

## Public concepts of CCS: Understanding of the Dutch general public and its reflection in the media

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### ARTICLE INFO

#### Article history:

Received 16 March 2012  
Received in revised form 31 July 2012  
Accepted 30 August 2012  
Available online 30 October 2012

#### Keywords:

Public perception  
Carbon capture and storage  
Media  
Climate change  
Energy production  
Awareness  
Opinion

### ABSTRACT

This study aims to increase understanding of the public view on CO<sub>2</sub> capture and storage (CCS) and energy innovations in the Netherlands. The study is based on the premise that to understand the public's concerns and to predict their future opinion, it is necessary to know how people arrive at their evaluations about CCS. The study described in this paper aimed to enhance insight into currently held beliefs and awareness among the general public about CCS and CO<sub>2</sub> as well as to investigate the role of the media as a vehicle for knowledge transfer. To meet the first aim, we interviewed 15 lay people to identify commonly held beliefs. Next, we investigated the prevalence of these beliefs by administering a questionnaire among 401 respondents. To meet the second aim, we analyzed the 430 articles mentioning CCS in all major Dutch newspapers from mid-2009 to mid-2010 and investigated respondents' media use and exposure to recent media events about CCS. The survey revealed several beliefs that were shared by a large group of respondents, some of which were factually incorrect. The media analysis did not yield evidence that national newspapers reinforce or create particular misperceptions such as found in the survey.

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### 1. Introduction

The Netherlands continues to strive to meet national targets for climate change mitigation and energy use. CO<sub>2</sub> capture and storage is one of the options, that is, seen by some as a possibility to achieve those national targets. The extent to which the Dutch society understands and supports this option is an important research question because this will define if and how CCS will be implemented in the Netherlands. This was recently demonstrated when a planned storage demonstration project was called off due to public protest (Brunsting et al., 2011), where the public made very clear that they had wanted a voice in the debate. It could be argued that a successful energy transition strategy depends on the involvement and support of the public. The better the public understands the energy and climate change issues, the better it can contribute substantially and meaningfully to the discourse and take appropriate actions. That begs the question how much people currently understand of these issues. This study aims to increase the understanding of the public view on CO<sub>2</sub> capture and storage (CCS) in the Netherlands.

In recent years, several studies have investigated public awareness of CCS. These show that CCS is a relatively new topic for the general public. In the Netherlands, a mere 3.6% of a random sample of the general Dutch population stated that they were aware

of CCS technology in 2004 with 20.2% stating to have heard of it a little. These percentages increased to 10.4% and 46.7%, respectively, by 2008 (de Best-Waldhober and Daamen, 2011). In a study comparing the United States, the United Kingdom, Sweden and Japan, Reiner et al. (2006) found similar results. Between 22% of respondents in Japan and 4% in the U.S. confirm to have heard of CCS. Studies in Australia show similar results as well (Ashworth et al., 2009). Notwithstanding the low awareness among the general public, several demonstration projects have met with strong public opposition. Some were even cancelled solely due to opposition of local politicians and public (Brunsting et al., 2011; Feenstra et al., 2010). The Dutch project that was cancelled due to public protest might have had some impact on the awareness of the Dutch general public regarding CCS though, as this awareness seems to have increased after the start of public protest. At the end of 2009, 44.5% of 555 respondents drawn from the general Dutch population stated to have heard of CCS, while 5.5% stated to have heard quite a bit (Pietzner et al., 2011).

Contrary to expectations though, this rise in self-reported awareness does not seem to be accompanied by an increase in knowledge of CCS. In fact, the study of Pietzner et al. (2011) shows that less than 3% of respondents correctly identify mitigation of global warming as the sole goal of CCS among a list of several environmental problems, including inter alia ozone depletion and acid rain. A longitudinal comparison by de Best-Waldhober and Daamen (2011) of public awareness and knowledge between 2004 and 2008 also shows a lack of increase in knowledge, combined with only

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a small increase in awareness late 2008. Although there are no studies in other countries that compare the development of public awareness with the development of knowledge regarding CCS over time, there are other studies showing a discrepancy between self-reported awareness and actual knowledge. A study in Canada (Sharp et al., 2006) for instance showed that although between 10% of respondents in Alberta and Saskatchewan and 15% of respondents in the rest of Canada said to have heard of CCS, only very few of the respondents were able to correctly identify the problem CCS<sup>1</sup> addresses. It seems that awareness of CCS therefore does not directly imply knowledge of the technology. When interpreting these results, it is important to keep in mind though that measuring knowledge was only a small part of these studies. This means that these measurements of knowledge were not very elaborate. Two earlier studies in the USA and in Switzerland studied the ideas and beliefs of lay people about CCS and related topics much more elaborately (Palmgren et al., 2004; Wallquist et al., 2009). In-depth interviews with lay people were conducted for both studies, which revealed that people had concerns about the risks of CCS. This included fears that the pressure in the storage site would be too high and therefore damage the storage site or that the CO<sub>2</sub> would rise to the surface and leak because it is a gas. Some compared it to nuclear waste storage and some would attribute negative properties to CO<sub>2</sub> such as “unhealthy and smelly”, or that it could alter DNA of organism.

The elaborateness of the measurements of knowledge is not the only difference between the latter two studies and those mentioned before that. Where the first mentioned studies mostly measured knowledge by comparing what people know to what experts think they should know, a more top down approach, the latter two studies studied the ideas and beliefs that people have themselves, mostly before they have talked to experts. That raises the question what valuable knowledge is on this topic and how this relates to people’s actual knowledge, including ideas and beliefs. Earlier research in the Netherlands shows that what constitutes relevant information for people to develop their opinion is neither straightforward nor easily foreseen by CCS experts (de Best-Waldhober et al., 2008, 2009). To enable people to contribute to the debate about energy options it is therefore essential not only just to understand what constitutes relevant information for people, but also to understand what they know already and how this knowledge is developing. Although several studies have addressed parts of these research questions, none have addressed both knowledge and the development thereof, or have combined measurements of the “top down” kind of knowledge with “bottom up” measurements of lay beliefs. Moreover, the studies that have addressed lay beliefs have been done outside the Netherlands. The current study investigates both kinds of knowledge among the Dutch public.

