Energy Research & Social Science 46 (2018) 1–9

Contents lists available at ScienceDirect

Energy Research & Social Science

journal homepage: www.elsevier.com/locate/erss

Original research article

Ambivalence, naturalness and normality in public perceptions of carbon capture and storage in biomass, fossil energy, and industrial applications in the United Kingdom

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ARTICLE INFO

Keywords:
Public acceptance
Naturalness
CCS
Bioenergy
Risk perceptions

ABSTRACT

Carbon dioxide capture and storage (CCS) is a promising yet controversial climate change mitigation technology. While numerous studies have addressed perceptions of CCS in fossil energy applications, less attention has been paid to how other applications of the technology may be viewed by lay groups. This article reports on findings from a twoday deliberative focus group held near Drax power station; a coal-biomass co-firing power plant in the north of England. In so doing we adopt a broad, psycho-socially inspired conception of perceived naturalness in order to explore how perceptions of CCS in biomass, fossil fuel, and industrial applications are formed in the context of a range of potential technologies for supporting low carbon energy system transitions. In particular, we explore how perceptions of naturalness and interdependency shaped perceptions of different CCS applications. Our analysis illustrates how perceptions of CCS as threatening, uncanny disruptions to natural systems may shift when re-contextualised to include concerns relating to the intermittency of renewable energy, or be ameliorated through perceptions of industrial and bioenergy applications as supporting natural and economic interdependencies.

1. Introduction

Carbon dioxide capture and storage (CCS) occupies an ambiguous role in literatures on climate change mitigation as both a key technology for emissions reduction and a source of concerns relating to its feasibility and public acceptability. CCS refers to the process of capturing carbon dioxide (CO_2) from power plants and other industrial sources, transporting it by pipeline, compressing it and then burying it in deep geological formations. CCS is thus intended to permanently prevent CO_2 from reaching the atmosphere and contributing to climate change. CCS boasts numerous strengths as a CO_2 abatement technology. It can be built into new thermal power plants or retrofitted onto older facilities, and is viewed by some as offering a means to significantly reduce emissions in advance of more complex transitions to renewable energy systems [1]. Moreover, CCS is the only currently available technology for decarbonising fossil-fuel-intensive industries such as cement, fertiliser and steel manufacture [1]. Assessments conducted for the IPCC and other bodies have identified CCS as a low risk and cost-effective emissions reduction technology [2–4]. Scenario modelling focussed on limiting global average temperature rises to below 2 °C suggests that CCS could contribute one-sixth of total emissions reductions by 2050 [5]. Projected costs for maintaining a 2 °C limit were found to be 40% higher in scenarios where CCS was unavailable [5]. While the feasibility of such plans remain highly contested, it has also been suggested that combining CCS with bio-energy may represent a relatively benign means of generating electricity, while removing and permanently separating CO_2 from the atmosphere [6,7]. Given the hitherto slow progress on global emissions reductions, 'negative emissions' provided by bio-energy with CCS (BECCS) may provide a means of reducing atmospheric concentrations of CO_2 in scenarios where cumulative emissions over-shoot recommended levels [8]. Indeed, the recently stated goal of the Paris Agreement to 'pursue efforts' to limit temperature increases to 1.5 °C means that BECCS has gained salience in mitigation planning and may be essential if more ambitious targets are to be met [9].

Since the early 2000 s, a rich literature has emerged aiming to examine how various publics interpret CCS and engage in issues surrounding it [10]. Rationales for this expansion have varied. Chief among those cited have been previous socio-technical controversies that may be analogues for poorly-implemented CCS deployments, and

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https://doi.org/10.1016/j.erss.2018.06.007
Received 30 November 2017; Received in revised form 5 June 2018; Accepted 7 June 2018

high profile project cancellations in Germany and the Netherlands where vocal public opposition played a key role [11]. More significantly, the growth of this literature represents the realization that:

> 'CCS enters the energy and climate change arena with several disadvantages from the perception point of view: it is related to fossil fuels, which are at the heart of the problem, it is new and not fully understood, it involves waste disposal, and it is presently high-cost.' [12]

Whilst various elements of CCS systems have been found to be problematic, it is generally thought that the storage component raises the most significant concerns among lay publics. Such concerns have often been attributed to perceptions of risk, such as concerns that CO_2 injection and storage could induce seismic disturbances, cause explosive gas releases, or pose toxic hazards that may contaminate nearby freshwater deposits or ecosystems [13,14]. Other studies have focused on public concerns over the trustworthiness and competence of project developers [15], or on longer-term ethical considerations relating to the sustainability, distributional and inter-generational effects of long term geological storage [16]. It has been suggested that situating geological storage offshore, away from population centres, may reduce the potential for public concern and anxiety relating to CCS [17]. However, studies explicitly examining this issue have suggested that sub-seabed storage does not eliminate concerns regarding the unsustainable, fossil-fuel-driven nature of many proposed CCS projects, nor the desire to protect future generations and non-human living systems from unforeseen long-term consequences of CCS deployment [18,19].

Other researchers have provided thorough overviews of the existing research into perceptions of CCS and this study does not aim to replicate their efforts [cf. 10]. Consistent findings indicate that awareness of CCS among lay publics is generally low [20–22], and that CCS tends to be perceived less favourably than renewable alternatives unless carefully contextualised within wider processes of decarbonisation and energy system change [23–25]. Acceptance of CCS is often contingent on early engagement with relevant communities, and on local perceptions of its relative risks and benefits. These in turn can be mediated by a wide range of contextual factors including:

- Context-specific characteristics of a project associated engagement processes [11,12,26];
- Trust in government and industrial organisations [24,27,28];
- Environmental values and beliefs [23,29,30];
- Self-identity and worldviews [30–32].

Where relevant we refer to this literature below, however in this article we focus on a more specific set of issues that remain underexplored in light of recent upheavals surrounding the technology in the UK. These include the cancellation of the UK government's £1 billion CCS competition in 2015 and the subsequent abandonment of CCS demonstration projects at power plants in Aberdeenshire and North Yorkshire. Moreover, given the newfound centrality of BECCS in many scenarios for meeting ambitious CO_2 targets [7,9], relatively little research exists into how BECCS may be perceived. At present there appears to be no strong body of research examining perceptions of CCS in communities where projects have been cancelled [although see: 33] however, there is some evidence suggesting that the suspension and subsequent downgrading of CCS demonstrations has reduced community support for deployments in Illinois [34]. Given that trust in project actors has consistently been found to be a mediating factor in CCS acceptance [28,35,36], further examination of cases of policy instability are necessary in order to understand how cancellations may affect perceptions of the sincerity and competence of CCS proponents.

2. CCS, nature and risk perception

To the best of our knowledge, only two studies have addressed public perceptions of CCS in non-fossil-energy applications, both of which found participants to be more accepting of CCS in bioenergy and industrial manufacturing applications [37,38]. The capacity for CCS to protect employment in fossil-dependent regions has been identified as one of the core benefits perceived by members of the public in relation to both energy and industrial applications [39–41]. These benefits may be perceived even more strongly for industrial CCS, which can be presented as both protecting employment in existing industries, and providing infrastructure that may attract new investment and employment opportunities [42]. Deliberative research into decarbonisation priorities among lay groups in the UK has found participants to be more supportive of CCS in industrial applications than energy production, in part attributing this to unique employment and economic opportunities such industry is thought to provide [43,44]. Such findings mirror those from risk perception studies whereby potentially risky technologies are often sources of ambivalence that may be viewed more positively due to associations with employment in a given locality [45,46]. More broadly, they speak to deeply entrenched cultural narratives of industrial modernity and manufacturing employment [47,48]; which despite processes of de-industrialisation taking place in some advanced capitalist economies since the 1980 s, remain powerful markers of identity and social progress.

