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‘I reject your reality and substitute my own!’ Why more knowledge about CO_2 storage hardly improves public attitudes

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Abstract

Lack of societal acceptance of energy (transition) technologies is often attributed to a lack of knowledge among the public. The underlying assumption is that more knowledge improves attitudes about a technology. This assumption will be tested in this paper by examining the influence of the scores on a CCS Knowledge Test on attitudes towards CO_2 capture and storage (CCS). Furthermore the paper will examine the influence of perceptions of CCS (ideas that cannot be deemed ‘true’ or ‘false’) on attitude towards CCS and will analyse how knowledge and perceptions jointly influence attitude as well as in interaction. Implications of the results for communication about CCS are discussed.

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1. Introduction

Lack of societal acceptance of energy (transition) technologies is often attributed to a lack of knowledge among the general public and the local community in which implementation of a new technology is planned. The underlying assumption is that more knowledge improves attitudes about a technology. This 'Information Deficit model' [1] is still omnipresent in the energy transition debate, also when it comes to societal acceptance of CO_2 Capture and Storage (CCS) demonstrations. In this paper we will address two causes of the persistence of the information deficit model among decision makers and project developers as well as within the science community.

First, whereas 'knowledge' refers to statements that can be classified as true or false such as 'CO2 is something you can smell', 'perceptions' refer to statements that are subject to discussion such as 'CCS is needed to achieve the CO_2 reduction targets'. In dialogues about energy transition, or about any complex issue for that matter, this distinction is often not made. However the distinction is relevant because increasing knowledge and correcting misconceptions requires a different approach to stakeholder communication and participation than discussing perceptions. Since perceptions are topics of discussion they cannot be deemed 'true' or 'false' by anybody. Perceptions are rooted in particular perspectives on a technology and for a constructive dialogue each of these perspectives should be given equal validity [2].

Second, it is often assumed that knowledge about a technology and attitude about that technology are closely and positively related. Closely meaning that what one knows strongly influences thoughts about the technology; Positively meaning that what one knows positively influences thoughts about the technology, including both perceptions and attitudes. Conversely, lack of knowledge is supposed to lead to unfavourable perceptions and attitudes.

In this paper, both of these points will be addressed. First, a clear distinction will be made between knowledge and perceptions. Second, we will investigate the influence of knowledge and perceptions on attitude towards CCS as well as the relation between knowledge and perceptions. The data presented in this paper are results from the second measurement in an ongoing monitoring study of developments in knowledge, perceptions, and attitudes about CCS among the Dutch public. The measurement instrument, called the 'Knowledge and Beliefs Test'[†], aims to measure knowledge and perceptions of CCS as well as the prevalence of knowledge and perceptions in shaping public attitudes [3]. We will test the assumptions in the Information Deficit Model using the following hypotheses:

H1. Knowledge Test scores and Perceptions are equally strong predictors of attitude towards CCS.
H2a. Better Knowledge Test scores lead to a more positive attitude towards CCS.
H2b. Better Knowledge Test scores lead to more positive perceptions of CCS.

2. Method

2.1. Respondents and Measurement Instrument

The first measurement using the Knowledge and Beliefs test was conducted in May 2010 among a representative sample of the Dutch public (N = 401). The questions about knowledge and perceptions of CO_2 and CCS had been based on open in-depth interviews with 17 respondents to explore lay knowledge and beliefs about these issues. The second measurement using the Knowledge and Beliefs Test was conducted in November 2011. In the present version the questions were partly replaced by new questions

[†] The terms 'Beliefs' and 'Perceptions' are often used interchangeably – here we use 'Perceptions' in the remainder of the paper.

to account for recent changes in the media debate about CCS as well as a shift in focus from onshore to offshore CO_2 storage and methods for CO_2 transport in the Netherlands resulting from a Ministerial decision in June 2011 not to permit onshore CCS in the Netherlands until further notice. The sample consisted of 936 respondents of at least 18 years of age and was a representative sample for the Dutch population.