One factor that seems obvious to take into account when studying how the public’s knowledge and beliefs of CCS develop is the media. One can argue that the media might have an influence on public opinion development, or at least that what is in the media reflects what is in the public opinion. Dowd et al. (2012) argue that mass media is understood to play a key role in generating public concern about particular issues and uncertainties associated with such new technologies. van Alphen et al. (2007) found an increase in the amount of articles about CCS in the Dutch written media up to 2007; following this Kliet (2010) states that this increase as well as the increase they find in later years reflects the development of public opinion. However, as mentioned before, public awareness of CCS has increased only slightly and not until 2008, and the few measures done in the Netherlands seem to indicate that

knowledge does not increase at all. This raises the question to what extent CCS in the media and public opinion regarding CCS interact in the Netherlands. Understanding not only what lay people know and belief about CCS but also what role the media might have as a vehicle for knowledge transfer will contribute significantly to decision making on communication efforts. Part of the study reported in this paper therefore investigates the role of the media as a vehicle for knowledge transfer.

## 2. Materials and methods<sup>2</sup>

This section is divided in two parts. First, the method of the study of lay knowledge and beliefs is explained. An overview of the design of this part will be given in Section 2.1, the specific measures are explained in more detail after that (Section 2.1.1). Second, the method of the study investigating the reflection of these concepts in the media is explained. An overview of the focus given in Section 2.2.1, after which both the research sample (Section 2.2.2) and the measures are explained (Section 2.2.3).

### 2.1. Method lay knowledge and beliefs study

The type of beliefs about CCS held by lay people, as well as the prevalence of these beliefs in the population, were measured by a questionnaire especially developed for this purpose. This questionnaire did not only include questions about CCS, but also topics related to CCS technology; CO<sub>2</sub>, electricity production and climate change. We further refer to this questionnaire as the Knowledge and Beliefs Test for reasons of efficiency. To include relevant beliefs commonly held by lay people, input for the questionnaire was generated on the basis of 15 in-depth interviews with people that have no professional involvement with CCS, climate or energy. Previous studies have shown 15 interviews are sufficient to elicit most commonly held beliefs as after this amount the emergence of new beliefs is negligible (Palmgren et al., 2004). An open interview protocol was used to ensure free elicitation of beliefs about all aforementioned topics. This protocol was tested a few times, based on this three different orders of main topics were used. Respondents did neither receive any information, nor were they corrected in this part of the interview if they expressed factually erroneous beliefs. We interviewed an approximately equal number of men and women with different educational levels, backgrounds, and professions. The mean age of this group was 49 and ranged from 19 to 59.

Results of these in-depth interviews revealed respondents were well aware of climate change and CO<sub>2</sub>, but had more trouble identifying the exact causes of climate change, effects and sources of CO<sub>2</sub> and where our electricity comes from. Awareness of CCS was much lower and respondents did not have much knowledge about suitable capture points, goals of CCS and storage sites.

The beliefs mentioned by these respondents were included in the Knowledge and Beliefs Test. A selection was made of beliefs most closely related to CCS technology and those most often mentioned by respondents. Additionally attention was paid to ensuring there was a balance between correct and incorrect answer options as well as a division of knowledge items, which could be categorized as either correct or incorrect and items measuring perception

<sup>2</sup> Part of the methodology section and results section of this paper have been made public before in the CATO2 report “The Dutch general public’s opinion on CCS and energy transition: Development in awareness, knowledge, beliefs and opinions related to information and media coverage.” (Paukovic, Brunsting, and De Best-Waldhober, 2011). Small parts of the results were reported in our conference paper for the GHGT10, “Awareness, knowledge, beliefs, and opinions regarding CCS of the Dutch general public before and after information”, de Best-Waldhober, Paukovic, Brunsting and Daamen, Energy Procedia, 2011, 4, 6315–6321.

<sup>1</sup> Sharp et al. used the abbreviation GDC (Geological disposal of CO<sub>2</sub>) in their survey, instead of CCS.

or awareness. It included measures of: characteristics, effects, and sources of CO<sub>2</sub>; attitude towards CO<sub>2</sub>; knowledge about CO<sub>2</sub> capture and storage technology; methods for electricity production used in the Netherlands; climate change; evaluative statements about CCS; news and events related to CCS; media use.

The questionnaire was administered to 401 Dutch respondents, who could fill in the questionnaire at home on their computer. The distribution of the sample was similar to the Dutch national population.

### 2.1.1. Measures

**2.1.1.1. Awareness.** Awareness of CCS, CCS project plans in the Netherlands, the IPCC and project plans in Barendrecht were all measured using the question: “have you heard of. . .” with 3 answer categories “No”, “A little” or “Yes”.

**2.1.1.2. CO<sub>2</sub> knowledge.** Respondents’ knowledge of CO<sub>2</sub> was measured using 32 items presenting either possible characteristics, effects or sources of CO<sub>2</sub>. For example “CO<sub>2</sub> is flammable” was one of the possible characteristics of CO<sub>2</sub>, “CO<sub>2</sub> influences the climate” was one of the effects and “CO<sub>2</sub> is released when spray cans with hair spray or deodorant are used” was one of the possible sources. The answers were measured on a 5-point scale ranging from 1: I am sure it is (or does) not, to 5: I am sure it is (or does). This way the scale not only measures whether respondents think a statement is true or false, but also measures how sure they are of their answer. This scale was tested in several think out-loud interviews and respondents stated to correctly understand the meaning of the scale. The mid-point ‘3’ meant the respondent was not sure of the answer or in other words ‘I don’t know’. The 5-point scale proved to work better than the 7-point scale for this specific scale, respondents in the think out-loud interviews indicated to find this easier. We have used 7-point scale for the other measurements because these are mostly Likert scales which respondents preferred a 7-point scale for. Also because some of these scales had been used in previous research and staying with a 7-point scale makes comparison easier.

**2.1.1.3. CCS knowledge.** Respondents’ knowledge of suitable CCS capture points and the aims of CCS were measured by presenting respondents with a list of possible alternatives of which they could select as many as they believed to be correct.

**2.1.1.4. Perception of storage.** Respondents’ perceptions of possible CO<sub>2</sub> storage was measured using 7 items which described a possible storage option, for example “The CO<sub>2</sub> will be stored in large barrels, tanks or containers” and “The CO<sub>2</sub> will be stored underground in the existing rock formations”. For each description respondents could indicate how likely they perceived it to be the CO<sub>2</sub> would be stored in such a storage. This was done on a 7-point scale ranging from 1: very unlikely, to 7: very likely.

