Summary:

Public perceptions and preferences regarding large scale implementation of six CO_2 capture and storage technologies.

Well-informed and well-considered opinions
versus
uninformed pseudo-opinions
of the Dutch public

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Summary

In the past four years, the Centre for Energy and Environmental Studies of Leiden University has engaged in a research project that focussed on studying informed opinions of the general public regarding Carbondioxide Capture and Storage options (CCS options). This study has investigated the choices the general public would make after having received and evaluated expert information on the consequences pertaining to these choices. The method used to collect these informed preferences is called the Information-Choice Questionnaire (ICQ). By comparing informed public preferences, obtained through administration of the ICQ, with current public opinions and preferences regarding CCS options, collected in a more conventional survey, the outcomes of this project can indicate what options would be considered acceptable given sufficient knowledge, and how much and in what respect the current situation deviates from this possible future situation.

Information-Choice Questionnaire
The method of the ICQ was originally developed by Saris, Neijens and De Ridder (1983a/b, see e.g. Neijens, 1987; Neijens et al. 1992) to assess preferences for different ways of generating electricity in the Netherlands. The aim of the ICQ is not only to provide respondents with the necessary information to reach an informed opinion, but also to help them make use of this information to form opinions about different policy options: part of its aim is to guide respondents' information processing. Before respondents in the ICQ choose between policy options, they receive information to make a more informed choice. First, the choice is explicitly framed as a decision problem and respondents are informed about the background of the decision problem (e.g. they are told why these specific options are included in the decision problem). Second, respondents are provided with information about the consequences of the different policy options. To stimulate information processing and to help respondents reach a decision, they 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"). On the basis of these quantitative evaluations, the subjective utility of each option may be determined, to evaluate each option overall and to choose which option is preferred and which option(s) is (are) unacceptable (paragraph 1.2).

The effects and usefulness of the ICQ has been studied in extensive evaluation research (Neijens, 1987; Neijens, de Ridder & Saris, 1988; Van Knippenberg & Daamen, 1996; Van der Salm, Van Knippenberg & Daamen, 1997). Combined, the results from prior research analyzing the ICQ suggest that the ICQ's effect on respondents' preferences is due to both the information provided – which may wholly or in part contain new information relevant to the decision problem – and to better integration of the available information (due to the ICQ's structuring of information processing) (paragraph 1.2). The fact that ICQ respondents may report different preferences than respondents in a more traditional survey shows that it may indeed be worth the trouble to use the ICQ in public opinion research. At the same time it implies that the results of an ICQ do not necessarily reflect *present* public support for a policy. Rather, the ICQ is especially suited 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.

Development of the ICQ on CCS options
The current study focuses on a complex environmental problem (global warming) and on the complex, future energy technologies that may contribute to solving this problem. When informing lay people about such complex matter via an ICQ, several precautions are needed 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 (paragraph 1.3).
First, it is essential to define a clearly specified and policy relevant choice problem that is not overly demanding for respondents. Furthermore, only *policy relevant* options to solve the problem should be presented, that is, options which are according to experts viable and not unlikely to be implemented. Three leading experts on CCS were consulted (NWS, Ecofys, ECN) to carefully define the policy problem and choose the most viable options (paragraph 2.2.1). The policy problem was defined as:

"Which CCS option is the best to implement in the Netherlands by 2030 at the latest in order to reduce CO_2 emissions by 20% compared to the status quo?"

Six CCS options were chosen by the experts as most likely to be implemented on a large scale within 10 to 25 years in order to reduce CO_2 emissions. Each of these options on its own reduces CO_2 emissions by 20 % and thus solves the policy problem. These six options were (first the label for lay people[*], next –in italics- the expert label and finally, between quotation marks, the brief expert label for the option, which we will use in this summary):

1. Large modern coal fired power stations (for private and commercial use) with CO_2 capture and storage *(Integrated Gasification Gas Combined Cycles with CCS for all kinds of end use)* "IGCC with CCS"

2. Conversion of natural gas into electricity (for private and commercial use) with CO_2 capture and storage *(Solid Oxide Fuel Cells with CCS for private and commercial use)* "SOFC with CCS"

3. Large coal fired hydrogen stations (for industrial use and for bus and freight transport) with CO_2 capture and storage *(Hydrogen production via coal gasification with CCS for industrial use)* "Hydrogen production via coal gasification with CCS"

