficient evidence for a storyline's presence and coded accordingly. These are referred to by Hajer as 'ritual' characters: an "analytical term that unites several established concerns in research in the constructivist tradition" [52,53]. This is considered the best advice to analysts looking for storylines according to Hajer's understanding of the concept [54]. The analysis process was completed iteratively, with interpretation of the meaning of storyline language refined as the newspaper articles were read and re-read. After all newspaper articles were read a name was determined for the identified storylines which best reflected the language used to convey that storyline. We also looked for multiple storylines in each of the news articles analysed. To validate their contribution to the public debate, we required storylines in our analysis to be found across multiple years and in at least ten newspaper articles.

3. Results

After removing duplicates and irrelevant texts we analysed 166 newspaper articles. Of these, 77 came from national newspapers and 89 from regional newspapers, of which 67 and 69 respectively contained sufficient information for at least one storyline to be identified. We identified four broad framings of BECCS: *Necessary*, an *Opportunity*, *Dangerous*, and a *Distraction* (Table 1). These framings brought together eight storylines, of which four presented a positive narrative of BECCS and four were critical of the technology (Fig. 1). Aware that journalistic culture and newspaper political leaning could influence the results we detailed the political leaning and ownership of the newspapers analysed (Table S1). Discussion of BECCS was found across the political spectrum, distributed slightly unevenly, with the left-centre *The Guardian* and *The Independent* accounting for 42 of the 77 national newspaper articles. No BECCS articles were found in three newspapers (*The Sun*, *The Star*, and *The Mirror*).

3.1. Storylines framing BECCS as Necessary

A *Necessary mitigation tool* storyline was the only BECCS storyline occurring in over half of either of the national and regional newspaper articles, found in 48 and 52 of each respectively. This storyline featured language such as "critical", "vital", "limited but very important role", and "must be deployed", reflecting the IPCC's reports which have identified BECCS as crucial to meeting the 1.5 °C temperature limit [1]. BECCS was described in these terms by Drax CEO Will Gardiner more than any other actor. The storyline was also advocated by spokespersons of the UK government, the UK Committee on Climate Change (CCC), and Microsoft. Whilst the IPCC was not quoted in the news articles, their scenarios - which heavily feature BECCS - were frequently referred to.

It was often emphasised that biomass supply needs to be sustainable to enable the delivery of negative emissions from BECCS, and this storyline frequently featured Drax's defence of their supply chain as "sustainable biomass" which had achieved the "biggest decarbonisation project in Europe". In a letter to *The Yorkshire Post*, Drax's Director of Sustainability, Alan Knight, stated that the science showed bioenergy was sustainable because it "does not release additional, new CO_2 into the atmosphere - unlike coal". A UK government spokesperson declared "BECCS is the only sustainable way to continue biomass" whilst David Joffe of the CCC emphasised the importance of UK-grown biomass.

Several times this storyline took a regional dimension, with the *Hull Daily Mail* describing BECCS as "essential to decarbonising the Humber cluster". Ten national newspaper articles also emphasised the necessity of BECCS to "offset" emissions, discussed in relation to Microsoft's plans to remove their historical emissions from the atmosphere, and difficult to abate sectors of aviation, heavy industry, and agriculture. This reflects citizen comments from the UK Climate Assembly that BECCS might be needed to "mop up" remaining CO_2 [19], but also highlights a contentious part of the debate around BECCS: which sector's emissions are prioritised for these offsets? For example, one article in *The Guardian* ("No need to cut beef to tackle climate crisis, say farmers") cited the National Farmers' Union (NFU) proposals to offset farming emissions using BECCS. These NFU net-zero plans include using up to 22 Mt CO_2 removal per year using BECCS [61], between a quarter and a half of total BECCS in UK net-zero scenarios [60].

A second less prominent storyline framed BECCS as *Keeping the lights on*, advocated chiefly by Drax. This storyline featured primarily in the regional newspapers, where the Drax CEO Will Gardiner referred to BECCS as "critical" for delivery of "reliable, renewable, and secure power", contrasting it to "intermittent renewables" of wind and solar energy that "can't do it all". Drax generates approximately 7 % of the UK's electricity supply and its spokespersons were often quoted in the news media stating that the power station supported the electricity needs of four million homes and businesses. This storyline was notably prominent in 2022, featuring in the majority of the regional newspaper articles and a third of the national articles of that year, likely reflecting energy security concerns following Russia's invasion of Ukraine.