**2.1.1.5. Perceived consequences of CCS.** Respondents were presented with 12 statements about what could possibly be consequences of CCS, but not necessarily so. For each statement they were asked to indicate how likely they perceived the statement to be a consequence of CCS. Their answers were given on a 7-point scale ranging from 1: very unlikely, to 7: very likely.

**2.1.1.6. Evaluative statements of CCS.** Subsequently respondents were asked to state their agreement with 7 normative statements about CCS such as for example: “CO<sub>2</sub> storage is necessary to mitigate the rise in average temperature on earth” and “CO<sub>2</sub> storage carries too many risks for public health”. Their answers were measured on a 7-point scale ranging from 1: strongly disagree to 7: strongly agree.

**2.1.1.7. Attitude towards CCS.** Attitude towards CCS was measured using 8 semantic scales with each presenting respondents with 2 opposing adjectives. Respondents were asked to indicate which adjective described their perception best on a 7-point scale. The closer their answer was to one of the scale ends the more the nearest adjective described their perception. For subsequent analysis all 8 scales were aggregated into one measure of CO<sub>2</sub> attitude and CCS attitude where a lower score signified a more negative attitude, while a higher score signified a more positive attitude. Factor analysis of the 8 CCS scales revealed all the 8 items were indeed measuring the same construct and reliability analysis indicated the new CCS Attitude scale had a Cronbach’s alpha of .927, which is very high. This justifies aggregating the eight scales into one measure of CCS attitude.

**2.1.1.8. Media consumption.** At the very end of the questionnaire respondents were asked how much time they spend using four different media sources: newspapers, radio, television and Internet. For each they were specifically asked how much time they use the media source for information about political and current affairs topics. In both cases answers were given in categories ranging from “not at all” to “more than 3 h per day” with each category increasing in steps of 30 min per day. Additionally respondents were asked about the newspapers they read and how often they read each.

## 2.2. Method of the medialog

### 2.2.1. Population of media messages

The aim of this research is to investigate a representative sample of messages about CCS, which together reflect opinions on CCS currently present in society. To achieve this goal we have opted to focus the analyses on messages in the national newspapers. Most angles from which CCS is reported on, and the prominence of these angles, are reflected by newspaper articles. Events from the outside world, such as attention-getting television reporting on CCS, are most often reported on in the national media. Thus by analysing newspapers, a researcher obtains a comprehensive impression of the ways in which a topic, in this case CCS, is written about, by whom, using which arguments, leading to what types of opinions. We also recorded large media events other than newspaper articles in the weeks before and during the surveying period. Furthermore, we have added questions to the surveys to measure the extent to which respondents have been exposed to these events, to be able to check if and how these events have influenced their opinion. Social media (twitter, blogs, etc.) have been excluded from this research as their different nature would also require an entirely different approach to the media analysis.

### 2.2.2. Research sample

The research sample consists of 430 articles from all national daily newspapers: AD, Het Financieele Dagblad, Nederlands Dagblad, NRC.next, NRC Handelsblad, Reformatorisch Dagblad, De Telegraaf, Trouw, De Volkskrant, and the free newspapers Metro and Spits. The present sample also includes Parool, which is a newspaper for the Amsterdam region, and Agrarisch Dagblad, which is a specialist newspaper. Despite these titles being deviant in these respects from the other national newspapers, we have decided to retain them in the sample. Articles are retrieved from the database LexisNexis, [www.lexisnexis.nl](http://www.lexisnexis.nl). Data were collected using the following search string: (CO<sub>2</sub>! OR kooldioxide! OR koolstofdioxide!) AND (afvang! OR opslag!) (translated: (CO<sub>2</sub>! OR carbondioxide!) AND (capture! OR storage!)). For the present report we monitored from May 1, 2009, until the end of May, 2010, which is the end of the data collection period of the Knowledge and Beliefs Test.

To meet the aims of the media log and develop a codebook for capturing ‘essential knowledge’, a definition of this concept was

needed. The definition of ‘essential knowledge’ of CCS in the meaning of ‘being predictive of opinion’ is a topic of on-going research. To develop a solid working definition nonetheless, we approached this concept from three angles. Firstly, we examined what constitutes complete, relevant, and correct information on CCS according to experts. To this end, we used three sources of expert information: (1) the ‘Argument map’ of CCS (Kalshoven, 2010); (2) the IPCC report about most important barriers to CCS implementation (IPCC, 2005); and (3) expert information and knowledge test from the ICQ conducted in 2007 (de Best-Waldhober et al., 2008). Secondly, we examined what constitutes relevant knowledge from the point of view of respondents to the Knowledge and Beliefs Test. Thirdly, we sampled several months of news coverage from the media log itself to see how CCS and related topics are in fact covered.

### 2.2.3. Measures

A codebook was developed to systematically capture media content, focusing on two issues:

**2.2.3.1. Knowledge transfer.** To what extent is any factual knowledge transferred or explanation given about the topics CO<sub>2</sub> (e.g. characteristics, sources, effects), CCS (e.g. the chain of capture, transport, and storage), energy production and use (e.g. the amount of fossil fuels in the energy mix) and climate change (e.g. its relation to CO<sub>2</sub> emissions)?

**2.2.3.2. Misperceptions.** Does the article contain information about CCS or related topics that is clearly incorrect?

## 3. Results

In the first part of the results, the results from the Knowledge and Beliefs Test are discussed. In the second part, the results of the media analysis are discussed. As there are too many questions and scales used in this study to include all the descriptive statistics and the relations between all concepts, we will only mention the most relevant results. The criteria for selection were a prevalence of insecurities or misconceptions for more than 25% of the respondents of the Knowledge and Beliefs Test, or a correlation with CCS attitude above .20 or below  $-.20$ . The latter values of correlations were chosen for practical reasons. It was a natural cut-off point and increasing the value left too little data to discuss. For each reported concept (knowledge of CO<sub>2</sub>, electricity mix and CCS, awareness of CCS, knowledge of CCS and evaluative statements on CCS) we will describe both the survey results as well as the results of the media-log. For each concept, both the distribution of answers as well as any significant correlation above .20 or below  $-.20$  to CCS attitude are reported.

