Universiteit Leiden
The Netherlands

How do people perceive carbon capture and storage for industrial processes? Examining factors underlying public opinion in the Netherlands and the United Kingdom

Broecks, K.; Jack, C.; ter Mors E.; Boomsma, C.; Shackley, S.

Citation
Broecks, K., Jack, C., Boomsma, C., & Shackley, S. (2021). How do people perceive carbon capture and storage for industrial processes?: Examining factors underlying public opinion in the Netherlands and the United Kingdom. *Energy Research & Social Science*, *81*. doi:10.1016/j.erss.2021.102236

Version:	Publisher's Version
License:	Licensed under Article 25fa Copyright Act/Law (Amendment Taverne)
Downloaded from:	https://hdl.handle.net/1887/3221264

Note: To cite this publication please use the final published version (if applicable).

Energy Research & Social Science 81 (2021) 102236

Contents lists available at ScienceDirect

Energy Research & Social Science

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

Original research article

How do people perceive carbon capture and storage for industrial processes? Examining factors underlying public opinion in the Netherlands and the United Kingdom

Kevin Broecks [a,*], Corin Jack [b], Emma ter Mors [c], Christine Boomsma [c,d], Simon Shackley [b]

[a] TNO Energy Transition, Motion Building Radarweg 60, 1043 NT Amsterdam, the Netherlands
[b] School of GeoSciences, The University of Edinburgh, King's Buildings West Mains Road, Edinburgh EH9 3JW, United Kingdom
[c] Social Economic and Organisational Psychology Unit, Leiden University, Wassenaarseweg 52, 2333AK Leiden, the Netherlands
[d] RIVM National Institute for Public Health and the Environment, Antonie van Leeuwenhoeklaan 9, 3721 MA Bilthoven, the Netherlands

ARTICLE INFO

Keywords:
Carbon Capture and Storage
Industry
Public support
Proximity
Perceived safety
Trust

ABSTRACT

Carbon Capture and Storage at industrial processes (industrial CCS) is expected to play an important role in reducing industrial CO_2 emissions in the short term. Industrial CCS involves capturing CO_2 from industrial processes, such as steel and cement making, and storing the CO_2 underground. This study examined the public opinion of industrial CCS through an informed opinion survey in the Netherlands (N = 987) and the United Kingdom (UK; N = 974). On average, respondents were neutral to slightly positive about the implementation of industrial CCS in their country. UK respondents were slightly more positive (M = 4.66 on a 7-point scale) than Dutch respondents (M = 4.38). Awareness and perceived knowledge levels were somewhat higher in the Netherlands than in the UK. In both countries, perceived outcomes of industrial CCS (e.g. for climate change; safety; employment) were strongly associated with industrial CCS opinion, when compared to socio-demographics, proximity to industry (actual and perceived), and psychological variables. Differences between countries in outcome perceptions occur. For example, the safety of CO_2 transport is a larger concern in the Netherlands than in the UK, while cost-control is a larger concern in the UK than in the Netherlands. These findings suggest that the national context for CCS implementation matters. Our research suggests that public engagement strategies will benefit from focusing on the economic and climate impacts of industrial CCS, as well as from building trust in industry and addressing perceived safety concerns surrounding different aspects of industrial CCS.

1. Introduction

To meet global carbon dioxide (CO_2) emission reduction targets, the decarbonization of industrial processes needs to accelerate [1]. Some organizations envision Carbon Capture and Storage (CCS) as an important component of a portfolio of effective decarbonisation options for industry [2,3]. CCS is used to capture CO_2 at a large emission source, such as a steel factory or power plant, transport the CO_2 via pipeline or ship to an offshore or onshore geological storage site located deep underground, such as a saline formation or depleted oil or gas field, and store the CO_2 there permanently. Many heavy industries, such as steel and cement, currently have limited alternatives to CCS for large-scale reduction in CO_2 emissions in the short term [4,5].

In the Netherlands and the United Kingdom, plans have been made to implement CCS in the industrial sector (i.e. industrial CCS) in the near future. Governments in both countries have expressed ambitions for implementing industrial CCS and have supported these ambitions with policy instruments [6–9]. As a result of these ambitions, both countries currently have industrial CCS projects in preparation, such as the Porthos and Athos projects in the Netherlands and the Net Zero Teesside (NZT) project in the UK.

In both countries, CCS ambitions have shifted in recent years from power generation (e.g. at coal-fired power plants) to CO_2 capture at industrial facilities, such as steel, cement, chemicals and oil refining. Before the recent shift to industrial CCS, implementation had long been hampered after an initial period of enthusiasm for CCS [10,11]. Many

* Corresponding author.
E-mail addresses: kevin.broecks@tno.nl (K. Broecks), corin.jack@ed.ac.uk (C. Jack), emors@fsw.leidenuniv.nl (E. ter Mors), christine.boomsma@rivm.nl (C. Boomsma), simon.shackley@ed.ac.uk (S. Shackley).

https://doi.org/10.1016/j.erss.2021.102236
Received 4 December 2020; Received in revised form 22 July 2021; Accepted 30 July 2021
Available online 26 August 2021
2214-6296/© 2021 Elsevier Ltd. All rights reserved.

demonstration projects that aimed to bring CCS closer to large-scale implementation suffered from shifts in government support [11], often underpinned by a lack of public support [12,13]. Without such support, companies did not have a business case to invest in CCS. Whether industrial CCS can retain sufficient support for large-scale implementation from governments, the public and other stakeholders remains to be seen. We focus on evaluating public support for industrial CCS given that this is a potential barrier for implementation [12–14].

A lack of public support may weaken political support for CCS implementation, reduce deployment speed and affordability, and may limit the variety of useable transport and storage pathways [14]. The status of onshore CO_2 storage in the Netherlands exemplifies the latter: following public opposition to a CCS demonstration project near Barendrecht, which included onshore storage [14], the Dutch government decided to only use offshore storage in the foreseeable future [6]. Engaging with the public may build support for industrial CCS, while unearthing conflict in a constructive manner [15], improving decision making quality [16] and fostering trust in institutions [17]. Understanding how citizens' opinions of industrial CCS come about is vital to support public engagement practices.

This understanding is limited because few studies have explored the public opinion about *industrial* CCS. Recent quantitative comparative studies show that industrial CCS may be perceived as either slightly more negative [18] or positive [19] than CCS at coal-fired power plants. Another qualitative study showed little difference, but suggested that citizens interpret industrial and fossil fuel CCS differently: while CCS at coal-fired power plants was viewed as a way to protect local jobs, CCS at industry was seen as a means to not only protect, but expand desirable economic activities [20]. In a study conducted in Germany, opinions about industrial CCS were indeed influenced by how important respondents found industry for jobs, prosperity and economic development [19]. Further work in this area is needed to systematically explore how the characteristics of industrial CCS, as well as individual-level factors, affect citizens' opinions about industrial CCS.

Many factors that may potentially affect these opinions have already been explored by studies focused on CCS at power plants or on CCS described in general terms. These studies show that citizens' opinions about CCS are mixed: some citizens are positive, others are negative, and on average public opinion hovers around the 'neutral' midpoint [19,21–24]. Depending on their country of origin, roughly one quarter to three quarters of citizens have heard about CCS. Yet, they commonly know little about it [18,19,25–27]. After reading information about the various options for reducing CO_2 emissions from power generation, they tend to prefer other options, such as solar panels, wind turbines, or biomass, over CCS [18,23,28–32].

Citizens' opinions differ between CCS applications, such as CO_2 capture at coal- or biomass-fired power plants, and depend on the risks, costs and benefits associated with these applications [23–25,33]. For example, citizens commonly appreciate the contribution of CCS to climate change mitigation, job creation and improved air quality, while they tend to be concerned about its safety risks (e.g. CO_2 leakage) and rising electricity prices [22,23]. Citizens have also expressed concerns about the end-of-pipe nature of CCS [25] and its competition with renewable energy technologies for resources [34].

Citizens' opinions are further influenced by individual differences, such as knowledge about CCS, climate change belief, trust in CCS stakeholders, and socio-demographic factors [18]. Opinions about CCS tend to be more negative when citizens are sceptical toward climate change [18,35] or distrust CCS stakeholders [25]. Furthermore, younger and male citizens are more positive about industrial CCS [18,23]. Finally, knowledge about CCS tends to have limited or mixed effects on their opinion about CCS [25,35]. These factors may partially explain how citizens' opinions about *industrial* CCS come about, but several factors have remained unexplored.

First, the influence of citizens' perceptions of the economic impact of implementing CCS on CCS opinion remains unexplored. Decarbonizing industry via CCS – and introducing policy instruments for decarbonization – may have substantial effects on companies, consumers, and government spending. These effects may include job creation, rising prices for consumer products, reductions or boosts in industrial companies' competitiveness, increases in government spending via subsidies, and detrimental effects on investments in other decarbonization options [1,36]. Focus groups conducted in the UK have shown that some citizens view industrial CCS as providing societal benefits through growth in manufacturing industries, while others were concerned about industrial CCS imposing costs that could damage employment [20]. Yet, previous studies into opinions of the economic costs of implementing CCS have focused exclusively on rising electricity prices for households and companies as a result of implementing CCS at power plants [23,31]. In this study, we investigate a spectrum of *'outcome perceptions'* to foster the understanding of how industrial CCS opinions come about. We define '*industrial CCS opinions'* as the opinions of citizens about the implementation of industrial CCS in their country, and '*outcome perceptions*' as citizens' perceptions of the anticipated risks, costs, or benefits of this implementation, which includes climate, safety and economic outcomes.

Second, findings for the effect of the *'proximity'* of citizens' households to CCS infrastructure on their opinions about this infrastructure are inconclusive. Some studies find positive effects on opinion of the proximity of citizens' households to CO_2 capture sites [18,22], while other studies find negative effects on opinion for proximity to CO_2 storage sites [33,37]. For offshore storage, the proximity of citizens' households to the coast may also play a role: in a study in Germany, offshore CO_2 storage was seen as a slightly better option than onshore storage among the general public, but citizens of coastal regions were equally negative about both storage options [38]. Citizens' perceptions of the outcomes of implementing CCS have often been used to interpret proximity effects: citizens that live, or perceive themselves to live, close to industry may benefit from the direct and indirect jobs that these industries provide, but may also be exposed to health, safety and environmental risks due to the proximity of these industries to their homes [39,40]. Other explanations that are given for proximity effects focus on the history and familiarity that citizens living close to industry have with these industries [18]. These citizens may have formed a strong sense of industrial identity [41–44], expressing a sense of pride in the industrial legacy of the region where they live [45], or perceiving industrial decline as a great threat to the local community [43]. Such positive *'industry attitudes'* may foster positive opinions about projects these industries undertake, such as CCS. It is unclear whether any proximity effects remain when citizens' perceptions of economic outcomes, as well as industry attitudes, are taken into account.