Table 1
In the news media discourse on BECCS there is one 'coalition' of actors in favour of the technology and one opposed to it. Each of these coalitions is constructed of frames and their associated actors and storylines.

Coalition	Frame	Main actor group	Main actors	Storyline	Language used
Pro-BECCS	*Necessary*	Government, industry, scientists	Drax, Drax CEO Will Gardiner, Microsoft, UK Committee on Climate Change (CCC), CCC's Dr. David Joffe, government spokespersons (including for BEIS), IPCC	- *Necessary mitigation tool*	- "critical to combat climate change"; "vital"; "sustainable biomass"; "sustainable working forests" "; "sawmill residue"; "carbon neutral"
				- *Keeping the lights on*	- "keep the lights on"; "reliable, renewable and secure power"; "critical to energy security", "flexible back-up"; "volatile gas prices pushing up bills"
	Opportunity	Industry, local politicians, local newspapers	Drax, Drax CEO Will Gardiner, Energy Minister Claire Perry MP, MPs local to Drax: Nigel Adams MP, Lia Nici MP, and Andrew Percy MP	- *Anchor for transition*	- "anchor decarbonisation"; "protecting jobs and the region's industrial heritage"; "unlock the potential"; "just transition"; "transformative for the region's economy"; "level up the North"
				- *Revolutionary technology*	- "revolutionary"; "game-changing"; "once in a generation opportunity"; "lead the world"
Anti-BECCS	*Dangerous*	NGOs, politicians, scientists, national newspapers	Ember, RSPB, NRDC, Fern, Biofuelwatch, Extinction Rebellion, Seline Saxby MP, Kwasi Kwarteng MP, Dr. Michael Norton	- *Worse than coal*	- "worse than coal"; "green con"; "greenwashing"; "shipping emissions"; "deforestation"; "not carbon neutral"
				- *Environmental disaster*	- "devastating for wildlife"; logging "precious primary forest"; risks a "humanitarian or ecological disaster"
	Overhyped	NGOs, scientists, national newspapers	Ember, Biofuelwatch, Dr. Kevin Anderson, Dr. Oliver Geden, Dr. James Dyke, Dr. John Shepherd, Dr. Ajay Gambhir and Dr. Simon Lewis	- *No silver bullet*	- "untested"; "speculative"; "not credible"; "too good to be true"; "will not work at scale"; "magical thinking"; "Negative emissions at this scale are the stuff of fantasy."
				- *Distraction*	- "not an alternative to emission cuts"; "get out of jail free card"; "license to keep emitting"; "moral hazard"