### 3.1. Knowledge of CO<sub>2</sub>, electricity mix and climate change

Before introducing the topic of CCS respondents were asked about their knowledge of CO<sub>2</sub>. After introducing the topic of CCS, respondents were asked about their knowledge of energy production and perceptions of climate change.

#### 3.1.1. CO<sub>2</sub>

The overall results show that large numbers of respondents are unsure about the characteristics, effects and sources of CO<sub>2</sub>. Of a large number of statements a third or more of the respondents did not know what the correct answer was. For example, 38% of the respondents are unsure about whether CO<sub>2</sub> causes cancer or not. Similarly 34% are unsure whether CO<sub>2</sub> is harmful if it comes in contact with skin and 32% are not sure whether CO<sub>2</sub> makes a liveable climate on earth possible. The same uncertainty can be found about the sources of CO<sub>2</sub>; 39% are unsure whether it is released during

the production of natural gas and 29% about whether it is released during production of nuclear energy. Results also show that uncertainty about CO<sub>2</sub> affects perceptions of CCS, for example about the safety of CO<sub>2</sub> storage. Respondents who believe CO<sub>2</sub> is flammable or are unsure about it, believe it is significantly more likely that a CO<sub>2</sub> storage facility may explode because the CO<sub>2</sub> catches on fire than respondents who are somewhat sure CO<sub>2</sub> is not flammable and those who are very sure it is not ( $M=2.39$ ,  $M=3.23$ ,  $M=3.71$  respectively;  $F_{(2,398)}=37.82$ ,  $p<.001$ ).

To explore the relation of CO<sub>2</sub> knowledge with CCS attitude the knowledge items were correlated to CCS attitude. The relations were not very strong, ranging from  $r=-.01$  to  $r=-.29$ . The strongest positive relation with CCS attitude was with the statement “CO<sub>2</sub> is necessary for the growth of plants and trees”  $r=.25$ . The highest negative relation was found between CCS attitude and the statement that CO<sub>2</sub> is released during energy production from nuclear power  $r=-.29$ , followed by the statement that CO<sub>2</sub> is explosive  $r=-.25$ .

#### 3.1.2. Electricity mix

Out of the 401 respondents 337 gave an indication of what our electricity mix was made up of, while the rest chose the ‘I don’t know’ option. The results reveal a general underestimation of the use of fossil fuels, especially coal and natural gas, while the amount of renewable energy sources is overestimated. Respondents indicated coal accounts for 15% of our electricity mix on average and solar and wind account for 12% and 8% respectively. This while in 2008 the real figure for coal was 21% and wind and solar 4% and 0.03%, respectively.

The perceived share of fossil fuels in the electricity mix shows a weak correlation to CCS attitude. The amount of renewable energy, specifically the amount of solar and wind energy, in the current energy mix shows a slight negative correlation to CCS attitude, with respondents being more negative about CCS the more renewable energy they believe is used,  $r=-.22$ . It is possible that respondents who are generally aware these sources do not emit CO<sub>2</sub> consider CCS to be redundant the more of these sources they believe are used.

#### 3.1.3. Climate change

When asked whether they had heard of climate change, only 2% state not to have heard of it, while 19% and 79% indicate to have heard a little or plenty about it, respectively. 65% of the respondents are to some extent convinced the climate on earth is becoming warmer on average and 53% are to some extent convinced this is a result of CO<sub>2</sub> emission by human actions. Only 7% of the respondents are very convinced that man-made CO<sub>2</sub> emissions are the cause of global warming.

Notable is the hardly existent correlation between beliefs about climate change and attitude about CCS. The correlations range between  $-.06$  and  $.03$ . This indicates whether a respondent believes climate change is happening or not has hardly any connection to his or her perception of CCS.

#### 3.1.4. Understanding of the causal chain between energy use and climate change

It can be argued that knowledge of a couple of aspects of our current energy production is necessary to understand the need for CCS, whether it has an influence on evaluation of CCS or not. This includes knowledge about the fact that a large amount of our electricity is produced from fossil fuels, that fossil fuels release CO<sub>2</sub>, that CO<sub>2</sub> is a greenhouse gas and affects the climate and that average world temperatures are rising because of it. In the survey several items measured this knowledge. A schematic of this sequence from fossil fuels to climate change and the corresponding items that measured each step can be seen in Fig. 1. The upper

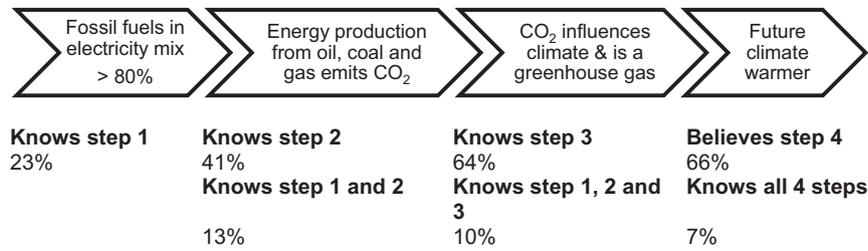


Fig. 1. The climate chain reasoning chain and percentage of respondents following each step.

row of text boxes shows the item and the percentage of respondents correctly answering the particular question, while the row of percentages beneath shows how many percent of the total sample correctly answered all the questions in the reasoning chain so far. Even though the real correct answer to the question about the percentage of fossil fuels in the electricity mix would have been approximately 93%, an estimate of 80% or higher was counted as correct as this still indicates respondents' understanding that fossil fuels make up a vast amount of the energy mix. For the item measuring whether a respondent believes average temperatures will be higher in the future, answer categories 5, 6 or 7 on the 7-point scale were counted as correct. For the items about fossil fuel sources of CO<sub>2</sub> and CO<sub>2</sub>s influence on climate answer categories 4 and 5 on the 5-point scale were counted as correct, 5 meaning 'I'm sure it does'. Fig. 1 shows the percentage of respondents that answered each item correctly and the percentage of respondents that answered all the previous items correctly.

The results, shown in Fig. 1, reveal a steep decline in the amount of correct answers after each step. Only 27% of respondents indicated fossil fuels accounted for at least 80% of the electricity mix. Of these respondents roughly half also knew these fossil fuels emit CO<sub>2</sub>, leaving 13% of the original sample. Only 10% of the total was left after questions were added about CO<sub>2</sub> being a greenhouse gas and influencing the climate. 7% of the total knew all this and agreed that the average world temperature was rising.

