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What a waste! Assessing public perceptions of Carbon Dioxide Utilisation technology

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INTRODUCTION

Carbon Dioxide Utilisation (CDU) technologies hold promise by helping to limit atmospheric releases of CO_2 while simultaneously generating saleable products **[1]**. However, while there is growing investment in the research and development required to test the technical and economic viability of CDU **[e.g., 2, 3]**, to date there has been very little systematic research into public perceptions of the technology.

The importance of gauging public opinion should not be underestimated. Numerous analogues exist to illustrate where a failure to properly assess the acceptability of new technologies and then appropriately engage with the general public and/or anticipated 'host' communities, can negatively affect the ease, speed or chance of real-world, commercial-scale deployment. Examples include GM food, **[4]** and renewable energy **[5]**. Recently, these public failures have prompted shifts towards more participatory and 'upstream' forms of public engagement around the introduction of new technologies, for example in nanotechology **[6]**, which seek to engage the public at a much earlier stage **[7, 8]**. With this in mind we firmly believe that research and development of CDU would benefit from systematic research into public perceptions and acceptance of the technology.

THE CURRENT RESEARCH

In view of the present lack of research into public opinion of CDU, as part of the new UK Centre for Carbon Dioxide Utilisation (CDUUK) and through the CO2Chem network (http://co2chem.co.uk/) we are conducting a series of studies aimed at learning more about the perceived benefits, risks, utility and relevance of CDU among members of the UK public. This communication will report briefly upon the results of a small pilot study, conducted on 16 participants (10 male, 6 female; 19-54 years) recruited from a University of Sheffield volunteers list, designed to: (a) design and test a *methodology* for investigating public perceptions of CDU; and (b) elucidate *new understanding* of people's attitudes towards the technology. We hope that, as with ongoing research into CCS communication **[9-12]**, the

understanding yielded by our research can be used to aid the development of better means of engaging and communicating with members of the general the *publics* about CDU.[1]

METHOD

As a new, unfamiliar family of technologies, CDU presents a challenging context for attitude research. Cognate research into CCS has indicated, for example, that unfamiliarity and low-levels of awareness can leave people prone to registering 'pseudo-opinions' **[13-14]**; 'uninformed' opinions that are problematic as they tend to be weak, changeable, and non-directive of people's behaviour. As such, these opinions are not ideal for making policy, investment or facility siting decisions.

In our current programme of studies we are using a mixed methods approach, which combines qualitative focus groups and a follow-up information choice questionnaire (ICQ) to assess opinion as described below. Both these techniques have been utilised successfully in studies assessing public opinion of cognate technologies, such as CCS, and offer good forums for the provision and deliberation of information about unfamiliar and/or contentious topics and thus have been associated with the registering more 'informed' opinions **[11, 14]**.

For general guidance on the application of social science methods to real world research settings, see, for example, Robson **[15]** and Bickman and Rog **[16]**.

Focus Groups

The aim of the focus group element of the research was to inform participants about CDU and to promote general discussion of the technology. After completing a short questionnaire designed to record basic demographics and initial awareness about CDU, participants received a short verbal introduction to the technology and watched a short video

[1] The term *publics* is used deliberately so as to recognise the inherent diversity that exists within society; diversity that might co-determine interest, understanding, involvement and opinion of technological innovation, including Carbon Capture Storage and Use technologies.

illustrating the purpose and process of CDU.[2] Using the video a stimulus, participants were then guided through a discussion of CDU technology for approximately 45-60 minutes and were invited to comment on their general perceptions of the technology, perceived risks and benefits, and the utility of CDU in tackling climate change relative to other options.

Information Choice Questionnaire (ICQ)

All participants then completed an ICQ within which they were invited to compare CCS and five CDU process/product options: cement production, plastics manufacture, transport fuel production, methanol production and enhanced oil recovery based on seven criteria: (1) investment payback time; (2) market potential for the products; (3) carbon reduction or abatement potential; (4) safety; (5) cost benefit to the consumer; (6) date to commercial viability; (7) ability to promote 'business as usual' operations. Table 1 summarises the details of the assessment criteria. Information about each option was provided in a comparative 'top trumps' style format.[3] Brief annotations and an illustrative pictorial image were provided alongside a 0-10 expert rating for each criterion.[4] A depiction of our 'methanol production' CDU 'top trumps' card can be seen in Figure 1 (see Electronic Supplementary Information for full criterion definitions and averaged expert ratings of the technology options).

[2] The video and other key materials associated with the research (e.g., 'Top Trumps' comparison cards) are publically available at: www.co2chem.co.uk/research-clusters/public-perception.

[3] 'Top trumps' is a card game where you compare things (e.g., cars or superheroes) on selected criteria (e.g., speed or strength). The higher the score for each criterion the better the thing is. The CDU 'top trumps' were developed in accordance with this concept.