Distinct from CCS, bioenergy has itself been the subject of a significant body of perceptions research. Despite controversies over biofuels and bioenergy in the first decade of the 2000 s, more recent public perceptions work has shown mixed results. Some studies have shown low to moderate support, with others finding greater enthusiasm for the technology, provided it does not come into conflict with food production and other valued land uses [49–51]. More wide ranging ethical reflections on BECCS have noted similar issues, arguing that resource demands for BECCS feedstocks have the potential to adversely effect food and water availability, particularly in developing countries that are least responsible for, but most vulnerable to climate change processes [6]. Furthermore, given continued uncertainty over biomass availability and lifecycle emissions, several authors have suggested BECCS and other negative emissions technologies pose a moral hazard, potentially delaying urgent measures to reduce emissions, particularly in richer countries [52,53].

While no perception studies have explicitly addressed BECCS in the UK, Wallquist et al. [37] found that questionnaire respondents in Germany were more prepared to accept CCS deployments near their homes when bioenergy was described as the CO_2 source. This was the case when compared to both fossil energy and industrial emissions sources. The authors suggest this may be attributable to a halo effect around the term 'bio', the German translation of which equates to 'organic', carrying positive connotations with health and nature. However, given that study did not elicit the rationales underlying CCS perceptions, this explanation remains speculative. No previous research has explored this issue in the context of the UK, or attempted to qualitatively examine why BECCS may be perceived in more positive terms than fossil energy and (possibly) industrial CCS applications.

2.1. Perceived naturalness

Notwithstanding the lack of data specifically relating to BECCS perceptions, there are sound theoretical reasons for suggesting that associations with nature can shape technology acceptance. Scholars of risk perception have noted that humans tend to underestimate risks posed by natural hazards, attributing this phenomenon to values and beliefs about the benefits nature confer on humans [54–56]. More sociological accounts position nature and naturalness as a socially constructed form of normative evaluation, often rooted in long standing myths and cultural narratives that grant nature the status of moral agency, capable of punishing humans for transgressing its boundaries [57–60].

The implications of such insights for different CCS applications are

at present unclear. Oltra, Sala and Boso [61] suggest that CCS tends to be more positively viewed when evaluated alongside information emphasizing the naturalness of CO_2. In existing perceptions research on CCS, geological sequestration of CO_2 has been variously interpreted as humans overstepping natural limits, 'playing god', and leaving a Pandora's box of CO_2 stores for future generations to manage indefinitely [18,30,62,63]. However, given the storage mechanism for BECCS and industrial CCS are the same as for fossil fuels, it is unclear why the former should be viewed as particularly negative or unnatural. Furthermore, as Siipi [64] points out, colloquial usages of the term 'natural' has often been used to denote states of affairs that are taken to be normal, expected or beneficial, expanding beyond the non-human world to economic and social relationships more broadly. Given the economic and social importance of energy and industrial employment in those areas where CCS is likely to be deployed, it is therefore possible that CCS technologies may be subject to quite different moral evaluations locally than elsewhere. Under such circumstances it is unclear how perceptions of normality and naturalness might interact. In the following analysis, we draw on data from a two-day deliberative workshop held in Selby, North Yorkshire, in order to explore how CCS and other low carbon technologies may be interpreted as threatening or reinforcing natural processes and normalised economic and social relations.

3. Methods

Although we aimed to examine CCS perceptions in an area previously earmarked for deployment, the upstream nature of CCS and low levels of existing knowledge among wider publics necessitated a flexible approach capable of anticipating and responding to different levels of knowledge and expertise. When researching perceptions of little-known topics such as CCS, quantitative questionnaire-based research methods can risk eliciting unreliable 'pseudo-opinions' that may be unstable, inconsistent or lacking in conviction [65]. This is particularly important given the insight that perceptions of energy technologies often vary depending on the contextual information provided. Several studies have found that providing information on cost and renewable intermittency can sometimes improve relative preferences for CCS [23,66], although others have shown that this is not always the case [cf. 24,67].

It has also been consistently demonstrated that under the right conditions, lay publics are more than capable of constructing detailed an nuanced responses to unfamiliar and complex technological issues in relatively short periods of time through the provision of appropriately constructed stimulus materials and the space in which to consider them [23,68]. Deliberative workshops, in which small groups convene to learn about and discuss an issue, have been shown to be particularly effective in eliciting critical reflection on the ethical, social and technological implications of a broad range of technologies including CCS [44,68–70]. Work in this tradition aims to facilitate open-ended, value-rational discussion of emergent technologies interspersed with the provision of information, allowing non-expert groups to develop familiarity with new technologies through interactive discussions which aim to better reflect the social processes through which perceptions form in practice. Deliberative methods thus aim to use social interaction to explore participants' interests, concerns and uncertainties, and encourage discussion, questioning and clarification of feelings and opinions relating to them [59,71–73]. While their reasons for doing so vary, psychologically and sociologically informed theories of techno-scientific risk have argued for deliberative approaches as an important means for managing areas of ambiguity in which technical uncertainties, competing social goals and values intersect [70,74,75].

The workshop was convened in Selby, a small town in North Yorkshire with a population of approximately 18,000, close to Drax Power Station. Opening in 1973, Drax is the UK's newest and largest coal power station and consequently the single largest point source of CO_2 in the country. Originally most fuel for Drax was sourced from local collieries but since the 1980 s this has been substituted for lower-cost imports. Nevertheless Drax continues to employ 700 workers in the local area and estimates another 3650 jobs in the wider region depend on the plant [76,77]. Since 2012 Drax has converted three of its six generating units to biomass and, until the cancellation of the CCS competition in 2015, was one of the two preferred sites bidding for funding to demonstrate the UK's first CCS retrofit plant.

In order to reflect a diverse range of views within the local community, a professional market research company was hired to recruit participants. Recruiters were given a quota to ensure gender balance, and to reflect a broad range of socio-economic and demographic perspectives. However, given the small size of the group, we did not aim for it to be statistically representative of the local or national population. As such, our findings are not generalisable to the population level but rather, in the tradition of much case study research, they are generalisable to theory [78,79]. Findings from Selby thus reflect a range of perspectives present in the local community, which we may expect to find in similar instances of proposed CCS deployment. 12 participants attended the workshop, which lasted 14 h over two consecutive days in August 2016.

The first day consisted of initial discussions about how the participants saw their local area and top-of-the-mind associations with terms associated with CCS such as 'climate change', 'underground' and 'CO_2'. Following this, a brief presentation was given to introduce CCS in the context of climate change. Later in the day, we facilitated group discussions around two posters and accompanying handouts detailing potential risks and benefits identified from the wider CCS literature (see Supplementary files 1 & 2). In order to ensure accuracy and balance, the presentation and other materials were checked and validated by an expert panel of geologists and engineers attached to the project, and piloted with members of the public in Cardiff prior to use. Group discussions following the presentation and poster tasks were framed as taking place in the context of potential deployments of sub-seabed storage in the Southern North Sea, connected to capture facilities at Drax power station and in the surrounding region. Participants were informed that similar proposals had been developed under the UK CCS competition, but that plans for Drax had been cancelled following the withdrawal of demonstration funding.