2.2. Measures

2.2.1. Knowledge Test Scores

CO_2 *sources, characteristics, and effects.* Respondents' knowledge of CO_2 was measured using 15 statements on possible characteristics, effects or sources of CO_2 (see Table 1). 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). A factor analysis of the 15 CO_2 items using VARIMAX rotation revealed three factors with an eigenvalue of 1 or higher. Together the factors explained 51% of the variance. The first factor contained only statements about CO_2 that were incorrect and was therefore labeled 'CO_2 incorrect'. The second factor contained only statements about CO_2 that were correct and was therefore labeled 'CO_2 correct'. The third factor contained correct statements about CO_2 being 'natural' and was therefore labeled 'CO_2 natural'. Reliability analysis showed that the items within each of the factors formed a good scale. For each scale a total score per respondent was calculated by taking the mean score of the items on the scale.

CO_2 *storage options.* Respondents' knowledge of possible CO_2 storage was measured using three correct and three incorrect statements about possible storage options for CO_2 (see Table 1). For each description respondents could indicate the likeliness that the statement was correct on a 7-point scale ranging from 1: very unlikely, to 7: very likely. To arrive at a total score for this question, whereby 7 represents the lowest score and 42 represents the highest score, the incorrect statements about CO_2 storage were recoded and then the scores on the six items were summed.

The goal of CO_2 *storage.* Respondents' knowledge of the goal of CO_2 storage was measured by presenting respondents two correct and two incorrect statements about the goal of CO_2 storage (see Table 1). Respondents were asked to select the statements that they believed to be correct. Respondents were given 1 point for every correct answer and 1 penalty for every incorrect answer. Because the list contained 2 correct answer options and 2 incorrect ones, a score of 2 meant a respondent had selected only correct goals and a -2 that a respondent had selected only incorrect goals.

2.2.2. Perceptions and Attitude

Consequences and desirability of CCS. Respondents were presented with 20 statements (see Table 2) that stated either a possible consequence such as 'The stored CO_2 will end up in the ground water' or a normative statement in favour of or against CCS such as 'CCS is necessary to mitigate climate change.' For each consequence statement respondents 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. For each normative statement, answers were measured on a 7-point scale ranging from 1: strongly disagree to 7: strongly agree. The statements were based on consequences indicated by respondents in the lay interviews of the previous edition of this study or derived from arguments relating to CCS used in the media or in expert communications about CCS.

Table 1. Knowledge Test Statements, Factor loadings, and Scales

Knowledge Test Statements	Factor Loadings
CO_2 correct - score on correct statements about CO_2 (Cronbach's α. = 70)	
CO_2 is a greenhouse gas	.74
CO_2 influences the climate	.71
CO_2 is released during energy production from natural gas	.57
CO_2 is released during energy production from coal	.69
CO_2 natural - score on statements that CO_2 is natural (Cronbach's α = .76)	
CO_2 occurs naturally	.73
CO_2 makes a liveable climate on earth possible	.76
CO_2 is released when you exhale	.73
CO_2 is released during energy production from biomass	.60
CO_2 incorrect - score on incorrect statements about CO_2 (Cronbach's α = .74)	
CO_2 is explosive	.58
CO_2 is used to protect metals from corrosion	.52
CO_2 emits hazardous radiation	.67
CO_2 is harmful if in contact with skin	.64
CO_2 is released when spray cans with hair spray or deodorant are used	.57
CO_2 is released when old batteries leak	.74
CO_2 is released during energy production from nuclear power	.64
CO_2 storage - accuracy of knowledge on CO_2 storage methods	N/A
The CO_2 will be stored underground in certain existing rock formations	
The CO_2 will be stored in the sea, where it is absorbed by the seawater*	
The CO_2 will be stored in underground bunkers with solid, impermeable walls*	
The CO_2 will be stored underground in caves and large cavities*	
The CO_2 will be stored under the sea bed	
The CO_2 will be stored in deep underground layers of salt water (acquifers)	
CCS goal - accuracy of knowledge on the goal of CCS	N/A
Mitigate climate change	
Protect the ozone layer	
Limit rise in temperatures	
Improve air quality in the Netherlands	

* statement recoded to make a higher score correspond to a more correct answer.

