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Persuasiveness, importance and novelty of arguments about Carbon Capture and Storage

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ABSTRACT

Carbon Capture and Storage (CCS) is a promising technology for reducing carbon emissions, but the public is often reluctant to support it. To understand why public support is lacking, it is crucial to establish what citizens think about the *arguments* that are used by proponents and opponents of CCS. We determined the persuasiveness, importance and novelty of 32 arguments for and against CCS using a discrete choice experiment in which respondents made consecutive choices between pairs of pro or con arguments. We used latent class models to identify population segments with different preferences. The results show that citizens find arguments about climate protection, which is the primary goal of CCS, less persuasive than other arguments, such as normative arguments (for example 'a waste product such as CO_2 should be disposed of properly') or arguments about benefits of CCS for energy production and economic growth. This discrepancy complicates communication that aims to convince citizens of the benefits of CCS for climate protection.

1. Introduction

Climate change mitigation requires substantial modifications to energy production and consumption patterns. Yet, the technologies needed to change these patterns often lack public acceptance (Wustenhagen et al., 2007). Carbon Capture and Storage (CCS) is such a technology. CCS involves capturing CO_2 at a large emission source (e.g. a power plant or factory), transporting the CO_2 to a storage location (e.g. a natural gas field) and injecting the CO_2 into a rock formation for permanent storage (see Reiner, 2016 for an overview of recent CCS developments). CCS is a critical component of climate change mitigation strategies as fossil fuel consumption is increasing and carbon-intensive industries remain prominent (IPCC, 2014). If CCS is to become a viable option policy makers and industry must encourage its development (IEA, 2013; Scott et al., 2012). However, the public is reluctant to support this technology (De Best-Waldhober et al., 2012; L'Orange Seigo et al., 2014b; Upham and Roberts, 2011). This discourages stakeholders, such as energy or industrial firms, policy makers and NGOs, from moving toward large-scale implementation (Markusson et al., 2012). Stakeholders need to communicate with citizens to build support for CCS (Ashworth et al., 2010).

Existing studies offer comprehensive guidelines for effective communication processes (see Brunsting et al., 2011; L'Orange Seigo et al., 2014a) for a review of CCS communication studies). Yet, citizens' reactions to the *content* of stakeholder's messages are partially understood. This hampers communications efforts (Reiner, 2008). Studies into message content focus primarily on neutral, descriptive information. Examples are studies into monitoring information (L'Orange Seigo et al., 2011), storage terminology (Ha-duong et al., 2009), figures (L'Orange Seigo et al., 2013), labels (Van Rijnsoever et al., 2015), natural analogues to CO_2 storage (Tokushige et al., 2007a), entities responsible for managing risk (Sharp et al., 2009), basic properties of CO_2 and CCS (Dowd et al., 2014; Tokushige et al., 2007b; Wallquist et al., 2011) or different sets of CO_2 capture and storage technologies (De Best-Waldhober et al., 2012, 2009; Wallquist et al., 2012). Such information is unlikely to foster substantial support for the stakeholder's opinion, unless it is reinforced with arguments that resonate with the values of citizens (Kahan et al., 2012). Recent studies tackled this issue by also showing which *positive* or *negative* characteristics of CCS significantly affect citizen's attitude toward CCS (De Best-Waldhober et al., 2012,2009; Kraeusel and Möst, 2012; Oltra et al., 2012; Tokushige et al., 2007b; Wallquist et al.,

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2011). Despite this progress, three issues remain largely unaddressed.

First, positive or negative characteristics comprise only a *subset* of the arguments communicated by stakeholders (see Boyd and Paveglio, 2014; Buhr and Hansson, 2011; van Egmond and Hekkert, 2012) for an overview). Stakeholders also use counterarguments (e.g. CCS is *not* necessary for climate change mitigation), analogies (e.g. CCS is safe, just as natural gas storage is safe; see Tokushige et al., 2007a), or arguments that appeal to norms (e.g. a waste product such as CO2 *should* be disposed of properly; see Cialdini, 2003). None of the existing studies investigated this broader range of CCS arguments.

Second, existing studies often ignore heterogeneity among citizens by only presenting average opinions (see Allenby and Rossi, 1999) for an overview of the concept). Citizens have diverse reactions to communication about energy technologies (Van Rijnsoever et al., 2015). Arguments that most citizens find irrelevant might be important to a particular population segment. Understanding heterogeneity facilitates the design of segmented communication materials.

Third, existing studies rarely examine message effectiveness beyond persuasiveness or attitude change. Yet, attitude change can be unstable and short-lived or stable and long lasting. Dual processing models suggest that stable attitudes require elaborate or systematic processing (see Chen and Chaiken, 1999; Petty and Wegener, 1999 for an overview). Citizens will process information in depth if they are motivated and knowledgeable about the topic in question. They will therefore likely not scrutinize unimportant or new arguments, but will resort to cognitive shortcuts instead, leading to less stable opinions. A communicator attempting to encourage the audience to adopt a specific, stable opinion should select arguments that the audience perceives as *persuasive*, *important* and are not completely *novel* to them. It is therefore important to include importance and novelty in studies into message effects.