Third, the effects of outcome perceptions, proximity and industry attitudes on industrial CCS opinion may differ between countries due to differences in culture [46–48], historical experiences with technology [49], or strategic and local planning procedures [50]. However, cross-country comparisons of these effects are rarely conducted, with some notable exceptions [18,48]. One of these studies shows that the country of origin (UK, NL, USA and Norway) affects pre-information support for CCS (in general), as well as change in support after information about CCS is read [18]. Another study shows that country level differences in national culture affect the perceptions of risks and benefits of CCS (in general) in these countries (12 EU countries) [48]. Yet, these studies have not focused on industrial CCS, nor have they examined how proximity and industry attitudes have different effects in different countries.

In this study, we compare opinions between the Netherlands and the UK, where industrial CCS is likely to be implemented in the near future. These countries share a common national narrative for CCS implementation [13], but differ in their historical experiences with CCS — most notably the local public opposition and negative media attention that accompanied demonstration projects for onshore storage in the Netherlands [51]. Comparing the determinants of public opinion, such

as outcome perceptions, industry attitudes and proximity, between these countries may indicate how the national context of CCS implementation (e.g. narratives, historical experiences) influences these determinants.

To fill the three literature gaps, we answered the following research questions:

1. What opinions do citizens have of implementing industrial CCS and of the outcomes that are associated with implementation?
2. What is the relationship of citizens' outcome perceptions, industry attitudes and the proximity of their household to industrial installations with their opinions about implementing industrial CCS?
3. To what degree do these opinions and relationships differ between the UK and the Netherlands?

To answer these research questions, we conducted a cross-country informed opinion survey in the Netherlands and the UK. We used an informed opinion survey because citizens tend to have limited knowledge of CCS, the creation of CO_2 emissions by burning fossil fuels and the relationship between CO_2 emissions and climate change [27]. In an informed opinion survey, respondents read information about a topic before giving their opinion about it. Opinions gathered after information is given are more stable and more predictive of future opinions than uninformed opinions, especially when knowledge levels are low [23,28,52]. In our informed opinion survey, respondents read information that was reviewed by experts from various research fields to ensure the information represents the state-of-the art.

In the survey, we included items to measure outcome perceptions, industry attitudes, and the actual and perceived proximity of citizens' households to industry. To examine what these factors add to explaining industrial CCS opinion compared to previous research, we conducted a regression analysis that included other factors that have been shown to affect CCS opinions: knowledge about CCS, climate change belief, trust in CCS stakeholders, proximity to the coast and socio-demographic factors. We also asked respondents to the survey to explain their opinion about industrial CCS in a few sentences. We then conducted a content analysis of these explanations to investigate the arguments respondents used to substantiate their opinion. Investigating these arguments provides context for the results of the regression analysis and may help to identify influential factors that were not included in the regression.

By filling in the knowledge gaps set out above, this research contributes to a better understanding of how citizens' opinions of decarbonization technologies that require large-scale infrastructure come about. As such, the findings also provide insight into likely influential factors for citizens' opinions of other industrial decarbonization technologies, such as green hydrogen, blue hydrogen, or geothermal energy. Although each technology presents its own context, many parallels can be drawn with industrial CCS. In the coming years, many countries, such as the UK and the Netherlands, will likely move toward implementation of these types of technologies. The insights we present are vital to support the engagement and site selection strategies that need to go along with implementation.

2. Method

2.1. Participants

For both the survey in the Netherlands and the survey in the UK, two groups were sampled: 1) respondents living close to industry and 2) respondents from the general public (including some respondents living close to industry).[1]

To determine the relevant postcodes for respondents living in the vicinity of industry, two criteria were applied based on spatial proximity to business parks and/or large industrial companies along with the levels of CO_2 emissions (kton per annum). In the Netherlands, all postcodes located within a 1 km range from a business park with CO_2 emissions over 10 kton per annum were included in the postcode database. In the UK, all postcodes lying within a 5 km range of large industrial facilities and all emitting 50kton CO_2 per annum or more were identified and located. All facility CO_2 emission figures in the Netherlands were gathered from the National Institute for Public Health and the Environment (RIVM) and from The Environment Agency in the UK. The differences between the UK and Dutch sampling approaches were designed to take into account the different population densities located around industrial areas.

The sampling strategy resulted in a total of four groups of respondents. Respondents from these four groups of ages eighteen and above were recruited for the study by a market research company (Dynata) with an equal distribution of respondents between groups. Respondents received an incentive for their participation (e.g. panel points that they could use for various means). For the general public subsamples, the aim was to obtain a nationally representative sample in terms of age, gender and education level (see Table 1). The surveys conducted in the UK and the Netherlands were both administered in November 2019.

The total number of completed surveys from the UK and the Netherlands was 2215. The survey data was inspected for outliers (i.e. filling out the survey too quick/slow, flatliners, nonsense qualitative responses) prior to the analyses. In total 254 responses were deleted from the dataset resulting in a final sample of 1961 respondents. Table 1 shows the demographic characteristics of the final sample used for the analyses.

2.2. Procedure and materials

As the survey focused on measuring informed opinions about industrial CCS, respondents received information prior to assessing opinions. The information used in this study was based on previous literature on the topic of CCS [23,28,53]. Some additional details were added by the research team where needed. All information was reviewed by fourteen experts from academia, research institutes and industry, and subsequently updated and checked by the research team. Additionally, a lay-person piloting ($N = 8$) of the survey was conducted to check for comprehension. Ethical approval for this study was obtained by the Ethics Committee of one of the authors' universities.

Two versions of the informed survey were created, one in English and one in Dutch. Each version referred only to the implementation of industrial CCS in the respondent's respective country. The surveys were identical except for minor details. See Table 2 for an overview of structure of the survey, Appendix A for the information materials

[1] In the UK, 25.3% of the general public subsample lived in the vicinity of industry. In the Netherlands, 2.5% of the general public subsample lived in the vicinity of industry, while 6.5% of this subsample could not be classified due to incomplete postcode data. We have conducted a robustness check on all analyses in the paper, reclassifying these respondents as living close to industry (respondents with incomplete postcode data were excluded). The pattern of results was identical to that reported in the paper.

Table 1
Demographics of final sample (N = 1961).

		UK		NL	
		Close to industry (*N* = 491)	General public (*N* = 483)	Close to industry (*N* = 501)	General public (*N* = 486)
Gender	Male	41.3%	48.2%	43.9%	46.1%
	Female	58.5%	51.8%	56.1%	53.9%
	Other	0.2%			
Age	18–24	5.4%	9.3%	9.2%	9.2%
	25–34	12.2%	13.3%	11.5%	12.5%
	35–44	18.8%	14.9%	15.7%	14.3%
	45–54	18.8%	19.4%	21.8%	20.3%
	55–64	19.2%	20.0%	18.4%	20.8%
	65–75	25.8%	23.2%	23.3%	22.9%
	Mean	51.0	49.7	50.1	49.6
	Standard deviation	15.2	16.0	16.1	16.0
Education level	No qualification	10.0%	13.3%	0.4%	0.8%
	Primary school	2.2%	1.7%	4.0%	3.9%
	GSCE or equivalent	29.9%	30.4%		
	A-levels or equivalent	24.4%	21.5%		
	Secondary school			25.3%	47.9%
	MBO/HBO [1]			56.9%	38.9%
	University degree	28.5%	29.6%	11.6%	7.4%
	Doctoral degree	4.1%	2.7%	1.2%	0.8%
	Don't know/ rather not say	0.8%	0.8%	0.6%	0.2%

Note. [1]based on the European qualifications framework (EQF) this education level includes qualifications equivalent to the UK: GCE, A-level, HNC, HND and Honours degree.

(including the outcomes), and Section 2.3 for an explanation of the measurement items.

After filling in an informed consent form, respondents read information and answered questions alternately. The survey first covered information about CO_2 and climate change and asked respondents about climate change belief. After introducing the options for reducing CO_2 emissions (e.g. saving energy, switching to alternative energy sources, or CCS), respondents were asked about their awareness and knowledge of CCS. The survey then proceeded to an explanation of how industrial CCS works, followed by questions about industry attitudes.

Respondents were then presented with a credible implementation scenario for industrial CCS in their country, and its associated outcomes (see Appendix A). The aim was to give respondents enough information to understand the anticipated outcomes of implementing industrial CCS in their country. The scenario focused on a credible technological configuration for industrial CCS based on current policy discussions in the UK and the Netherlands: (1) CO_2 capture at steel, (and also from cement works in the UK), chemicals industries and at waste incineration plants, (2) onshore and offshore transport via pipelines, and (3) offshore storage in depleted gas fields or saline formations located deep below the seabed.

Respondents were then presented with nine likely outcomes of implementing industrial CCS in their respective country. The outcomes were grouped into four main topic blocks (see Table 2). The order in which the blocks of outcomes was presented to respondents was randomized to prevent any effects on opinions based on the order in which the outcomes were presented. After each outcome, respondents rated the respective outcome on importance and gave an evaluation on a negative-positive response scale. Respondents were familiarized with the format of the outcome rating questions through a sample question on an unrelated topic (i.e. smartphone use).

Table 2
Overview of survey components.

Topic block	Information topics	Measurement items
Climate change	CO_2, climate change, approaches for reducing CO_2 emissions	Climate change belief
CCS awareness and knowledge		CCS awareness and knowledge
Industrial CO_2 emissions and CCS	CO_2 emissions from industry, industrial CCS, CO_2 capture, CO_2 transport, CO_2 storage	Industry attitudes
CCS implementation scenario & outcomes	Summary of previous information	Outcome perceptions
	Scenario: CO_2 capture at industrial facilities, onshore and offshore pipeline transport, offshore CO_2 storage, need for investments in facilities and infrastructure	
	Outcome block (climate): climate change	
	Outcome block (economy): employment, subsidies, effects on companies & consumers, effects on other options	
	Outcome block (transport): construction work on pipelines, safety onshore CO_2 pipelines, safety offshore CO_2 pipelines	
	Outcome block (storage): safety offshore CO_2 storage	
CCS opinion		Industrial CCS opinion
		Explanation of opinion
Other questions		Trust in CCS stakeholders
		Perceived proximity
		Gender
		Age
		Education level

After rating the outcomes, respondents gave their opinion on the implementation of industrial CCS in their country and provided an explanation of their opinion via an open response question. Subsequently, respondents answered all remaining questions (i.e. trust in CCS stakeholders, perceived proximity and socio-demographics). At the end of the survey, respondents were thanked and debriefed.

2.3. Measures

The remainder of this section discusses the measurement items that were included in the analyses of this paper. The survey included additional items to fulfil the aims of the research project this study was a part of.

2.3.1. CCS awareness and knowledge

We assessed awareness and knowledge of CCS using items from a previous study [23]. CCS awareness was measured with the question "Have you ever heard of CO_2 capture and storage?" with three answer categories: (1) "No, never heard of it", (2) "Yes, heard of it, but know hardly anything about it", (3) "Yes, heard of it and know quite a bit about it". Only if respondents answered the awareness question affirmatively, they were asked a follow-up question about their knowledge about CCS.