[4] The information and ratings used to create the 'top trumps' cards were produced and validated by 10 academic experts working in the field of CDU, contacted *via* the CO2Chem Network.

Table 1 Description of the 'top trumps' assessment criteria used to compare different CDU options.

Criteria	Description
Investment payback time	How long it will take the money invested in the storage process or the new technology to be paid back. *The lower the rating, the longer it will take and so the less economically efficient it is.*
Market potential	Whether the product produced by the captured CO_2 will have the potential to sell. *The higher the rating the more potential it has.*
Carbon reduction	Refers to how much carbon is actually being taken out the atmosphere or used to produce another product. *The higher the rating, the more carbon that is removed and therefore the more effective it is.*
Cost benefit to consumer	Refers to whether the price of capturing the CO_2 or transforming it into another product will cost the customer through increased energy prices or whether the profits from the end product will offset this cost. *A higher rating means that the technology is less likely to make energy prices increase.*
Business as usual	Refers to the extent to which the option will enable/disrupt the current ways in which business and society operate; how much 'business' will remain as usual. For example, are we still able to live our day lives and use transport to the same extent. *A higher rating suggests business as usual is more achievable.*
Commercial availability[1]	Measures, in years, how long it will be before this technology is on the market (i.e. available for commercial use). *The greater the number of years the lower the commercial availability.*

[1] 'Commercial availability' was the only criterion where a higher value equated to a less favourable evaluation.

Having read about the CDU/CCS technologies, participants were asked to: (1) rank the options in order of preference (most to least preferred); (2) rate the extent to which they based their decisions on each assessment criterion; (3) rate how good or bad each option was in the context of reducing CO_2 emissions from industry; and (4) rate the quality of the provided information for bias, trustworthiness, credibility, sufficiency and understandability.

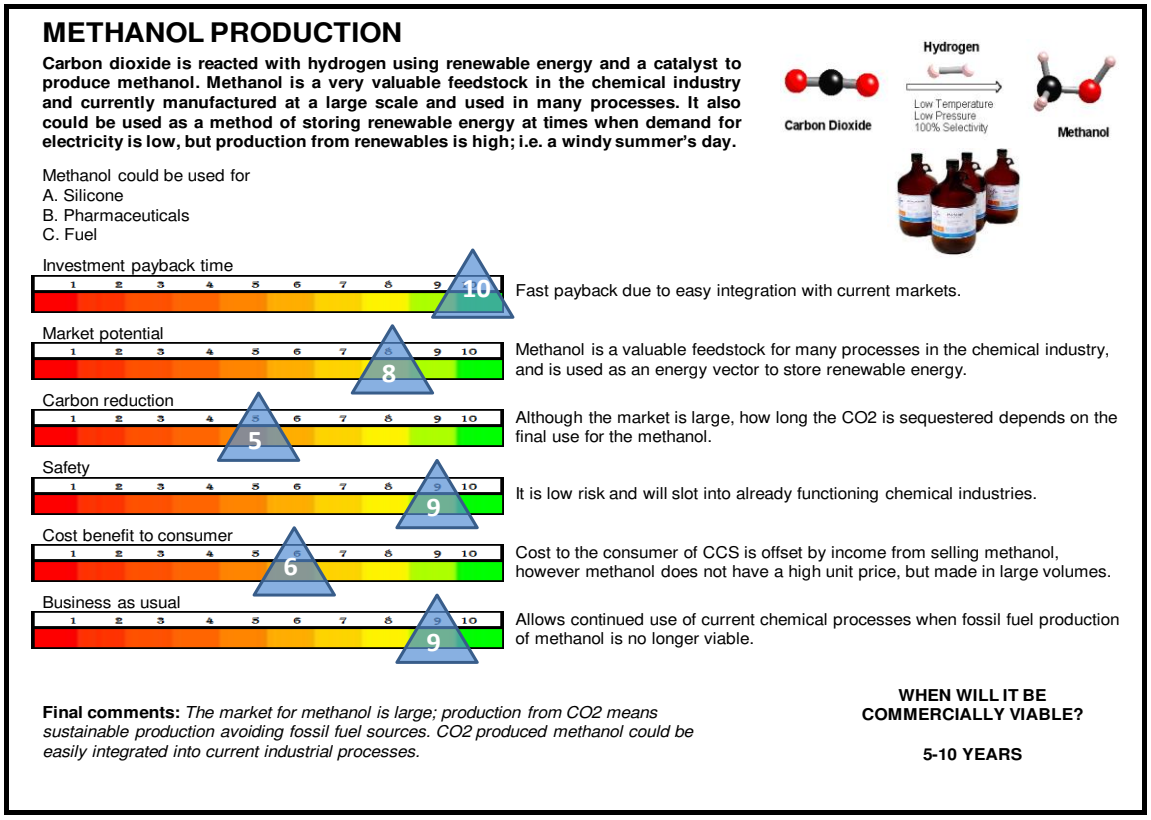

Figure 1 Example CDU 'Top trump' card. Card illustrates methanol production option and provides expert ratings (and justifications) for the option on key evaluative criteria.