Table 2. Perceptions and Attitude, Factor loadings, and Scales

Perceptions: Statements about consequences, pro's and con's of CCS	Factor loadings
CCS Lockin_costs - CCS being not ready, creating a lock-in, or being too costly (Cronbach's α. = .61)	
With the possibility to use CCS technology energy companies will build more coal fired power plants	.63
CCS technology is not developed enough for large scale use	.61
Compared to other CO_2 mitigating measures CCS is too costly	.54
CO_2 storage will slow the development of large scale use of renewable energy	.46
CO_2 storage will decrease the value of properties in the immediate surroundings	.51
CCS Benefits_trust - benefits of CCS and trust in organizations involved (Cronbach's α. = .84)	
Implementing CCS will give us time to develop renewable energy sources such as wind and solar energy	.59
CCS is necessary to mitigate climate change	.73
Investing in carbon capture and storage will give the Netherlands a technological advantage over other countries	.67
CCS will help the Netherlands meet international agreements on CO_2 emission mitigation	.78
If we want to keep using fossil fuels, while lowering our CO_2 emissions, CCS is a logical solution	.75
I trust that CO_2 storage will be properly monitored by designated authorities over the long term.	.64
I trust the legal norms CO_2storage has to adhere to are strict enough to make implementation of the technology acceptable	.63
CCS Leakage - chances and consequences of CO_2 leakage from storage on land or at sea (Cronbach's α. = .82)	
The stored CO_2 will end up in the ground water	.60
People will suffocate if CO_2 leaks to the surface	.64
The CO_2 storage will explode because it is under pressure	.78
If CO_2 leaks from storage under the seabed the (sea)water could acidify	.61
CO_2 will leak from the storage to the surface	.51
If the CO_2 would leak form storage under the seabed it would drastically affect the sea ecosystem	.53
When CO_2 is captured hazardous substances are released in the vicinity of the factory	.70
CO_2 storage under the seabed poses risks for people	.56
CCS Attitude - extent to which one thinks positively about CO_2 capture and storage	N/A

The 20 items were included in one factor analysis using VARIMAX rotation. A forced three-factor outcome produced the clearest results and revealed three factors with an eigenvalue of 1 or higher. Together the factors explain 48% of the variance. The first factor contained statements about positive consequences or positive evaluations of CCS (such as 'CCS is necessary to mitigate climate change') as well as two statements on trust in legislation and monitoring authorities (such as and 'I trust the legal norms CO_2 storage has to adhere to are strict enough to make implementation of the technology acceptable'). This factor is named 'CCS Benefits_trust.' The second factor included mainly statements about the chances on and consequences of CO_2 leakage either on land or at sea (such as 'CO_2 will leak from the storage to the surface'). This factor is named 'CCS Leakage.' The third factor contained two statements implying the creation of a lock-in in the current energy system if CCS is implemented. The third factor furthermore contained three statements about the readiness and costs of CCS. This factor is named 'CCS Lockin_costs. Reliability analysis showed that the items within each of the factors formed a good scale. For each scale a total score per respondent was calculated by taking the mean score of the items on the scale.

Attitude towards CCS. Respondents were asked about their attitude towards CCS on a 7-point semantic scale with the ends "positive – negative". Answer category 1 meant 'negative' described their perception best, while answer category 7 meant 'positive' described their perception best. Thus a lower score signified a more negative attitude, while a higher score signified a more positive attitude.