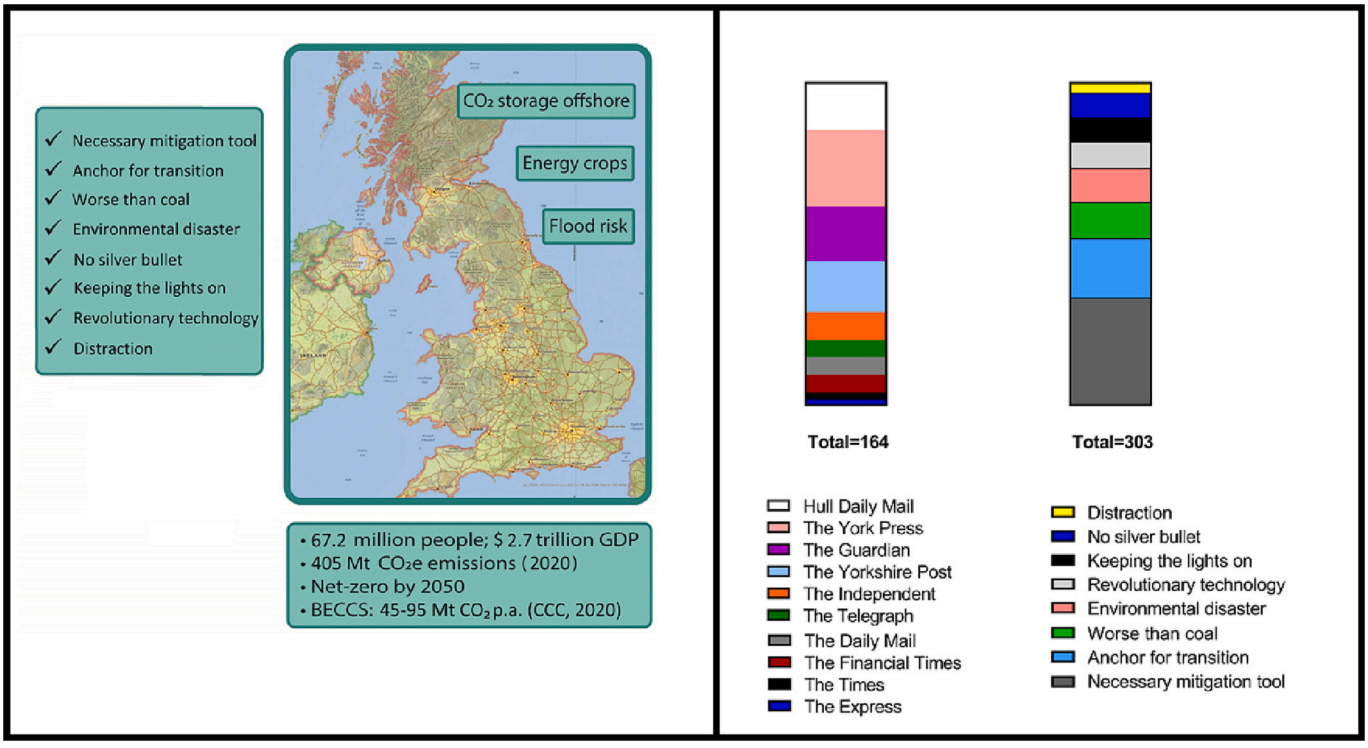

Fig. 1. Left-hand pane: ticked marks represent the eight storylines identified in the articles of the top circulating UK national newspapers and in the top three circulating newspapers of the Yorkshire and the Humber region. Data on potential ambitions for mid-century BECCS deployment taken from the Committee on Climate Change's modelling [60]. Right-hand pane: two stacked bars represent the breakdown of the newspaper articles reviewed ($n = 164$), and the breakdown of storyline counts ($n = 303$) by storyline name. Note: most newspaper articles featured more than one identified storyline.

3.2. Storylines framing BECCS as an Opportunity

Two storylines framed BECCS as a socio-economic *Opportunity*. The *Anchor for transition* and the related *Revolutionary technology* storylines were mostly found in regional newspapers describing the BECCS project at Drax. Both *The Yorkshire Post* and *Hull Daily Mail* noted the Humber region's status as the highest emitting industrial corridor of the UK. Drax described their BECCS project as an 'anchor' or 'cornerstone' which could support the region's decarbonisation transition: regional newspapers also used this language to describe the project. This support was described in terms of protecting jobs and the region's industrial heritage, with local MPs Andrew Percy and Lia Nici referring to the economic potential for the north of England as an opportunity for "closing the North-South divide". Similarly, Drax CEO Will Gardiner described the project as enabling a "just transition". Shortly before becoming Prime Minister, Yorkshire MP Rishi Sunak was quoted in *The Yorkshire Post* as

describing the Drax BECCS project as "transformative for the region's economy". The storyline conveys a sense of local pride that this industrial region could lead the decarbonisation transition in the UK.

National newspapers contained this storyline to a notably lesser extent, with a small number of references to the Drax project and its ability to support employment in the north of England. *The Daily Mail* referenced a scientific paper finding that coal industry workers in the US could transition to a BECCS industry [62]. Similarly, members of the UK Climate Assembly liked the coal to biomass conversion story because it protected jobs and facilitated "economic revitalisation" [19]. It was also presented in our results that BECCS could protect existing jobs in manufacturing, through the industrial CCS cluster proposed at the Humber, where Drax would be a partner. A recent study of these 'industrial clusters' stated "The potential to sustain well-paid skilled jobs in sectors otherwise likely to be in decline is central to the national and individual cluster narratives." [63].

