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Informed Public Opinions on CCS in comparison to other mitigation options

Marjolein de Best-Waldhober[a]*, Dancker Daamen[a], Andrea Ramirez Ramirez[b], André Faaij[b], Chris Hendriks[c], Erika de Visser[c]

[a]*Centre for Energy and Environmental Studies, Dept. of Psychology, Leiden University, Wassenaarseweg 52, 2333 AK Leiden, the Netherlands*
[b]*Copernicus Institute, Group Science, Technology and Society, Utrecht University, Heidelberglaan 2, 3584 CS Utrecht, the Netherlands*
[c]*Ecofys, Kanaalweg 16-g, 3526 KL Utrecht, the Netherlands*

Abstract

In this study, an Information-Choice Questionnaire (ICQ) was used to find out how a representative sample of the Dutch public (n=971) would evaluate and choose between seven mitigation options after having been thoroughly informed. The results suggest that due to the comparison with other mitigation options, people are less positive about CCS options. Still, only few respondents firmly reject the CCS options.

ICQ; public opinion; public perception; CCS; acceptance; choice; information

1. Introduction

There has been much attention in recent years for the global change in climate. To be able to drastically reduce CO_2 emissions in the atmosphere, many aim to develop relevant new technologies and knowledge. However, the development of knowledge and technologies relevant to the reduction of CO_2 emissions in the atmosphere only constitutes a first step towards the deployment of this knowledge. The development of social support can be crucial for the actual implementation of such new technologies. One of the goals of the current study was to learn more about the factors which affect public perception and acceptance or rejection of CO_2 capture and storage (CCS) technologies. Earlier research in the Netherlands [1] shows that a large percentage of the public is not aware of CCS and has little knowledge about it. Studies from other countries such as the US, the UK, Sweden, Japan, Australia and Canada show similar results [2,3,4]. When there is a possibility for low awareness or knowledge of an issue, studying public opinion regarding this issue becomes a delicate balancing act. People tend to give their opinion even if they have no information on the issue at hand [1, 5]. Such opinions are known as “pseudo-opinions” or “non-attitudes”, and are known to be unstable and easily changed by contextual information [1,5,6]. Therefore, the current

* Corresponding author. Tel.:+31-71-5273809; fax: +31-71-5273169.
E-mail address: mbest@fsw.leidenuniv.nl.
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study uses the Information-Choice Questionnaire method [see e.g. 7,8], which takes these possible problems into account.

1.1. Information-Choice Questionnaire

The ICQ aims at several goals. The first is to provide respondents with the necessary information to reach an informed opinion. The ICQ furthermore aims to help respondents make use of this information to form opinions about different policy options: one goal of the methodology is to guide respondents' information processing. Respondents are given information regarding a policy problem, the policy options and their consequences, in order to make a more informed choice. The choice between policy options is explicitly framed as a decision problem. Respondents are provided with information regarding the background of the decision problem (e.g. respondents are explained why these specific options are included in the decision problem). Moreover, respondents are given information regarding the consequences of the different policy options, and are requested to give a quantitative evaluation of each consequence (a rating on a scale with nineteen response categories ranging from -9 "a very big disadvantage" via 0 "totally irrelevant" to +9 "a very big advantage"). This aims to stimulate information processing and to help respondents reach a decision. By letting respondents quantify their evaluations of the consequences, respondents are furthermore helped to evaluate each policy option overall. Moreover, it helps them to choose which policy option is preferred and which policy option (s) is (are) unacceptable.

The usefulness of the ICQ as well as it effects have been studied in extensive evaluation research [7], [8], [9], [10]. All together, these studies indicate that the ICQ's effect on the preferences of respondents is not only due to the information provided, but is furthermore due to better integration of the available information (as a result of the ICQ's structuring of information processing). Considering the fact that respondents may report different preferences after an ICQ than respondents after a more traditional survey, suggests that it is worth the effort to use the ICQ in public opinion research. But it simultaneously implies that the results of an ICQ do not necessarily reflect *present* public support for a policy. Rather, the ICQ is specifically equipped to assess how public opinion may be *after* the public is informed about an issue or to assess the *potential* (i.e. after extra information is provided to the public) support for alternative policies.

