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Public Understanding of Carbon Sequestration in Australia: Socio-Demographic Predictors of Knowledge, Engagement and Trust

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Abstract

This article explores the extent to which socio-demographic characteristics influence knowledge, trust, risk perception and acceptance of an emerging scientific technology, geosequestration or carbon dioxide capture and storage (CCS) in geological formations, which is positioned as a possible response to the build-up of greenhouse gases in the atmosphere. An online survey of 1273 Australian adults highlighted the general public's lack of knowledge about CCS yet willingness to engage and learn about this technology. Compared to men, women were less accepting of CCS and more concerned about safety, risk and effectiveness. Those with a higher education were more aware of the greenhouse gas debate and supportive of CCS, whilst younger Australians were more trusting of information providers to "tell the truth" about CCS. By identifying key attitudes, expectations and fears of specific sub-groups towards CCS, this research provides an initial basis for developing effective public policy and community engagement, risk communication and education strategies for this emerging technology in Australia.

Keywords: Carbon sequestration; perception; trust; knowledge; socio-demographic differences

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INTRODUCTION

Issues associated with the excessive build up of greenhouse gases in the atmosphere, such as climate change, and potential solutions to this problem are receiving increasing attention from government and policymakers both within Australia and internationally. Carbon dioxide accounts for the largest component of greenhouse gas emissions and is continuing to rise with estimates predicting that by 2020, global emissions of carbon dioxide will be 52 per cent higher than they were in 2000 (Nielsen 2005). Major causes of carbon dioxide emissions result from society's reliance on fossil fuels for power generation, transportation and industrial processes (Intergovernmental Panel on Climate Change (IPCC) 2005). Proposed strategies to deal with the human induced build up of carbon dioxide and other greenhouse gases in the atmosphere include the use of renewable energy sources (wind, solar, hydro, biomass), increased nuclear power, reduced use of carbon-intensive fuels and energy efficiency improvements. Another emerging technology proposed to reduce carbon dioxide emissions from fossil fuel sources is carbon capture and storage (CCS). Carbon capture and storage involves capturing carbon dioxide from large stationary sources, such as fossil fuel power plants, and transporting to long-term storage sites either in deep geological formations (geosequestration), direct injection into the ocean (ocean sequestration) or via mineral carbonation (IPCC 2005).

The focus of this research is on geosequestration, that is, the geological storage of carbon dioxide into pre-determined underground sites, such as depleted oil and gas reservoirs, landfills, coal seams or saline aquifers under the sea-bed (IPCC 2005). For simplicity, geosequestration will be referred to, in this paper, under the broader yet more concise acronym of CCS. Scientists from the Australian Cooperative Research Centre for Greenhouse Gas Technologies (CO2CRC, formerly Australian Petroleum CRC) believe geosequestration will be one of the earliest acceptable, technologically sound and economically attractive climate change mitigation options available (Bradshaw, Bradshaw, Allinson, Rigg, Nguyen & Spencer 2002). As CCS does not rely on significant change to energy consumption patterns, it is perceived by some as an ideal "bridging option" whilst new societal norms and alternative energy technologies are developed (Australian Greenhouse Office 2003). However, others have noted that CCS may lead to a continued reliance on fossil fuels and detract from other viable climate change mitigation options and investment in alternative power sources (Climate Action Network Australia 2004).

CCS in Australia and Internationally

Although there are at least ten experimental carbon sequestration sites currently in operation in countries such as Canada, Norway, United States, Netherlands, and Japan (IPCC 2005), knowledge of public perceptions of CCS as a solution to the greenhouse problem is extremely limited with researchers focussing almost exclusively on the technical, economic or environmental aspects (Bradshaw et al. 2002; Working Party on Fossil Fuels 2003; International Energy Agency 2004; Smekens & van der Zwaan 2004; CO2CRC 2005). As the trialling and possible establishment of carbon storage sites internationally has the potential to produce a wide range of social impacts for surrounding communities, as well as prompting vigorous public debate about the risks and acceptability of CCS technology for combating the greenhouse problem, understanding and benchmarking contemporary public perceptions is a priority. To date, however, despite the Petroleum Exploration Society of Australia (PESA) describing Australia as "one of the most promising countries in the world for underground disposal of carbon dioxide" (PESA News 2005) and the Australian Federal Government naming geosequestration a national research priority (Fyfe

2004), research investigating how the Australian public perceive CCS is virtually non-existent. This is despite the fact that 65 possible CCS sites have been identified in Australia and two are already under development: the Otway project in south-west Victoria which commenced in 2006 at a cost of A$30 million (ABC News Online 2006) and the Gorgon project in Western Australia which is expected to start in 2009 (Carbon Sequestration Leadership Forum 2005; IPCC 2005).

Thus, the primary goal of this research is to explore current knowledge and perceptions of CCS in Australia, thereby providing an invaluable benchmark of contemporary knowledge and expectations prior to any widespread communication or education campaigns. This article explores the extent to which socio-demographic characteristics, such as gender, age, income and education, influence knowledge, trust and acceptance of CCS as a response to the greenhouse gas problem. The findings highlight the key attitudes, expectations and fears of specific sub-groups towards CCS and provide an initial basis for developing effective public policy, community engagement, risk communication and education strategies for this emerging technology in the Australian context.