CCS knowledge was measured with the question "How much do you know about CO_2 capture and storage?". Respondents rated their knowledge levels on a 7-point response scale ranging from 1 (nothing at

all) to 7 (a lot). Respondents who indicated that they had never heard of CCS in response to the awareness question, were given a score of 1 (i.e. nothing at all) on knowledge.

2.3.2. Outcome perceptions

For each industrial CCS outcome, respondents were asked to what extent they considered the outcome to be important on a 7-point response scale ranging from 1 (very unimportant) to 7 (very important), and to what extent they evaluated the outcome as negative or positive on 7-point response scale ranging from 1 (very negative) to 7 (very positive).

2.3.3. Industrial CCS opinion

To measure opinion about industrial CCS, respondents were asked: "To what extent do you perceive the implementation of industrial CCS in [the UK/the Netherlands] to be positive or negative?" Answers were given on a 7-point response scale ranging from 1 (very negative) to 7 (very positive).

2.3.4. Qualitative response: explanation of opinion

To gather additional insights into citizens' opinion about the implementation of industrial CCS in their country, after respondents answered the opinion question, we asked them to explain their opinion using an open-ended question. This encouraged respondents to elaborate on their arguments behind their opinion about industrial CCS.

2.3.5. Climate change belief

To measure respondents' belief in climate change, respondents were asked "Do you personally think the world's climate is changing or not?" This item was adapted from previous research [54] and used to measure a dimension of climate change scepticism referred to as "trend scepticism". The question had four response categories: (1) definitely not changing, (2) probably not changing, (3) probably changing, and (4) definitely changing. For the analyses, these categories were recoded into two categories: (1) definitely or probably not changing, and (2) definitely or probably changing.

2.3.6. Industry attitudes

To measure the respondents' attitudes towards the industries mentioned in the information materials (steel, cement, chemicals and waste incineration), we used four items. We used three statements with a 7-point response scales ranging from 1 (strongly disagree) to 7 (strongly agree): "I feel connected to these industries", "I am proud of these industries", "I like to keep up with changes regarding these industries". These items were based on items measuring place attachment [55], but were adapted to fit the context of the current research. We also used one question with a 7-point response scale ranging from 1 (very negative) to 7 (very positive): "To what extent do you perceive these industries as positive or negative?" The responses to these four items were averaged to construct one industry attitudes scale. The reliability of the scale was good ($\alpha = 0.84$).

2.3.7. Trust in CCS stakeholders

We assessed trust separately for three types of CCS stakeholders: industry, scientists and national government. We used two questions: (1) "To what extent would you trust the following parties with regards to providing information on implementing industrial CCS in [the UK/the Netherlands]?", and (2) "To what extent would you trust the following parties with regards to making decisions about implementing industrial CCS in [the UK/the Netherlands]?". Answers were given on a 7-point response scale ranging from 1 (not at all) to 7 (completely). For each CCS stakeholder, the responses to these two questions were averaged to construct one trust scale. The reliability of the scales was good ($rs = 0.81–0.87$, $ps < 0.001$).

2.3.8. Actual and perceived proximity

To assess the effect of *actual proximity* of respondents' households to industrial installations, we included a dummy variable in the analyses for the subsample: general public subsample versus close to industry subsample. To asses *perceived proximity* to industry and to the coast, respondents were asked: "On a scale ranging from 1 (close) to 5 (distant), how distant or close do you feel your home is to the nearest [industrial area/coast]?". Answers were given on a 5-point response scale ranging from 1 (close) to 5 (distant).

2.4. Content analysis

The explanations respondents gave for their opinion about industrial CCS through open responses were analysed using content analysis. In Step 1, all responses ($N = 1961$) were assigned a primary level code based on the general orientation of the response; positive, negative, neutral, mixed or responses unrelated to the question (other). In Step 2, if applicable, more specific secondary level codes were assigned to the responses. These secondary level codes were identified through a thematic analysis of the responses. Once the coding framework was finalised, an inter-coder reliability test was performed between two coders to assess the external consistency of the coding framework using a randomised subsample of responses ($N = 141$). This reliability test was achieved by comparing the percentage agreement between the two coders (number of matched codes / total number of codes). The resulting percentage agreement (72%) was above the minimum agreed threshold of 70% [56] and was therefore deemed suitable for application to the full sample.

3. Results

In this section, we first discuss CCS awareness and knowledge levels, perceptions of the outcomes of implementing industrial CCS in the UK and the Netherlands, as well as overall opinion of industrial CCS. Second, we explore the reasoning respondents used to explain their opinion through a content analysis of the open responses. Finally, we explore the relationship between industrial CCS opinion and outcome perceptions, industry attitudes, and proximity. We modelled these relationships separately for the UK and the Netherlands to explore country differences in these relationships.

3.1. CCS awareness and knowledge

At the start of the survey, respondents were asked for their awareness about CCS (see Table 3). Most respondents in the survey had heard of CCS (64.2%), but most respondents indicated that they know hardly

Table 3
CCS awareness and knowledge per country and in total.

		UK (N = 974)	NL (N = 987)	Total (N = 1961)
CCS awareness ("Have you ever heard of CO_2 storage?")	No, never heard of it	44.3%	27.4%	35.7%
	Yes, heard of it, but know hardly anything about it	46.6%	59.2%	52.9%
	Yes, heard of it and know quite a bit about it	9.1%	13.5%	11.3%
CCS knowledge ("How much do know about CCS?")	1 (nothing at all)	48.0%	33.5%	40.7%
	2	14.8%	18.9%	16.9%
	3	10.3%	15.3%	12.8%
	4	13.9%	16.6%	15.2%
	5	8.1%	11.4%	9.8%
	6	3.0%	3.7%	3.4%
	7 (a lot)	2.0%	0.4%	1.2%
	Mean	2.36	2.66	2.51
	Standard deviation	1.64	1.56	1.61

anything about it (52.9%) rather than quite a bit about it (11.3%).

Crosstab analyses were used to test for differences in CCS awareness between countries and subsamples. Awareness of CCS differed significantly between the two countries, χ^2 (2) = 61.90, $p < .001$, whereas no significant difference in CCS awareness was found between the general public and industry subsamples, χ^2 (2) = 1.46, $p = .482$. Awareness of CCS was found to be somewhat higher in the Netherlands than in the UK (see Table 3).

After the awareness question, respondents that had heard of CCS were asked to indicate how much they thought they knew about CCS. Respondents who indicated that they had never heard of CCS in response to the awareness question, were given a score of 1 (i.e., nothing at all) on CCS knowledge. Table 3 depicts the results found for CCS knowledge. Overall, many respondents in the survey indicated to know nothing at all about CCS (40.7%) and self-reported knowledge about CCS was low, on average ($M = 2.51$, $SD = 1.61$).

We tested for differences in CCS knowledge between countries and subsamples using two-way ANOVA. The ANOVA showed that CCS knowledge was significantly predicted by country, $F(1, 1957) = 17.55$, $p < .001$, $\eta_p^2 = 0.01$ (i.e. a small effect size), but not by subsample, $F(1, 1957) < 1$, $p = .734$, nor by the interaction between country and subsample, $F(1, 1957) < 1$, $p = .447$. Knowledge of CCS on average was somewhat higher in the Netherlands than the UK (see Table 3)[2].

3.2. Outcome perceptions

After reading information about an outcome of implementing industrial CCS, respondents rated the outcome on its importance and whether they perceived it as positive or negative (see Table 4). Overall, respondents perceived all outcomes of implementing industrial CCS in their country as relatively important. Furthermore, the outcomes of industrial CCS for *climate change*, *effects employment*, *effects industrial companies, effects other options* and *need subsidies* were seen by respondents as quite positive, whereas outcomes for *safety transport onshore, safety transport offshore, safety offshore storage*, and *new pipelines* were seen as neutral to slightly negative.

We tested for differences in outcome perceptions between countries and subsamples using a two-way MANOVA with Pillai's trace. The MANOVA showed that outcome perceptions were significantly predicted by country, $F(18, 1940) = 4.67$, $p < .001$, $\eta_p^2 = 0.04$, and by the interaction between country and subsample, $F(18, 1940) = 1.96$, $p = .009$, $\eta_p^2 = 0.02$, but not by subsample, $F(18, 1940) = 1.49$, $p = .082$. Follow-up two-way ANOVAs on outcome importance showed small, significant effects of country: respondents from the UK perceived the outcomes *climate change*, *new pipelines*, *safety offshore storage*, *effects employment*, *effects industrial companies*, and *need subsidies* as somewhat more important than respondents from the Netherlands, $Fs(1, 1957) \geq 3.88$, $ps \leq 0.049$, $\eta_p^2 s \leq 0.02$. No significant differences in outcome importance between countries were found for the outcomes *safety transport onshore, safety transport offshore,* and *effects other options*, $Fs(1, 1957) \leq 3.07$, $ps \geq 0.080$.

The ANOVAs further showed small, significant effects of country on outcome evaluations: respondents from the UK evaluated the outcomes *climate change*, *safety transport onshore, safety transport offshore, new pipelines*, *safety offshore storage*, *need subsidies*, and *effects other options* as somewhat more positive than respondents from the Netherlands, $Fs(1, 1957) \geq 4.08$, $ps \leq 0.044$, $\eta_p^2 s \leq 0.01$. No significant differences in outcome evaluations between countries were found for the outcomes *effects employment* and *effects industrial companies*, $Fs(1, 1957) \leq 1.21$, $ps \geq 0.271$.

Furthermore, the ANOVAs revealed small, significant interaction effects between country and subsample for the importance of the outcome *effects industrial companies,* and the evaluation of the outcome *safety offshore storage* only, $Fs(1, 1957) \leq 6.19$, $ps \leq 0.013$, $\eta_p^2 s \leq 0.01$. Even though the overall statistical test on the importance of the outcome *effects industrial companies* was statically significant, follow-up tests showed that both in the UK and in the Netherlands respondents in the industry sample did not consider the *effects industrial companies* outcome differently ($M_{UK} = 4.99$, $SD = 1.37$; $M_{NL} = 4.63$, $SD = 1.25$) compared to respondents from the general public sample ($M_{UK} = 4.83$, $SD = 1.28$; $M_{NL} = 4.72$, $SD = 1.30$), $ps \geq 0.057$. Regarding the interaction effect on the evaluation of the outcome *safety offshore storage* in the UK, respondents in the industry subsample were somewhat more negative about the outcome ($M = 3.85$, $SD = 1.65$) than respondents from the general public subsample ($M = 4.13$, $SD = 1.59$), $p = .007$. In the Netherlands, respondents in the industry subsample were equally positive about the outcome ($M = 3.68$, $SD = 1.53$) compared to respondents in the general public sample ($M = 3.60$, $SD = 1.58$), $p = .445$.