4. Conversion of natural gas into hydrogen in large plants (for private and industrial use and bus and freight transport) with CO_2 capture and storage *(Hydrogen production via steam reforming with CCS for private and industrial use)* "Hydrogen production via steam reforming with CCS"

5. Retrieval of methane gas by storing captured CO_2 in coal beds *(Enhanced Coal Bed Methane for similar use as natural gas)* "ECBM"

6. Conversion of natural gas into hydrogen (for motor vehicles) with CO_2 capture and storage *(Small Scale reforming based on membrane technology with CCS for motor vehicles)* "Small Scale reforming based on membrane technology with CCS"

[*] Obviously, these options were not merely labeled in the ICQ but fully described for lay people. For an example of such a description for "SOFC with CCS" see table 2 at the end of this summary.

Second, when informing people about the defined policy problem and about the consequences of the options that can solve this problem, it is essential that this information is valid and balanced. In the case of complex topics 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. With relatively complex and controversial topics such a selection could arouse debate. The information for this ICQ is therefore compiled by experts from different backgrounds and different organizations and checked by another, similarly differentiated group of experts. Fourteen experts of institutions such as the Central Plan Bureau, the ministries of Economical Affairs and VROM, the ECN, EcoFys, NOVEM, NAM, Natuur en Milieu, TNO-MEP, TNO-NITG and the Departments of Anorganical Chemistry and of NW&S of Utrecht University were interviewed and a literature study was done by several researchers of Utrecht University on the basis of which more quantification of storage potential and price was achieved. Seven experts checked the final document with all information (paragraph 2.2.2 and 2.2.3). This information was translated by psychologists to lay language and then checked again by a different group of independent experts ("the resonance committee") (paragraph 2.2.4). After this, the information for lay people and the procedure of the current ICQ was tested twice, on a sample of 23 teenagers on a low education level (VMBO), and furthermore on a sample of 100 average Dutch citizens (paragraphs 2.2.4 and 2.3. See appendix 2 for the English translation of the final information for lay people). The resonance committee judged the final information as valid, impartial and even-handed. Per 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 aspects and consequences, ranging from 8 to 12 per option, that were presented at this point concerned requirements for new installations and lines, for technological breakthroughs or vehicles, safety-issues, environmental issues, reliability, economic consequences, price, and number of years the technology may be applied (given the energy stocks and the CO_2 storage capacity). As an example, the information on "SOFC with CCS" that was presented to respondents is depicted table 2 in this summary. It is essential to realize that although many details that experts have given will not be mentioned literally in the translation for lay people, these details are the basis for the consequences that are described in the translation for lay people. For instance, efficiency of a technology is an aspect that was frequently specified by experts. However, efficiency will not be mentioned in the translation, but taken into account for the specification of the price of energy, which will be mentioned in the translation, mostly stated as the percentage customers have to pay extra for energy or fuel. Therefore, although it might seem that a lot of expert information has been omitted, this information will in fact have been taken into account for the statements in the translation for lay people.

The final ICQ was administered to a representative sample of the Dutch population (995 respondents) in November and December 2004. The questionnaire was send to respondents as a computer program by TNS-NIPO to fill in at home (See chapter 3 for the procedure and appendix 3 for the text of the entire questionnaire).

The more traditional questionnaires

Simultaneous with the administration of the ICQ, another questionnaire was given to a different smaller sample of respondents from the same access panel of TNS-NIPO (327 respondents). This questionnaire was designed to address both current public knowledge and overall evaluations of global warming, overall evaluations of CCS, and overall evaluations of six CCS options, as well as to study the preference for a certain CCS option. It was furthermore designed to test the usefulness and stability of uninformed opinions (see paragraph 3.2 for the procedure and appendix 4 for the text of the questionnaire). A second more traditional questionnaire was administered a year later to a different sample of 300 respondents from the access panel of TNS-NIPO. This questionnaire was designed to give a deeper insight in the factors that influence uninformed opinions. This questionnaire also addressed both current public knowledge and overall evaluations of global warming and of CCS options, as well as the presentation of the choice problem (paragraph 3.3). Neither of the two more traditional questionnaires contained the full descriptions of the options and the descriptions of the aspects and consequences that were in the ICQ, although the same labels for the options were used in all three questionnaires.