Public Perceptions of CCS

The scarcity of research investigating the social dimension of CCS is illustrated by the fact that, to date, there have been just four refereed journal articles focusing specifically on public perceptions of carbon sequestration technologies. In two studies, Shackley, Gough and colleagues (Gough, Taylor & Shackley 2002; Shackley, McLachlan & Gough 2005) have documented with both qualitative and quantitative research that the British currently know very little about CCS. Utilising a qualitative approach, Gough et al. (2002) conducted two focus groups in the United Kingdom with graduate students and general workers who were acquaintances of the researchers. Although most participants were initially unaware of the technology and expressed concerns about trust, regulation, ownership and risk of leakage, CCS was generally accepted as a viable bridging policy whilst other options were developed. More recently, Shackley et al. (2005) utilised convenience sampling to survey people at Liverpool airport and also conducted citizen's panels on CCS. They found that although people were initially uncommitted or opposed to CCS, a slightly more positive attitude was formed after the provision of information and education about the reasons for CCS. Importantly, however, even after learning more, participants still expressed general concerns over the risks of CCS, unknown effects and distrust of those promoting the technology.

In the United States, Palmgren, Morgan, de Bruin and Keith (2004) also found that the public is largely unaware of CCS. The findings of their face-to-face interviews with a convenience sample of 18 non-technical respondents and a survey of 126 community members led Palmgren et al. (2004) to conclude that the American public currently has limited knowledge and mixed feelings about CCS, expressing concern over unforeseen negative consequences, efficacy and costs. Notably, in comparison to other greenhouse gas mitigation strategies, CCS is viewed as the least preferred option both before and after detailed information was provided. In light of such findings, Palmgren et al. (2004: 6449) offered a blunt warning about the importance of transparent and effective public communication and engagement, noting that "an arrogant approach such as the one adopted in the past by the industries responsible for nuclear power and genetically modified crops could create a level of public distrust that makes the widespread implementation of carbon sequestration in the United States difficult, if not impossible". Most recently, Miller, Summerville, Buys and Bell (in press) examined the public perception of CCS in the Australian context and the implications for risk perception and communication strategies,

using the Public Acceptability of Controversial Technologies (PACT) framework as a guiding principle. The online survey of 1273 Australians revealed that most people had little knowledge of CCS. People were keen to participate in public discussions and learn more before forming a definite opinion, although many had "not-in-my-backyard" (NIMBY) reactions and raised concerns about the risks and effectiveness of technology and the trustworthiness of organisations.

Despite the dearth of refereed journal articles, however, several conference papers from the annual International Conference on Greenhouse Gas Control Technologies have focussed on issues surrounding public awareness and acceptance of CCS. These papers offer an international perspective and reveals that most people have limited knowledge of CCS and reservations about the technology. In the United States, Curry, Reiner, Ansolabehere and Herzog (2004) found that few people understood issues of global warming and were unaware of CCS or what environmental concern it addressed. Lack of awareness was also evident in Japan, with Itaoka, Saito and Akai (2004) finding that only 31% had previously heard of CCS, primarily from newspapers or television; interestingly, over 80% still reported at least conditional support for CCS. Similarly, in another Japanese study, Uno, Mori, Tokushige and Furukawa (2004) found that whilst the pubic had little knowledge of CCS, nearly half believed the technology was needed. Demonstrating typical NIMBY concerns, however, approximately half did not want the site near their home and, due to safety fears, were undecided about whether it should be used in distant areas. NIMBY concerns were also revealed in a Dutch study in which de Coninck and Huijts (2004) interviewed 112 people about CCS and found that the technology was more supported "elsewhere" than locally and despite an overall neutral opinion of CCS, most considered the drawbacks to be greater than the benefits. In general, the limited studies of public perceptions of CCS to date suggest that the public has little awareness or knowledge of CCS and, while some recognise the need for the technology, many have concerns about the risks, especially if proposed near their community. Precisely how the Australian public will perceive CCS is unclear.

Socio-Demographic Differences in Perception and Acceptance of CCS

Whilst these past studies have provided some insight into the public perception of CCS, little is known about how different demographic groups perceive CCS. The issue of socio-demographic differences in perception and acceptance of emerging scientific technologies is significant, as specific sub-groups of the public may have different attitudes, expectations and fears about CCS. Moreover, understanding the social structuring of beliefs and how key socio-demographic differences in gender, age, education and income might shape awareness, engagement and acceptance of CCS will ensure pertinent issues for particular sub-groups of the public are identified and addressed. To date, however, researchers have not specifically focused on the extent to which socio-demographic characteristics might influence knowledge, trust and acceptance of CCS as a possible response to the greenhouse gas problem. Only one of the studies mentioned above drew some conclusions regarding socio-demographic differences and CCS, with Uno et al. (2004) finding that women and adult respondents (compared to students) were less likely to agree with the need for local referendums for important social decisions, preferring decisions were reached through community discussions. Also, adult men were more likely to agree that 'restrictions on personal freedom should be permitted for reasons of public convenience'. As only limited research has focused on how socio-demographic factors impact on public perceptions of CCS, further information can be found in other socio-demographic studies. Fortunately, the

experience of emerging scientific technologies (for example, genetic engineering, biotechnology), environmental risk technologies (for example, nuclear power) and hazardous waste disposal (for example, nuclear waste) provides some guidance in predicting how socio-demographic differences might determine the perception and acceptance of CCS.

Gender and Novel Environmental Technologies

A vast literature consistently reports that men are more accepting of technology than women. For example, in the context of nuclear power, women are more likely than men to express safety concerns (Slovic 1997), outweigh negative consequences (Solomon, Tomaskovic-Devey & Risma 1989) and express NIMBY anxieties (Clancy & Roehr 2003). The general consensus from the risk perception literature is that men view risks as smaller and less problematic than women (Slovic 1997), and report greater levels of trust in formal institutions, particularly science, technology and government (Siegrist 2000). The role gender plays in determining engagement with environmental issues is less clear, although women generally rate environmental concerns greater than men (Burger, Roush, Sanchez, Ondrof, Ramos, McMahon & Gochfeld 2000). In the context of CCS, therefore, it is hypothesised that there will be clear gender differences in support for this technology, with women less trusting and expressing greater concerns than men.