Previous research on CCS perceptions has suggested that when presented in isolation, participants tend to articulate preferences for alternatives technologies, without subjecting them to detailed critical scrutiny [23]. For this reason, day two was designed to introduce a wider range of technologies and issues surrounding energy system change, with the aim of better contextualising CCS options. Participants were given a second presentation placing CCCs in the context of the UK's current energy system and decarbonisation targets, in order to sensitise them to issues of resource dependency and renewable intermittency, thus broadening the climate change framing provided on day 1. While every effort was made to ensure the factual accuracy of these materials, they were introduced with the explicit aim of providing alternate framings to stimulate broader reflection and critical discussion. During the afternoon participants were provided with short narratives describing life in 2050 under three scenarios: 'business as usual', detailing a world in which unabated fossil fuel use had persisted; 'incremental changes', describing a high CCS scenario, and 'low carbon living', a high solar and wind energy scenario requiring significant lifestyle changes as a response to issues of intermittency (see Supplementary materials 3). Adapted from scenarios produced by Butler, Parkhill and Pidgeon [43] for deliberative work around UK energy transitions, our scenarios were designed as archetypes, intended to provide a wider range of possibilities and narrative resources for participants to draw upon in thinking about uncertain future developments [43,80]. The aim here was not to convince participants of the benefits of CCS, nor to override or abandon previous framings of CCS as a climate change mitigation technology carrying specific risks. Rather it

aimed to open up discussion to alternative possibilities we anticipated (and subsequently found) would be relevant to participants.

Day two culminated in a ranking activity in which participants were asked to imagine themselves as citizens attending a planning meeting in 'Barcott', a fictional town similar to Selby but hosting a more significant chemicals industry (included to facilitate reflection on industrial CCS). Participants were presented with short summaries of six proposals for redeveloping the site of an ageing coal power station and asked to discuss and rank them in order of preference (see Supplementary materials 4). Options included retrofitting the power station with CCS, construction of a new BECCS power plant or a collection terminal for a larger industrial CCS network. The other three options comprised unabated bioenergy, coal and wind power stations, and were included in order to provide participants with space to question or reject the workshop's emphasis on CCS and decarbonisation. Summaries contained a short introduction to the technology and information on potential benefits for emissions reduction and local employment, as well as potential impacts to the environment and human safety. While a wider range of alternative technologies could have been included, we decided to limit options available in order to make the ranking task more manageable within the constraints of a workshop methodology, and avoid overloading participants with information. Solar and nuclear energy were presented and discussed as options in the scenario task and elsewhere in the workshop, but were not presented for the purposes of ranking.

3.1. Analysis

Audio recordings of the workshops were transcribed verbatim and subjected to a combination of thematic and narrative analysis in order to identify how participants came to interpret and situate themselves in relation to CCS. Initially transcripts were coded to identify key themes which were then examined for the ways in which they emerged and evolved as the workshop proceeded. In practice, this involved an iterative process in which initial readings of transcripts yielded indexical codes [81], initial signposts to topics of discussion and ways of thinking about CCS which were added to an Nvivo file containing the workshop transcripts and were used to ease navigation of the data set. Through multiple re-readings, index codes were aggregated into broader themes which captured key ways in which participants interpreted and discussed CCS. The development of themes at this stage was informed by a back and forth movement between the data and wider literatures on risk and technology perception which provided a theoretical scaffolding that remained grounded in the data at hand. Once themes had been identified, analysis shifted focus to individual extracts coded within them, allowing comparisons between participants and ensuring codes were internally homogeneous and externally heterogeneous [82]. In line with well established procedures of qualitative analysis, this was an iterative process involving multiple re-readings of the data and constant cross comparison between themes and narrative extracts [71,83]. All coding was undertaken by the lead author using Nvivo, some quotes have been lightly edited post-analysis for clarity.

In addition to the thematic focus of analysis, attention was also paid to the changing emphasis given to different themes as the workshop progressed, using indexical codes to identify how discussion within themes evolved across activities. This work proceeded until a narrative account could be generated that translated the rich discussion present in the raw data into an analytically comprehensible form which nevertheless preserved the range of perspectives emerging from the workshop [84,85]. Interpreted through the lens of wider literatures on CCS, technology and risk perception, the account below developed out of the intersection between three themes: nature and naturalness, naturalised society and the uncanny. Short summaries of individual themes can be found in Supplementary file 5.

4. Findings

4.1. Messing with nature: CCS and project cancellation

In line with the findings from many surveys, no participant at Selby had any knowledge of CCS prior to the workshop. Indeed, the participants' general lack of connection to the local power plant was suggestive of a generalised ambivalence found at other sites hosting large infrastructure [46,86]. They described the plant as normally blending into the background of daily life, but on occasion as a source of anxiety triggered by unexpected loud noises (mistaken for explosions) or reports of illness in the local population. Participants' sense of disconnection from the plant meant they were generally unconcerned by learning of the cancellation of the Drax CCS proposal. Several questioned whether the cancellation was due to risks associated with CCS, but appeared satisfied by the government's explanation that the cancellation was necessitated by budgetary constraints. The cancellation played little role in subsequent discussions and was not mentioned by any participant as a reason for supporting or opposing CCS in the future.

Given participants' lack of familiarity with CCS, initial discussions focused on their perceptions of CO_2 and other associated concepts. Top-of-mind associations describing CO_2 as a gas and a pollutant proved salient, sometimes associated with emission sources such as energy, factories and transport. Global warming or climate change were mentioned as specific effects of CO_2 emissions, as were poison and toxicity. Conversely, the underground was generally constructed as 'dark' and 'uninspiring', with underground rail and horror movie settings mentioned as everyday reference points. These feelings foreshadowed participants' initial responses to CCS once introduced to the technology by the research team.

Following introductions to CCS, initial responses to the technology were mixed. While all expressed concern over climate change, CCS evoked a range of feelings and was viewed by some as transgressing important barriers between natural and human worlds. Risks to human and animal life from leakage or induced seismicity tended to be interpreted as posing lasting, potentially irreversible damage to complex living systems. While participants were willing to accept assurances that properly selected, managed and maintained storage sites posed little risk, they remained concerned that unforeseen processes may, over time, lead to improper management or undermine the conditions under which storage sites were originally selected. In some cases, concerns were raised that while CCS may be properly managed in the UK, the same could not be guaranteed if the technology was adopted elsewhere in the world:

> Clive: We're going to have hundreds, if not thousands, of storage sites, and not every country would be, probably, as careful where they put these sites. There is a chance- more than a chance I would say- almost a certainty, there will be leaks. And the oceans are one of our most important natural resources.

While the above extract from Clive focuses on the trustworthiness of organisations that might be responsible for CCS outside the UK, it articulates a sense of inevitability that by interfering in sub-seabed spaces, CCS would result in disruption to ecological and geological systems upon which humans depend. In this view, although expert monitoring formed an essential precondition for supporting CCS, participants remained concerned that intervening in the ocean subsurface would provoke complex reactions that may resist prior attempts at measurement and prediction, with potentially catastrophic consequences.

Other participants articulated similar concerns, but located them not in the trustworthiness of organisations but in unforeseen processes, possibly occurring over long timescales that could undermine the conditions upon which previous safety assessments were predicated. Underlying such concerns was a view of the subsurface as an unseen and mysterious world in which humans ought not to meddle:

> Joanne:… I don't know whether it's down to films and whatever else but you think of underground being full of these gases that have mixed down there for years and years and what happens when they get into the oxygen and, you know, San Andreas Fault and all this sort of stuff, you just think…
> Caroline: Or the 'Journey to the Centre of the Earth'. You see I quite like that film, there's a secret universe down there.