3. Results

H1. Knowledge Test scores and Perceptions are equally strong predictors of attitude towards CCS. To test H1, regression was performed with all Knowledge Test scores and Perceptions scales as independent variables and Attitude CCS as dependent variable. Means, Standard Deviations, and Correlations between all scales are given in Table 3. The result of the regression analysis is shown in Table 4. Results show that of the Knowledge Test scores only the score on CO_2 storage has a direct, significant, and positive effect on attitude. In contrast, all Perceptions scales are direct and significant predictors of attitude. Moreover, the effects of the two Perceptions scales CCS benefits_trust and CCS lockin_costs are much stronger than the effect of CO_2 storage. This means that H1 is rejected: Perceptions scales are generally stronger predictors of attitude than Knowledge Test scores.

Table 3. Means, Standard Deviations, and Correlations between Knowledge Test scales, Perceptions scales, and Attitude CCS.

	M	SD	1	2	3	4	5	6	7	8
CO_2 correct	3.98	.74								
CO_2 natural	3.49	.97	.398**							
CO_2 incorrect	2.47	.72	-.152**	-.300**						
CO_2 storage	26.02	3.81	.267**	.208**	-.275**					
CCS goal	.77	1.00	.195**	.221**	-.206**	.100**				
CCS lockin_costs	4.47	.89	.168**	.102**	.017	.011	.010			
CCS benefits_trust	4.33	1.01	.017	-.092**	.063	.093**	-.001	-.401**		
CCS leakage	4.07	.96	-.103**	-.143**	.384**	-.213**	-.140**	.473**	-.239**	
Attitude CCS	4.07	1.50	.022	.009	-.070*	.155**	.042	-.462**	.662**	-.354**

** Correlation is significant at the 0.01 level (2-tailed).

* Correlation is significant at the 0.05 level (2-tailed).

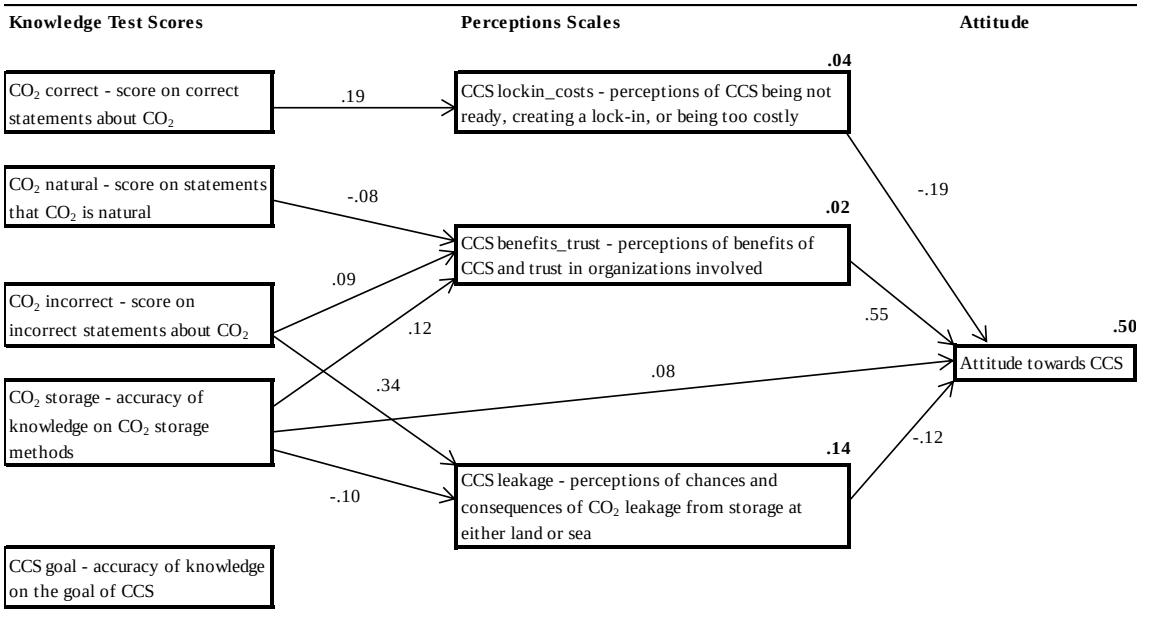
Table 4. Regression Analysis with Knowledge Test scales and Perceptions scales on Attitude CCS.