We address these shortcomings by eliciting the *perceived* persuasiveness, importance and novelty of 16 pro and 16 con CCS arguments for different population segments. To this end, we asked citizens to make eight consecutive choices between two arguments in a discrete choice experiment (DCE). By exploring the persuasiveness, importance and novelty of arguments we advance understanding of citizens' reactions to the content of stakeholder's messages. Our results help to improve communication strategies for CCS. They are also insightful for energy technologies with similar public acceptance issues.

2. Methods

We elicit the *perceived* persuasiveness, importance and novelty of arguments by asking a sample of citizens to make eight consecutive choices between two arguments in a discrete choice experiment (DCE) (see Amaya-Amaya et al., 2008) for an overview of DCEs) that was included in an online survey. Other CCS studies used DCEs to identify the importance of technological or economic characteristics of CCS, such as price and amount of CO_2-emission reductions (Kraeusel and Möst, 2012; Sharp et al., 2009; Wallquist et al., 2012). To the best of our knowledge, DCEs have not yet been used to study arguments.

Table 1
Pro and con CCS arguments.

No.	Pro arguments	Label
P1	The climate problem cannot be solved without CO_2 storage	Climate problem
P2	CO_2 storage is needed to honor international climate agreements	International climate agreements
P3	CO_2 storage requires fewer lifestyle changes	Lifestyle changes
P4	The Netherlands should set an example when it comes to CO_2 storage	Set an example
P5	CO_2 storage reduces the need for nuclear energy	Reduces need for nuclear
P6	CO_2 storage can be used in industries where there are no other options for reducing CO_2 emissions	Industrial applications
P7	CO_2 storage makes it feasible to use large supplies of coal for cheap energy	Cheap coal
P8	The development of technology for CO_2 storage contributes to employment and economic growth	Economic benefits
P9	CO_2 storage is cheaper than solar or wind energy in the medium to long term	Relatively cheap
P10	The Netherlands has a good starting position because of its experience with natural gas	Natural gas experience
P11	Other countries have used technologies for CO_2 storage safely for many years	Used in other countries
P12	CO_2 storage is already being used to recover more oil from oilfields	Enhanced Oil Recovery
P13	CO_2 storage is safe. CO_2 is stored in natural gas fields where natural gas was stored for millions of years	Safety of natural gas fields
P14	CO_2 storage uses less space than solar panels or wind turbines	Space requirements
P15	Gas or coal plants with CO_2 storage are a stable supplement to the inconsistent supply of solar and wind energy	Stable energy supply
P16	A waste product such as CO_2 should be disposed of properly	Dispose of CO_2 garbage
No.	**Con arguments**	**Label**
C1	The climate problem can be tackled without CO_2 storage	Unnecessary for climate problem
C2	CO_2 storage promotes the use of new coal-fired power plants	Promotes coal
C3	CO_2 storage is more expensive than solar or wind energy in the long term	Relatively expensive
C4	It is not certain that there will be a return on large investments in CO_2 storage	Investment uncertainty
C5	Storage sites for CO_2 have to be monitored indefinitely	Indefinite monitoring
C6	Real estate prices near CO_2 storage facilities may fall	Falling real estate prices
C7	CO_2 storage detracts from the development of renewable energy	Detracts from renewables
C8	Electricity bills will be higher because of CO_2 storage	Higher electricity bills
C9	CO_2 storage is new and has never been applied on a large scale, so the risks are not fully understood	Risks not fully understood
C10	It is better to avoid generating CO_2 than to store the CO_2	Avoid generating CO_2
C11	If a lot of CO_2 leaks on a windless day, a suffocating cloud of CO_2 could be created	Suffocation
C12	Groundwater might become acidified if CO_2 were to leak out of an underground pipeline	Groundwater acidification
C13	CO_2 storage can cause small earthquakes, comparable to those caused by natural gas extraction	Earthquakes
C14	Hazardous chemicals are used in the capture of CO_2.	Hazardous chemicals
C15	Power plants with CO_2 storage require 10–40% more energy	Energy requirements
C16	There is little public support for CO_2 storage	Lack of public support

Note: The arguments refer to 'CO_2 storage', because the Dutch media use this term instead of 'Carbon Capture and Storage'.

2.1. Argument selection

We selected the arguments from the pool of arguments used in public debate on CCS in the Netherlands, identified in a previous study (Van Egmond and Hekkert, 2012). We only included arguments that are perceived as valid by experts (i.e. common misconceptions were excluded), straightforward enough to be written down clearly in one or two sentences, and refer to the use of CCS in general, rather than specific policies (e.g. mandatory CCS at power plants). We consulted a panel of CCS experts from academia, knowledge institutes and industry, as well as communication experts, to construct a set of the most prominent 16 pro and 16 con arguments (see Table 1; labels are included for ease of reference). The consultation consisted of a workshop about the goals and design of the study and feedback on the concept survey.

2.2. Sample and data collection

We collected data by using a Dutch, national, online marketing panel ($n = 920$). The sampling procedure used quotas for age, gender, education level and state of residence to ensure that the sample was representative of the adult (i.e. at least 18 years) Dutch population. Respondents in the sample are slightly older ($M = 51.66$ years; SD = 13.41) and slightly more likely to be female (53.4%), highly educated (37,5%) and to live in the south of the Netherlands (31.9%). To control for these differences, we included a weight factor in the analysis based on these characteristics. Panel members received compensation for their participation, they were assured of the anonymity of the results and they were debriefed at the end of the survey.