Discussions such as the exchange above constructed CCS as intervening in an underground wilderness that may harbour instability or unseen worlds, perhaps (as in the Journey to the Centre of the Earth) containing undiscovered or fantastic forms of life. Joanne and Caroline invoke the San Andreas Fault and a secret universe not as direct analogues for the geological formations that might be used for CO_2 storage. Rather they are consciously drawing on cultural narratives in order to articulate what they find troubling about CCS. Writing on the effects of nuclear technologies on the public psyche, Joseph Masco [87] notes the ways in which fears over unseen radiation and nuclear conflict manifest in wider society, including cultural representations of mutation and disaster. Adapting Freud's concept of the unhomely, he coins the phrase 'nuclear uncanny' to describe how society processes the catastrophic potential for radiation to disturb formerly familiar and taken-for-granted environments and routines. Similarly, Caroline and Joanne invoke metaphors of dangerous gases and hidden worlds in order to give voice to concerns that CCS risks disturbing forces that may threaten human life or natural wonders that, while unseen, may nevertheless be emotionally and morally significant.

4.2. Messing with lifestyles: intermittency and reluctant acceptance

While CCS was initially interpreted as potentially threatening natural systems, subsequent presentations and scenario discussions led to a gradual shift in how participants interpreted the technology. In particular, scenario materials emphasising renewable intermittency as necessitating more flexible energy use practices, elicited greater scepticism towards wind and solar energy from some participants. This was reflected in the final ranking activity in which wind scored poorly relative to the CCS options. A detailed breakdown of participants' rankings is presented below, alongside cumulative rankings for the group as a whole (Table 1). Such rankings reflect participants' perceptions near the close of the workshop and should not be taken as representative of wider populations. In the following sections we discuss this ranking process in more detail in order to explore the ways in which initial concerns over CCS as unnatural and uncanny gave way to more sympathetic assessments.

When responding to scenario materials which emphasised renewable intermittency and demand response practices, several participants appeared to view certain changes such as working from home, rigorous energy conservation practices, and time-of-use pricing for electrical appliances as going well beyond doing the 'little things' they previously felt preferable to CCS. Although several felt that aspects of such changes would be manageable within their own lives, they expressed concerns that such practices were out of keeping with cultural expectations of convenience and a busy modern life, and would not be adopted by others within their community: *'It is like people are rushing to do something but they don't actually have anything to do, it is strange'* (James). For others, emphasis on demand response practices led to concerns that life under a renewable-based energy system may become regimented or robotic, in ways that undermined valued relationships and lifestyles: "*it is a bit like a dead house, I don't like it, I have got stuff going on everywhere in my house*" (Emma). For some, behaviour changes were seen as ways of saving money or fostering desirable characteristics such as personal responsibility; however even in these cases lifestyle change tended to be framed in terms of sacrifice:

> Joanne: I prefer that freedom of movement and freedom to choose but would it be so bad to have to just change and yes, you would haveto be more organised but you could still have your social life, you could still go and do what you wanted to do couldn't you? You would just be helping the environment… you could still do what you wanted to do, you'd adapt to whatever it was… you would still have your life. I just don't think it would be that bad.
> Carol: You like it don't you?
> Joanne: I wouldn't, given the choice say, 'Yeah, please, go yeah, me, me, me,' but I wouldn't be devastated I don't think… I'll just go with the flow.
> Carol: Yeah some people like regimentation don't they, they prefer to know what they are doing and when they are doing it.

Discussing demand reduction in light of her existing lifestyle, Joanne emphasises the manageability of a shift incorporating demand reduction and time-of-use electricity billing. Whilst she doesn't find it particularly attractive, Joanne nevertheless views this shift as an environmentally friendly option that remains compatible with her desired lifestyle. In contrast, Carol's response, and her suggestion that some (other) people like regimentation, indicates her own dissatisfaction with the concept of demand reduction. 'Regimentation', a 'dead house', and practices deemed to be overly 'robotic' were metaphors used by several participants to capture perceived intrusions into the fabric of the home and daily life. Such metaphors point to a sense in which demand response came to be perceived as undermining commonly-held expectations of convenience and family life, and as threatening a less social, and to an extent, less 'human' future that appeared unfamiliar and threatening.

In reframing and rendering ambivalent previously unproblematic perceptions of wind and solar energy, discussions during day two of the workshop provided space for CCS to be re-considered. This is not to say CCS came to be seen as unproblematic, rather its fit within wider relationships of dependence came to be re-assessed in light of anxieties relating to intermittency and associated lifestyle changes. The below extract from Emma illustrates how, in spite of perceived risks, CCS came to be seen as potentially supporting and maintaining valued forms of life:

> Emma: Yeah so we can live how we live without giving up too much or, going down on the other end, doing the capture so it is clean so I suppose you compromise and you are risking being poisoned or maybe having to live next to pipe lines just so we can do what we do, live how we live.

Such discussions tended towards what Bickerstaff, Lorenzoni, Pidgeon, Poortinga and Simmons [45] refer to as 'reluctant acceptance', a renegotiation prompted by recontextualising a technology in relation to another risk issue, in this case renewable intermittency. This

Table 1
Final Preference Rankings for CCS and non-CCS technologies.

	Option Ranking[a]:					
	Bioenergy	BECCS	Coal	Coal CCS	Industrial CCS	Wind
Participant Scores:	1	2	6	3	4	5
	2	1	6	4	3	5
	2	1	6	4	3	5
	2	1	6	3	4	5
	4	3	5	2	1	6
	4	2	6	1	3	5
	5	1	6	2	4	3
	4	6	2	3	1	5
	2	4	6	3	5	1
	2	1	5	4	3	6
	5	3	6	4	1	2
	5	4	6	2	3	1
Cumulative Rankings:	38	29	66	35	35	49

[a] Lower scores represent preferred options.

renegotiation did not eliminate initial concerns relating to CCS. Toxicity risks and a sense of messing with natural processes remained. However as wind and solar came to be perceived as threatening to lifestyles and social interdependencies, CCS came to be viewed as more ambivalent, posing potential benefits as well as threats.

4.3. Industrial CCS and BECCS: a more natural fit?

If participants interpreted CCS as harbouring unfamiliar risks to complex living systems, the previous section illustrated how this effect was partially mitigated by reframing the technology in relation to renewable intermittency. Additional re-interpretations occurred when issues of local employment, BECCS and industrial CCS were introduced. When presented as the sole option for curtailing manufacturing emissions, or as a process tied to managed forestry and the carbon cycle, CCS became viewed as a more intuitive and natural process. While containing ambiguities and ambivalences, these reframings allowed the three CCS technologies to emerge as the most (although not universally) preferred options in the ranking task, albeit with conditions attached. This section explores that second process of reframing.

Unlike unabated coal and wind, overall rankings for unabated bioenergy were far closer to the more preferable rankings given for the three CCS options. This was primarily due to its presentation as a CO_2 neutral technology and associations with 'naturalness' that will be discussed further below in relation to BECCS. However it is also notable that unabated bioenergy was accorded higher rankings, second only to BECCS, by the two participants with personal ties to workers at Drax Power Station where biomass is currently burnt. For these participants, bioenergy provided a means of reducing emissions while keeping old combustion plants open, thus protecting jobs and leaving open the possibility for CCS to be added later should negative emissions be required.