	Beta	t	Sig.
CO_2 correct	-.006	-.245	.806
CO_2 natural	.043	1.643	.101
CO_2 incorrect	-.033	-1.241	.215
CO_2 storage	.069	2.742	.006
CCS goal	.009	.390	.697
CCS lockin_costs	.561	21.842	.000
CCS benefits_trust	-.093	-3.137	.002
CCS leakage	-.197	-6.770	.000

F(8, 927) = 120,40, p < .001, Adjusted R2 = .51.

H2a. Better Knowledge Test scores lead to a more positive attitude towards CCS. H2b. Better Knowledge Test scores lead to more positive perceptions of CCS. To investigate the influence of Knowledge Test scales on Attitude CCS as well as on Perceptions scales, we built a model in which the impact of all scales on attitude towards CCS is calculated at once, taking into account covariances between the predictors. For this we used a statistical procedure called structural equation modelling using the program SPSS AMOS Version 20.0.0 [4,5]. The conventional test of statistical significance when evaluating a structural equation model is the chi-square goodness-of-fit index. For this index, better fit is represented by lower chi-squares, and higher chi-squares indicate worse fit. A non-significant chi-square test statistic indicates that the difference between the estimated and observed variance-covariance matrices is not reliable; hence, that model fits the data well. Other indices provide additional information about the fit of the model and are designed to provide more stable estimates of fit. We report the Comparative Fit Index (CFI) and the Root Mean Square Error of Approximation (RMSEA) [4]. The CFI is an index of the degree to which the model in question is superior to a null model, which specifies no covariance between the variables. CFI may vary from 0 to 1, with 0 indicating no fit and 1 indicating a perfect fit. Values greater than .90 are generally considered to reflect adequate fit of the model to the data. Similar to chi-square, RMSEA is an index of absolute fit. The index ranges between 0 and 1, with an RMSEA of .05 or lower indicating a good fit.

In the final model (see Figure 1) we first allowed the Knowledge Test scales to covariate as is also the case in multiple regression analysis. Second, we added all significant relationships between Knowledge Test scales, Perceptions scales, and Attitude CCS. Third, we removed all relationships that were not significant. Fourth, we allowed the error terms of the Perceptions scales to covariate. The final model (see Figure 1) fit the data well: $\chi 2(13) = 17{,}735$, $p = .168$, CFI = .997, RMSEA = .02. This model accounted for 50% of the variance in attitude towards CCS. The numbers besides the arrows indicate the strength and the direction of the relationship between two scales. The higher the number the stronger the relation. A positive number indicates that an increase in one scale leads to an increase in the other whereas a negative number indicates that an increase in one scale leads to a decrease in the other.



All relationships significant at the level p < .002

Figure 1. Structural Equation Solution for the Knowledge Test scales, Perceptions scales, and Attitude towards CCS model.

The model shows that perceived benefits of CCS and trust in legislation and authorities (CCS benefits_trust) is the strongest positive predictor of attitude towards CCS followed at distance by perceptions of CCS causing a lock-in and being expensive (CCS lockin_costs) and perceptions of chances and risks of leakage (CCS leakage). With regard to the influence of Knowledge Test scores on Perceptions scales and Attitude CCS, accuracy of knowledge about how CO_2 can be stored (CO_2 storage) has a relatively small but significant positive effect on Attitude CCS and has a somewhat stronger indirect positive effect via CCS benefits_trust. Furthermore, accuracy of knowledge about how CO_2 can be stored (CO_2 storage) reduces worries about chances and consequences of leakage (CCS leakage). This supports H2a and also demonstrates that effects of knowledge on attitude are partially mediated by perceptions.