1.2. Earlier research in the Netherlands: ICQ with six CCS technologies

In 2006, extensive research regarding the Dutch public perceptions of CO_2 emission reduction options was made public [1,11]. This study used the same ICQ method to collect informed preferences. That ICQ focused on six CCS technologies, that were chosen by experts as most likely to be implemented on a large scale within 10 to 20 years in order to reduce CO2 emissions. Each of these technologies on its own reduces CO2 emissions by 20% and thus solves the policy problem, that experts had defined as: *"Which of six CCS options is the best to implement in the Netherlands by 2030 at the latest in order to reduce CO2 emissions by 20% compared to the status quo?"* The results of this 2006 ICQ study showed that most people know little about the process of global warming and even less about the possibility of using carbon capture and storage technologies to reduce CO2 emissions. However, after processing valid and balanced information regarding the consequences of six CCS technologies, most respondents evaluated the technologies as adequate. Overall, the results suggested that after processing relevant information, people are likely to agree with large scale implementation of each of the six CCS technologies. However, an important reservation of this study concerned the context of the choice problem that was presented to respondents. Because little was known about public perceptions of CCS, the choice problem restricted the choice of respondents for energy options to CCS technologies. This was useful to assess public perceptions of specific CCS technologies and their consequences. But although this gives us insight into the evaluation of specific consequences, it does not show how public perception of CCS overall compares to other mitigation options.

When CCS options are compared with other energy options, which is usually the case in real life, overall evaluations might change. The current study therefore addresses a broader choice problem. In this study, an Information-Choice Questionnaire (ICQ) was used to investigate how a representative sample of the Dutch public would evaluate two CCS options in comparison with five other possible mitigation options, and choose between these seven options after having been thoroughly informed.

2. Method

This study focuses on a complex environmental problem (global warming) and on the complex, sometimes future mitigation options that may contribute to solving this problem. As a representative sample of the public consists mostly of lay people who are not familiar with such complex matter, several precautions should be taken when informing them. This is necessary to guarantee that the public is presented with a relevant policy problem and with valid and balanced information regarding a restricted set of viable options to solve this problem. One essential aspect is the definition of a clearly specified and policy relevant choice problem that is not overly demanding for respondents. Second, an ICQ should present only *policy relevant* options to solve the problem, more specifically options which are according to experts viable and not unlikely to be implemented. To establish the most probable policy problem regarding CO2 emissions in the Netherlands, diverse groups of stakeholders, including experts in CCS as well as environmental NGO representatives, were consulted. This was finally defined as "*How can the Dutch demand for energy be fulfilled in 2030 in such a way that emissions of carbon dioxide will be reduced by 50%?"*. A group of researchers and stakeholders selected seven options. Three of these seven options have to be employed fully to achieve a reduction of 50%:

1. Improvement of energy efficiency;
2. Improvement of energy efficiency and decreased use of material and energy;
3. Electricity from wind turbines at sea;
4. Conversion of biomass to car fuel and electricity;
5. Large plants where coal or gas is converted into electricity with CCS
6. Large plants where natural gas is converted into hydrogen with CCS;
7. Electricity from nuclear plants

Third, it is essential that the information that is given to people about the defined policy problem and about the consequences of the options that can solve this problem, is valid and balanced. Because CCS is a complex topic which comes with extensive expert knowledge, this means that in order to keep the amount of information manageable for all respondents, one must make a selection of the available expert information. To avoid controversy regarding this selection, the information for this ICQ was compiled by experts from different backgrounds and different organizations and checked by another, similarly differentiated group of experts. To gather the most recent, accurate and balanced information about the consequences of these seven options, a literature study as well as consultation of many experts in each technological field was done. An external group of experts improved the accuracy and balance of the information that was thus gathered. It was then translated to lay language by psychologists. Based on the judgment of the experts, the amount of information was reduced by omission of less important consequences, in order to not exceed the limited capacity of lay people to absorb information. After this, the information for lay people and the procedure of the current ICQ was tested twice, on a sample of 31 teenagers on a low education level, and furthermore on a sample of 109 average Dutch citizens. Based on these tests, the information was improved further. The group of independent experts judged the final information as valid, impartial and even-handed.