RESULTS

The results below detail the headline findings from our pilot research activity. These findings should be considered a prelude to ongoing and more comprehensive work in this area.

Focus Group

Pre-participation awareness of CDU was low with only one respondent registering that they had heard of CDU. All participants indicated that they did not know a lot about the technology. Nine participants had no opinion of CDU, three said they were neutral and four said they were fairly or very positive to the technology.

Content analysis of the written notes and audio-recordings from the focus groups has identified a number of key themes/issues raised by participants, which apparently have implications for how CDU is presented and communicated.

(1) *Delaying the inevitable:* People believe that CDU may only delay the inevitable release of CO_2 to the atmosphere at high cost, both in terms of financial and energy-related costs. There is a feeling that the considerable energy used for CDU could be put to better, and more direct, use elsewhere, for example in providing homes with electricity. This concern is augmented by the belief that the potential carbon savings actualised by investment in CDU will be small, leading people to question the perceived utility, impact and worth of the technology, particularly as a means of tackling climate change. Indeed, while people do appear to generally value the principle of CDU as an attempt to mitigate climate change, and believe that CDU could help 'buy time' in the fight against climate change, this strength is caveated by the energy intensive nature of the processes, the suggestion that CDU presents only a short term solution to the issue of climate change, concern that CDU does not present the 'right solution' for tackling climate change and could draw funding from other technology and uncertainty about the long term effects of the technology.

(2) *Preventing societal change:* By making use of CO_2 people feel that CDU could be used by the public as an excuse to continue with their current wasteful lifestyles, thereby delaying or undermining efforts to promote action on climate change. CDU is to some extent seen to conflict with carbon reduction policies and as something that will only really address the symptoms of climate change as opposed to its root causes (i.e. wasteful behaviour practices). With this in mind, it is reasoned that investment should target behaviour change campaigns to reduce energy use rather than technological fixes, like CDU.

(3) *Employment and economic prospects:* Investment in CDU is anticipated to create new employment opportunities and produce useful, saleable products. Indeed, the employment prospects are seen to be a major strength of the technology, with people tending to see greater economic benefits than environmental benefits from the technology.

Information Choice Questionnaire (ICQ)

Participants tended to agree that the information provided within the ICQ was moderately-largely unbiased, trustworthy, credible, sufficient and understandable. While participants noted that they had considered all the information provided to moderate-large extent, they relied mostly on the 'carbon-reduction potential' information and least on the 'business as usual' information when making their decisions.

Methanol production was the most preferred technology option, followed by concrete manufacture, plastics manufacture, fuel production, EOR and CCS as shown in Table 2. These rankings were roughly comparable to the overall evaluations provided to the options in terms of tackling CO_2 emissions from industry; however, in this context concrete was the most preferred option and CCS was preferred to plastics, fuel manufacture and EOR.

Table 2 Comparative preferences for CDU options and mean evaluation of each option as a means of tackling CO_2 emissions from industry.

	Sum of ranks[1]	Mean evaluation (SD)[2]
Methanol production	32	3.31 (0.95)
Concrete manufacture	35	3.60 (0.91)
Plastics manufacture	45	3.00 (1.07)
Fuel production	54	2.73 (1.33)
Enhanced Oil Recovery (EOR)	68	2.31 (1.02)
CCS without CDU	81	3.44 (1.21)

[1] Lower sum score means option was more preferred.

[2] Responses made on 5-point scale (1 = very bad to 5 = very good).

DISCUSSION

New understanding

The results of this preliminary research suggest that while the concept of CDU is not rejected by people, it is greeted with caution. This caution would appear to stem from scepticism over the long-term impact of the technology in tackling climate change and a concern that investment in CDU might prevent necessary societal change.

These concerns are reflected in participants' general preferences for the different CDU options and also are perhaps evident in the differences in their self-reported reliance on the different assessment criteria when making their decisions, 'carbon reduction potential' > 'business as usual'. In relation to the long-term impact on climate change it is noteworthy that the only CDU option to be more favourably evaluated than CCS was concrete manufacture. Arguably this is because participants saw concrete manufacture as a process that would both make use of CO_2 and fix the carbon indefinitely. That is, the other options were likely to be seen as only delaying (and in the case of EOR increasing) an inevitable release of CO_2 to the atmosphere. Similarly, in terms of preventing societal change, our results indicate that people are apparently least favourable to those options more obviously related to facilitating current wasteful lifestyles, such as a reliance on oil through EOR, plastics and carbon-based transportation.