Table 4
Industrial CCS outcome perceptions per country and in total.

		UK ($N = 974$)		NL ($N = 987$)		Total ($N = 1961$)	
		M	*SD*	*M*	*SD*	*M*	*SD*
Outcome importance (1 = very unimportant, 7 = very important)	Climate change	5.28	1.37	5.13	1.34	5.20	1.36
	Safety transport onshore	5.11	1.47	4.99	1.44	5.05	1.46
	Safety transport offshore	5.09	1.44	4.99	1.41	5.04	1.43
	New pipelines	4.86	1.43	4.45	1.39	4.65	1.42
	Safety offshore storage	5.15	1.44	4.96	1.45	5.06	1.45
	Effects employment	4.91	1.33	4.79	1.31	4.85	1.32
	Effects industrial companies	4.91	1.33	4.67	1.28	4.79	1.31
	Need subsidies	4.97	1.39	4.79	1.33	4.88	1.36
	Effects other options	4.87	1.32	4.77	1.24	4.82	1.28
Outcome evaluation (1 = very negative, 7 = very positive)	Climate change	5.11	1.47	4.92	1.39	5.01	1.43
	Safety transport onshore	4.06	1.59	3.77	1.55	3.91	1.58
	Safety transport offshore	4.05	1.63	3.71	1.58	3.88	1.62
	New pipelines	4.11	1.51	3.88	1.34	3.99	1.43
	Safety offshore storage	3.99	1.62	3.64	1.56	3.81	1.60
	Effects employment	4.89	1.37	4.82	1.24	4.85	1.31
	Effects industrial companies	4.28	1.44	4.21	1.33	4.24	1.38
	Need subsidies	4.62	1.51	4.49	1.41	4.56	1.46
	Effects other options	4.19	1.42	3.98	1.39	4.09	1.41

[2] For the Netherlands, the levels of CCS awareness and knowledge found in our study are similar to studies conducted 6–10 years ago [22,23,27,57]. For the UK, awareness was substantially higher in our study than in studies conducted in that time period [22], a finding that is corroborated by recent research [18], suggesting that CCS awareness in the UK has risen in the past years.

3.3. Industrial CCS opinion

After having read an introduction about industrial CCS, the specific CCS scenario for their country and information about the outcomes of implementing CCS in their country, respondents indicated their overall opinion about the implementation of industrial CCS in their country (see Table 5). Respondents in the survey reported a range of opinions, although most opinions reported were neutral to positive. On average, respondents were neutral to slightly positive about industrial CCS implementation in their country ($M = 4.52$, $SD = 1.45$).

We tested for differences in industrial CCS opinion between countries and subsamples using a two-way ANOVA. The ANOVA showed that industrial CCS opinion was significantly predicted by country, $F(1, 1957) = 19.15$, $p < .001$, $\eta_p^2 = 0.01$ (i.e. a small effect size), but not by subsample, $F(1, 1957) < 1$, $p = .695$, nor by the interaction between country and subsample, $F(1, 1957) < 1$, $p = 0.808$. As can be seen in Table 5, UK respondents were on average somewhat more positive towards the implementation of industrial CCS in their country compared to respondents from the Netherlands.

3.4. Content analysis of respondents' explanation of their industrial CCS opinion

Open responses were analysed to provide insights into the reasoning behind respondents' opinion about industrial CCS. This section will present the main findings both regarding the broader orientation of responses in the primary coding, as well as for the specific secondary themes identified. A comparison between countries' responses will be discussed, as well as parallels between the findings reported in Sections 3.2 and 3.3.

Overall, the findings for the primary level coding presented in Fig. 1 display a somewhat even division of codes applied across the five primary level categories. However, there were some differences when comparing the open responses between the UK ($N = 974$) and Dutch samples ($N = 987$). In line with the distribution of industrial CCS opinion displayed in Table 5, the primary level coding in Fig. 1 shows that there was a somewhat higher level of exclusively positive arguments in the UK sample (29%) compared to the Dutch sample (22%), and slightly more exclusively negative arguments in the Dutch sample (22%) compared to the UK sample (19%). In both countries the relatively high number of 'neutral' and 'other' arguments may suggest that many respondents did not have a strong opinion on industrial CCS. This is in line with the neutral to slightly positive opinions about industrial CCS implementation discussed in Section 3.3.

The secondary level codes provided more detailed insights into the specific arguments used by respondents to explain their opinion of industrial CCS. Depending on the content of the response, respondents were either assigned no, one, or multiple secondary level code(s). As a result, the total number of secondary codes differs from the primary level codes ($N_{UK} = 1037$, $N_{NL} = 897$). The common arguments raised by respondents are presented in Table 6 (positive arguments), Table 7 (negative arguments), and Table 8 (neutral arguments). The highest proportion of the arguments was negative, followed by positive and neutral arguments. The most apparent difference between countries was in the balance of positive and negative arguments raised. In the UK responses, there was an 8% higher proportion of positive arguments cited when compared with the Dutch responses (39% and 31% respectively) and a higher proportion of negative arguments cited in the Dutch responses when compared to UK responses (51% and 44% respectively).

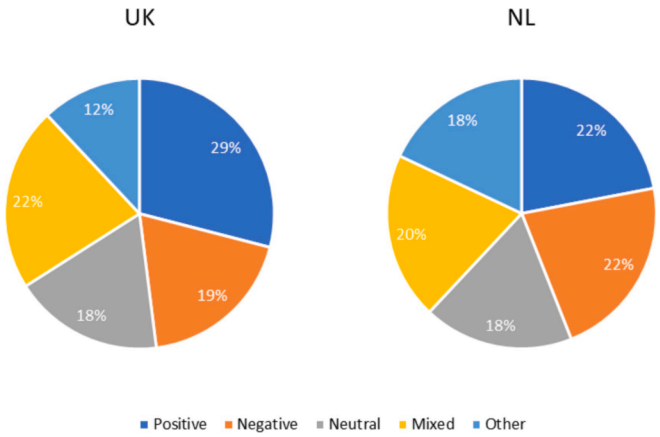

Fig. 1. Proportion of primary level codes applied to respondents' opinion explanations for the UK (N = 974) and the Netherlands (N = 987).

Table 5
Industrial CCS opinion per country and in total.

		UK (N = 974)	NL (N = 987)	Total (N = 1961)
Industrial CCS opinion(To what extent do you perceive the implementation of industrial CCS in [the UK / the Netherlands] to be positive or negative?")	1 (very negative)	4.2%	4.2%	4.2%
	2	4.0%	5.9%	4.9%
	3	8.6%	13.8%	11.2%
	4	27.2%	25.9%	26.6%
	5	28.2%	30.0%	29.1%
	6	16.0%	15.1%	15.6%
	7 (very positive)	11.7%	5.2%	8.4%
	Mean	4.66	4.38	4.52
	Standard deviation	1.47	1.41	1.45

Table 6
Positive secondary codes of respondents' opinion explanations.

Code label	Example quotes	% of total positive codes UK (N = 407)	% of total positive codes NL (N = 282)
Economic/industry benefits	"If this means that all economic activities in the Netherlands can take place such as strong agriculture and home construction, this is great and protects economic growth for the future."	2.7	3.9
Climate change/ environmental benefits	"If it's less pollution in the atmosphere that's has to be a good thing."	38.1	41.1
Best available/ temporary solution	"I believe it has its advantages and disadvantages. But for now, it is a temporary solution to deal with the climate problem."	13.3	19.1
Good for the future/ long-term	"It will have little effect on my life but for my grandkids I think it is important."	5.2	5.0
Climate change action needed	"The world has to wake up and do whatever is needed urgently."	18.4	17.7
Industrial CCS positives outweigh the negatives	"There are small risks, but the overall result should be positive."	13.0	3.9
Industrial CCS safe/ low risks	"I feel it's safe to proceed this way as any leaks can be sorted."	6.4	5.7
Industrial CCS employment benefits	"If it helps to reduce CO_2 emissions and creates jobs at the same time then it's a good thing."	2.9	3.5

Table 7
Negative secondary codes of respondents' opinion explanations.

Code label	Example quotes	% of total negative codes UK (*N* = 451)	% of total negative codes NL (*N* = 456)
Safety/risk/ monitoring concerns	"Risks of leaks and danger to people and wildlife is worrying."	45.9	44.5
Industrial CCS does not solve the problem	"[…] Sustainable methods of production for these industries are more important than short term solutions."	13.7	13.6
Support alternatives to industrial CCS	"I'm concerned that this may provide a slower than otherwise effort to reduce CO_2 production."	17.5	20.0
Industrial CCS storage capacity	"How far down do you intend to store CCS and what or how will it be done, what if there is no more room to store underground where will you store it next – in space?"	1.3	1.8
Industrial CCS expensive/ increased taxes/ consumer costs	"The more money required for this will mean we get taxed more."	11.3	6.8
Distrust CCS stakeholders	"It is yet another money-making scheme for the wealthy and another burden for the less well-off who will in the end, end up paying more money out."	3.8	3.9
Responsibility/ accountability needed from CCS stakeholders	"Companies must look for a solution and pay, if not stop the company."	3.1	5.0
Limited job opportunities	"We are going to get a lot of unemployed again."	1.1	0.9
Climate change scepticism	"In my opinion, this is not necessary, it is a purely natural process which you cannot change."	2.2	3.5

Table 8
Neutral secondary codes of respondents' opinion explanations.

Code label	Example quotes	% of total neutrall codes UK (*N* = 179)	% of total neutral codes NL (*N* = 159)
Unsure about CCS/ more research required	"Industrial CCS offers solutions, but I am not yet fully convinced."	58.1	54.7
Individual need for more information	"I'm not 100% sure how I feel, I don't think I've been given enough information to make an informed choice."	17.3	13.2
Too complex/ difficult topic	"I am careful with my judgement because it is all fairly new, and I don't understand much of it."	11.2	11.3
International participation needed for industrial CCS	"The Netherlands is a dot on the world map. How can that help if countries such as China, America, Eastern European countries, etc. do not cooperate.''	13.4	20.1

The proportion of exclusively neutral arguments was equal between UK and Dutch respondents (18% respectively).

In both samples, the proportion of negative primary and secondary level codes applied were relatively large when compared to the industrial CCS opinion ratings shown in Table 5. This may reflect that some respondents are more open to expressing negative arguments in relation to CCS when given an open question than when asked to rate the technology on a scale.