For every CO_2 mitigation option, respondents were presented with a general description of the option, such as how it works and when, where and in what form it would be implemented. The consequences that were presented at this point concerned requirements for new installations and lines, for technological breakthroughs or vehicles, use of natural resources, consequences for buildings, industry, consumers, wildlife and land-use, safety-issues, environmental issues, reliability, economic consequences, price, and reduction of CO_2 emissions. By presenting each aspect or consequence separately and by having respondents evaluate each consequence, the processing of the information concerning consequences was facilitated. An example of the information regarding consequences can be found in Figure 1. Furthermore, the structure in the decision making process aimed to aid respondents in making an informed and well-considered decision, including comments to aid respondents to avoid common decision making errors. Respondents received the information regarding the seven options in six different orders. This served initially to avoid the effect of one particular order, but also made it possible to test if there is an effect of comparison of options by testing the effect of position of an option in the order. After respondents had received all the information

regarding the seven options, they were asked to choose three options they preferred out of the seven options. There were some restrictions in the combinations of options respondents were allowed to choose, as for instance the combination of three electricity generating options produces too much electricity, and the combination of two options generating fuel for transport would produce to much fuel for transport. Respondents were furthermore asked to state which, if any, options they found so unacceptable, that they considered taking action when this technology were to be implemented on a large sale in the Netherlands. The final ICQ was administered on-line to a random sample of 971 respondents in May 2007. This sample proved to be representative of the Dutch population

3. Results

After respondents had seen an overview of their evaluations of the consequences of an option and calculated the total advantage and disadvantage score, they were asked to give their overall evaluation of this option. Respondents were asked to grade the option on a scale from 1 to 10, with 1 meaning the lowest score possible and 10 meaning a perfect score. A 6- means you did just good enough to pass in the Dutch grading system, but not any better. Table 1 contains the distribution of the overall evaluations per option and the mean overall evaluation given by respondents in the ICQ. On average, not all options are evaluated as adequate (>5.5). The two CCS options, "Large plants where coal or gas are converted into electricity with CCS" and "Large plants where gas is converted into hydrogen with CCS", were evaluated somewhat negatively by most respondents. The first CCS option was graded below 6 on average (5.34), the second CCS option was graded just below 6 on average (5.92). In comparison, respondents evaluated most of the other options in the questionnaire rather positively. The first efficiency option was evaluated 7.33 on average, the wind energy option was evaluated 7.15 on average and the biomass option was evaluated 7.41 on average. Respondents were also less positive about the second efficiency option, "Improvement of energy efficiency and decreased use of material and energy", and the nuclear energy option, which on average were evaluated 5.84 and 5.29 respectively. Although the average overall evaluation of one of the CCS options (5.34) is not very different from the average overall evaluation of the nuclear energy option, Table 1 shows that the distribution of evaluations is different. The nuclear energy option was evaluated as very negative (a 1,2 or 3) of very positive (an 8, 9 or 10) by substantially more respondents than the CCS option was.

Table 1: Overall evaluations of seven options in the ICQ: percentages for grades, mean grades and percentages respondents who choose and reject an option. [2]

Option	1-3	4-5	6-7	8-10	Mean	Choice	Reject
Efficiency	0.7	5.5	47.7	46.0	7.33	90.2%	0.4%
Efficiency plus	7.1	32.3	47.9	12.8	5.84	24.0%	5.9%
Wind	1.7	8.7	46.5	43.2	7.15	75.4%	1.9%
Biomass	1.3	5.0	42.2	51.4	7.41	70.0%	1.5%
Powerplants + CCS	11.2	41.0	41.3	6.40	5.34	6.9%	11.0%
Hydrogen + CCS	6.1	28.8	53.1	12.1	5.92	10.6%	6.8%
Nuclear	19.4	31.1	36.9	12.7	5.29	22.9%	20.0%

After evaluating all options and their consequences, respondents were asked to choose three out of the seven options to solve the policy problem. Most respondents choose either the first efficiency option (90.2%), the wind energy option (75.4%), or the biomass option (70%). A substantial percentage chooses all three of these options (44.8%). The second efficiency option was chosen by almost a quarter of respondents as one of their preferred three options

[2] Obviously, the technical labels used in this paragraph for the options were translated. For the label of the options in lay terms see the method section. Furthermore, the choice percentages add up to 300%, because respondents had to choose three preferred options.