Age and Novel Environmental Technologies

Precisely how age might impact on the acceptance of, trust in and engagement with novel environmental technologies is less clear. Some studies have demonstrated that younger people are more accepting of scientific technologies such as biotechnology (Grobe, Douthitt & Zepeda 1997) and genetic engineering (Gamble, Muggleston, Hedderley, Parminter & Richardson-Harman 2000), whilst other studies on nuclear power have shown younger people are more concerned (Houghton, Murray & Ball 1999). The risk literature offers one explanation for these divergent findings, with Fischer, Morgan, Fischhoff, Nair & Lave (1991) postulating that younger people are more concerned about long-term environmental risks while older people are more concerned about health, safety and personal risks. Precisely how age might impact on acceptance of CCS is unclear, as this technology is described by some as a suitable option to reduce the long-term environmental risks of global warming yet does pose some potential personal safety risks. However, given the high profile nature of the greenhouse gas debate, the importance younger people typically place on ensuing the sustainability of the planet and the widespread acceptance of advanced technology, it is expected that young people will be more aware of the problem, more involved in environmental debates and more accepting of technology designed to address a global problem. In other words, because they have grown up in a highly technological world, younger people may be more accepting of the proposed technological response of CCS to climate change than older adults. However, with younger people often described as a more cynical and questioning generation, it is expected that they will be more distrustful of traditional information-providers, such as the government, and place greater trust in environmental organisations to “tell the truth” about CCS.

Socio-Economic Status and Novel Environmental Technologies

Socio-economic status, as captured by income and education, is an inconsistent predictor of people’s reactions to novel environmental technologies. On the one hand, education and income often predict engagement with, trust and acceptance of science, technology and risks. For example, people with higher educations and incomes were more accepting of

genetically modified food (Cuite, Aquino & Hallman 2005), whilst income predicted greater acceptance, perceived safety and willingness to live near nuclear power plants (Farhar, Unseld, Vories & Crews 1980). On the other hand, education and income are often associated with greater environmental concern (Samdahl & Robertson 1989) and political engagement (Rotberg 1999). How acceptance of CCS, a technology proposed to address a global problem but with local risks, will differ as a function of income and education is unclear. Thus, it is tentatively hypothesised that education and income will predict engagement in environmental debates, knowledge of CCS and desire to learn more.

Current Study

As published research examining public perceptions of carbon sequestration in Australia is virtually non-existent, a key goal of this study was to gather current normative data from a large sample of Australian adults (n=1273) prior to any widespread communication and education campaigns. The current study also extends previous international research by simultaneously exploring the role demographic differences play in predicting acceptance of CCS technology, engagement with environmental issues and trust of information providers. Given the limited research into public perceptions of carbon sequestration, this study represents an initial investigation into how demographic differences in age, gender, income and education might determine (1) awareness and importance of the greenhouse gas problem; (2) knowledge, support and perceptions of CCS; (3) willingness to be involved in public debates about CCS and greenhouse gas emissions; and (4) who would be trusted to provide information on carbon sequestration. In terms of gender, it was hypothesised that men would be more accepting of CCS technologies and report greater trust in information providers than women. In terms of age, it was hypothesised that younger Australians would be more involved in the environmental debate, accepting of the potential benefits of the novel CCS technology and distrustful of information-providers. Finally, in terms of income and education, it was hypothesised they would predict greater interest in the issue and desire to learn more. Rather than investigating the broadly defined 'public perception' of carbon sequestration in Australia, the overarching aim of this study was to identify and highlight the differing perspectives of various sub-groups within the 'public'.

METHOD

Participants

Participants in this non-representative sample were members of an Australian market research company's online panel who regularly participate in on-line research in order to enter prize draws and/or earn reward points which can be redeemed for products (see http://www.opinionspaid.com/). A total of 1273 people responded, with the majority female (79%). The mean age of the sample was 36.6 years, ranging from 18 to 79 years. Approximately 60% of respondents were married or in a defacto relationship, with the remainder single (32%) or divorced or widowed (9%). Participants reported relatively high levels of educational achievement and household income, with over one-third (36%) possessing a university degree and over half (58%) reporting an annual household income above $50,000. The majority (80%) were born in Australia, with only 20% reporting overseas birthplaces, primarily the UK/Europe (55.2%), Asia (18.3%) and New Zealand (17.1%). Few identified as Aboriginal or Torres Strait Islander (1.6%). Table 1 below outlines a socio-demographic breakdown of participants, illustrating how the sample compared to the Australian population. Participants in this study were more likely to be female, younger,

better educated and report higher incomes. As the majority of respondents were female, chi square analysis was performed to test for association between gender and other socio-demographic variables. Notably, gender was associated with age, with there being significantly more females than males who are younger than 36 years (60% vs. 48%, $\left(\chi^2 = 13.9, p = 0.000\right)$), but was not associated with education $\left(\chi^2 = 1.9, p = 0.17\right)$ or income $\left(\chi^2 = 3.6, p = 0.06\right)$.