With regard to the influence of high scores on incorrect statement in the Knowledge Test on perceptions and attitude towards CCS, the model demonstrates that a higher score on incorrect statements about the characteristics and effects of CO_2 (CO_2 incorrect) is strongly related to perceptions of chances and consequences of leakage (CCS leakage). This relation is positive, meaning that when people have more misconceptions about CO_2 and its effects they tend to perceive the chances and risks of leakage as higher, which in turn has a negative influence on attitude towards CCS. This supports H2b.

However, higher scores on correct statements in the Knowledge Test do not always lead to more positive perceptions, and higher scores on incorrect statements in the Knowledge Test do not always lead to more negative perceptions. Firstly, a higher score on correct statements about CO_2 (CO_2 correct) relates to stronger convictions that CCS may create a lock-in and may be too costly (CCS lockin_costs). This relation is quite strong. Secondly, knowing that CO_2 is natural (CO_2 natural) decreases perceived benefits of CCS and trust in legislation and monitoring authorities (CCS benefits_trust). Both of these results defy H2a. Thirdly, a higher score on incorrect statements about CO_2 (CO_2 incorrect) slightly increases perceived benefits of CCS and trust in legislation and monitoring authorities This defies H2b. Finally,

accuracy of knowledge about the goal of CCS (CCS goal) has no significant impact on either Perceptions scales or on Attitude CCS. In all, H2 can only be partially accepted.

4. Discussion

All Perceptions scales have a significant as well as intuitively logical influence on Attitude CCS, neither of which is true for many of the Knowledge Test scores. Most of these scores only influence attitude indirectly via perceptions. The only type of knowledge that has a direct effect on attitude is the extent to which one correctly recognizes the storage options for CO2, but this effect too is partially mediated by perceptions of benefits and trust. The strongest indirect effect is from incorrect ideas about CO2 on attitude, which significantly increases fear of leakage which in turn creates significantly more negative attitudes towards CCS. It can thus not be said that the role of knowledge is unimportant. However, it will also be clear that to improve societal attitudes towards a technology more needs to be done than improving knowledge and correcting misconceptions. Besides effects of knowledge on attitude towards CCS being indirect, the effects are not straightforward. Firstly, more knowledge does not by definition lead to more positive perceptions about CCS. A higher score on correct statements about CO2 significantly strengthens respondents' beliefs that CCS is not ready, that applying CCS will cause a lock-in for other technologies, that it will be too expensive, and may decrease property value. And knowing that CO2 is 'natural' decreases beliefs in the benefits of applying CCS and trust in authorities to monitor the process. Secondly, misconceptions about CO2 do not by definition lead to more negative perceptions about CCS. In the present model they have a slightly positive effect on benefits of applying CCS and trust in authorities to monitor the process.

These findings may impose a dilemma upon those in favor of CCS, since they imply that to create positive attitudes the public better not be told that CO2 is a natural gas or that it is actually not leaking from batteries. However, from a democratic perspective as well as by law, people are entitled to full and accurate information. Therefore this finding demonstrates that while providing people with 'correct' knowledge is important and even legally required, it will not necessarily create more positive perceptions of CCS and attitudes towards CCS. Instead, the present study demonstrates that the role of knowledge in shaping public opinions on transition technologies is limited and that perceptions play a much more important role. However, as said in the introduction of this paper, perceptions are manifestations of a particular perspective on the technology and cannot be classified as 'correct' or 'incorrect'. The only way to discuss perceptions and underlying perspectives is by dialogue. Public education and information provision are important components of energy transition. However, many choices societies will have to make in years to come about the energy system cannot be solved by simply referring to facts, and one cannot deem perceptions as 'misperceptions' since the view on what constitutes a misperception differs by stakeholder. We can only decide which energy future we as a society find desirable by means of a well-informed dialogue involving all perspectives on energy technologies.

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