(24.0%). The nuclear energy option was chosen by a few percent less respondents, 22.9%. The two CCS options were chosen by a small percentage of respondents as one of their three preferred options, 6.9 % and 10.6% respectively.

After respondents had chosen three options, they were asked if any options were unacceptable to them. Respondents were asked if large scale implementation of any of the seven options is so unacceptable to the respondent that he or she considers taking action if this was planned. The first efficiency option, the wind energy option and the biomass option are evaluated as unacceptable by very few respondents, 0.4%, 1.9% and 1.5% of respondents, respectively. The second efficiency option is rejected more often than the first efficiency option, 5.9% of respondents reject this option. The first CCS option ("Large plants where coal or gas is converted to electricity with CCS") is rejected by 11.0% of respondents. The second CCS option ("Large plants where natural gas is converted to hydrogen with CCS") is rejected by less respondents, 6.8%. The nuclear energy option is rejected by a substantial percentage of respondents, 20.0%.

To avoid the possible influence of order effects on the overall evaluations, the order in which respondents received the information on consequences of the seven options was not the same for all respondents. By varying the order in which respondents evaluated the options, the chance that an option receives higher or lower evaluations than the other options purely based on its position in the questionnaire becomes very small.

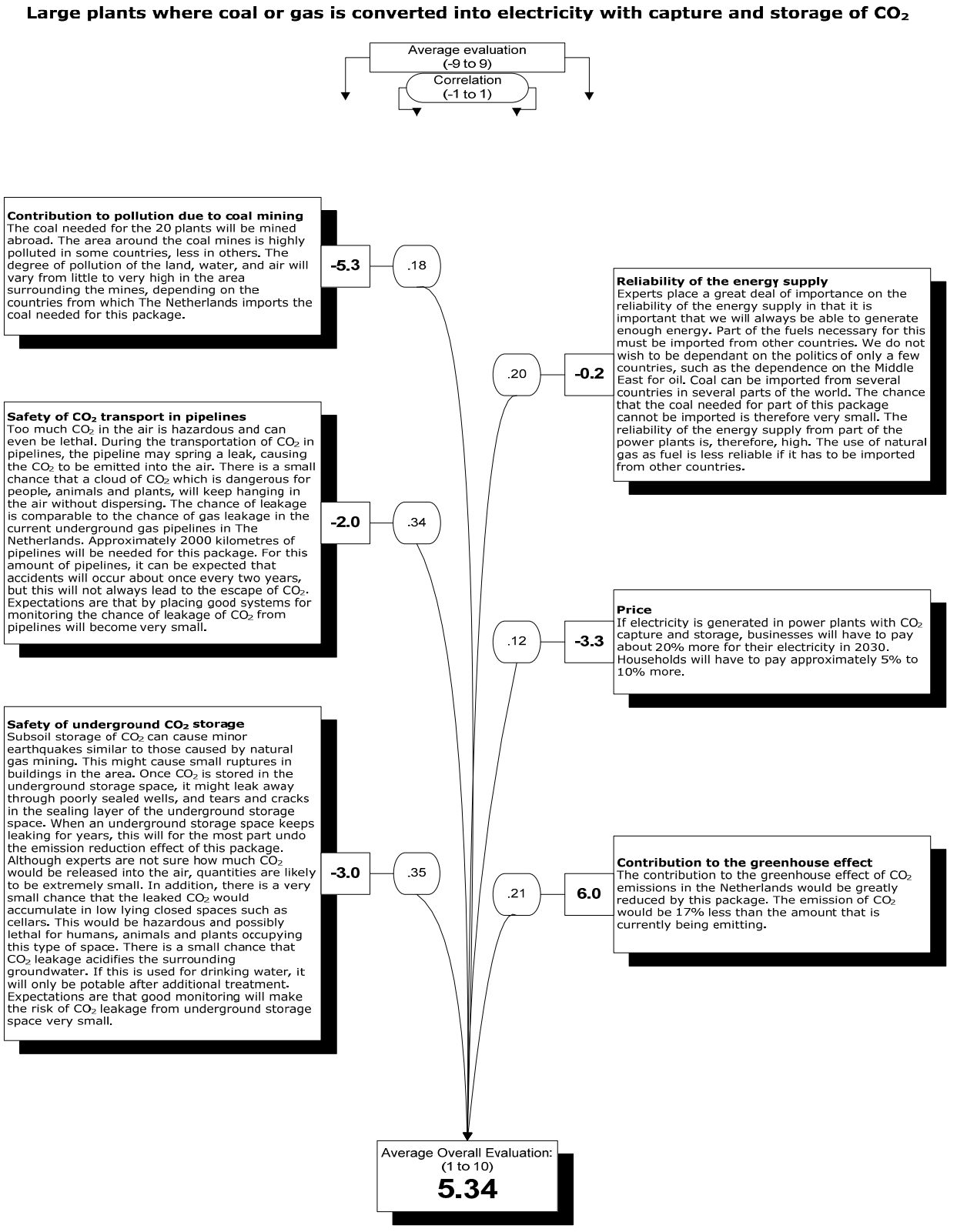
Six versions of the ICQ were made with different orders. The order of the first version was Option 1 ("Improvement of energy efficiency"), O2 ("Improvement of energy efficiency and decreased use of material and energy"), O3 ("Electricity from windmills at sea"), O4 ("Conversion of biomass to car fuel and electricity"), O5 ("Large plants were coal or gas are converted into electricity, with CCS"), O6 ("Large plants were gas is converted into hydrogen with CCS"), O7("Electricity from nuclear plants"). The order of the other versions was O4-O7-O6-O1-O2-O3-O5, O7-O6-O5-O4-O3-O1-O2, O5-O1-O2-O6-O3-O7-O4, O3-O5-O4-O7-O1-O2-O6, and O6-O4-O1-O2-O7-O5-O3.