Table 1. Demographic profile of respondents.

	n	Percent	Australian Public
Gender			
Male	273	21%	49%*
Female	1000	79%	51%*
Age			
35 and younger	734	58%	35%*
36 and older	538	42%	65%*
Level of Education			
Secondary School	484	38%	49%**
Higher Education	789	62%	51%**
Income			
$50,000 and below	540	42%	81%*
$50,000 and above	733	58%	19%*

*ABS (2001; **ABS (2006)

Procedure

To examine public perceptions of carbon sequestration, an Australian market research company was commissioned to survey members of a national online panel in August 2005. Online panel members were emailed an invitation to complete the on-line survey in return for entry into a prize draw (up to $2000 worth of gift vouchers). Before completing the survey, respondents were provided with the following brief information about Carbon Sequestration:

> Geological sequestration of carbon dioxide is a new scientific technique that proposes storing carbon dioxide gases deep in the earth, specifically through the injection of semi-liquid carbon. It is described as one of the most environmentally-friendly ways to address the issue of increasing CO_2 emissions, yet there is a small risk of leakage.

Measures

Socio-demographic differences were measured for gender, age, marital status, highest education, annual income and country of origin, with this article focusing on four key socio-demographics for analysis: gender, age, education and income. Respondents indicated their highest level of education (secondary school, apprenticeship/TAFE, university degree), which was recoded into secondary school only or tertiary education. Respondents indicated their household's annual income, which was re-coded into either under or over $50,000. A median split was used to categorise respondents into two age groups: 35 years and younger and 36 years and older. Participants were then asked a series of questions about their interest in the greenhouse gas problem, their knowledge and perception about proposed

carbon sequestration technologies and which organisations they would trust to tell the truth about CCS. The specific questions and response scales are outlined below.

Awareness and Importance of Greenhouse Gas Effect

Two items assessed the perceived importance of the greenhouse problem. Participants were asked to indicate, on a 4 point Likert scale anchored at "very closely" (1) and "not at all" (4), how closely they had followed the debate about reducing greenhouse gas emissions and indicate, on a 5 point Likert scale anchored at very important (1) and not at all important (5), how important they believed it was for Australia to reduce its greenhouse gas emissions.

Knowledge, Support and Perceptions of CCS

Two items assessed participants' knowledge of CCS in geological formations. *Current knowledge* of CCS was measured dichotomously, with participants reporting whether they had prior knowledge of carbon sequestration or not. *Desire for knowledge* was measured by asking participants to indicate, on a five-point Likert scale anchored at strongly agree and strongly disagree, whether they needed more information to form a clear opinion about storing carbon underground. *Support* for CCS was assessed using three questions, on a 5-point Likert scale anchored at definitely and definitely not, whether participants would approve of carbon capture and storage technologies in general, within Australia and in their community. Three questions, on a five-point Likert scale anchored at strongly agree and disagree, measured *expectations and perceptions* in terms of fear (I would be afraid if underground carbon storage technologies were used near my community), safety (I am confident that, if it proceeds, the development of storing carbon underground will be safe and carefully regulated) and effectiveness (I think storing carbon underground is a "quick fix" solution that will not solve the greenhouse gas problems).

Willingness to Engage in Greenhouse and CCS Debate

Three items, on a 5-point Likert scale anchored at strongly agree and strongly disagree, measured participants' willingness to engage in the debate about greenhouse gases and the proposed solution of CCS. Participants indicated the extent to which they thought the government should consult the public about how to reduce greenhouse gas emissions, if the government should encourage public participation and debate about new developments in science and technology and whether they would personally be prepared to take part in a public discussion about reducing greenhouse gas emissions and storing carbon underground.

Trust in CCS Information Providers

Trust of information providers was assessed by asking respondents to indicate the extent to which they would trust each of seven organisations or people to tell the truth about geological sequestration or underground carbon storage. Using a 5 point Likert scale anchored at distrust a lot and trust a lot, participants rated the trustworthiness of the biotechnology industry, scientists/researchers working for government, scientists/researchers working for Universities, local authorities, the national government, CSIRO (Commonwealth Scientific and Industrial Research Organisation) and environmental organisations.

Analysis

Basic statistics such as frequencies, percentages, and means were calculated for all of the respondents (n=1273), and are presented in tables. Chi-square tests and t-tests were

conducted to compare responses according to socio-demographic variables that typically influence risk perception and decision-making – gender, age, education and income, with the effect sizes for significant results reported to illustrate the degree of difference. For simplicity, all socio-demographic variables were dichotomised.

RESULTS

Overview of Findings

Regardless of socio-demographic differences, most participants felt it is very important for Australia to reduce its greenhouse gas emissions (58%), yet the majority had not followed the greenhouse debate very closely (43%) or at all (19%). Less than a fifth (18%) of participants had heard of CCS prior to the survey, with approximately half (53%) neutral about whether storing carbon underground was a good idea. There was a strong NIMBY effect, with support for CCS reducing as the technology was proposed closer to the respondent's community, with nearly half reporting that they would be afraid if CCS was to be used near their community (42%) and believing that CCS was a quick fix that would not solve the greenhouse gas problem (41%). Notably, only 21% of respondents were confident that CCS would be safe and carefully regulated. Overall, however, participants reported neutral responses regarding the safety and effectiveness of CCS, with the majority (85%) reporting that they needed more information to form a clear opinion about storing carbon underground. The majority of respondents believed the government should encourage public participation and debate about new developments in science and technology (85%) and should consult the public about how to reduce greenhouse gas emissions (80%), with most (84%) willing to take part in public discussions about greenhouse gas issues and CCS. The key finding was that while participants had little prior knowledge of CCS, most were willing to learn more about this technology (see Miller et al. (in press)).

