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The development and deployment of low-carbon energy technologies: The role of economic interests and cultural worldviews on public support

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Abstract
Large-scale deployment of low-carbon energy technologies is crucial to mitigating climate change, and public support is an important barrier to policies and projects that facilitate deployment. This paper provides insights to the origins of public opposition that can impede the adoption of low-carbon technologies by investigating how perceptions are shaped by local economic interests and individual cultural worldviews. The research considers both carbon capture and storage and wind energy technologies because they differ in maturity, economic impact and resource base. Further, for each technology, the research examines support for two types of policies: deployment in local community and public funding for research and development. Results indicate the influence of economic interests and cultural worldviews is policy specific. Individual cultural worldviews do not affect support for the deployment of technology, but they do significantly influence a person's support for publicly funded research and development. Conversely, local economic interests have a significant role in determining support for deployment, while they do not affect support for research and development.

Keywords
CCS; Wind energy; Public support; Economic interests; Cultural worldview

1. Introduction

Climate change continues to be a daunting challenge for the global community. This is illustrated by the lack of meaningful international cooperation to mitigate greenhouse gas emissions. The difficulty arises largely from the perceived economic costs of reducing energy production's reliance on fossil fuels. Though efficiency gains provide a potential for progress, long-term solutions will entail the production of energy from non-fossil fuel resources, such as wind energy. However, the existing energy infrastructure presents considerable challenges for the production and delivery of energy from non-fossil fuel resources. An alternative approach that mitigates carbon emissions while working within current energy structures is Carbon Capture and Storage (CCS). Rather than shifting away from fossil fuels to avoid generating CO_2, CCS is a family of technologies that capture and store CO_2 from large point sources to prevent it from being released into the atmosphere (Ansolabehere et al., 2007 and Metz et al., 2005).

The development and deployment of low-carbon technologies is largely dictated by public support. The IPCC special report on renewable energy, for instance, argues that "large-scale implementation [of renewable energy] can only be undertaken successfully with the understanding and support of the public" (Edenhofer et al., 2012: 129). Understanding public support for low-carbon technologies is a necessary first step towards overcoming this critical barrier to large-scale technology deployment. To this end, we examine how support for low-carbon energy technologies is shaped by economic interests and cultural worldviews. Economic interests are defined as the extent that the household and local economy depend on the related energy sector while cultural worldviews are defined by the perspective from which a person sees and interprets the world (Kahan et al., 2011). We consider two technologies with different properties: wind energy and CCS. While wind energy is a relatively mature and well-known technology, CCS remains in an early development stage with less public awareness. Also, we consider support at two different phases of the technology life cycle: development and deployment.

The literature on public perceptions of CCS has explored many issues, including the influence of knowledge and information (e.g., Ding et al., 2011 and Itaoka et al., 2012), trust in various stakeholders (e.g., Bradbury et al., 2009 and Terwel and Daamen, 2012), views on energy strategies (e.g., Fleishman et al., 2010 and Kraeusel and Möst, 2012), and local issues (e.g., Bradbury et al., 2009 and Terwel and Daamen, 2012). As wind energy is being deployed more widely "it has been increasingly recognized that there is one factor that can potentially be a powerful barrier to the achievement of renewable energy targets: social acceptance" (Wüstenhagen et al., 2007). The literature on public attitudes towards wind energy has focused on the NIMBY (not-in-my-backyard) effect (e.g. Craig et al. 2012; Heintzelman and Tuttle, 2012). Behavioral as well as institutional factors are important determinants of individual attitudes, but have not always been given due consideration in the literature (Devine-Wright, 2008). Our objective is to systematically compare public acceptability for CCS and wind energy technologies, and to extend the literature by investigating how public perceptions are shaped by both local economic interests and cultural worldviews. We investigate how these factors affect perceptions at the development and deployment phases.

Economic interests are determined by the economic consequences arising from a given project or outcome. At the local level, the economic interests and consequences related to a project can vary across communities. By examining how these economic interests shape individual perceptions of low-carbon technologies, we offer new insights on the basic tension between economic self-interest and the collective goal of addressing climate change. A number of studies indicate that compensation to communities can help overcome local opposition to CCS and wind deployment (e.g. Craig et al., 2012 and Heintzelman and Tuttle, 2012) and this suggests that economic considerations affect the support of low-carbon energy technologies.

While cultural worldviews have been recognized as an important determinant of individual perceptions (Kahan et al., 2011), little is known about their role in shaping attitudes towards energy technologies. Cultural worldviews are defined as the general perspective from which a person sees and interprets the world, and according to Kahan et al., (2009), cultural cognition is the "tendency of people to base their factual beliefs about the risks and benefits of a putatively dangerous activity on their cultural appraisals of these activities". The central idea in the literature on cultural worldview is that our preferences over complex issues such as risks, public policies and new technologies are derived from only a few clues using social filters (Wildavsky, 1987). For instance, Kahan et al., (2011) find that people seem to be "fitting their perceptions of scientific consensus to their values" on a range of issues, including handgun control and climate change. We consider how individuals might form perceptions of low-carbon technologies to match existing cultural worldviews, which will inform our understanding of the tension between individual values and collective action problems related to energy and climate change.

2. Materials and methods

To investigate the influence of economic interests and cultural worldviews on support for low-carbon technologies, we conducted a national survey of US households. By considering two technologies (CCS and wind) and two phases (development and deployment), the survey facilitates a more robust analysis that can potentially uncover technology- or phase-specific relationships.