With regards to the positive arguments raised in relation to industrial CCS (see Table 6) the pattern of responses between countries was largely comparable with a few notable differences. The most frequently expressed positive argument for industrial CCS in both the UK and the Netherlands was in relation to *'Climate change/environmental benefits'* (38.1% and 41.1%). These responses highlighted the positive benefits industrial CCS could have on tackling climate change mitigation. Similarly, in the UK, the second most frequent argument also related to a general urgency to tackle climate change as captured in *'Climate change action needed'*; however, in these cases no reference to CCS was made (18.4%). In the Netherlands, the second most frequently expressed positive argument presented industrial CCS as the *'Best available/temporary solution'* (19.1%), which was 5.8% higher in the Dutch responses than in the UK responses. These responses expressed the opinion that CCS would either be the leading solution to tackle decarbonising industrial emissions or that it would be the most appropriate temporary solution available. The other main notable percentage difference in positive codes between countries was in relation to a 9.1% higher expression of the opinion in the UK that *'Industrial CCS positives outweigh the negatives'*, i.e. that the possible positive features associated with CCS would outweigh the possible negative features.

Regarding the negative arguments raised against industrial CCS implementation by respondents (see Table 7), the percentages for each country were comparable across all negative codes. Furthermore, they shared similar patterns of responses with 'Safety/risk/monitoring concerns' as the most frequently expressed theme covering almost half of all negative arguments (44.5–45.9%). Concerns about the risk of adverse impacts of CCS upon public welfare, wildlife and the environment were expressed.

The second most common argument raised related to *'Support alternatives to industrial CCS'* whereby respondents indicated that they would prefer to have an alternative mitigation approach in place of industrial CCS. The largest percentage difference between countries was for the theme *'Industrial CCS expensive/ increased taxes/consumer costs'* where the UK had a 4.5% higher percentage of such responses when compared with the Dutch responses. Also of note was that three of the negative themes identified from the open responses *'Industrial CCS storage capacity'*, *'Distrust CCS stakeholders'*, *'Responsibility/accountability needed from CCS stakeholders'* related to topics that either were not directly discussed in the information provided.

The final set of secondary codes related to neutrally orientated themes, i.e. subjects that were neither positive nor negative in nature (see Table 8). Within this category, the most commonly expressed theme was *'Unsure about CCS/more research required'*, which amassed over half of neutral codes used in both the UK and the Netherlands (58.1% and 54.7%). In the UK, the second most frequent neutral opinion cited by respondents was an *'Individual need for more information'*, which concerned respondents own desire to obtain further information in relation to industrial CCS. The percentage of this code was 4.1% higher in the UK than in the Netherlands. The largest percentage difference between countries was in relation to the second most frequently raised point of view in the Netherlands regarding *'International participation needed for industrial CCS'* which was expressed by 6.7% more respondents in the Dutch responses than in the UK. This theme was not included within the information provided to respondents and therefore highlights further considerations influencing citizens' evaluations of CCS implementation.

The most prevalent positive and negative themes were consistent with the outcome perceptions reported in Section 3.2, which demonstrated that combatting climate change and the safety of CO_2 transport and storage were considered important outcomes of industrial CCS. Furthermore, regarding industrial CCS opinion, the frequencies between each of the primary level codes were relatively similar, suggesting that there was not a predominant orientation of opinions expressed overall. This may also be reflected in the number of neutral secondary level coded responses which indicated various degrees of uncertainty, complexity, as well as requiring more information about industrial CCS to aid in decision making.

While most of the themes raised by respondents were consistent with the information provided within the survey, several additional themes were also identified. The most prominent of these themes was in relation to a sense of distrust, and perceived lack of responsibility and accountability of industrial CCS stakeholders to act upon reducing their carbon footprint. Another theme questioned whether other industrialised countries would also participate in implementing industrial CCS. Additional concerns were also raised in relation to the capacity for CO_2 storage and the availability of storage sites. These additional topics provide relevant considerations for future communication of industrial CCS activities as well as for inclusion in further research.

3.5. Effects of outcome perceptions, industry attitudes and proximity on industrial CCS opinion

To examine what factors predict respondents' opinion about the implementation of industrial CCS in their country, we carried out a hierarchical multiple regression analysis for the UK and the Netherlands separately. The predictors were included in five steps (i.e. hierarchical regression analysis, enter method), in order of known predictors and expected importance to the model based on previous research (see Table 9). Due to missing data and excluded categories for the socio-demographic variables in the analyses, the sample for the multiple regression analyses was slightly smaller ($N_{UK} = 954$, $N_{NL} = 967$) than the total sample ($N_{UK} = 974$, $N_{NL} = 987$).

The change in the R^2 value shows how much the variables added in the later steps contribute to predicting industrial CCS opinion, on top of the variables already included in the analysis. The model summary shows that socio-demographics on their own predicted around 1–2% of the variance in overall opinion about the implementation of industrial CCS (Step 1); this percentage did not increase significantly when actual proximity to industry was added to the model (Step 2). Adding the outcome perceptions to the model meant that 61–62% of the variance in industrial CCS opinion could be predicted (Step 3). Moreover, adding the psychological variables (Step 4) and perceived proximity to industry and to the coast (Step 5) to the model only led to a small increase in explanatory power for the model (1–3%). The final models were significant predictors of industrial CCS opinion in the UK, $F(31, 922) = 51.67$, $p < .001$, and in the Netherlands, $F(31, 935) = 51.37$, $p < .001$.

These results indicate that the outcome perceptions played an important role in predicting respondents' industrial CCS opinion, whereas socio-demographics, actual proximity, psychological variables and perceived proximity played a small role. In the interest of brevity, only the results of the full model (Step 5) of the hierarchical regression are displayed in Table 10 and discussed below. No substantial differences with what is presented in Table 10 from model step 5 were found in model steps 1 through 4.

The models for the UK and the Netherlands show both similarities and differences in the relationship of outcome evaluations with industrial CCS opinion. In the UK, the outcome evaluations that were shown to be significant predictors of industrial CCS opinion were: *climate change*, *safety transport offshore*, *new pipelines*, *safety offshore storage*, *effects employment*, *effects industrial companies*, and *need subsidies*. Out of these, *need subsidies*, *climate change*, and *effects industrial companies* contributed most to the overall model based on the standardised beta values. The more positively respondents evaluated these outcomes, the more positive their opinion about industrial CCS was.

In the Netherlands, the outcome evaluations that were shown to be significant predictors of industrial CCS opinion were: *climate change*, *safety transport onshore*, *new pipelines*, *safety offshore storage*, *effects employment*, *need subsidies*, and *effects other options*. Out of these, *safety offshore storage*, *new pipelines*, *climate change*, and *safety transport onshore* contributed most to the overall model based on the standardised beta values. The more positively respondents evaluated these outcomes, the more positive their opinion about industrial CCS was.

These results imply that opinions about industrial CCS for respondents from the Netherlands are relatively strongly predicted by how positive they are about the safety of industrial CCS and the need for construction work on pipelines, while opinions for respondents from the UK are relatively strongly predicted by how positive they are about the costs of industrial CCS being manageable for companies and consumers, as overseen by government. In both countries, respondents' opinions about industrial CCS are relatively strongly predicted by how positive they are about the climate change mitigation benefits of industrial CCS.

The industrial CCS opinion of respondents in the Netherlands was also predicted by the perceived importance of the *climate change* and *need subsidies* outcomes. The more important respondents perceived these outcomes to be, the more positive they were about industrial CCS.

While the outcome perceptions were overall the most important predictor of industrial CCS opinion in both the UK and the Netherlands, other factors predicted industrial CCS opinion as well. Although industry attitudes did not significantly predict industrial CCS opinion in our models, trust in industry and in scientists did. The results show that the more trust respondents from the UK and the Netherlands have in industry, the more positive they are about industrial CCS implementation.

Table 9
Hierarchical regression model summary.

			UK ($N = 954$)			NL ($N = 967$)		
Step	Variable group added	Variables added	R^2	ΔR^2	Sig.	R^2	ΔR^2	Sig.
Step 1	Socio-demographics	Age Gender Education level	0.01	0.01	0.013	0.02	0.02	0.000
Step 2	Actual proximity	General public vs. close to industry	0.01	0.00	0.663	0.02	0.00	0.584
Step 3	Outcome perceptions	Outcome evaluation Outcome importance	0.61	0.60	0.000	0.62	0.59	0.000
Step 4	Psychological variables	CCS knowledge Climate change belief Industry attitudes Trust – industry Trust – scientists Trust – government	0.63	0.02	0.000	0.63	0.01	0.000
Step 5	Perceived proximity	Perceived distance to industry Perceived distance to coast	0.64	0.00	0.156	0.63	0.00	0.280

Table 10
Hierarchical regression coefficients.

	UK ($N = 954$)				NL ($N = 967$)			
Variable	*B*	*SE B*	*β*	Sig.	*B*	*SE B*	*β*	Sig.
(Constant)	0.33	0.29		0.256	−0.07	0.29		0.809
Socio-demographics								
Female (vs. male)[1]	−0.21	0.06	**−0.07**	0.001	−0.11	0.06	−0.04	0.073
Age	0.00	0.00	0.04	0.110	0.00	0.00	0.01	0.501
High education level (vs. low)[2]	−0.10	0.10	−0.03	0.307	−0.12	0.16	−0.03	0.470
Medium education level (vs. low)[2]	−0.04	0.09	−0.01	0.667	−0.11	0.14	−0.03	0.429
Actual proximity								
General public (vs. close to industry)	−0.03	0.06	−0.01	0.668	0.00	0.06	0.00	0.976
Outcome evaluation								
Climate change	**0.18**	0.03	**0.18**	0.000	**0.14**	0.03	**0.14**	0.000
Safety transport onshore	0.02	0.03	0.03	0.451	**0.12**	0.03	**0.13**	0.000
Safety transport offshore	**0.08**	0.03	**0.09**	0.013	0.06	0.03	0.06	0.078
New pipelines	**0.06**	0.03	**0.07**	0.027	**0.15**	0.03	**0.15**	0.000
Safety offshore storage	**0.06**	0.03	**0.07**	0.023	**0.15**	0.03	**0.16**	0.000
Effects employment	**0.06**	0.03	**0.06**	0.047	**0.09**	0.04	**0.08**	0.012
Effects industrial companies	**0.15**	0.03	**0.15**	0.000	−0.03	0.03	−0.03	0.324
Need subsidies	**0.18**	0.03	**0.19**	0.000	**0.06**	0.03	**0.06**	0.046
Effects other options	0.05	0.03	0.05	0.107	**0.06**	0.03	**0.06**	0.022
Outcome importance								
Climate change	0.06	0.04	0.06	0.100	**0.12**	0.04	**0.11**	0.001
Safety transport onshore	−0.06	0.04	−0.06	0.076	−0.04	0.03	−0.04	0.221
Safety transport offshore	0.01	0.04	0.01	0.741	0.00	0.03	0.00	0.998
New pipelines	−0.01	0.03	−0.01	0.817	−0.04	0.03	−0.04	0.105
Safety offshore storage	−0.01	0.03	−0.01	0.837	−0.04	0.03	−0.04	0.206
Effects employment	0.06	0.04	0.06	0.065	0.04	0.03	0.04	0.183
Effects industrial companies	0.01	0.04	0.01	0.700	0.02	0.03	0.02	0.588
Need subsidies	−0.01	0.04	−0.01	0.822	**0.10**	0.04	0.09	0.004
Effects other options	−0.03	0.03	−0.02	0.416	0.00	0.03	0.00	0.914
Psychological variables								
CCS knowledge	0.01	0.02	0.01	0.733	0.00	0.02	0.01	0.808
Climate change belief	−0.12	0.10	−0.02	0.246	0.03	0.10	0.01	0.738
Industry attitudes	0.02	0.03	0.02	0.454	0.03	0.03	0.03	0.261
Trust – national government	0.01	0.03	0.01	0.780	0.00	0.03	−0.00	0.880
Trust – industry	**0.06**	0.03	**0.07**	0.041	**0.10**	0.03	**0.11**	0.001
Trust – scientists	**0.10**	0.03	**0.11**	0.000	0.04	0.03	0.04	0.171
Perceived proximity								
Perceived distance to industry	−0.03	0.03	−0.02	0.288	−0.01	0.03	−0.01	0.811
Perceived distance to coast	−0.03	0.02	−0.03	0.137	−0.04	0.02	−0.03	0.135

Note. $N_{UK} = 954$, $N_{NL} = 967$. [1] The 'other' category was excluded from these analyses; [2] Education level was recoded into three categories low (no qualification; primary school), medium (GSCE or equivalent; A-levels or equivalent in the UK: secondary school; middle/higher vocational education in the Netherlands) and high (university degree; doctoral degree), and two dummy variables (education level low vs. high; low vs. medium) were computed.