Socio-Demographic Differences in Awareness of Greenhouse Gas Issues

In terms of socio-demographic differences, women were more likely to think it is important for Australia to reduce greenhouse gas emissions yet were less likely to have followed the greenhouse gas debate. Overall, as Table 2 reveals, the greenhouse debate was more likely to be followed by males, those aged 36 years and older, with a higher education and earning more than $50,000 a year. The effect sizes were small for income (0.14) and age (0.23), and medium for level of education (0.4). For gender, the effect size was large for those who followed the debate (0.79) and medium for those who think that it is important for Australia to reduce greenhouse gases.

Socio-Demographic Differences in Knowledge, Support and Perceptions of CCS

While few participants had heard of CCS prior to the survey (18%), chi-square tests reveal that men were significantly more likely to have heard of CCS than women (29% versus 16%, $\left(\chi^2 = 26.7, p = 0.000\right)$) as well as those with a higher education (22% versus 13%, $\left(\chi^2 = 18.2, p = 0.000\right)$) or with incomes greater than $50,000 (20% versus 16%, $\left(\chi^2 = 4.2, p = 0.039\right)$). There was no significant difference as a function of age (18% versus 19%).

Table 2. Socio-demographic differences in mean awareness and importance of greenhouse gas issues.

	Followed debate about reducing greenhouse gases	**Important for Australia to reduce greenhouse gases**
Gender	***Mean (SD)***	***Mean (SD)***
Male	**2.52***** (0.82)	4.38 (0.77)
Female	2.15 (0.79)	**4.53**** (0.64)
t value (effect size)	*6.66[a] (0.79)*	*-2.86[a] (0.36)*
Age		
35 and younger	2.15 (0.81)	4.48 (0.67)
36 and older	**2.34***** (0.80)	4.52 (0.68)
t value (effect size)	*-4.11[b](0.23)*	*-1.04[b]*
Level of Education		
Secondary School	2.05 (0.77)	4.46 (0.68)
Higher Education	**2.34***** (0.81)	4.52 (0.67)
t value (effect size)	*-6.35[a](0.40)*	*-1.66[b]*
Income		
<$50,000	2.16 (0.81)	4.53 (0.63)
>$50,000	**2.28*** (0.81)	4.47 (0.71)
t value (effect size)	*-2.42[b] (0.14)*	*1.59[a]*

Notes: Questions were rated on a 1-5 scale, with higher scores representing greater agreement. ****p*<0.001, ***p*<0.01, **p<0.05*
[a]equal variances not assumed, [b]equal variances assumed

Table 3 outlines key socio-demographic differences in support for CCS use in general, in Australia and within the participant's own community. In all instances, support for CCS

Table 3. Socio-demographic differences in mean support for CCS.

	Support CCS use in general	**Support CCS use in Australia**	**Support CCS use near own community**
Gender	***Mean (SD)***	***Mean (SD)***	***Mean (SD)***
Male	**3.21***** (0.86)	**3.17***** (0.96)	**2.67***** (1.09)
Female	2.99 (0.80)	2.91 (0.82)	2.36 (0.92)
t value (effect size)	*3.91[a] (0.47)*	*4[a] (0.49)*	*4.31[a] (0.54)*
Age			
35 and younger	3.05 (0.78)	2.99 (0.81)	2.46 (0.94)
36 and older	3.01 (0.87)	2.94 (0.92)	2.38 (0.99)
t value (effect size)	*0.93[a]*	*0.91[a]*	*1.32[b]*
Level of Education			
Secondary School	2.98 (0.82)	2.90 (0.88)	2.35 (0.94)
Higher Education	3.07 (0.82)	**3.01*** (0.84)	**2.47***(0.96)
t value (effect size)	*-1.75[b]*	*-2.05[a](0.13)*	*-2.22[b](0.13)*
Income			
<$50,000	3.01 (0.80)	2.93 (0.87)	2.37 (0.96)
>$50,000	3.06 (0.82)	3.00 (0.85)	2.46 (0.96)
t value (effect size)	*-1.09[b]*	*-1.39[b]*	*-1.75[b]*

Notes: Questions were rated on a 1-5 scale, with higher scores representing greater agreement. ****p*<0.001, ***p*<0.01, **p<0.05*
[a]equal variances not assumed, [b]equal variances assumed

lessened as it was proposed closer to the participant's community, suggesting NIMBY sentiments among the participants. With regards to gender, men were more accepting of CCS and were more likely to believe CCS was a good idea in general, in Australia and within their own community. The effect size was medium, ranging from 0.47 to 0.54. People with a higher education were also more likely to support CCS and believed it should be used in Australia or in their own community, although the effect size for both was small (0.13). Factors of age and income revealed no significant differences.

Differences in age, education and income did not significantly influence perceptions of CCS. As Table 4 illustrates, gender was the only socio-demographic difference to impact on CCS opinions, with small to medium effect sizes. Women were more likely to report concerns about the risks, safety and effectiveness of CCS technology than men. Interestingly, women also had a greater desire for knowledge, needing more information to form a clear opinion about CCS.

Table 4. Socio-demographic differences in mean CCS perceptions and expectations.