2.3. Discrete choice experiment

The respondents were introduced to the goal of the DCE in the beginning of the survey. They read the following description: *"The use of CO_2-storage is being considered in the Netherlands, as well as abroad. To make a decision, a trade-off is being made between arguments pro and con CO_2-storage. We therefore find your opinion about these arguments very important".*

Half of the respondents in the experiment then chose between eight consecutive pairs of pro arguments ($n = 465$), while the other half chose between con arguments ($n = 455$). We investigated pro and con arguments independently to control for differences in their persuasiveness, importance and novelty. Since citizens generally give greater weight to negative objects or events (Rozin and Royzman, 2001), con arguments are often more salient and persuasive than pro arguments (Cobb and Kuklinski, 1997; Sen and Lerman, 2007; Skowronski and Carlston, 1987).

The experimental design included every combination of two pro or two con arguments. We divided the 240 choice sets into 30 blocks to reduce the number of choice sets per respondent to eight. Respondents were randomly assigned to a survey version. The experimental design was generated using the software package Ngene. Fig. 1 displays an example choice set.

2.4. Pre- and post-test of CCS attitude

Before and after the DCE respondents indicated their agreement with three statements using five-point Likert items ('totally disagree' (1) to 'totally agree' (5)): 'I am positive about CO_2 storage', 'CO_2 storage is dangerous', and 'CO_2 storage is useful'. We averaged the scores for the three items to construct an indicator for attitude toward CCS. The reliability of the attitude scale is adequate (Cronbach's α; before = 0.76, after = 0.81).

2.5. Data analysis

We first tested whether the range of arguments to which an individual was exposed had any effect on attitude towards CCS. To this end, we compared the means of the pre- and post-test of CCS attitude using paired sample *t*-tests. We then estimated conditional logit models and latent class models (Vermunt and Magidson, 2002) using the software package Latent Gold 5.0. We estimated separate models for persuasiveness, importance and novelty using choice as a binary dependent variable and the arguments as independent, nominal variables. The conditional logit models are regression models for the probability that respondent *i* selects alternative *m* at replication *t*, given the values of the attributes of the alternatives (z_{it}^{att}). The conditional logit model therefore has the following form:

$$P(y_{it} = m | z_{it}^{att}) = \frac{\exp\left(\eta_{m|z_{it}}\right)}{\sum_{m'=1}^{M} \exp\left(\eta_{m'|z_{it}}\right)} \quad (1)$$

where y_{it} denotes the value of the binary dependent variable and M denotes the number of alternatives. In our models $\eta_{m|z_{it}}$ is a linear function of the attribute effects (β_p^{att}) and an alternative specific

Argument 1	*Argument 2*
"A waste product such as CO_2 should be disposed of properly."	"CO_2 storage can be used in industries where there are no other options for reducing CO_2 emissions."
Which of the two arguments…	
…..do you think is most persuasive?	
☐ Argument 1	☐ Argument 2
…..do you think is most important?	
☐ Argument 1	☐ Argument 2
….. is most new to you?	
☐ Argument 1	☐ Argument 2

Fig. 1. Example choice set.

constant (β_m^{con}):

$$\eta_{m|z_{it}} = \beta_m^{con} + \sum_{p=1}^{p} \beta_p^{att} z_{itmp}^{att} \quad (2)$$

where the p index refers to a particular attribute. Each of our models included a nominal attribute with sixteen levels that represents the arguments. This attribute was effects coded in the model, which means that the parameters of the levels sum to zero. The alternative specific constant controls for whether the alternative was on the right or left of the choice set. A latent class model extends this model by assigning respondents that make similar choices to the same segment. A categorical latent variable captures the segment membership (x) of each respondent. The model includes separate parameters for each latent segment. The latent class model therefore has the following form:

$$P(y_{it} = m|x, z_{it}^{att}) = \frac{\exp\left(\eta_{m|x,z_{it}}\right)}{\sum_{m'=1}^{M} \exp\left(\eta_{m'|\mathbf{x},\mathbf{z}_{it}}\right)} \quad (3)$$

The linear function $\eta_{m|x,z_{it}}$ is

$$\eta_{m|x,z_{it}} = \beta_{xm}^{con} + \sum_{p=1}^{p} \beta_{xp}^{att} z_{itmp}^{att} \quad (4)$$

As we included sampling weights based on the sociodemographic characteristics of the respondents, Pseudo ML (PM) estimation is used to estimate the parameters in the model (see Vermunt and Magidson, 2005 for additional information on the exact estimation methods). We explored models consisting of one to four latent segments. We used respondents' choices, socio-demographics and attitudes before the experiment to identify segments. In line with best practice for LCA (Nylund et al., 2007), we selected the models with the lowest Bayesian Information Criterion (BIC).