Furthermore, the more trust respondents from the UK have in scientists, the more positive they are about industrial CCS implementation.

The actual and perceived proximity of respondents' households to industrial installations did not significantly predict industrial CCS opinion. This implies that there was no significant difference in opinion between respondents from the general public subsample and respondents living close to industry, when other factors that predict industrial CCS opinion are taken into account. Similarly, the perceived distance of respondents' homes to industry did not significantly predict industrial CCS opinions. Further, the perceived distance of respondents' homes to the coast was not found to be a significantly predictor of industrial CCS opinion.

Finally, regarding socio-demographic factors, gender was found to be a significant predictor of industrial CCS opinion in the UK. Female respondents were less positive about industrial CCS implementation than male respondents. Age, education level, CCS knowledge, and climate change belief, did not significantly predict industrial CCS opinion.[3]

4. Discussion

Because many countries, such as the UK and the Netherlands, are moving toward implementing industrial Carbon Capture and Storage (CCS) in the coming years, insights into citizens' opinions are vital to support the engagement and site selection strategies that need to go along with implementation. Because studies have rarely investigated citizens' opinions about *industrial* CCS, several factors that may explain these opinions have remained unexplored. In this study, we aimed to answer the following research questions using a cross-country informed opinion survey in the Netherlands and the UK:

[3] These relationships are not discussed further but are consistent with previous studies. The gender effect is consistent with previous studies [18,23]. The lack of an effect of CCS knowledge is not surprising, as studies tend to find mixed or weak knowledge effects [25,35]. The lack of an effect of climate change belief as shown in previous studies [18,35] is likely due to the inclusion of climate change outcome perceptions in our models.

1. What opinions do citizens have of implementing industrial CCS and of the outcomes that are associated with implementation?
2. What is the relationship of citizens' outcome perceptions, industry attitudes and the proximity of their household to industrial installations with their opinions about implementing industrial CCS?
3. To what degree do these opinions and relationships differ between countries?

Regarding the first question, our results imply that citizens in the Netherlands and the UK are, on average, neutral to slightly positive about the implementation of industrial CCS in their country after they have read information about CO_2, climate change, industrial CCS and its outcomes. Other studies into industrial CCS opinion have shown similar results [18,19]. Similar to studies conducted into opinions about CCS at power plants, or CCS as described in general terms [21–24], opinions about industrial CCS in our study tended to hover around a neutral midpoint. Overall, this implies that the public, on average, neither strongly supports nor strongly opposes industrial CCS.

In our survey, respondents were shown a scenario specifying how CO_2 would be captured at industrial facilities (i.e. steel, cement, chemicals and waste incineration), transported via onshore and offshore pipelines and stored offshore deep underground in depleted gas fields or saline formations. Following this information respondents were shown a range of outcomes of implementing industrial CCS for a range of topics. One of the outcomes described the effects industrial CCS may have on climate change mitigation. Akin to previous studies [22,28], our findings imply that citizens perceive the contribution to climate change mitigation as an important and positive outcome of implementing industrial CCS in their country.

Other outcomes in our survey described the risks of CO_2 transport and storage to human health, wildlife and the environment, including measures taken to reduce risk to a credible minimum (e.g. the advanced state of pipeline technology, zoning regulations, monitoring systems, careful site selection). Our results imply that citizens perceive these 'safety' outcomes as important and as slightly negative, on average. Citizens' concerns about safety had already been noted in previous CCS studies [22,23,28], but those studies commonly limited their descriptions of risks to onshore transport and storage of CO_2. Our results show that descriptions of CCS implementation scenarios with *offshore* CO_2 transport and storage still elicit safety concerns from citizens.

Another set of outcomes described the economic effects of decarbonizing industry via CCS – and introducing policies for decarbonization. This description included effects industrial CCS may have on companies, consumers and government spending; job creation or loss, rising prices for consumer products, reductions or boosts in industrial companies' competitiveness, increases in government spending via subsidies, and detrimental effects on investments in other decarbonization options. Our results imply that citizens in the Netherlands and the UK perceive these outcomes as important and slightly positive, on average. Previous studies had shown that citizens respond negatively to increases in electricity prices as a result of implementing CCS at power plants [23,31]. However, our results imply that responses are slightly positive when an encompassing description of economic impacts is presented to respondents. The importance of these economic impacts was already alluded to in previous studies [19,20], but these studies had not shown how citizens perceive these impacts and how these perceptions affect their opinions about industrial CCS.

The findings from the regression are corroborated by our analysis of respondents' explanations of their opinions in an open response question. On the positive side, many respondents emphasized the climate change mitigation benefits of industrial CCS and the urgency of climate action. Some respondents perceived industrial CCS as a temporary solution for climate change mitigation or that its benefits outweighed its risks. On the negative side, many respondents expressed safety concerns, indicated that CCS does not solve the climate problem, or mentioned that alternatives to CCS should be supported instead. The latter argument may reflect the struggle some citizens have to reconcile CCS with their values, according to previous studies [25,34,57]. In our industrial CCS description, we did not include such normative concerns, but only focused on tangible effects industrial CCS may have on the climate, safety, and the economy.

Our analyses showed that citizens' perceptions of the outcomes of implementing industrial CCS are a strong predictor of their opinions of industrial CCS. As many studies have shown for other CCS applications [25], the more important and positive such perceptions are, the more positive citizens are likely to be about industrial CCS. These outcome perceptions explained most of the variance in citizens' opinions about industrial CCS in our study, consistent with the findings of previous studies using informed opinion surveys [23,28,52].

Contrary to our expectations, citizens' industry attitudes did not significantly predict their opinion about industrial CCS. Part of the relationship between industry attitudes and opinions may have been captured by the inclusion of trust in industry in our models. Previous studies have shown that the more citizens trust CCS stakeholders the more positive they are about CCS [25]. Our results indeed show that citizens whom have more trust in industry regarding providing information and making decisions about industrial CCS are more positive about industrial CCS. In the open responses, some citizens also expressed a sense of distrust in CCS stakeholders as well as a need for more engagement and accountability for industrial emissions by stakeholders. Further studies should unpack what 'industry' means to citizens in today's economies, given the changing nature of these economies, citizens' jobs and their everyday lives. Such insights may help to develop more fine-grained indicators of industry attitudes and determine the added value of this concept besides commonly used trust indicators.

Our models also did not show a statistically significant relationship of industrial CCS opinion with the perceived and actual proximity of respondents' households to industrial installations. This finding may indicate that proximity effects are more fruitfully captured by focusing on concepts that measure citizens' associations with industry and the activities industry employs directly. Alternatively, proximity effects may have more complex relationships with citizens' opinions about the activities employed by industry, as well as with place-related factors, such as place meaning or place attachment [18,58]. Further studies may conceptualize proximity differently by, for example, investigating the impact of the densities of industrial and infrastructural development on opinions about new infrastructure needed for climate change mitigation technologies.

Although proximity seems to have limited value for explaining opinions, our findings imply that small differences between countries may be present. Our results show that, on average, UK respondents were somewhat more positive than Dutch respondents about industrial CCS, as well as about some of the outcomes of developing industrial CCS. The former result is corroborated by a recent cross-country comparison of CCS support in six countries (including the Netherlands and the UK), although country differences for support for the *specific types* of CCS (coal-fired or industry) are not presented in that study [18].

While the opinions of all respondents were strongly predicted by their perception of the climate change outcome of industrial CCS, respondents from the UK and the Netherlands differed slightly in how outcome perceptions predicted their opinions about industrial CCS. Opinions of UK respondents were relatively strongly predicted by how positive they were about effective management of the costs of industrial CCS for companies and consumers by the government, while the opinions of Dutch respondents were relatively strongly predicted by how positive they were about the safety of industrial CCS and the need for construction work on pipelines. Although these differences were small, they imply that citizens from these two countries perceive industrial CCS differently.

Yet, it is currently unclear what may have caused these differences to come about, as studies that aim to explain cross-country differences in opinions about energy or climate change mitigation technologies are

limited [46,49,50]. Some studies have pointed at possible explanations in variations in culture [46–48], historical experiences with the technology [49], or strategic and local planning procedures [50], but more research is needed to be able to explain cross-country differences.

By focusing on the UK and Netherlands we have sampled citizens from countries that are relatively similar in their characteristics (western, educated, industrialized, rich and democratic), and their national narratives surrounding CCS implementation [13]. The development of CCS differs between these countries, most notably in terms of the past focus on *onshore* CO_2 storage in the Netherlands – and the local public opposition and negative media attention that accompanied demonstration projects for onshore storage [51]. In contrast, the UK government had already decided early on to focus on offshore CO_2 storage [9]. It is unclear whether the differences we found were brought about by such historical differences or by other – institutional, cultural [48], demographic or geographical – differences. Further studies should expand the scope to countries with varying histories, institutions, demographics and national cultures, especially to countries outside Western-Europe, Japan, North America and Australia – where most studies into CCS opinions have been conducted so far [25,59].

When interpreting our results, several caveats should be considered. First, we presented panel members with a realistic, but hypothetical scenario for implementing industrial CCS in their country. These panel members read extensive information about CO_2, climate change and industrial CCS – interspersed with questions about these topics – before they gave their opinion about industrial CCS. These opinions are thus contingent upon the method used to attain them. For example, question sequencing effects may have been present that we did not control for [60]. Our sampling strategy may also have selected a group of citizens that differs from the general public in important aspects, although our sample aimed for representativeness of the general population in terms of age, gender and education levels. Responses to CCS implementation in practice may differ from what was presented in our study, especially when these responses are uninformed.