In a related and less prominent narrative, the *Revolutionary technology* storyline described BECCS as the "holy grail of power generation", a "game-changing technology" which could "revolutionise" the economy. This storyline claims that BECCS is an opportunity for the Humber and UK to be "world-leading" and "on the map". The techno-optimistic language was used by the Drax CEO, business leaders in the Humber, national government, and reporters in regional news media. In news articles during 2018–19, the pilot CCS project at Drax was described by then Energy and Clean Growth Minister Claire Perry MP as "cutting-edge", and a "game-changing technology" that had put the UK on the map. The York Press described this project as at the "forefront of the green industrial revolution". In regional news articles Drax CEO Will Gardiner frequently referred to the Drax transition from coal to biomass stating "now we're taking it a step further with a world-leading ambition to be carbon negative by 2030".

3.3. Storylines framing BECCS as Dangerous

A storyline which directly challenged the *Necessary mitigation tool* storyline of BECCS described biomass combustion, particularly the Drax supply chain, as *Worse than coal*. This storyline was found in 34 articles, two thirds of which were published during 2021–2, mostly in national newspapers. It featured critical language such as "worse than burning coal", "accounting trick", and "green con". These claims reflect one side of the active debate concerning whether bioenergy is a sustainable and low-carbon source of energy. Environmental NGOs represented the primary voice of this storyline, claiming that BECCS cannot deliver negative emissions because biomass combustion results in similar or greater CO_2 emissions than coal combustion, that this carbon may not be re-absorbed from re-planted trees, and that supply-chain emissions from biomass imports add to this carbon cost [64]. The *Worse than coal* storyline has risen in prominence: it was the most frequently occurring in the national news media in 2022, when it featured in a BBC Panorama documentary on Drax's supply chain [65], remarks by then Cabinet Minister Kwasi Kwarteng MP, and Parliamentary debate [66]. Following this debate, *The Yorkshire Post* spoke to scientist Michael Norton, quoting his concerns on the climate impact of bioenergy. In the regional newspapers, *The York Press* reported on a NGO's criticism of Drax as "false, renewable energy" that was "Britain's top polluter" and cited local opposition from local protest groups.

The second storyline framing BECCS as *Dangerous* drew attention to the wider environmental risk that it posed: an *Environmental disaster* storyline was found in 32 articles. This storyline conveyed the risk of BECCS to food security and prices, starvation, biodiversity and wildlife, and particularly, to rainforests. Several articles highlighted the importance of forests in mitigating climate change and both NGOs and scientists who stated that BECCS risks undermining this if it leads to deforestation. The scale of BECCS and its land-use demand was discussed, with high BECCS deployment scenarios seen as potentially "devastating for wildlife" if natural ecosystems are lost. This echoes concerns from the UK Climate Assembly of the sustainability of biomass imports [19]. The results included several opinion pieces, including one written by environmentalist George Monbiot in *The Guardian*, who claimed that BECCS "is likely to trigger an ecological or humanitarian disaster" and advocated instead for 'natural climate solutions' of habitat restoration and forest protection and restoration. A second opinion piece, written in *The Independent* by scientists James Dyke, Robert Watson, and Wolfgang Knorr ("Climate scientists: concept of net-zero is a dangerous trap"), argued that BECCS would bring about devastating environmental and societal consequences.

3.4. Storylines framing BECCS as Overhyped

We found several techno-resisting storylines which collectively framed the promise of BECCS as *Overhyped*. In a storyline pushing back against the techno-optimism of the *Revolutionary technology* narrative, the *No silver bullet* storyline was found in 23 national newspaper articles, but no regional newspapers. Here BECCS was described as "too good to be true", "untested", "speculative", "not credible", and "not feasible", with attention drawn to the scale and timescale at which it is envisaged. "You can rule out a silver bullet" stated scientist John Shephard on NETs; the terms "silver bullet" or "magic bullet" were regularly used to argue that BECCS was being treated as a magical, mythical or faith-based technology which could serve as a climate "saviour" or "holy grail".