Results

Evaluations

Before asking respondents in the ICQ about the CCS technologies, they were first explained how CO_2 emissions affect the climate. Respondents were given information regarding nine consequences of a temperature rise caused by the greenhouse effect to read and evaluate. Overall, the greenhouse effect is evaluated quite negatively: on a scale from 1 (very bad) to 7 (very good), the mean overall evaluation is 2.29. After evaluation of the greenhouse effect, respondents were given information on CO_2 emission reduction goals and how those could be achieved. CO_2 capture and storage was suggested as a possible technology that could reduce CO_2 emissions.
After having read and evaluated five consequences of CO_2 capture, transport and storage, respondents were asked for their overall evaluation. Overall, CO_2 capture, transport and storage is evaluated positively. On the same scale as the greenhouse effect was evaluated, the mean overall evaluation is 5.54. This means CO_2 capture, transport and storage is generally considered to be quite good (paragraph 4.2.1.1-4.2.1.2).

To further investigate how people evaluate specific CCS technologies after reading and evaluating the technologies' aspects and consequences, respondents were asked to grade the six specific CCS technologies in the questionnaire. In the Dutch school system, grades are on a scale from 1 to 10, with 1 meaning the lowest score possible and 10 meaning a perfect score. A 6 is considered a just acceptable score ("adequate"). This means in the Dutch grading system you did just good enough to pass but not any better. 5 or lower means you failed the test.

In the ICQ, all technologies are evaluated as "adequate" on average (see for grades table 1 in this summary). Only "ECBM" is evaluated very slightly lower than a 6 on average (5.94). The gas options are graded higher than the coal options, although "hydrogen production via steam reforming with CCS" is evaluated only very slightly higher than "hydrogen production via coal gasification with CCS" and "IGCC with CCS" are. Statistically, the mean overall evaluation of "IGCC with CCS" does not differ from that of "hydrogen production via coal gasification with CCS", and the latter does not differ from the mean overall evaluation of "hydrogen production via steam reforming with CCS". "SOFC with CCS" and "small scale reforming based on membrane technology with CCS" both receive a significantly higher mean overall evaluation than the other CCS technologies. "ECBM" receives a significantly lower mean overall evaluation than the other CCS technologies in the ICQ. Although the average overall evaluations of several CCS technologies are significantly different, the absolute differences are small. This does not mean that respondents all feel slightly positive about the CCS options and do not differentiate. Although on average the differences are small, the percentages of respondents with more extreme grades should not be neglected. Depending on the specific CCS option, 12% ("ECBM") to 24% ("SOFC with CCS" and "small scale reforming based on membrane technology with CCS") of respondents is very positive about the technology (grades 8, 9 or 10). Percentages of respondents that give extremely low grades (1 – 3) to the CCS options are restricted to 4% regarding five of the six options, and to 6% regarding "ECBM". These very low percentages of very low grades are in line with the very low percentages of respondents that consider specific CCS options unacceptable.

In the more traditional questionnaires, not all CCS technologies were evaluated as adequate. All coal options are graded below 6 on average. This is different from the average grades in the ICQ and shows respondents in the ICQ have been affected by the expert information they were given. In the more traditional questionnaires, respondents were asked to evaluate the CCS options again after a bit of information or no information. After a little bit of information, the grades mostly went slightly up, although they are mostly still different from the average grades in the ICQ. After no information, but an annoying irrelevant filler task, two of the grades remained equal, but four went down. Similar to what others (e.g., Strack, Schwarz & Wänke, 1991) have found before this study, the uninformed opinions in the more traditional questionnaire were easily changed and very unstable. Large percentages of the respondents in the traditional questionnaire admitted not to have heard of the specific CCS options (between 60.0% and 91.4% depending on CCS option),. Still, a substantial part of the respondents did not refrain from giving their overall evaluation (63.0-76.9%). This resulted in evaluations that were easily changed within 12 minutes. Only 9% of the variance of the second evaluation can be explained from the first evaluation. As these overall evaluations can hardly predict the exact same overall evaluations within 12 minutes, they are totally worthless for predicting future evaluations of the CCS options by the Dutch -public.