Second, our findings are based on a cross-sectional study into citizens' opinions. Therefore, our findings establish correlational (i.e. when X is high, Y is high) rather than causal relationships (i.e. X determines Y) between industrial CCS opinion, industry attitudes, proximity and outcome perceptions. To fully understand how citizens' opinions for industrial CCS, or related technologies, come about, longitudinal studies are needed that measure these factors consistently at different moments in time. Such studies can also be used to investigate changes in opinions over time as a result of changes in the context in which industrial CCS is applied (e.g. policies, media attention). However, such studies are rarely conducted [25].

Third, our findings contribute to understanding public opinion for industrial CCS technology on a general level. To fully understand how industrial CCS may develop, insight is also needed into the support of local communities for CCS infrastructure near their homes, as well as specific government policy and market support for CCS applications [61]. At this local level, many additional factors are likely to come into play, such as how local benefits and burdens are balanced by community compensation [62]. Some studies have also differentiated community-level support from individual-level support and investigated how social capital (i.e. citizens' relationship networks) influences such community-level support [35]. Further research should investigate how these different types of support interact and how they affect the implementation rates of technologies.

5. Conclusion

The present study suggests that an informed public does not especially support industrial CCS, but nor do they oppose it. Our findings imply, however, that more supportive opinions are likely to develop if citizens are made aware of the anticipated outcomes of industrial CCS upon the economy, jobs, companies and government spending, in addition to its role in abating CO_2 emissions. Yet, concerns around potential risks, such as of CO_2 leakage from pipelines or from storage sites under the seabed, are prevalent and will need to be appropriately managed and effective communications devised.

Industries such as steelmaking, refining and petrochemicals, are still key parts of the economies of the UK and the Netherlands and make a significant contribution to employment in some regions. Yet, such industries have become more 'remote' from everyday lives due to the loss of employment opportunities. Whereas certain communities once had a strong relationship with steelmaking and chemicals [63], in post-industrial societies there is a risk that this connection has eroded. The continuing importance of industry needs to be highlighted by Government (at all levels) with respect to jobs, revenue and added value, skills and knowledge retention.

The European Green Deal, the Green Industrial Revolution (UK), and the Climate Accord (NL) are the vehicle for Government, working with industry and civic partners, to promote, plan for and implement industrial CCS. Such planning (and its communication) needs to be cognisant of the currently ambivalent reaction of the public towards industrial CCS as well as the rather low trust in industry. A clear, well-articulated and realistic plan for industrial CCS from the relevant authorities is necessary and is likely to help build support from the public.

To enable successful implementation, trust in industry needs to be strengthened, especially in those communities living close to industrial hubs. Re-building trust requires industry to be taking on its share of responsibility and contributing to the solution accordingly. Our findings suggest that fostering trust in industry is likely to lead to more positive opinions about the implementation of industrial CCS. Particular attention needs to be devoted to addressing the negative perceptions of the safety outcomes of industrial CCS, which do not in general accord with expert ones (on the proviso that projects are implemented using state-of-the-art knowledge and monitored with care) [64].

Qualitative methods involving in-depth discussion may well be a useful addition to enable communities to have a say on industrial CCS implementation in their area. Such activities can use the survey findings reported here as useful ways of identifying the key 'sticking points' as well as the more positively perceived aspects of industrial CCS. A further innovation that can help to address the safety and risk issues, and which responds to respondents' requests for more research, is to enable more intensive engagement between citizens and experts. This could involve creating, for example, a joint panel of scientists and citizens for discussing safety and risks, with plenty of opportunity for questions, answers, discussion, etc., as well as the option of drafting in additional experts as required. Such a panel might also jointly create monitoring systems and procedures to independently measure changes in the environment arising from industrial CCS infrastructure. These forms of intensive engagement can serve to build trust in the industrial CCS project developers and regulators [65,17] and can also result in communications that are better geared to the needs of the intended audience.

Offering information on the need for CCS in tackling the climate crisis is necessary, but what also counts is the view that citizens have of industry and any possible impacts on safety. We believe that the paper contributes to building a path forward for government, project developers, scientists, engineers, and civil society, including members of communities local to planned projects, to foster much needed public support for CCS and for other technologies that aim to decarbonize industry in the near future.

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.

Acknowledgements

The paper is part of the ACT ALIGN–CCUS Project (No 271501). This project has received funding from RVO (NL), FZJ/PtJ (DE), Gassnova (NO), UEFISCDI (RO), BEIS (UK) and is co-funded by the European Commission under the Horizon 2020 programme ACT, Grant Agreement No 691712.

We would firstly like to thank all those who participated in this study. Furthermore, for their assistance in reviewing the survey information we also wish to thank the following individuals: Peter Brownsort, Clair Gough, David Reiner, Stuart Gilfillan, Paul Fennel, Leslie Mabon, Alaa Al Khourdajie, Ben Wetenhall, David Reay, Andrea Ramirez, Tom Mikunda, Peter Van Os and Bob van der Zwaan. Additional thanks to Pim Piek, Diana-Maria Cismaru, Diana Schumann, Ruud van den Brink, Ana Serdoner and Renate Meier for their feedback and involvement with this work, as well as Jeffrey Sipma for constructing the postcode database for the Netherlands.

References

[1] J.H. Wesseling, S. Lechtenböhmer, M. Åhman, L.J. Nilsson, E. Worrell, L. Coenen, The transition of energy intensive processing industries towards deep decarbonization: characteristics and implications for future research, Renew. Sustain. Energy Rev. 79 (2017) 1303–1313, https://doi.org/10.1016/j.rser.2017.05.156.

[2] IEA, 20 Years of Carbon Capture and Storage – Accelerating Future Deployment, Paris, France, 2016. https://www.iea.org/publications/freepublications/publication/20YearsofCarbonCaptureandStorage_WEB.pdf (accessed February 23, 2018).

[3] IPCC, Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, United Kingdom, 2014.

[4] D. Leeson, N. Mac Dowell, N. Shah, C. Petit, P.S. Fennell, A Techno-economic analysis and systematic review of carbon capture and storage (CCS) applied to the iron and steel, cement, oil refining and pulp and paper industries, as well as other high purity sources, Int. J. Greenh. Gas Control. 61 (2017) 71–84, https://doi.org/10.1016/j.ijggc.2017.03.020.

[5] K. Onarheim, A. Mathisen, A. Arasto, Barriers and opportunities for application of CCS in Nordic industry — a sectorial approach, Int. J. Greenh. Gas Control. 36 (2015) 93–105, https://doi.org/10.1016/j.ijggc.2015.02.009.

[6] Ministerie van Economische Zaken en Klimaat, Klimaatakkoord, Den Haag, 2019. https://www.klimaatakkoord.nl/documenten/publicaties/2019/06/28/klimaatakkoord.

[7] BEIS, Clean Growth The UK Carbon Capture Usage and Storage deployment pathway An Action Plan, Clean Growth UK Carbon Capture Usage Storage Deploy. Pathw. An Action Plan. (2018). https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/759637/beis-ccus-action-plan.pdf.

[8] CCC, Net Zero: The UK's contribution to stopping global warming, Committe Clim. Chang. (2019) 275. https://www.theccc.org.uk/publication/net-zero-the-uks-contribution-to-stopping-global-warming/.

[9] Oxburgh, Lowest Cost Decarbonisation for the UK: The Critical Role of CCS. Report to the Secretary of State for Business, Energy and Industrial Strategy from the Parliamentary Advisory Group on Carbon Capture and Storage (CCS), 2016. http://www.ccsassociation.org/news-and-events/reports-and-publications/parliamentary-advisory-group-on-ccs-report/.

[10] A.M. Arranz, Hype among low-carbon technologies: carbon capture and storage in comparison, Glob. Environ. Chang. 41 (2016) 124–141, https://doi.org/10.1016/j.gloenvcha.2016.09.001.

[11] D.M. Reiner, Learning through a portfolio of carbon capture and storage demonstration projects, Nat. Energy. 1 (2016) 15011, https://doi.org/10.1038/nenergy.2015.11.

[12] E. Cuppen, S. Brunsting, U. Pesch, Y. Feenstra, How stakeholder interactions can reduce space for moral considerations in decision making: a contested CCS project in the Netherlands, Environ. Plan. A. 47 (2015) 1963–1978, https://doi.org/10.1177/0308518X15597408.

[13] R. Raven, F. Kern, B. Verhees, A. Smith, Niche construction and empowerment through socio-political work. A meta-analysis of six low-carbon technology cases, Environ. Innov. Soc. Trans. 18 (2016) 164–180, https://doi.org/10.1016/j.eist.2015.02.002.

[14] J. Watson, F. Kern, N. Markusson, Resolving or managing uncertainties for carbon capture and storage: Lessons from historical analogues, Technol. Forecast. Soc. Chang. 81 (2014) 192–204, https://doi.org/10.1016/j.techfore.2013.04.016.

[15] E. Cuppen, U. Pesch, S. Remmerswaal, M. Taanman, Normative diversity, conflict and transition: Shale gas in the Netherlands, Technol. Forecast. Soc. Change. 145 (2019) 165–175, https://doi.org/10.1016/j.techfore.2016.11.004.

[16] L. Whitmarsh, Å.G. Swartling, J. Jäger, Participation of experts and non-experts in a sustainability assessment of mobility, Environ. Policy Gov. 19 (4) (2009) 232–250.

[17] S. Fast, W. Mabee, Place-making and trust-building: the influence of policy on host community responses to wind farms, Energy Policy. 81 (2015) 27–37, https://doi.org/10.1016/j.enpol.2015.02.008.

[18] L. Whitmarsh, D. Xenias, C.R. Jones, Framing effects on public support for carbon capture and storage, Palgrave Commun. 5 (2019), https://doi.org/10.1057/s41599-019-0217-x.

[19] E. Dütschke, K. Wohlfarth, S. Höller, P. Viebahn, D. Schumann, K. Pietzner, Differences in the public perception of CCS in Germany depending on CO2 source, transport option and storage location, Int. J. Greenh. Gas Control. 53 (2016) 149–159, https://doi.org/10.1016/j.ijggc.2016.07.043.

[20] G. Thomas, N. Pidgeon, E. Roberts, Ambivalence, naturalness and normality in public perceptions of carbon capture and storage in biomass, fossil energy, and industrial applications in the United Kingdom, Energy Res. Soc. Sci. 46 (2018) 1–9, https://doi.org/10.1016/j.erss.2018.06.007.

[21] M. Paukovic, S. Brunsting, M. de Best-Waldhober, CATO-2 deliverable: The Dutch general public's opinion on CCS and energy transition : Development in awareness, knowledge, beliefs and opinions related to information and media coverage, 2011.