The *No silver bullet* storyline featured particularly frequently in *The Guardian*, including in two opinion pieces written by prominent academics ("Abandon hype in climate models" by a lead IPCC author Oliver Geden in 2015, and "The climate adviser's dilemma" by Oliver Geden, Tim Kruger, and Steve Rayner in 2016). These two opinion pieces present a similarly critical message of the climate economic modelling community for endorsing unproven technologies - particularly BECCS - in pathways which meet the Paris Agreement targets: it is "reckless in the extreme" for these models to rely on "science fiction" technologies. The second opinion piece argued that it is not the role of climate advisers to be optimistic and their support for the climate policy narrative that "Time is running out, but we can still make it if we start to act now" is scientifically inconsistent, a critique echoed five years later by another opinion piece in *The Independent* and *The Conversation* [67]. *The Guardian* featured this *No silver bullet* storyline in 17 articles, more than any other storyline.

The second storyline framing BECCS as *Overhyped* argued that it is a *Distraction* from the emission cuts needed in polluting industries. This storyline, found in 10 newspaper articles from *The Guardian* and *The Independent* only, and largely attributed to NGOs, featured language such as "license to keep emitting", "business as usual economics", "dangerous distraction", "get out of jail free card", and "protecting fossil fuels". Climate scientists Ajay Gambhir and Simon Lewis were both quoted in *The Independent* as saying that there is a limited role for NETs such as BECCS but that they also represented a risk to immediate emissions reductions. The ability of BECCS to offset emissions, such as for the fossil fuel sector, may mean that BECCS is used by those industries resistant to change. This storyline therefore appeared in opposition to the storyline that BECCS is an *Anchor for transition* and its promise of 'clean growth'. CCS, and to a lesser extent bioenergy, has been viewed by some of the UK public as a 'non-transition' technology, by deferring rather than solving a problem [68]. A more recent study on public attitudes towards NETs, including BECCS, found evidence of a similar sentiment, with participants concerned the root cause of climate change was not being addressed by these technologies [17]. One opinion piece in our results stated that "our future depends on de-growth" and not BECCS. A spokesperson for the NGO Biofuelwatch, which strongly opposes bioenergy, was quoted multiple times across the news articles reviewed, criticising BECCS as a distraction from the task of "deeply altering our entire relationship to energy consumption".

4. Discussion

Through analysing 166 national and regional newspaper articles, we identified four broad framings bringing together eight specific storylines and their associated actors, that present the contours of the current public discourse on BECCS in the UK. These storylines reflect both anticipatory debate, and debate specifically about a BECCS project at the Drax bioenergy power station. Drax's proposals have had a major influence on the UK debate on BECCS, driving more newspaper articles from three regional newspapers than all the national newspapers combined. It is important to acknowledge that BECCS technology can be delivered differently to the Drax approach, highlighting that the present debate is still relatively limited.

The development of the storylines across time appeared to be driven in part by their use to counter others: of the four positive storylines, three were directly opposed by critical storylines. This reflects similarities to the development of the recent fracking debate in the UK. Williams and Sovacool [54] concluded that the use of storylines by each of the pro-fracking and anti-fracking coalitions fuelled debate without either side able to achieve discursive dominance: there was a deadlock. Some of the storylines of the two debates are also similar: the *Distraction* storyline of BECCS is comparable to the critical fracking frame of 'fossil fuel-lock in', whilst fracking and BECCS also share a narrative around environmental risk [55,56]. However, the discursive power and resonance of the pro-BECCS storylines represents an interesting distinction from the fracking debate. A compelling storyline must meet three criteria according to Hajer: plausibility, trustworthiness, and acceptability [53]. Since our dataset comprised of newspaper articles, the satisfaction of these criteria is relevant in relation to the public.