3. Results

3.1. Attitude change

The average attitude score was neutral before exposure to the arguments (pro: $M = 3.03$, $SD = 0.76$; con: $M = 2.93$, $SD = 0.75$). Attitudes changed significantly after exposure to pro arguments ($M = 3.18$, $SD = 0.76$, $t = 6.92$, $p < 0.001$) and con arguments ($M = 2.71$, $SD = 0.75$, $t = 8.78$, $p < 0.001$). This implies that making consecutive choices between pairs of pro and con CCS arguments had a small, but significant effect on the attitude of respondents towards CCS. Con arguments had a slightly stronger effect on attitude ($\Delta = 0.21$) than pro arguments ($\Delta = 0.15$). The difference in size is significant at the 0.10 level ($t = 1.89$). As mentioned in Section 2.3, this difference is to be expected due to the higher salience of negative information in con arguments.

3.2. Conditional logit models

The conditional logit parameters reveal the *perceived* persuasiveness, importance and novelty of CCS arguments. In the interest of brevity, we will refer to persuasiveness rather than perceived persuasiveness in the results section. The parameters are based on effects coding, which means that the models compare the persuasiveness, importance and novelty of an argument to the *average* persuasiveness, importance or novelty of all arguments (see Table 2). The explanatory value of the models is adequate (McFadden $R^2 = 0.05–0.11$) (Louviere et al., 2000). The models predict between 59.6% and 64.9% of all respondents' choices correctly. Although respondents are indifferent between some pairs of arguments, the best and worst arguments have substantial predicted probabilities (lowest = 29% (P3), highest = 79% (C10)).

There is a strong *positive* correlation between the parameters of persuasiveness and importance (pro: $r = 0.92$ and con: $r = 0.93$). Important arguments are therefore likely to be persuasive. There is a moderate *negative* correlation between the parameters of persuasiveness and novelty (pro: $r = -0.34$ and con: $r = -0.41$) and importance and novelty (pro: $r = -0.46$ and con: $r = -0.29$). New arguments are therefore likely to be unpersuasive and unimportant. The following section discusses the results per dependent variable.

- *Persuasiveness of pro arguments:* Respondents find six pro arguments persuasive. The most persuasive argument by far is P6 (industrial applications), followed by P16 (dispose of CO_2 garbage) and P13 (safety of natural gas fields) after a substantial

Table 2
Conditional logit models.

Pro					Con				
No.	Label	Pers.	Imp.	New	No.	Label	Pers.	Imp.	New
P1	Climate problem	0.00	0.39**	−0.47***	C1	Unnecessary for climate problem	0.32**	0.54***	−0.40***
P2	International climate agreements	0.27*	0.14	−0.54***	C2	Promotes coal	−0.78***	−0.74***	−0.20
P3	Lifestyle changes	−0.91***	−0.85***	0.02	C3	Relatively expensive	0.09	0.12	0.05
P4	Set an example	−0.62***	−0.46***	−0.27*	C4	Investment uncertainty	−0.10	−0.22*	−0.03
P5	Reduces need for nuclear	0.03	0.20	0.06	C5	Indefinite monitoring	0.03	0.11	−0.04
P6	Industrial applications	0.90***	0.80***	−0.13	C6	Falling real estate prices	−0.10	−0.47***	−0.33**
P7	Cheap coal	−0.49***	−0.36**	0.19	C7	Detracts from renewables	−0.24*	0.05	0.10
P8	Economic benefits	0.44***	0.61***	0.40***	C8	Rising electricity bills	−0.26*	−0.49***	0.03
P9	Relatively cheap	−0.10	−0.26*	0.38***	C9	Risks not fully understood	0.72***	0.55***	0.09
P10	Natural gas experience	0.30*	0.09	−0.28*	C10	Avoid generating CO_2	1.31***	1.25***	−0.55***
P11	Use in other countries	−0.06	−0.37**	0.31**	C11	Suffocation	0.00	0.09	0.37***
P12	Enhanced oil recovery	−0.47***	−0.66***	0.54***	C12	Groundwater acidification	−0.10	0.16	0.24
P13	Safety of natural gas fields	0.57***	0.52***	−0.08	C13	Earthquakes	−0.07	−0.05	0.03
P14	Space requirements	−0.65***	−0.51***	0.21	C14	Hazardous chemicals	−0.30*	−0.20	0.66***
P15	Stability energy supply	0.17	−0.09	0.12	C15	Energy requirements	−0.40**	−0.48***	0.46***
P16	Dispose of CO_2 garbage	0.63***	0.84***	−0.46***	C16	Lack of public support	−0.11	−0.22	−0.48***
L/R		−0.24***	−0.15**	0.01			−0.21***	0.02	0.03
McFadden *R*-squared		0.11	0.11	0.05			0.09	0.10	0.05
% Choices predicted correctly		64.9%	64.6%	59.6%			62.6%	62.5%	60.2%

Note: displays parameters and significance level of *z*-test (*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$). The significance test indicates whether the parameter is significantly different from the average of all parameters.

drop in persuasiveness. Other persuasive arguments are P8 (economic benefits), P10 (natural gas experience) and P2 (international climate agreements). Respondents find five pro arguments unpersuasive. The least persuasive argument by far is P3 (lifestyle changes), followed by P4 (set an example) and P14 (space requirements) after a substantial jump in persuasiveness. Other unpersuasive arguments are P7 (cheap coal) and P12 (enhanced oil recovery).