Table 2: Order effects: mean overall evaluations depending on position in order

	Position						
	1	2	3	4	5	6	7
Efficiency	7.35	7.48	7.01	7.47	7.34	7.11	
Efficiency plus		5.86	6.0	5.43	6.05	5.8	5.68
Wind	7.36		7.14		6.88	7.06	6.92
					7.21		
Biomass	7.37	7.29	7.62	7.6			7.28
				7.28			
Powerplants + CCS	5.77	5.23	5.22		5.20	5.21	5.46
Hydrogen + CCS	6.03	6.19	5.88	5.98		5.61	5.82
Nuclear	5.52	5.53		5.01	5.08	5.52	5.18

Important to notice in Table 2 is the effect that the order of options has on the two CCS options. When the CCS option "Large plants where coal or gas are converted into electricity with CCS" is the first to be evaluated of all the options, the average overall evaluation is significantly higher ($F_{(5,965)}$=3.94, p=.002) than when the option is evaluated later. This is important because it shows an effect of the comparison with other options. Respondents are more positive about this CCS options when they have not received information about the other options yet. The second CCS option, "Large plants where gas is converted into hydrogen with CCS", is also evaluated significantly higher ($F_{(5,965)}$=3.14, p=.008) when it is the first to be evaluated, except for the situation where this CCS option is evaluated as the second option, after the nuclear energy option. When respondents have first been informed about the nuclear option and then second about this CCS option, the CCS option is evaluated even higher on average than when it is evaluated first. It seems that although the comparison with other options makes respondents slightly more negative regarding CCS, the comparison with the nuclear option makes respondents slightly more positive.

Figure 1. Lay people information of consequences, evaluation of consequences, overall evaluation and correlations between the latter two regarding the option "Large plants where coal or gas is converted into electricity with CCS".