Choice

The analyses of the overall evaluations in the ICQ show that the average grades for the CCS options vary between 5.9 and 6.5. This means that a substantial part of the respondents perceives only little difference in attractiveness between technologies. This makes the outcome of the choice task (pick one out of six) less informative than with big evaluative differences. However, we do find that the pattern of the evaluations is reflected in the choices respondents make. They seem to have a general preference for the gas options, which are chosen by more respondents than the coal options. Especially "SOFC with CCS" and "hydrogen production via steam reforming with CCS" are preferred by more respondents than the other technologies, by 23.2% and 23.0% of respondents, respectively. "IGCC with CCS" and "small scale reforming based on membrane technology with CCS" are preferred by a bit less respondents, by 16.7% and 19.4 % respectively. Less than 10% of respondents prefer "hydrogen production via coal gasification with CCS" (9.5%) or "ECBM" (7.7%).(Paragraph 4.2.3)

Acceptance

Only minute percentages (1.4 to 6.4%) of respondents stated to find specific CCS technologies so unacceptable, that they considered taking action when this technology were to be implemented on a large scale in the Netherlands. Of the six CCS technologies, "ECBM" was named most as unacceptable. Still, only 6.4% of all 995 respondents in the ICQ considered this technology unacceptable. “IGCC with CCS”, “hydrogen production via coal gasification with CCS” and “small scale reforming based on membrane technology with CCS” were considered unacceptable by less than 5% of respondents. “Hydrogen production via steam reforming with CCS” and “SOFC with CCS” were considered to be unacceptable by less than 3% and less than 2% of respondents respectively. It seems therefore unlikely that many Dutch residents would object to the implementation of any of these CCS technologies (paragraph 4.2.3).

Summary table 1: Overall evaluations of technologies in the ICQ: percentages for grades, mean grades, percentages of preference and rejection

Technology	Percentages for grades				Mean grade	Preferred option	Unacceptable option
	1-3	4-5	6-7	8-10			
IGCC with CCS	4%	21%	59%	17%	6.23	16.7%	4.9%
SOFC with CCS	4%	16%	57%	24%	6.51	23.2%	1.4%
Hydrogen production via coal gasification with CCS	4%	20%	60%	16%	6.27	9.9%	4.1%
Hydrogen production via steam reforming with CCS	4%	20%	55%	21%	6.35	23.0%	2.7%
ECBM	6%	27%	55%	12%	5.94	7.7%	6.4%
Small scale reforming based on membrane technology with CCS	4%	18%	54%	24%	6.46	19.4%	3.6%

We analyzed whether respondents background variables influenced overall evaluations, choices and acceptance of CCS options. Variables such as gender, education, involvement with the issue, donations to environmental NGO’s or involvement with the issue seem to cause little to no difference in the overall evaluations of the technologies (see paragraph 4.2.5. for more details).

Relationship between evaluations of aspects or consequences and CCS technology grades

Before respondents in the ICQ evaluated the CCS technologies overall, they were asked to evaluate the aspects and consequences of these technologies. By analyzing the relationship between the overall evaluations and the evaluations of the aspects and consequences, it becomes clear how respondents’ evaluation of the aspects and consequences influences respondents’ overall evaluation of a technology (paragraph 4.2.4). The analyses have shown that what respondents’ think of the aspects and consequences moderately influences how respondents evaluate the technologies overall (5 of 6 multiple regression coefficients above .50). In other words, although the respondents did base their judgment of the technologies for a reasonable part on the aspects and consequences of the technologies, part of their judgment is not explained by this. Although the aspects and consequences of the technologies in the ICQ were selected by experts as the most important aspects and consequences, it seems that either not all the arguments that are important to respondents are stated in the given information, or respondents had not quite made up their mind yet. An important conclusion that can be drawn from the low to moderate correlations between most of the aspects or consequences and the overall evaluations is that none of the overall evaluations seem to be based on one or a certain kind of aspect or consequence (see paragraph 4.2.4 for a detailed discussion).

Summary table 2: Example for one of the six CCS options (i.e. SOFC with CCS). Description of option in lay terms. Information on aspects and consequences. Average evaluations of aspects and consequences, average overall evaluation expressed as a grade between 1 and 10. And strength of the relation between these two evaluations expressed in a correlation coefficient.