- *Importance of pro arguments*: Five pro arguments are important to respondents. The most important arguments are P16 (dispose of CO_2 garbage) and P6 (industrial applications), followed at a considerable distance by P8 (economic benefits), P13 (safety of natural gas fields) and P1 (climate problem). Respondents find seven arguments unimportant. The least important argument is P3 (lifestyle changes), followed at a considerable distance by P12 (enhanced oil recovery) and P14 (space requirements). Other unimportant arguments are P4 (set an example), P11 (use in other countries), P7 (cheap coal) and P9 (relatively cheap).
- *Novelty of pro arguments*: Four pro arguments are new to respondents. In order of decreasing novelty, these arguments are P12 (enhanced oil recovery), P8 (economic benefits), P9 (relatively cheap) and P11 (use in other countries). Except for P8, all of these arguments are also unimportant and/or unpersuasive. Respondents find five arguments not new. In order of increasing novelty, these arguments are P2 (international climate agreements), P1 (climate problem), P16 (dispose of CO_2 garbage), P10 (natural gas experience) and P4 (set an example). Except for P4, all of these arguments are persuasive and/or important.
- *Persuasiveness of con arguments*: Respondents find three con arguments persuasive. The most persuasive argument by far is C10 (avoid generating CO_2), followed by C9 (risks not fully understood) and C1 (unnecessary for climate problem). The distance in score between these three arguments is substantial. Respondents find five con arguments unpersuasive. The least persuasive argument by far is C2 (promotes coal), followed by C15 (energy requirements) after a substantial jump in persuasiveness. Other unpersuasive arguments are C14 (hazardous chemicals), C8 (rising electricity bills) and C7 (detracts from renewables).
- *Importance of con arguments*: Three con arguments are important to respondents. The most important argument by far is C10 (avoid generating CO_2), followed at a considerable distance by C9 (risks not fully understood) and C1 (unnecessary for climate problem). Respondents find five con arguments significantly unimportant. The least important argument by far is C2 (promotes coal), followed at a considerable distance by C8 (rising electricity bills), C15 (energy requirements) and C6 (falling real estate prices). Another unimportant argument is C4 (investment uncertainty).
- *Novelty of con arguments*: Three con arguments are new to respondents. The newest argument is C14 (hazardous chemicals), followed at a considerable distance by C15 (energy requirements) and C11 (suffocation). Respondents find four con arguments not new. The least new argument is C10 (avoid generating CO_2), followed by C16 (lack of public support), C1 (unnecessary for climate problem) and C6 (falling real estate prices).

The conditional logit models show several patterns. First, citizens find arguments about climate change (P1, P2, C1) less persuasive and/or important than other arguments, even though climate change is the primary goal of CCS. Second, the most important pro and con arguments (P16, C10) use injunctive norms; they prescribe *desirable* actions by using the verb 'should'. Third, arguments about *specific* risks or the role of CCS in the energy mix are likely to be new, unpersuasive and unimportant. We return to these patterns in the discussion, but will first show how population segments differ from the average.

3.3. Latent class models

The latent class models illuminate differences between segments with respect to argument persuasiveness, importance and novelty (see Tables 3 and 4). The performance of the models is good (McFadden R^2 = 0.18–0.33) (Louviere et al., 2000). The models

Table 3
Latent class models for pro arguments.

		Persuasive			Important		New		
		1 Majority 85.8%	2 CCS in the energy mix 7.2%	3 Affordable, secure energy 7.1%	4 Majority 93.1%	5 International position of NL 6.9%	6 Majority 84.9%	7 Stakeholder actions 5.7%	8 Safety and security 9.5%
P1	Climate problem	0.05	−6.76***	1.46	0.48***	−5.95***	−0.21	−15.45***	−13.48***
P2	International climate agreements	0.56***	−8.97***	−3.07	0.12	5.84**	−0.77***	13.65***	−1.25
P3	Lifestyle changes	−1.03***	4.61***	−4.72***	−0.87***	−3.98***	0.17	−9.93***	−8.39***
P4	Set an example	−0.55***	−8.69***	−2.52	−0.59***	8.96***	−0.31**	12.79***	−3.73
P5	Reducing need for nuclear	−0.04	13.45***	−9.45***	0.36**	−19.16***	0.07	4.08***	−2.05
P6	Industrial applications	0.87***	7.12***	3.39**	0.89***	2.68***	−0.02	4.73***	−17.33***
P7	Cheap coal	−0.71***	7.31***	3.50**	−0.29*	−6.47***	0.28*	−9.11***	1.57
P8	Economic benefits	0.45***	−9.79*	9.87***	0.49***	15.55***	0.44***	4.79**	−1.35
P9	Relatively cheap	−0.37**	6.55***	5.10***	−0.27*	−6.35***	0.49***	−11.01***	4.04
P10	Natural gas experience	0.48***	−6.93***	−0.19	0.03	7.52***	−0.19	−4.06***	−3.35
P11	Used in other countries	−0.04	−0.20	−2.99*	−0.34**	−10.48***	0.21	8.68***	4.25
P12	Enhanced Oil Recovery	−0.52***	4.21***	−3.57*	−0.73***	0.02	0.46***	−3.78**	17.30***
P13	Safety natural gas fields	0.61***	−4.32***	3.45**	0.47***	10.00***	−0.30**	−2.99***	9.31**
P14	Space requirements	−0.68***	−7.83***	−1.59	−0.62***	9.09***	0.30*	−0.24	−2.24
P15	Stable energy supply	0.00	5.15***	10.62***	0.03	−14.93***	−0.01	−5.81***	12.48***
P16	Dispose of CO_2 garbage	0.93***	5.08**	−9.29***	0.84***	7.67***	−0.63***	13.65***	4.21
L/R		−0.28***			−0.17***		0.00		
McFadden *R*-squared		0.25			0.18		0.20		
% Choices predicted correctly		71.9%			67.8%		66.6%		