### 3.2. CCS awareness and knowledge

#### 3.2.1. CCS awareness

When asked whether they had ever heard of CCS, 35.4% of the respondents indicated they had not, 26.9% had heard a little and 37.7% stated they had heard of CCS. Out of the 151 respondents who have heard of CCS 95% have also heard about project plans in the Netherlands, answering 'yes' (77%) or 'a little' (18%). In fact 76% of the respondent who have heard of CCS have also heard about project plans in Barendrecht. Analysis of variance indicated there was a significant difference on the attitude towards CCS between people who have heard of CCS and people who have not ( $F_{(2,398)} = 13.781, p < .001$ ), and post hoc test (Tukey) showed people who answered 'yes' were significantly more positive about CCS ( $M = 4.33$ ) than people saying they have heard a little ( $M = 3.86$ ) or nothing at all ( $M = 3.66$ ).

Whether respondents had heard of CCS is correlated to the amount of time they spend reading newspapers in general ( $r = .21$ ) and slightly stronger to the amount of time they spend reading about political and current affairs topics ( $r = .27$ ) as well as the amount of such topics they watch on television ( $r = .20$ ). The other media sources, such as radio, Internet and general watching of television showed lower relations to awareness of CCS.

A very similar pattern is found between media consumption and the project plans in Barendrecht, where the highest relationship exists between awareness of these project plans and the amount of time respondents spend watching political and current affairs programmes on television as well as reading about political and

current affairs topics in the newspapers (for both  $r = .20$ ). Indeed as discussed previously, many respondents who state to have heard about CCS also report to have heard of specific project plans in The Netherlands and of the project in Barendrecht. This supports the notion that possibly most respondents hear about CCS only through information that reaches them about specific project plans.

#### 3.2.2. CCS knowledge – goals

Despite a lot of people thinking it is plausible climate change is the reason for CCS, only a small amount of people know enough to know this is the only environmental problem CCS aims to contribute to. Respondents could indicate which goals they thought CCS aimed to achieve and select as many goals as they wanted. As Tables 1 and 2 show, 'improvement of air quality' was chosen by the most respondents as a possible goal of CCS, with 67.3% of respondents selecting this answer category. 'Mitigation of climate change' was selected by 63.3%, and 57.4% of respondents thought CCS aimed to protect the ozone layer. Even though a large amount of respondents chose the correct answer category: 'mitigate climate change', only 8% of all respondents chose only one of the climate change related options ('limit rise in temperatures' and 'limit the increase

Table 1  
Respondents' perceptions of goals of CCS.

Goal of CCS	Percentage of respondents to select the category
Improve air quality	67
Mitigate climate change	63
Protect the ozone layer	57
Mitigate increasing greenhouse effect	57
Limit rise in temperatures	51
Prevent acid rain	36
To reduce pollution near factories	33
To use the CO <sub>2</sub> as an energy source in the future	26
To use the CO <sub>2</sub> as a raw material for products in the future	15
To warm the earth during the next ice age	4
Other	5

Table 2  
Respondents' perception of suitable capture points.

Capture point	Percentage of respondents to select the category
Electricity plant	60
Oil refinery	56
Intensive farming	46
Cars with a filter on the exhaust pipe	43
Steel factory	41
Natural gas extraction	39
Ammonia factory	37
Paint factory	30
Nuclear power plant	23
Hydrogen power plant	18
None of the above	11

of the greenhouse effect') without selecting any of the incorrect ones.

Respondents who believed mitigation of climate change, rise of average temperature and the greenhouse effect to be the goals were significantly more positive about CCS ( $M=4.06$ ,  $M=4.09$ ,  $M=4.10$ , respectively) than people who did not select these options ( $M=3.80$ ,  $M=3.83$ ,  $M=3.79$  and  $F_{(1,399)}=5.07$ ,  $p=.025$ ;  $F_{(1,399)}=5.28$ ,  $p=0.022$ ;  $F_{(1,399)}=7.08$ ,  $p=.008$  respectively). These were also the correct options that could be selected. Respondents who believed the goal was to use the CO<sub>2</sub> as an energy source in the future, were more negative about CCS (selected  $M=3.74$ , not selected  $M=4.04$ ,  $F_{(1,399)}=5.25$ ,  $p=.022$ ).

### 3.2.3. CCS knowledge – source points

In a similar way respondents were asked which capture points they believed were suitable for CCS. Most respondents selected one of the correct options, namely 'power plants' (59.6%), but they perceived intensive farming and filters on car exhaust pipes to be the second and third most plausible capture points, with 46.4% and 43.1% of respondents selecting these options, respectively.

Significantly more positive about CCS were respondents who selected either power plants, oil refineries or steel factories as a probable capture point ( $M=4.06$ ,  $M=4.14$ ,  $M=4.21$ , respectively) than those who did not ( $M=3.82$ ,  $M=3.75$ ,  $M=3.80$ , respectively;  $F_{(1,399)}=4.4$ ,  $p=.037$ ;  $F_{(1,399)}=11.89$ ,  $p=.001$ ;  $F_{(1,399)}=12.61$ ,  $p<.001$ , respectively). Significantly more negative about CCS were respondents who selected nuclear power plants as a capture point ( $M=3.62$ ) than those who did not select this ( $M=4.07$ ,  $F_{(1,399)}=10.84$ ,  $p=.001$ ).

### 3.2.4. CCS knowledge – storage

Respondents indicated their image of the CO<sub>2</sub> storage by evaluating how likely they believed it to be the CO<sub>2</sub> would be stored in each of the 7 presented options. As Table 3 shows, most respondents thought storage in underground rock formations to be somewhat to very likely (60%), a third of the respondents thought storage in underground bunkers to be somewhat to very likely, while only 19% believe storage under the seabed is likely. Storage in barrels or containers was believed to be very unlikely by the highest percentage of respondents (26%). The whole distribution of answers can be found in Table 3.

What type of storage people perceived to be plausible related to their attitude towards CCS. The more plausible people perceived CO<sub>2</sub> storage in underground rock formations to be, the more positive they were about CCS ( $r=.30$ ). Similarly the perceived likelihood of CO<sub>2</sub> being stored in empty salt mines was positively related to CCS attitude ( $r=.26$ ). Believing the CO<sub>2</sub> would be stored in tanks, barrels or containers above ground related negatively to CCS attitude ( $r=-.26$ ). This storage method was perceived to be somewhat to very likely by 25.9% of respondents.