While the potential for negative emissions motivated preferences for BECCS over unabated bioenergy, it was its perceived 'naturalness' that provided the primary rationale for participants' preferences for BECCS over all other technologies under discussion during day two. In particular, participants were drawn to the perceived congruence of biomass production and BECCS with the existing carbon cycle and natural processes of planting and growth. Some participants initially focussed on the counterintuitive nature of this process, and concerns regarding competition with agriculture and other land uses were raised by several participants. Avoidance of pressure on forests and agricultural land thus formed important preconditions upon which participants were prepared to consider biomass and BECCS: '*I just want to know really where it was coming from and set my mind at rest that trees weren't being chopped down to provide the wood to, you know - without being replaced' (Craig).* Subject to these conditions, in subsequent discussions associations with growing and planting shaped interpretations of bioenergy and BECCS as a natural process: "*Well it kind of seems a bit more natural and a bit more friendly, environmentally friendly*" (Claire).

In contrast to perceptions of fossil CCS as meddling with underground and oceanic systems upon which society is dependent, bioenergy was seen as working in a more virtuous cycle that supported these systems: *'I liked that its removing CO_2 from the atmosphere as well… It's almost like the circle of life isn't it?*' (Caroline). This was particularly true for participants that expressed strongest opposition to continued use of fossil fuels and were more prepared to consider renewable options despite issues of intermittency and behaviour change. While such views were expressed most strongly by this subgroup of participants, they reflected values expressed more broadly within the workshop and elsewhere for decarbonisation trajectories to be independent of fossil fuels and act in ways that work with the natural world [cf. 25]. For some participants, concerns over naturalness translated into a greater preference for biomass over BECCS and other CCS options. However across the group the idea of sourcing energy (and hence CO_2) from processes of tree growth and forestry led to the whole BECCS process being perceived as more natural. A discourse emerged in which BECCS was constructed as reinforcing societal relationships with the natural world in ways which supported the flourishing of both. Within this narrative, the perceived naturalness of BECCS was given equal, if not greater emphasis than its potential to generate negative emissions.

While some studies have suggested that lay publics tend to be more supportive of CCS in industrial applications, even when opposing it in energy applications [43], this was not reflected in the final ranking activity. Coal with CCS and industrial CCS received equal cumulative rankings and tended to be given similar scores by individual participants. However in broader discussions, there were distinct qualitative differences in the ways industrial and fossil fuel CCS were interpreted. Whereas preferences for coal CCS tended to be constructed in defence of local jobs, participants articulated more positive visions for industrial CCS as supporting growth in manufacturing industries deemed particularly desirable for the societal benefits they provide. Often such discussions mirrored those addressed by Butler, Parkhill and Pidgeon [43] as speaking to potential economic benefits accruing to the UK as a whole. However, for some participants such as Geoff, they took on a localised tone:

> Geoff: Based on the history of the town… as a citizen, I think I would be more akin to wanting… the CCS industrial capture more … because that is the history of the town and what they are used to.

In the above extract, Geoff outlines his rationale for ranking industrial CCS above coal CCS and wind turbines for the fictional town of Barcott. While scenario materials emphasised a local history of electricity generation and manufacturing in the region, it was the latter that was seen as more central to the town's history and experiences. This is not to say Geoff or other participants had direct experience of jobs in or dependence upon local industry. Rather, they subscribed to a cultural view of industrial employment as a particularly valued form of economic activity in the region and wider society. To an extent such feelings of a shared cultural fate also manifest in relation to power plant workers. However, while these were deemed to be in need of protection, concern for them was moderated by the competing desire to decarbonise energy generation. In contrast, the application of CCS to other industrial sectors was viewed more positively, as a means of not only protecting but expanding desired spheres of socio-economic activity. Speaking to feelings of embeddedness in wider systems of interdependency, such perceptions bear some similarities to those rooted in beliefs about naturalness. Here, constructs such as 'local jobs', 'economic growth' and 'British manufacturing' fulfil similar functions to the 'circle of life' and an unstable but foundational underground. Both represent culturally-mediated understandings of deeply rooted relationships on which participants felt dependent. Nevertheless, support for industrial CCS was not universal. As the only technology presented that did not offer an electrical output, some saw it as unproductive. Indeed, concerns that CCS may impose costs that could damage employment in local industries or power plants were raised by some participants as a reason to oppose its introduction, unless steps could be taken to retrain and re-employ industrial workers within the CCS sector. However, for Geoff and others, the potential of CCS to protect and rejuvenate historical patterns of employment made industrial CCS an attractive option for the area.

5. Discussion and conclusions

While this project initially aimed to explore perceptions of CCS and BECCS in light of recent project cancellations in the UK, the project cancellations aspect was not found to be particularly salient. Our participants were unaware of the cancelled CCS project at Drax, and we therefore found little to no impact on CCS perceptions. To the extent that the wider UK population is similarly unaware of CCS technology and attendant policy processes, this finding may well hold true more broadly. However, due to the lack of representation of citizens with

direct personal links to the power plant, we would urge caution in interpreting these findings as representative of citizens with direct knowledge of or involvement in CCS project cancellations, for example power plant workers. As such groups were not included in this study, it remains possible that direct experience of cancellation may have impacted trust in CCS technology more significantly among these groups. This is important because the support of those with a direct stake in the local power sector may be crucial to the success of future CCS proposals; therefore future research could be targeted to examine groups directly affected by project cancellations.

In this paper, we have developed an account of how different applications for CCS may be interpreted by lay publics. In so doing, we have adopted a broad understanding of perceived naturalness as the degree to which different CCS technologies and alternatives are seen to fit with existing systems of felt dependency. By this, we refer not only to the affective responses identified by individual subjects as practically, emotionally or morally significant, but also to shared understandings of the cultural, natural and socio-economic systems upon which society is dependent. In adopting such an approach we have illustrated how and why some CCS applications may be perceived as preferable to others, and examined some of the ambivalences and contingencies underlying such perceptions. Under some circumstances, CCS may be perceived as posing uncanny threats to emotionally and ethically significant ecological and geological systems; however, recontextualising the technology in relation to climate change, renewable intermittency and demand response can elicit renegotiation of responses more akin to ambivalence or 'reluctant acceptance' [45]. Such findings have implications for public engagement and communication around CCS that may be of use both to proponents and opponents of the technology. One implication for policy makers would be that concerns over naturalness, social and economic normality should be explicitly addressed in public debates and engagement activities around CCS, in order to open up such fora to a wider set of ethical concerns that may not be captured in standard risk-benefit communication exercises.

Given that reframing CCS in the context of intermittency was built into the structure of the workshop, it could be argued the findings of this study represent the result of a deliberately introduced bias. In response to such criticisms, we would argue that human perceptions do not exist pre-formed but are necessarily constructions negotiated in response to external stimuli which are never completely neutral or free from wider associations and interests [88]. More pertinently the issue of researcher and methodological bias was directly addressed prior to debriefing participants. While some felt their perceptions had shifted in response to materials presented, none felt that the research team or balance of information materials, had advocated for any particular interpretation or technology over the others.