Note: displays parameters and significance level of *z*-test (*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$). The significance test indicates whether the parameter is significantly different from the average of all parameters.

Table 4
Latent class models for con arguments.

		Persuasive		Important			New			
		9 Majority 90.3%	10 Local risks 9.7%	11 Uncertain, new technology 52.5%	12 Climate & norms 40.1%	13 Risks & costs 7.4%	14 Majority 62.8%	15 Uncertain, new technology 23.8%	16 Risks & costs 6.4%	17 Risks & public support 7.0%
C1	Unnecessary for climate problem	0.30*	0.95	0.11	1.48***	−1.44	−0.58***	0.31	−9.86***	−16.07***
C2	Promotes coal	−0.87***	−5.72***	−0.75**	−0.92*	−1.19	0.20	0.01	−20.35***	−16.44***
C3	Relatively expensive	0.09	−0.78	−0.60*	1.01	20.25***	0.30	−0.17	3.41*	−5.00
C4	Investment uncertainty	−0.05	−1.21	−0.10	−0.81**	5.60	−0.24	0.43	−13.61***	0.94
C5	Indefinite monitoring	−0.01	0.16	0.32	−0.01	−6.73***	−0.43**	0.82*	6.69***	−5.98***
C6	Falling real estate prices	−0.22	5.62**	0.25	−1.99*	−0.63	−0.35	−0.23	−19.83***	−0.50
C7	Detracts from renewables	−0.22	−5.31***	−0.54*	0.79	0.09	0.43**	−0.15	8.08*	−11.61***
C8	Higher electricity bills	−0.30*	0.33	−0.02	−1.79*	1.30	0.13	−0.16	8.18*	−2.62
C9	Risks not fully understood	0.65***	9.30***	0.77**	0.69	−11.44***	−0.39	1.45***	−14.96***	13.00***
C10	Avoid generating CO_2	1.32***	4.50***	0.50	3.76**	14.59***	−1.56***	0.54	9.24**	1.88
C11	Suffocation	−0.20	11.58***	0.27	−0.02	−7.49**	0.78***	−0.37	−0.54	3.32**
C12	Groundwater acidification	0.07	−7.24*	0.27	−0.31	10.68***	0.08	0.23	13.22***	7.92***
C13	Earthquakes	−0.24	16.58***	0.08	−0.71*	6.23***	0.36	−0.94*	−5.37**	9.94**
C14	Hazardous chemicals	−0.16	−7.25***	0.20	−0.63	−15.40***	1.46***	−0.87	2.54	12.81***
C15	Energy requirements	−0.20	−11.67***	−0.57*	−0.56	−2.70	1.00***	−1.01*	14.72***	−10.24***
C16	Lack of public support	0.03	−9.84**	−0.20	0.01	−11.71***	−1.18***	0.12	18.45***	18.66***
L/R		−0.22***		0.01			0.05			
McFadden *R*-squared		0.18		0.30			0.33			
% Choices predicted correctly		66.1%		72.1%			74.0%			

Note: displays parameters and significance level of *z*-test (*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$). The significance test indicates whether the parameter is significantly different from the average of all parameters.

predict between 66.1% and 74.0% of all respondents' choices correctly. The substantial improvement in precision demonstrates the value of uncovering observed heterogeneity. We characterize population segments by identifying common themes, words or

Table 5
Socio-demographics and CCS attitude per latent class.