**Table 3**  
Respondents' perception of likeliness of several types of storage.

Description of possible CO <sub>2</sub> storage	% of respondents to choose answer category						
	Very unlikely				Very likely		
	1	2	3	4	5	6	7
The CO <sub>2</sub> will be stored in large barrels, tanks or containers	26	15	10	23	14	8	5
The CO <sub>2</sub> will be stored underground in the existing rock formations	5	6	7	22	16	22	22
The CO <sub>2</sub> will be stored in underground bunkers with solid, impermeable walls	18	14	10	26	18	10	6
The CO <sub>2</sub> will be stored in empty salt mines	8	8	11	29	18	14	12
The CO <sub>2</sub> will be stored underground in caves and large cavities	14	15	12	28	16	11	5
The CO <sub>2</sub> will be stored under the sea bed	19	21	13	28	10	6	3
The CO <sub>2</sub> will be stored in old coal mines	15	15	14	29	18	7	4

### 3.2.5. Evaluative statements on CCS

Respondents were given statements about possible consequences of CCS that were mentioned by people in the interviews. They were asked to indicate how likely they thought these consequences were. Because a vast amount of these statements correlated significantly with CCS attitude we only report correlations above .30 or below  $-.30$  here. 35.9% of the respondents were very to slightly convinced that the CO<sub>2</sub> would escape to the surface, relating negatively to CCS attitude ( $r=-.42$ ). 32.4% of respondents were very to slightly convinced the CCS could escape during pile-driving work, also relating negatively to CCS attitude ( $r=-.45$ ). 25.2% were slightly to very convinced people would suffocate if the CO<sub>2</sub> leaks, which related negatively to CCS attitude ( $r=-.32$ ). 37.3% of respondents were very to slightly convinced a CCS storage site could be the target of terrorist attacks. Again, this belief was negatively correlated to CCS attitude ( $r=-.41$ ). Respectively, 17.6% and 14% of people were slightly to very convinced a CCS storage could explode either because the CO<sub>2</sub> is under pressure or because the CO<sub>2</sub> would catch fire, which had a negative relation with CCS attitude ( $r=-.48$  and  $r=-.38$ , respectively). Respondents who believed CCS would slow the development of renewable technologies (36.1% was convinced this is so) were also more negative about CCS ( $r=-.34$ ). The statement "developing CCS technology would give the Netherlands an economic advantage compared to other countries" related positively to CCS attitude  $r=.31$  (38.1% convinced this is so).

For another set of evaluative statements about CCS, expressed in interviews, respondents were asked to indicate the extent to which they agreed or disagreed with the particular statement. Results show that the more respondents agreed that a CCS storage site in the neighbourhood will not cause any inconvenience, the more positive their attitude towards CCS was (28.9% agreed fully or almost fully,  $r=.61$ ). A similar positive relation was found for agreement with the statement that storing CO<sub>2</sub> in the Netherlands makes sense given the presence of suitable empty gas fields (48.7% agrees this is so,  $r=.55$  with CCS attitude). However, agreement with the statement that CO<sub>2</sub> storage carries too many risks for public health had a strong negative relation with CCS attitude (38.4% agreed with this statement,  $r=-.68$ ).

## 3.3. Results from the media analysis

### 3.3.1. CO<sub>2</sub> in the media

In 189 of the articles (44%), some explanation is given about CO<sub>2</sub>. In 163 articles (38%), at least one feature of CO<sub>2</sub> is mentioned (e.g. 'same as carbon dioxide', or 'greenhouse gas'). In 112 articles (26%), at least one source of CO<sub>2</sub> is mentioned (e.g. 'coal-fired power plant'). In 34 articles (8%), at least one effect of CO<sub>2</sub> is mentioned (e.g. 'affects the climate').

Looking at the type of knowledge transferred about effects of CO<sub>2</sub>, 12 articles (less than 3%) mention that CO<sub>2</sub> affects the climate and/or contributes to the rise in temperature. Hardly any

article explains that CO<sub>2</sub> contributes to the greenhouse effect (3 mentions), or contributes to the growth of plants (3 mentions). Looking at the type of knowledge transferred about sources of CO<sub>2</sub>, 12 articles (2.8%) report that CO<sub>2</sub> is released at power plants and 10 articles (2.3%) mention that CO<sub>2</sub> is released at electricity production facilities. 9 articles (2.1%) explain that CO<sub>2</sub> is released when burning fossil fuels. Specifying fossil fuels, 14 articles (3.3%) mention that CO<sub>2</sub> is released when burning coal, 9 articles (2.1%) mention gas as a CO<sub>2</sub> source, 8 articles (1.9%) mention oil, and only one article (0.2%) mentions biomass.

### 3.3.2. Electricity mix in the media

Only 51 (11.9%) of the 430 articles analyzed provide some knowledge about energy production methods, users of energy, demand for energy, electricity production, use of fossil fuels, and the relation between use of fossil fuels and CO<sub>2</sub> emissions. Of these 51 articles, 31 (7.2%) relate the use of fossil energy to CO<sub>2</sub> emissions. 21 (4.9%) 23 articles (5.3%) mention one or more methods for electricity production, and 8 of these articles (1.9%) also mention something about the share of the method in total electricity production.

### 3.3.3. Climate change in the media

The issue of climate change is mentioned in 84 articles (19.5%). Climate change is mentioned in 58 articles (13.5%). Of these articles, 15 articles (3.5%) mention one or more effects of climate change. In 14 articles (3.3%), climate change is related to the use of fossil fuels.

The issue of temperature rise is mentioned in 44 articles (10.2%). Of these articles, 11 (2.6%) mention effects of temperature rise and 12 articles (2.8%) mention that temperature rise is related to the use of fossil fuels. The target to keep temperature rise at or below 2°C is mentioned in 16 articles (3.7%).

### 3.3.4. CCS awareness in the media

One of the most noticeable results of the medialog is the fact that most of the time CCS is discussed in relation to a specific project and even more specifically in relation to the project in Barendrecht. In 287 articles (66.7%), at least one location is mentioned, 245 of which mention Barendrecht.