	I am confident that, if it proceeds, the development of storing carbon underground will be safe and carefully regulated	**I would be afraid if underground carbon storage technologies were used near my community**	**I think storing carbon underground is a quick fix solution that will not solve the greenhouse gas problems**	**I need more information to form a clear opinion about storing carbon underground**
Gender	***Mean (SD)***	***Mean (SD)***	***Mean (SD)***	***Mean (SD)***
Male	**3.16***** (0.90)	3.16 (0.96)	3.38 (0.90)	4.14 (0.81)
Female	2.89 (0.84)	**3.84***** (0.90)	**3.53*** (0.90)	**4.33***** (0.81)
t value (effect size)	*4.44[a] (0.53)*	*-5.17[b] (0.35)*	*-2.48[b] (0.17)*	*-3.46b (0.24)*
Age				
35 and younger	2.98 (0.86)	3.42 (0.90)	3.48 (0.87)	4.27 (0.84)
36 and older	2.90 (0.86)	3.40 (0.96)	3.53 (0.95)	4.31 (0.78)
t value (effect size)	*1.63[b]*	*0.23[b]*	*-1.04[a]*	*-0.84[b]*
Level of Education				
Secondary School	2.90 (0.85)	3.45 (0.96)	3.51 (0.91)	4.24 (0.83)
Higher Education	2.97 (0.86)	3.38 (0.90)	3.49 (0.90)	4.31 (0.80)
t value (effect size)	*-1.39[b]*	*1.32[b]*	*0.30[b]*	*-1.59 [b]*
Income				
<$50,000	2.93 (0.87)	3.44 (0.96)	3.51 (0.94)	4.28 (0.84)
>$50,000	2.96 (0.84)	3.39 (0.90)	3.49 (0.88)	4.29 (0.79)
t value (effect size)	*-0.50[b]*	*1.10[a]*	*0.32[b]*	*-0.24 [b]*

Notes: Questions were rated on a 1-5 scale, with higher scores representing greater agreement.
****p*<0.001, ***p*<0.01, **p<0.05*
[a]equal variances not assumed, [b]equal variances assumed

Socio-Demographic Differences in Willingness to Engage in Greenhouse and CCS Debate

As Table 5 illustrates, though with small effect sizes, men were more prepared to take part in public discussions about reducing greenhouse gas emissions and CCS. However, despite men's greater commitment to be involved, women were more likely to believe in the importance for government to consult the public about how to reduce greenhouse gas

emissions. There were no significant differences as a function of age or income, although those with higher educations were significantly more willing to participate in public discussion on these issues.

Table 5. Socio-demographic differences in mean willingness to engage.

	The government should consult the public about how to reduce greenhouse gas emissions	**The government should encourage public participation and debate about new developments in science and technology**	**I am prepared to take part in a public discussion about reducing greenhouse gas emissions and storing carbon underground**
Gender	***Mean (SD)***	***Mean (SD)***	***Mean (SD)***
Male	3.98 (0.92)	4.15 (0.81)	**3.51**** (0.96)
Female	**4.15**** (0.86)	4.24 (0.78)	3.33 (0.99)
t value (effect size)	*-2.83 [b] (019)*	*-1.72[b]*	*2.69[b] (0.18)*
Age			
35 and younger	4.07 (0.90)	4.19 (0.79)	3.32 (1.00)
36 and older	4.17 (0.84)	4.27 (0.77)	3.43 (0.97)
t value (effect size)	*-1.90[b]*	*-1.91[b]*	*-1.81[b]*
Level of Education			
Secondary School	4.14 (0.83)	4.19 (0.80)	3.25 (0.97)
Higher Education	4.09 (0.90)	4.24 (0.77)	**3.44*****(0.99)
t value (effect size)	*-1.01[b]*	*-1.15[b]*	*-3.44[b](0.20)*
Income			
<$50,000	4.16 (0.91)	4.25 (0.82)	3.37 (0.98)
>$50,000	4.07 (0.85)	4.20 (0.75)	3.37 (0.99)
t value (effect size)	*-1.75[a]*	*-1.07[a]*	*-0.01[b]*

Notes: Questions were rated on a 1-5 scale, with higher scores representing greater agreement.
****p*<0.001, ***p*<0.01, **p<0.05*
[a]equal variances not assumed, [b]equal variances assumed

Socio-Demographic Differences in Trust of Information Providers

Table 6 reveals demographic differences in trust of organisations, with most having small effect sizes. Within all groups, the Commonwealth Scientific and Industrial Research Organisation (CSIRO) was the most trusted organisation (68.6% trust) while the National Government was the least trusted (20.4% trust). In terms of gender, males are more likely to trust scientists/researchers working for the government and CSIRO while females are more likely to trust environmental organisations. People who are aged 35 years and younger are more likely to trust all organisations excluding CSIRO, which is equally the most trusted by both age-groups. Those with a higher education are more likely to trust scientists/researchers working for universities and least likely to trust the biotechnology industry. Those who have income greater than $50,000 are more likely to trust scientists/researchers working for the government or university, and the national government. Overall, the most trusting group appears to be people aged under 35 years.

Table 6. Socio-demographic differences in mean trust of providers of CCS information.