To further investigate the relationship between the evaluations of the consequences of an option and the overall evaluation of the option, seven regression analyses were done. The multiple correlations between the evaluations of the consequences and the overall evaluation of most options is moderate[3], R's range between .45 and .66. This moderate correlation seems to implicate that although the information that is given about the consequences does influence the overall evaluation of the options, the overall evaluation is based on more than this information. A possible explanation for this could be that not all the arguments that are important to respondents are stated in the given information. Still, the information regarding the consequences is being used by respondents to base their overall evaluation of the option on, even for the options the public is relatively well known with. The "single" correlations between the evaluations of the consequences and the overall evaluation of the options differ from moderate to low. Figure 1 shows the correlations for the first CCS option. As can be seen in Figure 1, the consequences "very small chance of leakage from lines" and "very small chance of leakage from storage" have the highest correlations with the overall evaluation, .34 and .35 respectively. On average, these consequences are evaluated as slightly negative, though a substantial percentage of respondents does evaluate these consequences as very negative. This means that although the influence of these consequences on the overall evaluation is minor, these consequences do seem to have a negative influence on the evaluation of the first CCS option.

4. Conclusion

In this study, an Information-Choice Questionnaire (ICQ) was used to investigate how a representative sample of the Dutch public would evaluate two CCS options in comparison with five other CO_2 mitigation options, and choose between these seven options after having been thoroughly informed about the options and their consequences. The results imply that the general Dutch public is not very negative about CCS, but not positive either. The two CCS options, "Large plants where coal or gas are converted into electricity with CCS" and "Large plants where gas is converted into hydrogen with CCS", were graded below 6 on average, respectively 5.34 and 5.92 on a scale from 1 to 10. Respondents were also not that positive about the second efficiency option, "Improvement of energy efficiency and decreased use of material and energy", and the nuclear energy option. In comparison, respondents evaluated most of the other options in the questionnaire rather positively. This is reflected in the choices people make and the percentages of people that reject an option. The majority of people choose the first efficiency option, the wind energy option, or the biomass option as one of their three preferred options to solve the policy problem. These options are also hardly rejected by anyone. The CCS options are chosen much less, but not rejected by many people either, 11% and 6.8%. In contrast, the nuclear energy option was much more controversial, being chosen by more than a fifth of people, but rejected by an almost equal amount of other people.

The two CCS options in this study were evaluated slightly less positive than some comparable CCS technologies were evaluated in similar ICQ research comparing six CCS technologies [11]. A reasonable explanation seems to be that people are less enthusiastic regarding CCS options when these options are compared with other possibilities for CO_2 emission reduction. This explanation is supported by the difference in evaluation of CCS options that we found, depending on the place the option was given within the seven options. If people are less positive about CCS options due to the comparison with other possible CO_2 mitigation options, then the group that has evaluated a CCS options before any of the other options should be more positive about this CCS option than the group that has evaluated this CCS option after one or more of the other options. This is indeed what we found, with the exception that people are even more positive about the second CCS option "Large plants where gas is converted into hydrogen with CCS" when it is evaluated second, after the nuclear energy option.

The information regarding the options and their consequences in the questionnaire was carefully gathered by experts, with the help of many other experts. Apparently, it is possible to get consensus about information on the possible consequence of CO_2 mitigation options from experts [see also 12]. This information from experts was used

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[3] A subgroup of respondents was also asked for their overall evaluations of the options before any information was given in the questionnaire. The multiple correlations were much lower if the effect of the evaluations of consequences on the overall evaluations of options before information was analyzed. Especially for less known options such as CCS, respondents hardly based their uninformed opinions on their evaluations of consequences, but did base their informed opinions on their evaluations of consequences to a moderate extend.

by people to base their evaluations of the options on, although not solely. This is positive, because it means people are willing to take new information about energy options into account when forming their opinion. Individual consequences did not influence the overall evaluation of options very much though, which was indicated by the overall moderate to low correlations between the evaluations of the consequences and the overall evaluation of the options. This implies that changing a single consequence will probably result in only a minor change at best in the overall evaluations of an option. The CCS option "Large plants where gas is converted into hydrogen with CCS", was influenced slightly more by the evaluation of its consequences than the other CCS option, "Large plants where coal or gas are converted into electricity with CCS", and the former option was evaluated more positively overall. The association of CCS with the use of coal might make people less positive about CCS. In the case of Dutch public opinion, this might mean that the association of CCS with a specific technology can influence public opinion. Whether this influence is negative or positive depends on the technology that CCS is associated with.

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