Amongst the different CCS applications studied here, industrial CCS and BECCS emerged as preferable because they invoked culturally mediated understandings of economic and natural worlds as interdependent systems that may be subject to reinforcement as well as harm. Ecosystems can be enhanced through the planting of trees, and industrial employment can be boosted by the introduction of new technology. Such interpretations reflect not only the re-articulation of culturally derived values: the differences between participants also illustrate the space still open for a range of moral and emotional interpretations to emerge which may be rooted in different personal norms, values or other aspects of personal biography which this study has not had room to investigate [89]. Nevertheless, the finding that BECCS and industrial CCS tended to be discussed in more preferable terms to fossil energy applications raises important questions for decarbonisation scenarios and strategies that view the latter as the first stage en route to the former. While more widespread and representative work would be needed to verify these findings, it is possible that in instances where fossil CCS is deemed unacceptable by local populations other CCS options may remain viable. It is thus important that project developers consult early, preferably in advance of detailed planning, in order to assess what (if any) the most acceptable CCS application may be.

Notwithstanding the emergence of more positive evaluations for all CCS applications as the workshop proceeded, we would caution against interpreting our participants as unequivocally supporting or accepting any technology. A range of anxieties and ambivalences remained regarding all the CCS technologies mentioned and, in line with other studies of technology perception, support for CCS was qualified and conditional [44,90]. Participants' preparedness to consider BECCS and other CCS options was predicated on a range of factors that may be uncertain in real-world deployments, such as: restrictions on land-use for biomass; protection or extension of industrial spheres of economic production and employment; and a range of conditions regarding site selection and monitoring which some were skeptical could be met over the long term. Interestingly questions of international equity and moral hazard, identified in expert led ethical analyses of BECCS [53], did not emerge in Selby. Indeed where international issues did emerge it was in relation to the motivation and capacity of other countries to regulate CCS in a responsible manner. This may reflect the relatively small number of participants recruited and the overarching focus of the workshop on the implications of CCS at a local level. Nevertheless, it serves as a valuable reminder that lay publics do not poses a monopoly on ethical thinking, and that deliberation around emergent technologies is always partial and context specific.

In allocating two days to an in-depth deliberative process, research at Selby allowed for more nuanced examination of the ambivalences and ambiguities that emerge as lay publics interpret and respond to the relative risks and benefits of emergent low carbon energy technologies. In particular we have illustrated how, by rendering intermittent renewables more ambivalent, the provision of wider contextual information can give the impression of improving perceptions of CCS. While this may be the case in a relative sense, it masks underlying ambivalences and anxieties about CCS, particularly its sub-seabed elements. To the extent that other futures have been envisaged in which energy storage technologies reduce the need for demand response practices [91], future support for CCS may prove even more qualified than our findings suggest. Likewise, the finding that some participants viewed industrial CCS as unproductive and were concerned about the costs it may impose on local industries, points to an alternative possible interpretation of CCS as a threat to local employment. While such perceptions in part reflected the framing of the scenario and ranking activities, they illustrate how under some circumstances CCS may be perceived as a threat to key forms of social and economic interdependence that all participants valued. Had activity framings been more explicit in highlighting potential costs to industry, such perceptions may have been prone to change. Perceptions of industrial CCS as an unproblematic improvement to necessary industries may thus prove more contingent than previous studies have suggested.

Acknowledgements

This research was funded by the Economic and Physical Sciences Research Council project 'CO_2 injection and storage- short and long term behavior at different spatial scales' (grant EP/K035967/1). Nick Pidgeon's time was partially supported by the Engineering and Physical Sciences Research Council, award EP/L024756/1.

Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.erss.2018.06.007.

References

[1] IEA, Technology Roadmap: Carbon Capture and Storage, International Energy Agency, Paris, 2013.
[2] IEA GHG, Assessment of Sub-Sea Ecosystem Impacts, IEA Greenhouse Gas R&D