Pro	Age	CCS attitude	% Education-low	% Education-mid	% Education-high	% Male
Persuasive	$F = 0.886$ ($df = 472$)	$F = 0.222$ ($df = 472$)	$\chi^2 = 2.605$ ($df = 4$)			$\chi^2 = 2.239$ ($df = 2$)
1	46.0	3.01	31.9	42.3	25.8	49.5
2	44.5	3.03	20.0	50.0	30.0	61.9
3	50.4	2.91	39.1	30.4	30.4	60.9
Important	$F = 3.118$ ($df = 472$)	$F = 0.606$ ($df = 472$)	$\chi^2 = 3.754$ ($df = 2$)			$\chi^2 = 3.387$ ($df = 1$)
4	46.5	3.01	31.8	41.0	27.1	51.6
5	40.7	2.90	25.9	59.3	14.8	33.3
New	$F = 5.184^{**}$ ($df = 472$)	$F = 0.592$ ($df = 472$)	$\chi^2 = 3.056$ ($df = 4$)			$\chi^2 = 3.641$ ($df = 2$)
6	46.5	3.00	31.1	41.6	27.3	51.9
7	36.0	3.15	43.5	43.5	13.0	33.3
8	49.6	3.08	28.6	47.6	23.8	42.9
Con	**Age**	**CCS attitude**	**% Education-low**	**% Education-mid**	**% Education-high**	**% Male**
Persuasive	$F = 0.191$ ($df = 454$)	F = 1.508 ($df = 454$)	$\chi^2 = 2.108$ ($df = 2$)			$\chi^2 = 0.432$ ($df = 1$)
9	52.7	2.91	25.7	37.0	37.3	45.5
10	51.7	3.09	35.5	38.7	25.8	51.6
Important	$F = 1.822$ (df = 454)	$F = 1.242$ ($df = 454$)	$\chi^2 = 4.143$ ($df = 4$)			$\chi^2 = 4.570$ ($df = 2$)
11	52.3	2.95	30.2	34.7	35.1	41.6
12	53.6	2.87	21.7	40.2	38.1	51.9
13	48.3	3.11	23.8	38.1	38.1	42.9
New	$F = 4.188^{**}$ ($df = 454$)	$F = 1.124$ ($df = 454$)	$\chi^2 = 10.161$ ($df = 6$)			$\chi^2 = 6.119$ ($df = 3$)
14	53.7	2.91	24.2	35.6	40.2	45.9
15	51.2	2.97	32.6	37.1	30.3	39.3
16	47.3	2.79	31.6	52.6	15.8	68.4
17	45.1	3.21	31.3	50.0	18.8	56.3

$^{**}p < 0.01$.

concepts in the arguments that score significantly more or less than the average of arguments. We also tested whether there are significant differences between segments in socio-demographics or CCS attitude before the experiment (see Table 5). Only a few differences were significant, which could be caused by the small size of most of the segments.

3.3.1. Pro arguments

- *Persuasiveness of pro arguments*: Segment 1 (85.8%) resembles the average opinion closely (i.e. the conditional logit model). Segment 2 (7.2%) instead focuses on the interconnection between CCS and other energy technologies. The arguments they find persuasive often refer (in) directly to nuclear, solar, wind or fossil fuel based energy, such as P3 (lifestyle changes), P5 (reduces need for nuclear), P7 (cheap coal), P9 (relatively cheap), P12 (enhanced oil recovery) and P15 (stable energy supply). Unlike segment 1, they find arguments about climate change mitigation (P1, P2), economic benefits (P8) and opportunities (P10), and safety (P13) unpersuasive. Segment 3 (7.1%) focuses on the affordability and security of energy supply, rather than an encompassing perspective on the energy mix. This is evidenced by the persuasiveness of P7 (cheap coal), P8 (economic opportunities), P9 (relatively cheap), and P15 (stable energy supply). Segment 3 finds the normative argument P16 (dispose of CO_2 garbage) unpersuasive.
- *Importance of pro arguments*: Segment 4 (93.1%) resembles the average opinion closely. Segment 5 (6.9%) focuses on the international position of the Netherlands concerning CCS and climate change, evidenced by the importance of P2 (international climate agreements), P4 (set an example) and P10 (natural gas experience). In contrast to segment 4, they find P1 (climate problem) and P5 (reduces need for nuclear) unimportant.
- *Novelty of pro arguments*: Segment 6 (84.9%) resembles the average opinion closely. Segment 7 (5.7%) instead focuses on past or desirable actions of CCS stakeholders, evidenced by the novelty of P2 (international climate agreements), P4 (set an example), P11 (use in other countries) and P16 (dispose of CO_2 garbage). They also find arguments P5 (reducing need for nuclear) and P6 (industrial applications) new. Segment 7 ($M = 36.0$ years) is significantly younger ($F = 5.148$, d$f = 472$, $p = 0.006$) than segments 6 ($M = 46.5$ years) and 8 ($M = 49.6$ years). Segment 8 (9.5%) focuses on the safety and security effects of CCS in arguments about enhanced oil recovery (P12), storage in natural gas fields (P13) and beneficial effects on energy security (P15). Segments 7 and 8 are both relatively familiar with argument P1 (climate problem) and P3 (lifestyle changes).

Class memberships of persuasiveness and importance are not related ($\chi^2 = 0.772$; d$f = 2$; $p = 0.680$), neither are those for persuasiveness and novelty ($\chi^2 = 1.367$; d$f = 4$; $p = 0.850$). The solutions for importance and novelty are related ($\chi^2 = 13.578$; d$f = 2$; $p = 0.001$). The probabilities of being in segments 4 and 6 are related, but rather weakly ($r = 0.145$).

