Informed Public Opinions on CO_2-Capture and Storage Technologies

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Abstract
In this study, an Information-Choice Questionnaire (ICQ) was used to find out how a representative sample of the Dutch public (n=995) would evaluate six CCS options after having been thoroughly informed. All in all, the results of the ICQ suggest that, after processing relevant information, people are likely to accept large scale implementation of each of the six CCS options.

Keywords: Information-Choice Questionnaire, public opinion, CCS, acceptance, choice

Introduction

As the Dutch government is striving to reduce CO_2 emissions, the policy problem of which actions should be taken to attain this goal becomes an important question that is relevant to all Dutch citizens. Public opinion can be a decisive factor in determining how to reduce emissions. But public opinion about such new and complex technology is rarely known and therefore difficult to take into account before the stage of actual implementation of the solutions to the policy problem. If by that time the public rejects the solution(s), large amount of time and money have already been spent in vain. Consequently, it is recommendable to study public opinion in the early stages of development of new technologies, such as technologies that use CO_2 capture and storage. But as these technologies are still mostly in a developmental stage, it is likely that the public lacks the knowledge to have an opinion on these technologies. Although people are inclined to give their opinion even if they had no information on the topic at hand, these kinds of opinions are known to be unstable and easily changed by contextual information [e.g.[1], [2], [3], [4]]. The method that is used in the current study aims to inform respondents and aid them in their decision making process, so as to obtain more stable opinions and make a better prediction of future public opinion on CO2-capture and storage technologies.

Information-Choice Questionnaire
The method of the ICQ was originally developed by Saris, Neijens and De Ridder [5], [6], [7], [8], 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

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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.

The effects and usefulness of the ICQ has been studied in extensive evaluation research [7], [9], [10], [11]. 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). 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.

Method

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. 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 to carefully define the policy problem and choose the most viable options. 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, between quotation marks, the brief expert label for the option, which we will use in this paper):

1. Large modern coal fired power stations (for private and commercial use) with CO_2 capture and storage. “IGCC with CCS”
2. Conversion of natural gas into electricity (for private and commercial use) with CO_2 capture and storage. “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”
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”
5. Retrieval of methane gas by storing captured CO_2 in coal beds. “ECBM”

[*] Obviously, these options were not merely labeled but fully described for lay people. For an example of such a description for “SOFC with CCS” see Figure 1.

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”

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 diverse institutions were interviewed and a literature study was done on the basis of which more quantification of storage potential and price was achieved. Seven experts checked the final document with all information [see [12]]. This information was translated by experts in lay language. As the capacity of especially lay people to absorb information is limited, the information that was compiled by experts was diminished to lay people proportions by omission of less important consequences, as agreed upon by a different group of independent experts. After this, the information for lay people and the procedure of the current ICQ was tested twice, on a sample of 23 teenagers with a low education level, and furthermore on a sample of 100 average Dutch citizens. On the basis of the test results, the information to be inserted in the ICQ was further improved. The group of independent experts judged the final ICQ information as valid, impartial and even-handed.

Per CCS 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. Information on aspects and consequences were presented concerning requirements for new installations, lines, vehicles and for technological breakthroughs, safety-issues, environmental issues, reliability, economic consequences, price, and number of years the technology may be applied. The processing of the information concerning aspects and consequences was facilitated by presenting each aspect or consequence separately and by having respondents evaluate each aspect or consequence. The decision making process was structured, so as to aid respondents in making an informed and deliberated decision. Respondents also received suggestions aiding them to avoid common decision making errors. 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 to fill in at home.