Programme, Cheltenham (2008).
[3] IEA GHG, Induced Seismicity and its Implications for CO2 Storage Risk, Cheltenham (2013).
[4] IPCC, IPCC Special report on carbon dioxide capture and storage, Cambridge University Press, Cambridge, United Kingdom and New York, USA, Prepared by Working Group III of the Intergovernmental Panel on Climate Change (2005).
[5] IEA, Energy Technology Perspectives (2012), International Energy Agency, 2012.
[6] W. Burns, S. Nicholson, Bioenergy and carbon capture with storage (BECCS): the prospects and challenges of an emerging climate policy response, J. Environ. Stud. Sci. 7 (4) (2017) 527–534.
[7] N. Vaughan, C. Gough, Expert assessment concludes negative emissions scenarios may not deliver, Environ. Res. Lett. 11 (9) (2016) 1–7.
[8] IPCC, Climate change 2014: synthesis report, Geneva, Switzerland, Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change IPCC (2014).
[9] ETI, The Evidence for Deploying bioenergy With CCS (BECCS) in the UK, Loughborough (2016).
[10] S. L'Orange Seigo, S. Dohle, M. Siegrist, Public perception of carbon capture and storage (CCS): a review, Renew. Sustain. Energy Rev. 38 (2014) 848–863.
[11] P. Ashworth, J. Bradbury, C. Feenstra, S. Greenberg, G. Hund, T. Mikunda, S. Wade, Communication, Project Planning and Management for Carbon Capture and Storage Projects: An International Comparison, CSIRO, Canberra, 2010.
[12] J. Anderson, J. Chiavari, H. de Coninck, S. Shackley, G. Sigurthorsson, T. Flach, D. Reiner, P. Upham, P. Richardson, P. Curnow, Results from the project' Acceptance of CO_2 capture and storage: economics, policy and technology (ACCSEPT)', in: J. Gale, H. Herzog, J. Braitsch (Eds.), Greenhouse Gas Control Technologies, 9 Elsevier Science Bv, Amsterdam, 2009, pp. 4649–4653.
[13] L. Wallquist, V.H.M. Visschers, M. Siegrist, Impact of knowledge and misconceptions on benefit and risk perception of CCS, Environ. Sci. Technol. 44 (17) (2010) 6557–6562.
[14] C. Gough, I. Taylor, S. Shackley, Burying Carbon under the Sea: An Initial Exploration of Public Opinions, Tyndall Centre for Climate Change Research, Manchester (2001).
[15] B.W. Terwel, D.D.L. Daamen, E. ter Mors, T. Dixon, K. Yamaji (Eds.), Not in My Back Yard (NIMBY) Sentiments and the Structure of Initial Local Attitudes Toward CO_2 Storage Plans, Elsevier Science Bv, Amsterdam, 2013, pp. 7462–7463 Ghgt-11.
[16] L. Mabon, S. Shackley, Meeting the targets or re-imagining society? An empirical study into the ethical landscape of carbon dioxide capture and storage in Scotland, Environ. Value 24 (4) (2015) 465–482.
[17] M. Prangnell, Communications for Carbon Capture and Storage: Identifying the Benefits, Managing Risk and Maintaining the Trust of Stakeholders, GCCSI, Canberra, 2013.
[18] L. Mabon, S. Shackley, N. Bower-Bir, Perceptions of sub-seabed carbon dioxide storage in Scotland and implications for policy: a qualitative study, Mar. Policy 45 (2014) 9–15.
[19] D. Schumann, E. Duetschke, K. Pietzner, Public perception of CO_2 offshore storage in Germany: regional differences and determinants, in: T. Dixon, H. Herzog, S. Twinning (Eds.), Elsevier Science Bv, Amsterdam, 12th International Conference on Greenhouse Gas Control Technologies, Ghgt-12, 2014, pp. 7096–7112.
[20] Eurobarometer, Eurobarometer Survey on Public Awareness and Acceptance of CCS, DG-Research, Brussels, 2011.
[21] T.E. Curry, S. Ansolabehere, H. Herzog, A Survey of Public Attitudes Towards Climate Change and Climate Change Mitigation Technologies in the United States: Analyses of 2006 Results, Cambridge, MA (2007).
[22] E. Miller, J. Summerville, L. Buys, L. Bell, Initial public perceptions of carbon geosequestration: implications for engagement and environmental risk communication strategies, Int. J. Glob. Environ. Issues 8 (1-2) (2008) 147–164.
[23] L.A. Fleishman, W.B. de Bruin, M.G. Morgan, Informed public preferences for electricity portfolios with CCS and other low-carbon technologies, Risk Anal. 30 (9) (2010) 1399–1410.
[24] P. Upham, T. Roberts, Public perceptions of CCS: emergent themes in pan-European focus groups and implications for communications, Int. J. Greenh. Gas Control 5 (5) (2011) 1359–1367.
[25] C. Demski, C. Butler, K.A. Parkhill, A. Spence, N.F. Pidgeon, Public values for energy system change, Glob. Environ. Change 34 (2015) 59–69.
[26] N. Markusson, S. Shackley, B. Evar, The Social Dynamics of Carbon Capture and Storage: Understanding CCS Representations, Governance and Innovation, Earthscan, Abingdon, 2012.
[27] N.M.A. Huijts, C.J.H. Midden, A.L. Meijnders, Social acceptance of carbon dioxide storage, Energy Policy 35 (5) (2007) 2780–2789.
[28] B.W. Terwel, F. Harinck, N. Ellemers, D.D.L. Daamen, Competence-based and integrity-based trust as predictors of acceptance of carbon dioxide capture and storage (CCS), Risk Anal. 29 (8) (2009) 1129–1140.
[29] S. Brunsting, P. Upham, E. Dutschke, M.D.B. Waldhober, C. Oltra, J. Desbarats, H. Riesch, D. Reiner, Communicating CCS, Applying communications theory to public perceptions of carbon capture and storage, Int. J. Greenh. Gas Control 5 (6) (2011) 1651–1662.
[30] C.R. Palmgren, M.G. Morgan, W. Bruine de Bruin, D.W. Keith, Initial public perceptions of deep geological and oceanic disposal of carbon dioxide, Environ. Sci. Technol. 38 (24) (2004) 6441–6450.
[31] S.R. Carley, R.M. Krause, D.C. Warren, J.A. Rupp, J.D. Graham, Early public impressions of terrestrial carbon capture and storage in a coal-intensive state, Environ. Sci. Technol. 46 (13) (2012) 7086–7093.
[32] R.M. Krause, S.R. Carley, D.C. Warren, J.A. Rupp, J.D. Graham, Not in (or under) my backyard": geographic proximity and public acceptance of carbon capture and storage facilities, Risk Anal. 34 (3) (2014) 529–540.
[33] D. Reiner, Blog: Investigating Public Attitudes Towards CCS and Low-Carbon Technologies in the UK and Canada, (2017).
[34] N. Markusson, A. Ishii, J.C. Stephens, The social and political complexities of learning in carbon capture and storage demonstration projects, Glob. Environ. Change Hum. Policy Dimens. 21 (2) (2011) 293–302.
[35] S. Brunsting, M. de Best-Waldhober, B.W. Terwel, T. Dixon, K. Yamaji (Eds.), 'I Reject Your Reality and Substitute My Own!' Why More Knowledge About CO_2 Storage Hardly Improves Public Attitudes, Elsevier Science Bv, Amsterdam, 2013, pp. 7419–7427 Ghgt-11.
[36] E. Ter Mors, M.W.H. Weenig, N. Ellemers, D.D.L. Daamen, Effective communication about complex environmental issues perceived quality of information about carbon dioxide capture and storage (CCS) depends on stakeholder collaboration, J. Environ. Psychol. 30 (4) (2010) 347–357.
[37] L. Wallquist, S. L'Orange Seigo, V.H.M. Visschers, M. Siegrist, Public acceptance of CCS system elements: a conjoint measurement, Int. J. Greenh. Gas Control 6 (2012) 77–83.
[38] E. Duetschke, D. Schumann, K. Pietzner, K. Wohlfarth, S. Holler, Does it make a difference to the public where CO2 comes from and where it is stored? An experimental approach to enhance understanding of CCS perceptions, in: T. Dixon, H. Herzog, S. Twinning (Eds.), Elsevier Science Bv, Amsterdam, 12th International Conference on Greenhouse Gas Control Technologies, Ghgt-12, 2014, pp. 6999–7010.
[39] C. Oltra, P. Upham, H. Riesch, A. Boso, S. Brunsting, E. Dutschke, A. Lis, Public responses to CO_2 storage sites: lessons from five European cases, Energy Environ. 23 (2-3) (2012) 227–248.
[40] D.C. Warren, S.R. Carley, R.M. Krause, J.A. Rupp, J.D. Graham, Predictors of attitudes toward carbon capture and storage using data on world views and CCS-specific attitudes, Science Public. Policy 41 (6) (2014) 821–834.
[41] S. Brunsting, M. Pol, J. Mastop, M. Kaiser, R. Zimmer, S. Shackley, L. Mabon, R. Howell, F. Hepplewhite, R. Loveridge, M. Mazurowski, C. Rybicki, T. Dixon, K. Yamaji (Eds.), Social Site Characterisation for CO_2 Storage Operations to Inform Public Engagement in Poland and Scotland, Elsevier Science Bv, Amsterdam, 2013, pp. 7327–7336 Ghgt-11.
[42] Cambridge Econometrics, The Economic Impact of Developing a CCS Network in the Tees Valley: A Report for Tees Valley Unlimited, Cambridge (2015).
[43] C. Butler, K. Parkhill, N. Pidgeon, Transforming the UK Energy System: Public Values, Attitudes and Acceptability- Deliberating Energy System Transitions in the UK, UKERC, 2013.
[44] K. Parkhill, C. Demski, C. Butler, A. Spence, N. Pidgeon, Transforming the UK Energy System: Public Values, Attitudes and Acceptability, Synthesis Report, UKERC, 2013.
[45] K. Bickerstaff, I. Lorenzoni, N.F. Pidgeon, W. Poortinga, P. Simmons, Reframing nuclear power in the UK energy debate: nuclear power, climate change mitigation and radioactive waste, Public Underst. Sci. 17 (2) (2008) 145–169.
[46] K.A. Parkhill, K.L. Henwood, P. Simmons, D. Venables, N.F. Pidgeon, From the familiar to the extraordinary: local residents' perceptions of risk when living with nuclear power in the UK, Trans. Inst. Br. Geogr. 35 (1) (2010) 39–58.
[47] Z. Bauman, Work, Consumerism and the New Poor, McGraw-Hill Education, UK), 2004.
[48] B. Jessop, Cultural political economy and critical policy studies, Crit. Policy Stud. 3 (3-4) (2010) 336–356.
[49] ETI, Public Perceptions of Bioenergy in the UK, ETI, Loughborough, 2016.
[50] P. Upham, S. Shackley, H. Waterman, Public and stakeholder perceptions of 2030 bioenergy scenarios for the Yorkshire and Humber region, Energy Policy 35 (9) (2007) 4403–4412.
[51] R. Radics, S. Dasmohapatra, S.S. Kelley, Systematic review of bioenergy perception studies, Bioresources 10 (4) (2015) 8770–8794.
[52] K. Anderson, G. Peters, The trouble with negative emissions, Science 354 (6309) (2016) 182–183.
[53] D. McLaren, A comparative global assessment of potential negative emissions technologies, Process Saf. Environ. Prot. 90 (6) (2012) 489–500.
[54] P. Fleming, E. Townsend, K.C. Lowe, E. Ferguson, Social desirability influences on judgements of biotechnology across the dimensions of risk, ethicality and naturalness, J. Risk Res. 10 (7) (2007) 989–1003.
[55] L. Sjöberg, Perceived risk and tampering with nature, J. Risk Res. 3 (4) (2000) 353–367.
[56] P. Slovic, The Perception of Risk: New Perspectives on Risk Perception, Eathscan, Abingdon, 2016.
[57] A. Corner, K. Parkhill, N. Pidgeon, N.E. Vaughan, Messing with nature? Exploring public perceptions of geoengineering in the UK, Glob. Environ. Change 23 (5) (2013) 938–947.
[58] J.-P. Dupuy, The narratology of lay ethics, NanoEthics 4 (2) (2010) 153–170.
[59] P. Macnaghten, S.R. Davies, M. Kearnes, Understanding public responses to emerging technologies: a narrative approach, J. Environ. Policy Plan. (2015) 1–19.
[60] H. Haste, Myths, monsters, and morality: understanding' antiscience' and the media message, Interdisc. Sci. Rev. 22 (2) (1997) 114–120.
[61] C. Oltra, R. Sala, A. Boso, The influence of information on individuals' reactions to CCS technologies: results from experimental online survey research, Greenh. Gases-Sci. Technol. 2 (3) (2012) 209–215.
[62] L. Wallquist, V.H.M. Visschers, M. Siegrist, Lay concepts on CCS deployment in Switzerland based on qualitative interviews, Int. J. Greenh. Gas Control 3 (5) (2009) 652–657.
[63] M. Kearnes, L. Rickards, Earthly graves for environmental futures: techno-burial practices, Futures 92 (2016) 48–58.
[64] H. Siipi, Non-backward-looking naturalness as an environmental value, Ethics Policy Environ. 14 (3) (2011) 329–344.