	Biotech-nology Industry	Environ-mental Orgs	Scientists/ Researchers working for Government	Scientists/ Researchers working for Universities	Local Authorities	The National Government	CSIRO
Gender	***Mean (SD)***	***Mean (SD)***	***Mean (SD)***	***Mean (SD)***	***Mean (SD)***	***Mean (SD)***	***Mean (SD)***
Male	2.98 (1.04)	3.52 (1.06)	**3.12**** (1.05)	3.83 (0.99)	2.70 (0.95)	2.52 (1.07)	**4.01*** (0.96)
Female	3.10 (0.95)	**3.73**** (1.02)	2.92 (1.06)	3.79 (0.98)	2.76 (0.98)	2.50 (1.07)	3.86 (1.0)
t value	*-1.81[a]*	*-2.99[b]*	*2.69[b]*	*0.74[b]*	*-0.95[b]*	*0.30[b]*	*2.20[a]*
(effect size)			*(0.18)*				*(0.25)*
Age							
35 and younger	**3.13*** (0.95)	**3.76**** (0.99)	**3.04**** (1.00)	**3.86**** (0.94)	**2.89***** (0.93)	**2.60***** (1.00)	3.86 (0.98)
36 and older	3.00 (1.00)	3.59 (1.10)	2.87 (1.10)	3.71 (1.00)	2.56 (0.99)	2.36 (1.10)	3.93 (1.00)
t value	*2.33[b]*	*2.81[a]*	*2.76[a]*	*2.70[a]*	*6.00[a]*	*3.92[a]*	*-1.33[b]*
(effect size)	*(0.13)*	*(0.17)*	*(0.17)*	*(0.16)*	*(0.36)*	*(0.24)*	
Level of Education							
Secondary School	**3.15*** (0.94)	3.67 (1.00)	2.91 (1.10)	3.71 (0.99)	2.80 (0.96)	2.54 (1.10)	3.89 (0.98)
Higher Education	3.03 (0.99)	3.7 (1.10)	3.00 (1.10)	**3.85*** (0.97)	2.72 (0.98)	2.48 (1.10)	3.89 (1.00)
t value	*2.18[b]*	*-0.41[b]*	*-1.41[b]*	*-2.31[b]*	*1.50[b]*	*0.95[b]*	*-0.11[b]*
(effect size)	*(0.13)*			*(0.13)*			
Income							
$50,000 and below	3.07 (0.97)	3.70 (1.04)	2.88 (1.07)	3.71 (1.02)	2.73 (0.98)	2.43 (1.09)	3.85 (1.00)
$50,000 and above	3.08 (0.98)	3.68 (1.03)	**3.03*** (1.05)	**3.86**** (0.94)	2.76 (0.97)	**2.56*** (1.06)	3.92 (0.99)
t value	*-0.21[b]*	*0.37[b]*	*-2.46[b]*	*-2.68[a]*	*-0.56[b]*	*-2.14[b]*	*-1.19[b]*
(effect size)			*(0.14)*	*(0.16)*		*(0.12)*	

Notes: Questions were rated on a 1-5 scale, with higher scores representing greater trust.
****p*<0.001, ***p*<0.01, **p<0.05*
[a]equal variances not assumed, [b]equal variances assumed

DISCUSSION

This study, among the first to examine public perceptions of carbon sequestration in an Australian sample, extends our understanding of how socio-demographic differences impact on knowledge, trust and acceptance of an emerging scientific technology in several ways. First, it provides an important benchmark of current perceptions of the greenhouse gas problem and initial reactions to a potential solution offered by CCS from different groups of the public, prior to any large-scale awareness campaigns. The findings highlight the general public's lack of knowledge about CCS technologies; despite some scientists claiming Australia is an ideal site for CCS (PESA News 2005) and establishing two trial sites in Australia, the vast majority of participants had not heard of CCS prior to completing the survey. Second, by focussing on how socio-demographic differences might impact on

perceptions and acceptance of CCS, this research identifies the key attitudes, expectations and fears of specific sub-groups. Our hope is that the findings will guide policy development, in terms of identifying acceptable solutions to environmental problems, and assist in the formation of effective community engagement, risk communication and education strategies.

Gender and CCS

Our first objective was to understand how gender might impact on the CCS debate. As predicted, and consistent with previous research into other technologies such as nuclear power and genetic modification, women were less accepting of CCS and were more concerned about safety, risk and effectiveness than men. It is important to note that whilst men were generally more accepting of CCS technology, both men and women displayed NIMBY concerns, expressing greater concern when the technology was proposed closer to their community rather than in more distant locations. As NIMBY can be overcome through an open engagement process that promotes trust in the technology and information providers (Reiner & Herzog 2004: 9), this research highlights both the importance and difficulty of building public awareness and understanding about the global greenhouse problem and the proposed CCS response. Less than a third of Australian men and only sixteen percent of women had heard of CCS prior to the survey, despite a CCS site currently being developed in Victoria to store 100,000 tonnes of carbon dioxide underground and another site proposed for Western Australia (ABC News Online 2006). Whilst public engagement programs or strategies may have occurred on an informal, small-scale stage in proposed areas (CO2CRC 2004), they have not been made widely available nor reached the broader public. It is believed that lack of community engagement is due to the early stages of development of CCS and lack of attention it has received by the media, rather than from a conscious effort to avoid engagement with the public. However, as last minute engagement is likely to elevate levels of fear and distrust, early community engagement, no matter how difficult or time-consuming, needs to be a priority for new and emerging technologies like CCS.

A related issue concerns *who* Australian men and women trust to tell the truth about CCS, with local authorities, the biotechnology industry and the national government distrusted by both genders. Interestingly, scientists and researchers working for government are trusted significantly more by men than women, whilst women trust environmental organisations more. Such findings illustrate the importance of identifying the most appropriate communication channels and strategies to educate and engage the Australian public, suggesting that partnerships between CSIRO, scientists and researchers working for universities and environmental organisations will be trusted by both men and women. With recent Australian research by Farquharson and Critchley (2004) linking trust in new technologies with communicating through trustworthy groups (for example, CSIRO, universities) and transparency, it is clear that early and honest engagement is critical for the Australian public to accept CCS. Given the relatively low levels of public awareness captured in this research, a priority for CCS proponents is to educate and engage Australians about the greenhouse gas issues and the proposed CCS response (see Miller et al. (in press)).