Our results show that the *Necessary mitigation tool* is a storyline that meets the three criteria of discursive power, in both the national and regional news coverage. Unlike in the fracking debate, BECCS is closely linked to achieving the UK's net-zero target, and this narrative - supported by scientists as well as government and industry - gives plausibility to the *Necessary mitigation tool* storyline. Scientists are viewed by the public as a relatively respected and trusted group [69] and it is interesting that a similar narrative of necessity in the fracking debate was limited by a less trusted coalition of actors, lacking in scientist voices. The acceptability of this storyline to the public is likely supported by the way it was frequently presented as supporting a qualified role for BECCS, in offsetting 'difficult to abate' sectors and alongside deep emission cuts, rather than as a substitute for emission cuts across the economy. The frequency of a storyline does not guarantee its discursive power, though it can be supportive, particularly in relation to the frequency of any countering storyline.

The *Keeping the lights on* storyline, whilst less frequent than the *Necessary mitigation tool* storyline, was notable for being the only pro-BECCS storyline without a counter-narrative, although a small number of newspaper articles did criticise the public subsidies given to Drax. The intermittency of wind and solar energy is well-known, which combined with the recent global energy crisis likely enhanced the resonance of the *Keeping the lights on* storyline with the public. Interestingly, a similar framing in the fracking debate was found to be a dominant pro-fracking narrative [55].

The pro-BECCS coalition enjoyed greater discursive dominance in the regional news media, where the *Necessity* framing was complemented by techno-optimistic storylines specific to the Drax BECCS project. The *Anchor for transition* storyline appeared to have the greatest discursive power: a broad range of actors supporting it across the region, high apparent acceptability of the socio-economic benefits that BECCS would bring, and a plausibility driven by the techno-optimistic language used to describe the project. Additionally, there was an absence of any clear counter-narrative. The greater use of techno-optimistic language in the regional news media has also been found in other research [70]. In our study the portrayal of Drax's BECCS project in regional news media also showed signs of a 'hero story', where society is saved by a new technology [71]. There is a risk with 'hero' stories that expectation does not meet reality, and that a more realistic discussion of technological development - through a 'learning' story - could support BECCS projects as they are navigated through inevitable challenges [71].

Whilst the regional news media did feature some critical storylines, these were almost exclusively limited to the *Worse than coal* storyline. The absence from the regional news of the techno-oppressing storylines of *No silver bullet* and *Distraction* likely reflects the focus of these regional newspapers on one specific BECCS project rather than less tangible storylines on future BECCS risks. These distinctions found between national and regional newspapers reflect findings from Batel and Devine-Wright [72] who argue that the concept of a 'national - local gap' is exaggerated in public opinion studies of new energy infrastructure: questions tend to be posed theoretically in national studies and tangibly in regional studies. Relatedly, Williams and Sovacool [54] noted that the state of 'dead-lock' in the fracking debate might reflect its highly anticipatory nature; in this sense the regional debate of BECCS at Drax appears somewhat different, given their bioenergy technology is already well-established, though the CCS component is still in an exploratory stage.

Whilst we find the *Necessary mitigation tool* storyline to be a compelling storyline with discursive power both nationally and regionally, it has been undermined by critical storylines in the national news media that may be contributing to the relatively lukewarm public support for BECCS [17,19]. Scientists critical of BECCS are particularly active in advancing the *No silver bullet* storyline, and were also referenced in the three other critical storylines, reflecting the range of narratives found in expert assessments on BECCS by Haikola *et al* [49,50]. The *No silver bullet* storyline cautioned against over-reliance on BECCS, rejecting the feasibility of large-scale BECCS deployment, whilst the *Environmental disaster* storyline warned of the ecological costs of large-scale use of the technology. Read alongside the *Necessary mitigation tool* storyline's qualification for limited BECCS, there does appear to be agreement across storylines of a rejection of a high level of deployment of BECCS. This also reinforces findings from Haikola *et al* [50] of a lack of expert narratives supporting large-scale BECCS.