[22] European Commission, Special Eurobarometer 364. Public Awareness and Acceptance of CO2 capture and storage, (2011) 185. http://ec.europa.eu/public_opinion/archives/ebs/ebs_364_en.pdf.

[23] J. Mastop, M. de Best-Waldhober, C. Hendriks, A.R. Ramirez, Informed public opinions on CO2 mitigation options in the Netherlands: deliberating expert information and lay beliefs, 2014. https://www.co2-cato.org/publications/library1/informed-public-opinions-on-co2-mitigation-options-in-the-netherlands.

[24] A. Linzenich, K. Arning, J. Offermann-van Heek, M. Ziefle, Uncovering attitudes towards carbon capture storage and utilization technologies in Germany: insights into affective-cognitive evaluations of benefits and risks, Energy Res Soc. Sci. 48 (2019) 205–218, https://doi.org/10.1016/j.erss.2018.09.017.

[25] 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, https://doi.org/10.1016/j.rser.2014.07.017.

[26] P. Ashworth, S. Wade, D. Reiner, X. Liang, Developments in public communications on CCS, Int. J. Greenh. Gas Control. 40 (2015) 449–458, https://doi.org/10.1016/j.ijggc.2015.06.002.

[27] M. de Best-Waldhober, S. Brunsting, M. Paukovic, Public concepts of CCS: understanding of the Dutch general public and its reflection in the media, Int. J. Greenh. Gas Control. 11S (2012) S139–S147, https://doi.org/10.1016/j.ijggc.2012.08.016.

[28] M. de Best-Waldhober, D. Daamen, A.R. Ramirez, A. Faaij, C. Hendriks, E. de Visser, Informed public opinion in the Netherlands: evaluation of CO2 capture and storage technologies in comparison with other CO2 mitigation options, Int. J. Greenh. Gas Control. 10 (2012) 169–180, https://doi.org/10.1016/j.ijggc.2012.05.023.

[29] E.V. Hobman, P. Ashworth, Public support for energy sources and related technologies: the impact of simple information provision, Energy Policy. 63 (2013) 862–869, https://doi.org/10.1016/j.enpol.2013.09.011.

[30] 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 (2011) 1359–1367, https://doi.org/10.1016/j.ijggc.2011.06.005.

[31] J. Kraeusel, D. Möst, Carbon Capture and Storage on its way to large-scale deployment: Social acceptance and willingness to pay in Germany, Energy Policy. 49 (2012) 642–651, https://doi.org/10.1016/j.enpol.2012.07.006.

[32] P. Ashworth, Y. Sun, M. Ferguson, K. Witt, S. She, Comparing how the public perceive CCS across Australia and China, Int. J. Greenh. Gas Control. 86 (2019) 125–133, https://doi.org/10.1016/j.ijggc.2019.04.008.

[33] 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, https://doi.org/10.1016/j.ijggc.2011.11.008.

[34] 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, https://doi.org/10.1016/j.ijggc.2009.03.005.

[35] W.K. Moon, L.A. Kahlor, H.C. Olson, Understanding public support for carbon capture and storage policy: The roles of social capital, stakeholder perceptions, and perceived risk/benefit of technology, Energy Policy. 139 (2020), 111312, https://doi.org/10.1016/j.enpol.2020.111312.

[36] M. Åhman, L.J. Nilsson, B. Johansson, Global climate policy and deep decarbonization of energy-intensive industries, Clim. Policy. 17 (5) (2017) 634–649, https://doi.org/10.1080/14693062.2016.1167009.

[37] C. Braun, Not in my backyard: CCS sites and public perception of CCS, Risk Anal. 37 (2017) 2264–2275, https://doi.org/10.1111/risa.12793.

[38] D. Schumann, E. Duetschke, K. Pietzner, Public perception of CO 2 offshore storage in Germany: regional differences and determinants, Energy Procedia 63 (2014) 7096–7112, https://doi.org/10.1016/j.egypro.2014.11.744.

[39] T. Brenner, A. Gildner, The long-term implications of local industrial clusters, Eur. Plan. Stud. 14 (9) (2006) 1315–1328, https://doi.org/10.1080/09654310600933371.

[40] S. Moffatt, B. Hoeldke, T. Pless-Mulloli, Local environmental concerns among communities in North-East England and South Hessen, Germany: the influence of proximity to industry, J. Risk Res. 6 (2011) 125–144, https://doi.org/10.1080/1366987032000078901.

[41] J. Bush, S. Moffatt, C. Dunn, "Even the birds round here cough": Stigma, air pollution and health in Teesside, Heal. Place. 7 (2001) 47–56, https://doi.org/10.1016/S1353-8292(00)00037-X.

[42] S.E.L. Wakefield, S.J. Elliott, D.C. Cole, J.D. Eyles, Environmental risk and (re) action: Air quality, health, and civic involvement in an urban industrial

neighbourhood, Heal. Place. 7 (2001) 163–177, https://doi.org/10.1016/S1353-8292(01)00006-5.
[43] K. Burningham, D. Thrush, Pollution concerns in context: a comparison of local perceptions of the risks associated with living close to a road and a chemical factory, J. Risk Res. 7 (2004) 213–232, https://doi.org/10.1080/1366987042000158721.
[44] A. Mah, Devastation but also home: place attachment in areas of industrial decline, Home Cult. 6 (2009) 287–310, https://doi.org/10.2752/174063109X12462745321462.
[45] C. Gough, R. Cunningham, S. Mander, Societal responses to CO2 storage in the UK: media, stakeholder and public perspectives, Energy Procedia 114 (2017) 7310–7316, https://doi.org/10.1016/j.egypro.2017.03.1861.
[46] S. Que, K. Awuah-Offei, A. Demirel, L. Wang, N. Demirel, Y. Chen, Comparative study of factors affecting public acceptance of mining projects: evidence from USA, China and Turkey, J. Clean. Prod. 237 (2019), 117634, https://doi.org/10.1016/j.jclepro.2019.117634.
[47] F. Karimi, A. Toikka, J.I. Hukkinen, Comparative socio-cultural analysis of risk perception of Carbon Capture and Storage in the European Union, Energy Res. Soc. Sci. 21 (2016) 114–122, https://doi.org/10.1016/j.erss.2016.06.024.
[48] F. Karimi, A. Toikka, General public reactions to carbon capture and storage: does culture matter? Int. J. Greenh. Gas Control. 70 (2018) 193–201, https://doi.org/10.1016/j.ijggc.2018.01.012.
[49] Y. Kim, M. Kim, W. Kim, Effect of the Fukushima nuclear disaster on global public acceptance of nuclear energy, Energy Policy. 61 (2013) 822–828, https://doi.org/10.1016/j.enpol.2013.06.107.
[50] M. Suškevičs, S. Eiter, S. Martinat, D. Stober, E. Vollmer, C.L. de Boer, M. Buchecker, Regional variation in public acceptance of wind energy development in Europe: what are the roles of planning procedures and participation? Land Use Policy. 81 (2019) 311–323, https://doi.org/10.1016/j.landusepol.2018.10.032.
[51] B.W. Terwel, E. ter Mors, D.D.L. Daamen, It's not only about safety: beliefs and attitudes of 811 local residents regarding a CCS project in Barendrecht, Int. J. Greenh. Gas Control. 9 (2012) 41–51, https://doi.org/10.1016/j.ijggc.2012.02.017.
[52] M. de Best-Waldhober, D. Daamen, A. Faaij, Informed and uninformed public opinions on CO2 capture and storage technologies in the Netherlands, Int. J. Greenh. Gas Control. 3 (3) (2009) 322–332, https://doi.org/10.1016/j.ijggc.2008.09.001.
[53] 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. Næss, 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, https://doi.org/10.1016/j.ijggc.2013.07.015.
[54] W. Poortinga, A. Spence, L. Whitmarsh, S. Capstick, N.F. Pidgeon, Uncertain climate: an investigation into public scepticism about anthropogenic climate change, Glob. Environ. Chang. 21 (2011) 1015–1024, https://doi.org/10.1016/j.gloenvcha.2011.03.001.
[55] M. Lewicka, On the varieties of people's relationships with places: Hummon's typology revisited, Environ. Behav. 43 (2011) 676–709, https://doi.org/10.1177/0013916510364917.
[56] S. Stemler, J. Tsai, Best practices in interrater reliability three common approaches, in: J. Osborne (Ed.), Best Pract. Quant. Methods, SAGE Publications Inc, Thousand Oaks, CA, 2008, pp. 29–49.
[57] K.P.F. Broecks, S. van Egmond, F.J. Van Rijnsoever, M. Verlinde-van den Berg, M. P. Hekkert, Persuasiveness, importance and novelty of arguments about Carbon Capture and Storage, Environ. Sci. Policy. 59 (2016) 58–66, https://doi.org/10.1016/j.envsci.2016.02.004.
[58] P. Devine-Wright, S. Batel, My neighbourhood, my country or my planet? The influence of multiple place attachments and climate change concern on social acceptance of energy infrastructure, Glob. Environ. Chang. 47 (2017) 110–120, https://doi.org/10.1016/j.gloenvcha.2017.08.003.
[59] P. Tcvetkov, A. Cherepovitsyn, S. Fedoseev, Public perception of carbon capture and storage: a state-of-the-art overview, Heliyon. 5 (2019), e02845, https://doi.org/10.1016/j.heliyon.2019.e02845.
[60] M. Ferguson, P. Ashworth, Message framing, environmental behaviour and support for carbon capture and storage in Australia, Energy Res. Soc. Sci. 73 (2021), 101931, https://doi.org/10.1016/j.erss.2021.101931.
[61] P. Upham, C. Oltra, À. Boso, Towards a cross-paradigmatic framework of the social acceptance of energy systems, Energy Res. Soc. Sci. 8 (2015) 100–112, https://doi.org/10.1016/j.erss.2015.05.003.
[62] C. Boomsma, E. ter Mors, C. Jack, K. Broecks, C. Buzoianu, D.M. Cismaru, R. Peuchen, P. Piek, D. Schumann, S. Shackley, J. Werker, Community compensation in the context of Carbon Capture and Storage: current debates and practices, Int. J. Greenh. Gas Control. 101 (2020) 103128, https://doi.org/10.1016/j.ijggc.2020.103128.
[63] J. Warren, Industrial Teeside: Lives and Legacies. A Post-Industrial Geography, Palgrave Macmillan, 2018.
[64] J. Alcalde, S. Flude, M. Wilkinson, G. Johnson, K. Edlmann, C.E. Bond, V. Scott, S. M.V. Gilfillan, X. Ogaya, R. Stuart Haszeldine, Estimating geological CO2 storage security to deliver on climate mitigation, Nat. Commun. 9 (2018), https://doi.org/10.1038/s41467-018-04423-1.
[65] 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 (2009) 1129–1140, https://doi.org/10.1111/j.1539-6924.2009.01256.x.