Option, aspects and consequences	*Average evaluation (-9 to 9)*	*Correlation (-1 to 1)*	*Average overall evaluation (1 to 10)*
Conversion of natural gas into electricity (for private and commercial use), with CO_2 capture and storage. Natural gas is converted to electricity and heat in small fuel cells. Fuel cells are relatively cost-efficient, quiet and clean installations of various sizes in which fuel can be converted into electricity and heat. The CO_2 released through this process is captured and stored underground in the Netherlands. Hundreds of fuel cells would be necessary to ensure that 20 percent less CO_2 is released into the air annually. Nearly all of the electricity the Netherlands will need in the future is generated in these fuel cells. The electricity and heat are supplied to households, businesses and organisations. These fuel cells would be installed near businesses and within urban areas. This technology on such a large scale will probably not be possible to implement before 2020. The necessary technical advances are expected to have been realized by then, but this is not a complete certainty.			6.51
New installations needed In order to implement this technology, the existing large electricity plants would have to be replaced by smaller fuel cells which convert natural gas into electricity and heat.	1.2	.30	
New lines needed Many new electricity and warm water lines would have to be installed to supply users with the electricity and heat generated by the fuel cells. The necessary work would cause inconvenience.	-2.5	.20	
New CO_2 pipelines needed Many new pipelines would have to be installed to convey the CO_2 captured from fuel cells to storage. The necessary work would cause inconvenience because of groundwork.	-2.6	.20	
Contribution to the greenhouse effect The contribution to the greenhouse effect by generation of electricity would be greatly reduced through the use of this technology: The emission of CO_2 into the air would be less than one twentieth of the amount that is currently being emitted by existing electricity plants.	6.5	.38	
Contribution to acidification Acidification may lead to the extinction of plant and animal species, the death of trees, damage to agriculture, damage to monuments and property, the over-grassing of moors, and a lower quality of drinking water. The existing gas-fuelled electricity plants contribute less to acidification than they did twenty years ago. The modern gas-fuelled electricity plans would hardly contribute any more to acidification.	6.1	.35	
The number of years this technology can be used Including the gas supply from abroad, this technology could be used for a few centuries, but experts have calculated that the small-scale underground CO_2 storage space necessary for this technology is available in the Netherlands for at least 50 years, and possibly as long as 250 years.	2.1	.21	
Reliability of the energy supply Experts place a great deal of importance on our being able to generate enough energy. The use of gas as a fuel is less reliable when this gas must be imported from abroad, which will be the case as from 2020. In order to ensure high reliability it is possible to store reserves of gas for later use, but this leads to a higher gas price.	-3.2	.13	
Reliability of energy supply through fuel cells By using fuel cells, the reliability of energy supply improves. In order to do so the electricity network must be adapted.	-0.1	.19	
Price If electricity and heat are generated by means of fuel cells, businesses will have to pay approximately half more than they do now. Households will have to pay approximately one fifth more.	-3.9	.18	

Summary table 2 contains an example of the analyses that have been done for all six options. As is explained fully in paragraph 4.2.4, none of the aspects or consequences that are evaluated in the ICQ can solely predict the overall evaluation of a technology in the questionnaire. This suggests that it will be very hard to influence the publics overall evaluations of a technology by changing single aspects or consequences of a technology. On a more positive note, as all technologies are evaluated as adequate and as there seem to be no aspects or consequences that are such a negative influence that this could solely bring down the overall evaluations, there seems to be no reason to change single aspects or consequences.

General comments

In this study, it is clearly shown that the current public opinions on CCS options, assessed by traditional questionnaires, are mostly *pseudo-opinions*: they are unstable (change within twelve minutes) and are affected by tiny amounts of non-diagnostic information and by the mood of the respondent. These uninformed opinions are totally worthless for predicting future public opinions on CCS options

All in all, the results of the ICQ suggest that, after processing relevant information, people are likely to agree with large scale implementation of each of the six CCS options. Respondents find all CCS options on average “adequate”, seldom find these options unacceptable and do not choose one of the options over the others with a majority of respondents.

Some reservations are important when interpreting these ICQ results. The evaluations and choices are made by the respondents within the context of the presented choice problem. This choice problem restricted the choice of respondents for energy options to CCS options. When the CCS options are compared with other energy options, such as renewables, nuclear energy or efficiency options, overall evaluations might change.

Another reservation concerns the prediction the ICQ results can make for future opinions on CCS options. Respondents in the ICQ processed valid and balanced information on aspects and consequences of the CCS options. The evaluations that result from this are not as much an indication for current public opinions on CCS options, rather they are an indication for potential public support for CCS options after the public is fully informed about pro’s and cons of CCS options.