The *Worse than coal* and *Distraction* storylines, led by NGOs highly critical of BECCS, both presented a more fundamental challenge to the technology, rejecting its effectiveness as a climate mitigation tool. The *Distraction* storyline reflects ongoing debate regarding the appropriate absolute emission reductions needed and the reliance on NETs to balance 'residual emissions' [73]; if the deep and immediate emission cuts necessary for climate targets continue to be delayed, the *Distraction* storyline's resonance could increase, although conversely, this would also increase the need for negative emissions. As shown in Fig. 2, the *Worse than coal* storyline has become increasingly prominent and the debate over the climate impact of bioenergy could be of critical importance to the fate of BECCS. In this debate, claims are made regarding carbon storage changes in the forests, and the CO_2 emissions of biomass transport and at the power station smokestack. The *Worse than coal* storyline relies heavily on scientific claims and whilst these claims have been challenged by scientists in peer-review science [74], we did not find these voices in the news media. Drax also appeals to the science when challenging these claims in the *Necessary mitigation* tool storyline, though again we did not find scientist voices in the news articles. Thus, the *Worse than coal* storyline currently reflects debate primarily between NGOs and Drax, as seen in the 2022 BBC Panorama documentary on the topic [65].

Ultimately, BECCS needs to be accepted in the locations where it is proposed, which includes the locations for the power station, bioenergy crop cultivation, and CO_2 transport and storage infrastructure. These siting challenges may run counter to any national appeal of BECCS. The salience of the storylines of BECCS will likely be interpreted differently across the UK, reflecting different social, environmental, and economics factors. Previous NET research has stressed the importance to public support of moving beyond the direct benefit of CO_2 removal to consider

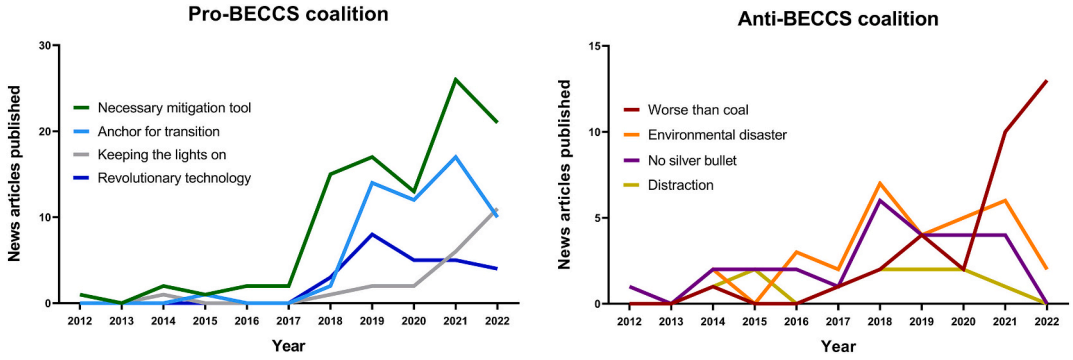

Fig. 2. Left-hand pane: lines represent the number of UK national and regional (Yorkshire and the Humber) newspaper articles featuring the four pro-BECCS storylines during 2012–2022. Right-hand pane: lines represent the number of UK national and regional (Yorkshire and the Humber) newspaper articles featuring the four anti-BECCS storylines during 2012–2022. Note: the first national newspaper featuring BECCS was published in 2012 whilst the first regional newspaper article featuring BECCS was published in 2018; some newspaper articles featured no storylines, whilst most featured at least one storyline; there was a drop in coverage during 2020 when news media attention focussed on the Covid-19 pandemic; scales are different between the two panes.

co-benefits to a community where the NET is deployed [5,39,75]. This is reflected in the prominent *Opportunity* framing in the news media of the Yorkshire and the Humber region. Where a BECCS project can support a region's decarbonisation transition, through protecting jobs and providing useful infrastructure or products for other industries, there is likely to be a powerful BECCS storyline: an *Anchor for transition*. This echoes the UK Climate Assembly and previous research finding high support for CCS in the industrial Teesside region of England [27,26]. Consequently, BECCS proposals in existing industrial regions would likely be discussed very differently - and more positively - than new-build BECCS proposals outside industrial regions.