3.3.2. Con arguments

- *Persuasiveness of con arguments*: Segment 9 (90.3%) resembles the average opinion closely. Segment 10 (9.7%) instead focuses on risks that citizens living near storage locations are exposed to, evidenced by the persuasiveness of C6 (falling real estate prices), C11 (suffocation) and C13 (earthquakes). They also find C7 (detracts from renewables), C12 (groundwater acidification), C14 (hazardous chemicals), C15 (energy requirements) and C16 (lack of public support) unpersuasive.
- *Importance of con arguments*: In contrast to most other models, the majority is split between two segments. Segment 11 (52.5%) only finds C9 (risks not fully understood) important. They find arguments about the role of CCS in the energy mix unimportant, such as C2 (promotes coal), C3 (relatively expensive), C7 (detracts from renewables) and C15 (energy requirements). Segment 12 (40.1%) instead finds arguments C1 (unnecessary for climate problem) and C10 (avoid CO_2 emissions) important. In contrast to segment 11, they find arguments about costs to citizens and firms unimportant, such as C4 (investment uncertainty), C6 (falling real estate prices) and C8 (electricity prices). Segment 13 (7.4%) focuses on the costs of CCS relative to solar and wind energy (C3) and risks of groundwater acidification (C12) and earthquakes (C13). Like segment 12, they find argument C10 (avoid CO_2 emissions) important.
- *Novelty of con arguments*: Segment 14 (62.8%) resembles the average opinion closely. Segment 15 (23.8%) instead finds the uncertainty surrounding CCS (C9) and the need for monitoring storage sites (C5) new. Segment 16 (6.4%) is unfamiliar with the costs of CCS (C3, C8), the interconnection between CCS and renewables (C3, C7), energy requirements (C15), risks of groundwater acidification (C12) and past or desirable actions of stakeholders or the public with regard to CCS (C10, C16). Segment 17 (7.0%) is instead unfamiliar with risks of CCS to human welfare (C9, C11, C12, C13, C14) and the lack of public support (C16). Segment 16 ($M = 47.3$ years) is significantly younger ($F = 4.188$, d$f = 454$, $p = 0.006$) than segment 14 ($M = 53.7$ years).

The solutions for persuasiveness and importance ($\chi^2 = 0.647$; d$f = 2$; $p = 0.724$), persuasiveness and novelty ($\chi^2 = 5.653$; d$f = 3$; $p = 0.130$) and importance and novelty ($\chi^2 = 8.333$; d$f = 6$; $p = 0.215$) are not significantly related.

The latent class models show that the majority of respondents (between 62.8% and 93.1%) perceives CCS arguments similarly. The majority is split in just one latent class model (importance of con arguments). A few small segments (between 5.7% and 23.8%) have distinct views on CCS arguments. Segments focus on the role of CCS in the energy mix (2), affordability and security of energy (3), the international position of the Netherlands concerning CCS and climate change (5), actions of CCS stakeholders (7), safety and security (8), local risks (10), CCS as an uncertain, new technology (11, 15), climate and norms (12), risks and costs (13, 16), and risk and public support (17).

4. Discussion

This study presents the persuasiveness, importance and novelty of pro and con CCS arguments for segments of citizens. We address three gaps in the understanding of citizens' reactions to the *content* of stakeholders' communication. First, we expand the range of investigated arguments. We show that most citizens find arguments about climate change less persuasive and/or important than other arguments, even though climate change mitigation is the primary goal of CCS. They instead prefer arguments about particular norms, industrial applications of CCS, economic benefits or safety. Second, we uncover heterogeneity by showing how population segments differ from the majority. In contrast to the majority, segments focus on arguments about the role of CCS in the energy mix, the affordability and security of energy supply, specific risks to citizens living near storage locations or the international position of the Netherlands with regard to CCS. Third, we examine message effectiveness beyond persuasiveness and attitude change. We show that important arguments that are not new to citizens are more likely to be persuasive.

The results imply that stakeholders will struggle to convey the importance of CCS for climate change mitigation, unless they discuss additional benefits of various mitigation technologies, such as industrial applications, economic benefits or energy security and affordability. We would not suggest that stakeholders misrepresent the value of CCS by focusing exclusively on additional benefits. Rather, we want to highlight the discrepancy between the primary goal of CCS and preferences of citizens for other arguments and issues. As citizens also prefer normative arguments, stakeholders should incorporate norms into arguments about climate change and into their overall engagement strategies.

Uniform communication can be somewhat effective as the majority of citizens has similar opinions about CCS. Yet, a segmented communication approach can use distinct CCS storylines to engage population segments, which can be an important factor in establishing public acceptance for a technology. Our results provide a foundation for the construction of such storylines. Further research should account for heterogeneity, as substantial deviations from the average opinion will otherwise be overlooked. Although some arguments are CCS specific, most arguments are also applicable to other energy technologies. Our results therefore offer tentative conclusions about citizens' reactions to arguments about energy technologies with a similar public image, such as wind energy or shale gas.

Two limitations to this study raise issues for further research. First, we examined arguments in isolation; our analysis did not attempt to account for interactions between arguments and the source of the message (Eagly et al., 1978), for different frames (Bickerstaff et al., 2008; Meyerowitz and Chaiken, 1987) or for the influence of other content. Future studies should extend the analysis to encompass full messages, with different sources and frames. Second, this study focused on a single country, which limits the generalizability of the results. The importance of norms or values and the perceived relevance of the climate change issue vary across countries and cultures. Future research should include between-country comparisons of the influence of arguments on attitude towards CCS.

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