Notably, whilst both men and women believed it was extremely important for the government to encourage public participation and debate about new developments in science and technology, men were more likely to follow the greenhouse gas debate and more willing to take part in public discussions about CCS. The gender discrepancy in interest and willingness to participate in debates may reflect entrenched gender roles, which restrict women's willingness to participate in debates about complex scientific issues whilst men are

traditionally more involved in scientific matters. Unfortunately, it is women who report the greatest concerns about the proposed CCS solution. The quandary is as follows: if people, and particularly women, do not follow the greenhouse debate and are less willing to participate in public discussions, how then can they learn about and accurately assess the appropriateness of proposed solutions such as CCS? One potential solution is to reduce the scientific jargon and establish trustful partnerships among expert and lay groups in the hope of engaging people with the issue and encouraging informed debate.

Age and CCS

Our second objective was to understand how age impacted on perceptions of CCS. Despite previous research on scientific and environmental technologies reporting significant differences in age with younger adults typically more accepting of technology and older adults more aware of risks (Farhar et al. 1980; Houghton et al. 1999; Gamble et al. 2000), in this study, age was not a predictor of people's acceptance of CCS, fears or willingness to engage in public debate. In part, this is probably because few Australians had heard of CCS and most wanted to learn more before making any judgements about risk or acceptability. Surprisingly, and contrary to expectations, younger people were not as cynical about the trustworthiness of traditional information-providers, such as the government, as hypothesised. Instead, younger Australians were the most trusting of all organisations, with the exception of CSIRO which was equally trusted by both age groups. Although further research is needed to determine how age might impact on the perceived trustworthiness of organisations to communicate truthfully about new technologies, it may be that older Australians, who were significantly more likely to follow the greenhouse gas debate, have greater appreciation of the complexity of the issue and hence are less trusting of 'simple' solutions. As the general public is forced to "substitute trust for knowledge" (Lang & Hallman 2005, p. 1243) when evaluating emerging scientific technology, it is clear that the organisation or institution promoting a technology will play a significant role in the acceptance or opposition to the use of CCS in geological formations in Australia. Given that Gilding and Critchley (2003) also found that the Australian public trusted CSIRO and universities for information about new technologies, it appears that these organisations are also the most appropriate for communicating with the Australian public about the potentially controversial and complex issues of CCS.

Socio-Economic Status: Education and Income and CCS

Our third objective was to explore the impact of socio-economic status. Education influenced perceptions of CCS, as people with higher education were more likely to follow the greenhouse debate, know about CCS and participate in public discussions and support the use of CCS in Australia or near their community. Given that almost half of all Australians aged 15-64 years do not have qualifications beyond secondary school (Australian Bureau of Statistics 2006), and that CCS sites are more likely to be located in rural and regional areas where participation in higher education is more limited, these findings suggest that engaging the "everyday" Australian in the CCS debate and fostering support for a CCS site near their community may be a challenging undertaking. However, as scientists/researchers working for universities and the CSIRO were highly trusted by both education groups, these organisations would be the most appropriate communicator about CCS to people from all education backgrounds. Notably, higher income also predicted knowledge of CCS and interest in the greenhouse debate, a finding which further suggests that those with the financial resources and educational ability are more likely to engage in higher-order issues concerning global environmental problems.

LIMITATIONS

The first obvious limitation of this study is the use of a large, non-representative predominantly female sample, comprising of members of a market research company's on-line poll who reported higher levels of income and education than the typical Australian. Notably, whilst further research with representative samples is essential to better understand public perceptions and reactions to the proposed CCS solution, the use of convenience samples is relatively common in the judgment and decision-making field as the cognitive processes involved are believed to be stable across different populations (Kahneman, Slovic & Tversky 1982; Palmgren et al. 2004). A second limitation resulted from the brief explanation of CCS, which obviously not sufficient, with over three-quarters of participants agreeing that they needed more information to form a clear opinion about storing carbon underground. Future research could benefit from providing a more comprehensive description of the CCS process. As explaining CCS accurately and without bias is essential, an important task for future research is to develop and test the impact of different explanations, the provision of pictures and perspectives that are affiliated to organisations such as Greenpeace, the United Nations and different national governments, on people's perceptions of and support for CCS. The ability to tease out the importance of credibility was beyond the scope of this project, but will become increasingly important as CCS develops into a mainstream topic. Clearly, identifying how a more representative sample of Australians might view CCS, and how differing definitions and explanations might impact on acceptance, is a task for future research. Finally, we need to emphasise that this article has not addressed the debate amongst scientists, policymakers and environmental groups over the appropriateness of CCS as a strategy to address the greenhouse gas problem, focussing only on understanding public perceptions of CCS.

CONCLUSION: WHERE TO FOR CCS?

The results of this study raise a number of important issues that future research should address, including the challenge of engaging the public with a global issue, the importance of different representations of CCS in the media, and the role, if any, of other socio-demographic differences. The acceptability of CCS will depend on the public's evaluation of the technology's risk/benefit ratio and how they balance the competing risk of increasing greenhouse gas emissions and the risk associated with endorsing this proposed technological solution (for example, leakage issues). Indeed, as the chief executive of the CO2CRC, Peter Cook, put it in a recent interview, "if we do nothing we will get a runaway greenhouse effect and this could have very profound impacts on human beings and life on Earth….it is a matter of balancing the risk of doing nothing against the risk of doing something" (cited in Fyfe 2004). As carbon sequestration has yet to enter mainstream public debate, future research is needed to fully understand how different sub-groups of the public might assess and evaluate the risks of the greenhouse problem versus the proposed CCS response.

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