With the *Worse than coal* and *Environmental disaster* storylines both critical of biomass imports, meeting some of the feedstock demands of BECCS domestically may disarm these narratives somewhat, whilst also presenting an opportunity to support economic transition in agricultural and rural communities, where farmers can shift towards 'carbon farming' by growing bioenergy crops [76]. In the newspapers we reviewed, the CCC was twice quoted advocating for UK-grown bioenergy supply, which is required for delivering BECCS in their net-zero scenarios [60]. This will require 0.7 million hectares of bioenergy crop land-use by 2050, including the use of agricultural land, which has been raised as a concern by the public [23], although low-value agricultural land is available for bioenergy crop cultivation [77]. Whilst the *Environmental disaster* storyline featured a discussion around the food security impact of BECCS, this was abstract and not specifically discussed in relation to land-use change in the UK. However, recent calls to reduce bioenergy crop land-use following the Russian invasion of Ukraine is one example of how public debate can develop quickly [78,79]. A separate UK development which will likely shape this debate over land-use and food security has been the reduction in *per capita* meat and dairy consumption, of 17 % since 2010 [80], and support for further reductions at the UK Climate Assembly [19], with the CCC stating that this will reduce the land-use intensity of UK diets and free up land for bioenergy crops to support BECCS delivery [60]. Whilst there may be conflict with food production, land-use change to bioenergy crops could also deliver important co-benefits, including for biodiversity and the landscape aesthetic [16], and for flood mitigation, particularly if bioenergy crops are sited in the flood-prone communities on the east coast of England, an area which overlaps with the industrial regions supportive of CCS [15,81].

The issue of CO_2 storage was notable for its absence in the UK national and regional news media. This is likely partly attributed to the UK opportunities for offshore CO_2 storage, found to have less public opposition than onshore sites [26,82]. There has also been an international trend in reduced concern over CO_2 storage, which may reflect how the increased discussion of BECCS has disarmed the claim that CCS perpetuates fossil-fuel use, whilst also bringing its own set of concerns to the fore [83]. Additionally, whilst location-based environmental and social impacts of BECCS are heavily weighted in public perception studies [84] they were not discussed in the news media, perhaps reflecting the level of maturity of the debate at present. Given Drax's announced plans to use some UK-grown biomass, and ambitious CCC scenarios for domestic supply, this topic may receive increased attention in the news media. As more BECCS projects are proposed in particular locations, and the technology is discussed less at the abstract level, it will be important to study local and national newspapers alongside the other media sources, including magazines, radio, television, and social media. Close attention will be needed in the 'industrial cluster' and oil and gas communities, given the importance of these regions to the technologies success [63,85]. Scientists have a role in facilitating public debate by measuring and communicating the location-based environmental and social impacts of BECCS, an under-developed research area at present [15,33,40].

5. Conclusions and policy implications

The public discourse represents an important arena in which new technologies are discussed, their social legitimacy influenced, and opinions and attitudes formed. BECCS features prominently in global scenarios that meet the Paris Agreement targets and in national scenarios for achieving net-zero emissions. Notwithstanding significant technological challenges, socio-economic and political barriers are considered to be greatest obstacles to BECCS policy development [87,86]. The UK government is relying on BECCS to help ensure delivery of their net-zero strategy, which will require deployment very soon, but there is a risk that policy is accelerating away from public understanding or acceptance. Our study shows that the struggle for discursive dominance between competing actor coalitions is well underway. The fate of this public debate will influence whether or not BECCS is rejected by the public and subsequently rejected by the government, as has happened with other new and innovative technologies, including genetically modified food crops, fracking, and onshore wind energy [37,88–91]. A recent government biomass consultation lacked coverage of socio-economic factors [92], suggesting that policymakers should be more engaged in considering the social legitimacy of BECCS and domestically grown bioenergy crops. Our results indicate that a targeted and limited deployment of BECCS, sourcing sustainable biomass, could receive broad national appeal in the public debate. Local support could be harnessed by targeting this deployment in industrial communities where the technology presents a transition pathway to net-zero emissions, connected to co-benefits, and is sensitive and receptive to public concerns over environmental issues. Public engagement is crucial and there

are key roles for policymakers, scientists, industry, and the media. If BECCS fails to achieve social legitimacy, then net-zero targets will need to be met from the fast-diminishing list of alternative technological and policy options.

CRediT authorship contribution statement

CD led data analysis and manuscript writing. KT supported with research design and data analysis. GT and CD conceived the project and all authors contributed to writing.

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.

Data availability

The codebook which was created and used to analyse and code the newspaper articles is available in an Excel format upon request.

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Appendix A. Supplementary data

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