[65] E.L. Malone, J.J. Dooley, J.A. Bradbury, Moving from misinformation derived from public attitude surveys on carbon dioxide capture and storage towards realistic stakeholder involvement, Int. J. Greenh. Gas Control 4 (2) (2010) 419–425.
[66] S. Shackley, C. McLachlan, C. Gough, The public perception of carbon dioxide capture and storage in the UK: results from focus groups and a survey, Clim. Policy 4 (4) (2005) 377–398.
[67] E.F. Einsiedel, A.D. Boyd, J. Medlock, P. Ashworth, Assessing socio-technical mindsets: public deliberations on carbon capture and storage in the context of energy sources and climate change, Energy Policy 53 (2013) 149–158.
[68] E. Ter Mors, B.W. Terwel, D.D.L. Daamen, D.M. Reiner, D. Schumann, S. Anghel, I. Boulouta, D.M. Cismaru, C. Constantin, C.C.H. de Jager, A. Dudu, A. Esken, O.C. Falup, R.M. Firth, V. Gemeni, C. Hendriks, L. Ivan, N. Koukouzas, A. Markos, R. Naess, K. Pietzner, I.R. Samoila, C.S. Sava, M.H. Stephenson, C.E. Tomescu, H.Y. Torvatn, S.D. Tvedt, D. Vallentin, J.M. West, F. Ziogou, A comparison of techniques used to collect informed public opinions about CCS: opinion quality after focus group discussions versus information-choice questionnaires, Int. J. Greenh. Gas Control 18 (2013) 256–263.
[69] W.A. Carr, C.J. Preston, L. Yung, B. Szerszynski, D.W. Keith, A.M. Mercer, Public engagement on solar radiation management and why it needs to happen now, Clim. Change 121 (3) (2013) 567–577.
[70] N. Pidgeon, B. Herr Harthorn, T. Satterfield, C. Demski, Cross-national comparative communication and deliberation about the risks of nanotechnologies, in: D. Scheufele, D. Kahan, K. Hall-Jameson (Eds.), Oxford Handbook of the Science of Science Communication, Oxford University Press, Oxford, 2017, pp. 141–156.
[71] T. Partridge, M. Thomas, B.H. Harthorn, N. Pidgeon, A. Hasell, L. Stevenson, C. Enders, Seeing futures now: emergent US and UK views on shale development, climate change and energy systems, Glob. Environ. Change 42 (2017) 1–12.
[72] W.C.G. Burns, J.A. Flegal, Climate geoengineering and the role of public deliberation: a comment on the national academy of sciences' recommendations on public participation, Clim. Law 5 (2-4) (2015) 252–294.
[73] J. Burgess, A. Stirling, J. Clark, G. Davies, M. Eames, K. Staley, S. Williamson, Deliberative mapping: a novel analytic-deliberative methodology to support contested science-policy decisions, Public Underst. Sci. 16 (3) (2007) 299–322.
[74] O. Renn, Risk Governance: Towards an Integrative Approach, International Risk Governance Council, Geneva, Switzerland, 2005.
[75] A. Stirling, Keep it complex, Nature 468 (7327) (2010) 1029–1031.
[76] Knottingley and Ferrybridge Online, Industry in Knottingley and Ferrybridge, 2006. (Accessed Feb 2018).
[77] Drax Group, About Us, (2018) (Accessed Feb 2018).
[78] R. Stake, Qualitative case studies, in: N. Denzin, Y. Lincoln (Eds.), The Sage Handbook of Qualitative Research Sage Publications, Thousand Oaks, 2005, pp. 443–466.
[79] B. Flyvbjerg, Five misunderstandings about case-study research, Qual. Inquiry 12 (2) (2006) 219–245.
[80] P. Macnaghten, Researching technoscientific concerns in the making: narrative structures, public responses, and emerging nanotechnologies, Environ. Plann. A 42 (1) (2010) 23–37.
[81] J. Mason, Qualitative Researching, Sage Publications, London, 2002.
[82] V. Braun, V. Clarke, Using thematic analysis in psychology, Qual. Res. Psychol. 3 (2) (2006) 77–101.
[83] Y. Lincoln, E. Guba, Naturalistic Enquiry, Sage, California, 1985.
[84] J. Creswell, D. Miller, Determining validity in qualitative inquiry, Theory Pract. 39 (3) (2000) 124–130.
[85] B. Flyvbjerg, Case Study, D.Y. Lincoln (Ed.), The Sage Handbook of Qualitative Research, Sage, California, 2011, pp. 301–316.
[86] K. Bickerstaff, P. Simmons, Absencing/presencing risk: rethinking proximity and the experience of living with major technological hazards, Geoforum 40 (5) (2009) 864–872.
[87] J. Masco, The Nuclear Borderlands: Then Manhattan Project in Post-Cold War New Mexico, Princeton University Press, Oxford, 2006.
[88] C. Seale, The Quality of Qualitative Research, SAGE Publications Ltd, London, 1999.
[89] G. Thomas, C. Groves, K. Henwood, N. Pidgeon, Texturing waste: attachment and identity in every-day consumption and waste practices, Environ. Value 26 (6) (2017) 733–756.
[90] C. Demski, Public Perceptions of Renewable Energy Technologies – Challenging the Notion of Widespread Support, School of Psychology, Cardiff University, Cardiff, 2011.
[91] P. Taylor, R. Bolton, D. Stone, X.-P. Zhang, C. Martin, P. Upham, Y. Li, R. Porter, E.P. Bonvallet, Pathways for Energy Storage in the UK, Centre for Low Carbon Futures, York (2012).