Our participants did, however, see some value to CDU in terms of creating useful products and job opportunities and, to some extent, did value the technology to the extent it was seen as symbolic of attempts to address climate change, although few believed that it was the 'answer' to climate change.

The methodological point

Initial awareness of CDU was very low among our participants. Only one participant registering that they had heard of CDU and all participants registered that they did not know a lot about CDU. Despite this, however, four participants still registered having a positive or very positive opinion of the technology, not including the person who had registered

awareness of the technology. This is indicative of these participants having initially registered pseudo-opinions. We argue that this finding validates our decision to employ more discursive and structured methods of attitude assessment within this research, rather than using a basic questionnaire-based survey.

As revealed by research into CCS, while it should not be assumed that such methods will produce more favourable attitudes *per se*, they should serve to improve knowledge of the technology and enhance attitude certainty **[e.g. 17]**. Importantly, this greater attitude certainty should mean that participants' opinions are more stable and thus likely to be more predictive of their future responses to CDU **[see 18]**.

Implications

The findings arising from this research have important implications for how communication about CDU technology within the public sphere should be framed. Studies abound to the importance of considering such issues when investigating and assessing attitudes **[19]**. Our preliminary results indicate that, due to the noted scepticism of CDU as a means of combating climate change, promotion of CDU on these grounds might not foster the support and acceptance of the technology that one might anticipate. Rather, by emphasising the benefits of the technology in terms of generating useful products and new employment opportunities might hold more value in this respect.

CONCLUSIONS

This short communication was designed with three key intentions: (1) to *raise awareness* of the importance of considering public perceptions of this emerging family of technologies; (2) to reveal some *new understanding* on this issue that we are generating through our ongoing research at CDUUK; and (3) to outline an innovative mixed-methods *approach* to assessing people's informed opinions of the technology.

Evidently the size and the university-based nature of the current sample potentially limit the transferability of these preliminary findings.[5] We are currently expanding upon the present research design to investigate the opinions of a greater number and diversity of individuals to establish if the themes arising from this research are more common among the general population and within particular stakeholder groups, such as those living in communities likely to host future CDU developments. We would encourage others to do the same.

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[5] The aim of *qualitative* research is not to generate generalizable findings (i.e. where the results of a sample population can be applied to the target population at large) as such, but rather to elucidate specific areas of interest to a researcher. Q*ualitative* studies tend to instead generate 'transferable' findings; i.e., findings which can be applied and tested by others in contexts beyond the immediate location of the study where similar people, situations or phenomenon exist **[see 16]**.

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Electronic Supplementary Information

'Top trumps' criterion definitions and expert ratings for CCS and CDU options.

The higher the score (out of 10) for each criterion, the better the experts rated it to be. See Table A for agreed expert ratings. To aid comparability, each option was evaluated in terms of the relative costs and benefits of installing a new CDU or CCS facility on a hypothetical new coal-fired power station. Copies of 'top trumps' cards are available on request.

Criterion definitions:

1. **Investment payback time:** How long it will take the money invested in the storage process or the new technology to be paid back. *The lower the rating, the longer it will take and so the less economically efficient it is.*
2. **Market potential:** Whether the product produced by the captured CO_2 will have the potential to sell. *The higher the rating the more potential it has.*
3. **Carbon reduction:** Refers to how much carbon is actually being taken out the atmosphere or used to produce another product. *The higher the rating, the more carbon that is removed and therefore the more effective it is.*
4. **Safety:** Refers to how safe the process of storing the CO_2 or transforming it into another product is. *The higher the score, the safer it is.*
5. **Cost benefit to consumer:** Refers to whether the price of capturing the CO_2 or transforming it into another product will cost the customer through increased energy prices or whether the profits from the end product will offset this cost. *A higher rating means that the technology is less likely to make energy prices increase.*
6. **Business as usual:** Refers to the extent to which the option will enable/disrupt the current ways in which business and society operate; how much 'business' will remain as usual. For example, are we still able to live our day lives and use transport to the same extent. *A higher rating suggests business as usual is more achievable.*
7. **When will it be commercially available?** Measures, in years, how long it will be before this technology is on the market (i.e. available for commercial use).

Table A.

Expert assessment of CCS and five CDU options on 'top trumps' comparison criteria.

	CCS	Fuel	Methanol	EOR	Plastics	Cement
Investment payback time	1	9	10	2	7	7
Market potential	0	9	8	8	7	6
Carbon reduction potential	9	4	5	5	4	6
Safety	4	7	9	3	8	7
Cost benefit to consumer	1	8	6	6	7	6
Business as usual	3	9	9	4	10	8
Timescale (years)	5-10	10-20	5-10	0-5	0-5	0-10

Note: For all criteria, except timescale, higher numbers equate to a better evaluation. We also appreciate that some readers might disagree with these ratings. If so we would invite you to contact the corresponding author such that the figures can be updated within future research.