### 3.3.5. CCS knowledge in the media

The media analysis also explored the knowledge conveyed about the capture, transport and storage of CO<sub>2</sub>. 165 articles (38%) mention either the capture, transport, or storage part of the CCS chain. Storage of CO<sub>2</sub> is mentioned in 150 articles (34.9%). Capture of CO<sub>2</sub> is mentioned in 59 articles (13.7%). Transport of CO<sub>2</sub> is mentioned in 29 articles (6.7%). Articles discussing the entire chain are rare, with only 17 articles (4.0%) discussing the entire chain.

Of the 59 articles mentioning capture, 51 (11.9%) also mention at least one source from which CO<sub>2</sub> is captured. Furthermore, 14 articles (3.3%) describe the process of capturing in detail. No significant differences between newspapers were found.

Of the 150 articles mentioning storage, 120 articles (27.9%) mention at least one method of storage (empty oil or gas fields, deep carbon layers, or saline aquifers). By far the most frequently mentioned method of storage is in an empty gas field (111 articles or 25.8%). Further details about storage are found in 31 articles (7.2%). Further specifying the location of potential storage sites, 88 articles (20.5%) mention an onshore site, 11 articles (2.6%) mention an offshore site, and 36 articles (8.4%) mention both. The depth of storage is discussed in 18 articles (4.2%) and the duration of storage is discussed in 5 articles (1.2%).

### 3.3.6. Newspapers as a source of misperceptions

In 9 articles information was encountered of which the correctness can be questioned or which could induce misunderstanding by

the way it was written down. For example, it was mentioned that CO<sub>2</sub> would be transported through an existing pipeline whereas transport would take place through a new pipeline within an existing corridor of pipelines. However, few instances of bare nonsense were found. Expressions that may possibly give rise to misperceptions (it is a topic for further research if they indeed do) were found in 51 articles. The most often occurring expressions were:

- ‘CO<sub>2</sub> storage in the soil’ (sounds as if storage is just below the surface);
- ‘(back) into the sea’ (sounds like CO<sub>2</sub> is pumped directly into the sea); and
- ‘helps to counter the greenhouse effect’ (instead of merely mitigating it). This phrase suggests that the greenhouse effect in itself is a bad thing. However, this phrase was only encountered a handful of times. In all, the greenhouse effect was only mentioned in 8 articles. It appears that the term is too complicated to mention and explain in a newspaper article.

The most often conveyed knowledge about CO<sub>2</sub> and CCS in the media is also what is generally best known already by respondents. About CO<sub>2</sub>, newspaper articles most often say it influences the climate, which in the test is stated correctly by 84% of the respondents. In articles usually at least one source of CO<sub>2</sub> is mentioned.

## 4. Discussion

This study aims to increase understanding of the public view on CO<sub>2</sub> capture and storage (CCS) and energy innovations in the Netherlands. The study is based on the premise that to understand the public's concerns and predict their future opinion, it is necessary to know how people arrive at their evaluations about CCS. Earlier research in the Netherlands shows that what constitutes relevant information for people to develop their opinion is neither straightforward nor easily foreseen by CCS experts (de Best-Waldhober et al., 2008). The study described in this paper aimed to enhance insight into currently held beliefs and awareness among the general public about CCS and CO<sub>2</sub> as well as to investigate CCS in the media, people's media use and exposure to news about CCS, and how this relates to their beliefs and awareness. To meet the first aim, we interviewed 15 respondents to identify commonly held beliefs. Next, we investigated the prevalence of these beliefs by questionnaire among 401 respondents. To meet the second aim, we analyzed the 430 articles mentioning CCS in all major Dutch newspapers from mid-2009 to mid-2010 and investigated respondents' media use and exposure to recent media events about CCS. In this section, we will discuss this studies' findings on the insecurities lay people have on the topic of CO<sub>2</sub>, energy use, climate change and CCS, as well as discuss how this relates to people's attitude towards CCS. Furthermore we will discuss the current public awareness of CCS. Finally we will discuss how lay public knowledge and beliefs relate to what is found in the media.

The results clearly show that a large number of the population is unsure about the characteristics, effects and sources of CO<sub>2</sub>. Of a large number of statements a third or more of the respondents did not know the correct answer. For example, 38% is unsure whether CO<sub>2</sub> causes cancer or not. The mostly doubted characteristics of CO<sub>2</sub> are whether CO<sub>2</sub> is flammable, is explosive, turns to stone, or emits radiation. A substantial percentage of people is also in doubt about the effects of CO<sub>2</sub>, about CO<sub>2</sub> causing acid rain, cancer, or smog, whether it is harmful in contact with skin, or if it makes the earth habitable. The sources of CO<sub>2</sub> are doubted as well; around a third, sometimes up to half of people do not know whether CO<sub>2</sub> is released when wood is burned, when old batteries leak, when steel

is produced, when plants and trees decompose, when electricity is produced using natural gas, or coal, or oil, or using nuclear power.

The most striking result though seems to be the amount of confusion among the Dutch public about our current energy use and its relation to climate change. A majority of people state to have some idea of global warming and understand that CO<sub>2</sub> emissions influence climate, but much less people can give a reasonable estimate of how much fossil fuel is used in the Netherlands or answer correctly that the use of gas, oil or coal for electricity production produces CO<sub>2</sub>. This finding has serious implications, not just for the possible use of CCS in the Netherlands, but for other technologies or options as well. If the vast majority of Dutch people do not understand why or how CO<sub>2</sub> emissions should be reduced, it is unlikely that they will support any action towards this goal or even take action themselves. It also implies that many people do not understand the major benefit of several mitigation options, which makes it harder to justify any disadvantages. Moreover, as opinions that are not well informed are unstable and easily changed (Bishop et al., 1986; Daamen et al., 2006) people who are unsure about such issues might easily be convinced with any new information, even if this information is not correct. This might cause unnecessary concern or otherwise poor judgement of the risk involved.