Results

After processing and evaluation of nine consequences of a global warming, the mean overall evaluation of global warming was quite negative: on a scale from 1 (very bad) to 7 (very good), the mean overall evaluation was 2.29. Respondents were then given information on CO_2 emission reduction goals, on how those could be achieved and on five consequences of CO_2 capture, transport and storage. Although a majority of respondents evaluated two of the five consequences (i.e. “small chance of damage to life under ground and basements” and “chance of small earthquake”) as moderate to big disadvantages, the mean overall evaluation of CO_2 capture, transport and storage was rather positive, 5.54 on a scale from 1 (very bad) to 7 (very good).
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 on a scale from 1 to 10, with 1 meaning the lowest score possible and 10 meaning a perfect score. All technologies were evaluated as “adequate” on average (see for grades Table 1). Only “ECBM” is evaluated very slightly lower than a 6 on average (5.94). 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. Only minute percentages (1.4 to 6.4%) of respondents stated to find specific CCS options so unacceptable, that they considered taking action when this technology were to be implemented on a large scale in the Netherlands. Table 1 also contains these percentages of respondents that do not accept specific options.

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" (9.9%) or "ECBM" (7.7%).

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

Expert labels for 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%

Before respondents in the ICQ evaluated the CCS technologies overall, they were asked to evaluate the aspects and consequences of these technologies. To determine if and how the evaluations of the consequences influence the overall evaluations of the technologies we performed multiple regression analysis. 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 are 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 lay people 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. Figure 1 contains an example of the analyses that have been done for all six options.

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.

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.

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.

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.

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.

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.

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.

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.

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.

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.

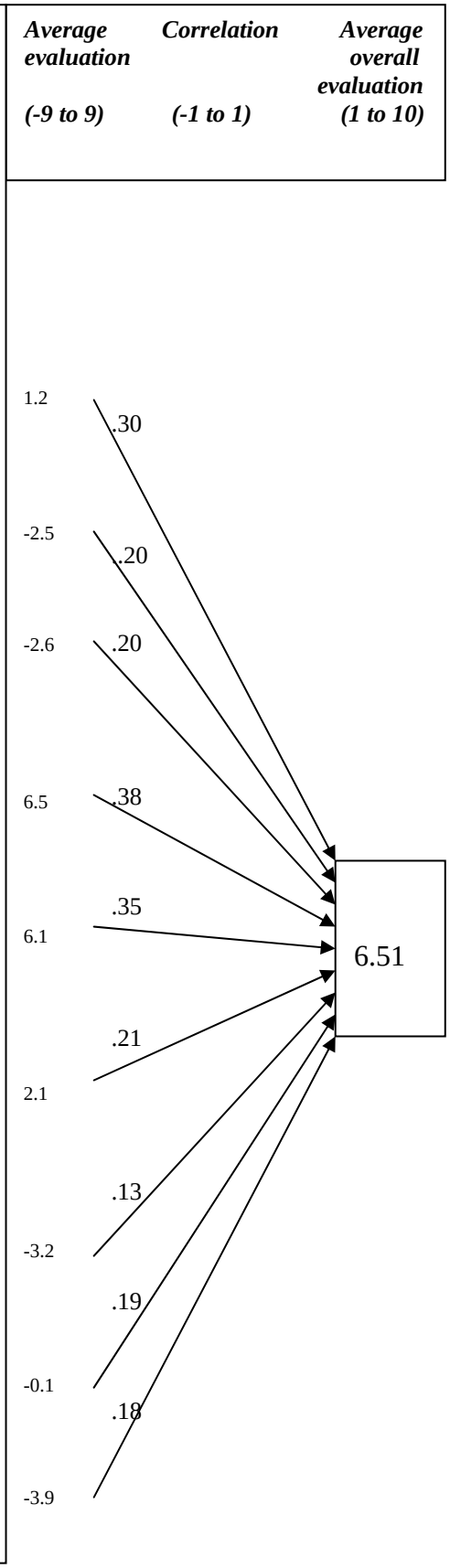

Figure 1 Example for one of the six CCS options (i.e. SOFC with CCS). Description of option in lay terms. Information on aspects and consequences. Average evaluations of aspects and consequences, average overall evaluation expressed as a grade between 1 and 10. And strength of the relation between these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

Conclusions and general comments

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. 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.

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. An ICQ study with such a broader choice context is currently in preparation. 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 pros and cons of CCS options.

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