When analyzing the effect that lay knowledge might have on attitude, we did not find a strong direct effect of knowledge about CO<sub>2</sub> and CCS on attitude towards CCS. We did find that knowledge is indirectly related to attitudes through perceptions of risks and benefits of the technology. Overall, people who are more positive about CCS tend to perceive CCS as posing less risks and provide more benefits, and also tend to have better understanding of the goals of CCS and the aim of CCS to mitigate climate change. Furthermore, they have a better understanding of the natural properties of CO<sub>2</sub> as well as the properties that CO<sub>2</sub> does not have, such as harmful radiation or the potential of causing cancer. People who are more negative about CCS show the opposite pattern. Compared to the more positive group of respondents, people who are more negative about CCS are less aware of the aim of CCS and hold more misperceptions about the storage of CO<sub>2</sub>. Specifically, compared to the more positive group they believe it is less likely that CO<sub>2</sub> will be stored in natural storage sites and that it is more likely that CO<sub>2</sub> will be stored in man-made storage such as barrels or containers. Furthermore, they have a poorer understanding of the natural properties of CO<sub>2</sub> and perceive CO<sub>2</sub> to be more hazardous.

It is important to keep in mind that although the group that is more positive about CCS has more knowledge, their overall evaluation of CCS is only slightly favourable towards CCS in absolute terms. This is in line with conclusions from our earlier work that being more informed leads to more informed and more consistent opinions on CCS, but not necessarily to more positive or negative opinions. Furthermore, the design of the study does not allow for inferences about causality of relationships. It is possible that more knowledge causes a more positive attitude towards new technologies, but the opposite could also be true. It is also possible that a third factor is in play here, affecting both knowledge and attitude towards CCS. More research on this relationship has been started by the authors, as this could provide valuable input for communication and participation efforts.

#### 4.1. Public awareness of CCS

The awareness of CCS among the public was slightly higher in the present survey than in a survey with comparable data half a year earlier, (Pietzner et al., 2011) with 35% of people reporting not to have heard of CCS. An interesting result that shows how people first learn of CCS as an option is that 95% of the people who state that they have heard quite a bit about CCS in general, also state

to have heard of specific plans for the deployment of CCS in the Netherlands. This seems to indicate that most people do not hear about CCS until they hear of specific plans. Given that knowledge levels around energy and climate seem to remain low among the majority of people, an important conclusion from these results is that most people have no idea or opinion about CCS, its advantages, disadvantages or necessity, until they are faced with actual project plans.

Regarding the public's awareness of necessity of CCS, it is often stated that the belief in man-made climate change is necessary for the support of the use of CCS technology. Counter to this reasoning, we found hardly any relation between the attitude towards climate change and the attitude towards CCS. Although a weak relation was found between the belief that climate change is a consequence of human behaviour and the belief that CCS is necessary to mitigate climate change, this belief has little impact on CCS attitude. Our interpretation of this pattern is that even though respondents who believe in anthropogenic climate change to a certain extent also believe CCS is necessary, this does not make them more positive about CCS. This corresponds with the often heard perception of CCS as a 'necessary evil'. The fact that some people think CCS is necessary, does not mean they will be more positive about it.

#### 4.2. Relation between opinion and media exposure

The results from the survey showed that intensity of newspaper reading is related to levels of public knowledge whereas the intensity of watching television, listening to radio, or browsing the Internet is not. We may therefore conclude that newspaper content seems to be a better indicator of public knowledge than the content of other news media. This strongly suggests that newspaper article analysis is a suitable tool for monitoring developments in public knowledge.

The analysis of newspaper articles that was done in this study showed that CCS is hardly linked to global warming with less than 4% of articles mentioning global warming as a problem (and CCS as a possible solution). Instead, most articles frame CCS as an economic, policy, or political issue. Attention for CCS in newspapers was short-lived in general. The project in Barendrecht did receive extensive coverage at times when an important decision about the project was made, but attention to this project and to CCS in general levelled off just as quickly as it arose. When interpreting these results it is important to keep in mind that this study was restricted to articles mentioning CCS or part of the CCS chain at least once. That means that we cannot conclude anything about the trend in opinions on global warming in relation to media exposure about this topic in general, but are limited to relating these trends to the extent that these topics were covered in relation to CCS.

Regarding knowledge transfer about topics related to CCS, the results showed that in 38% of the articles at least one feature of CO<sub>2</sub> is mentioned. The most often mentioned features are 'same as carbon dioxide', and 'greenhouse gas' whereas other features are mentioned much less frequently. The issues that are mentioned in less than one fifth of the articles are climate change, temperature rise, and the mix of measures or technologies we will need for energy production and/or emissions reduction. Only 11% of the articles provide some knowledge about energy production and use. Information that explains the necessity of CCS or the reason for employing the technology is seldom provided. Moreover, almost none of the articles explain the whole chain from using fossil fuels to climate change and all steps in between.

It appears that newspaper reading will contribute little if anything to correcting misperceptions or filling the 'blanks' in

people's knowledge. However, the analyses also demonstrate that national newspapers contain little if any information that is absolutely false. Although possibly counterintuitive to readers with bad experiences in media contact, the present results indicate that national newspapers do not reinforce or create particular misperceptions as found in the interviews and survey.

## 5. Conclusion

This study illustrates the nature and magnitude of doubts and knowledge gaps among the general Dutch public regarding our energy system, CO<sub>2</sub>, climate change and CCS. Only very few people understand how our current use of fossil fuels leads to CO<sub>2</sub> emissions which in turn lead to climate change, even though almost all people state to know about global warming. The test revealed several misconceptions that were shared by a major percentage of the respondents, some of which also influenced the general attitude towards CCS. However, attitude towards CCS was mainly related to perceived risks and benefits of the technology as well as to more normative evaluations of the use of the technology.

The media analysis did not yield evidence that national newspapers reinforce or create particular misperceptions as found in the interviews and survey. However, newspaper reading will also contribute little if anything to correcting misperceptions or filling the 'blanks' in people's knowledge. That said, we do not state that this should be a primary task of newspapers. News media and information media are two very different things. However, it is one of the tasks of journalists to take into account their readers' level of comprehension of the issue they write about. Since our research has shown that people have little knowledge, even the highly educated regular readers of newspapers, it could be argued that news articles on CCS may need to be enriched with a bit more context information to be understandable for and not to mention appealing to a wider audience beyond people who are already knowledgeable about CCS.

It can be argued that the knowledge gaps found in this study are not influential to attitudes towards CCS alone. If the general population does not understand the problem our society faces when we do not mitigate CO<sub>2</sub> emissions, it will be extremely hard to get their approval of any kind of CO<sub>2</sub> mitigation option, be it large wind turbine parks or home renovations to improve energy efficiency.

## Acknowledgement

This research has been made possible with funding from the CATO-2 Research Programme.

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