The survey was conducted by telephone between May 21st and July 2nd, 2012. A list-assisted method of random-digit-dialing was used to obtain phone numbers for households located in the contiguous US. The intent was not to obtain a representative sample for point estimates; rather, it was to get sufficient variation in the data to investigate the research questions. Therefore the sampling frame also included a random-digital-dialing oversample of the top 100 coal-producing counties within the contiguous states.[1] Within selected households, individuals 18 years and over were chosen at random for participation. The response rate was 25.1 percent (using formula #4 from the American Association for Public Opinion Research), which yielded 674 completed interviews.[2]

The survey consisted of five sections. After an introduction, the survey started with a *warm up section* that elicited background information on general economic, energy and policy issues and concluded with a *demographic section* that collected general socio-economics characteristics. [3] The survey's three remaining sections provide the primary basis to investigate the research questions—a support section, an economic interest section and a cultural worldview section. The *support section* elicited the level of support for CCS and wind energy technologies. For both technologies, the interviewer first read a short script that explained each technology before asking respondents to indicate their level of support across phases and technologies

"do you support or oppose the use of CCS[wind] technology" and

"do you support or oppose government funding to develop CCS[wind] technology".

These support questions were grouped by technology and the ordering of each group was randomized to avoid any bias from order-effects. There were five possible levels of support—strongly support, support, neither support nor oppose, oppose, and strongly oppose. Respondents could select 'don't know' or 'refuse', which were coded as opposed. A binary code of support and non-support was used in the analysis, with support being conservatively defined as 'strongly support' and 'support' while non-support was all other responses.[4] This section therefore provides the analysis with four referenda of support across two technologies (CCS and wind energy) and two phases of the technology life-cycle (deployment and funding for development). This section also included questions that elicited perceptions about the technology being successful and economically viable, important in reducing CO_2 emissions, and harmful to the local environment.

An *economic interest section* consisted of questions that focused on the role that different energy sectors have on individual households and local economies. Respondents were asked if anyone in their household was employed in the energy sector, and if so, which industry. Subsequent questions asked respondents to indicate the level of importance of the coal and wind energy industries to their local economy. Four levels of importance were possible—very important, somewhat important, not too important and not important at all. This section therefore generated a measure of economic interest specific to coal and wind industries. As a *first primary research hypothesis*, we expect that support for CCS technology will be positively influenced by having an economic interest in coal, and similarly, an economic interest in wind energy will positively impact support for wind energy.

A *cultural worldview section* presented a series of questions that elicited respondents' cultural worldview. We follow the literature and employ questions from the short-form cultural worldview measure developed by Kahan et al., (2011). This measure characterizes cultural worldview along two dimensions. The first is *hierarchy-egalitarianism*, which indicates "attitudes toward social orderings that connect authority to stratified social roles based on highly conspicuous and largely fixed characteristics such as gender, race, and class" (Kahan et al., 2011). The second is *individualism-*

communitarianism, which indicates "attitudes toward social orderings that expect individuals to secure their own well-being without assistance or interference from society versus those that assign society the obligation to secure collective welfare and the power to override competing individual interests" (Kahan et al., 2011). Table 1 provides the eight statements that the interviewer read to respondents (four for each dimension). After each statement, respondents were asked to indicate the degree to which they agreed or disagreed. Five levels of agreement/disagreement were possible—strongly agree, agree, neither agree nor disagree, disagree, and strongly disagree. One to five points were assigned to the answers, with stronger agreement in the direction of hierarchy and individualism receiving more points (one to five). Aggregating the responses from the four questions in each dimension yields a cultural worldview measure ranging from four to 20. Specifically, a higher (lower) score on the *hierarchy-egalitarianism* questions indicates a more hierarchical (more egalitarian) cultural worldview, and a higher (lower) score on the *individualism-communitarianism* questions indicate a more individualistic (more communitarian) cultural worldview. Our *second primary research hypothesis* is that support for deployment of energy technologies, and government funding for development, will be significantly influenced by both cultural worldview dimensions.

Table 1. Cultural worldview measure

Individualism–communitarianism

1. The government interferes far too much in our everyday lives.
2. Sometimes government needs to make laws that keep people from hurting themselves.*
3. It's not the government's business to try to protect people from themselves.
4. The government should do more to advance society's goals, even if that means limiting the freedom and choices of individuals. *

Hierarchy–egalitarianism

1. Our society would be better off if the distribution of wealth was more equal. *
2. We have gone too far in pushing equal rights in this country.
3. Society as a whole has become too soft.
4. Discrimination against minorities is still a very serious problem in our society. *

Note: Respondent indicated one of five responses (strongly agree, agree, neither agree or disagree, disagree, strongly disagree) and received five to one points for each response, respectively. Summing the points across questions within each dimension creates a spectrum between four and 20. For control purposes, the questions in each dimension were split between a positive and negative frame; those marked with * were reversed coded.

3. Results

Table 2 defines the variables used in the analysis and reports sample means. The numbers indicate considerable support for CCS technology among respondents, with 63.9 percent of respondents indicating support for deployment of CCS technology, and

57.3 percent indicating support for government funding for research and development of CCS technology. Most people are optimistic CCS will be successful and economically viable (54.8%), and believe CCS should be an important energy strategy to lower CO_2 emissions (69.3%). Respondents indicated greater support for wind energy technology, with 83.0 percent supporting deployment of the technology, and 65.8 percent supporting government funding for the research and development of the technology. A large majority of respondents also believed wind energy technology will be successful (70.1%), and should be an important strategy to lower CO_2 emissions (78.3%). Most respondents did not believe either technology would have a negative impact on the local environment in which facilities are built. Regarding economic interests, 65.6 percent of respondents indicated that coal was important to their local economy, while 31.5 percent stated that wind energy was important. For the cultural worldview measures, the hierarchy-egalitarian dimension averaged 13.5, and the hierarchy-egalitarianism dimension averaged 11.8 (both had max and min values at the end points of 4 and 20). The numbers suggest the sampling and survey methods generated data with sufficient variation for the research question.

Table 2. Variable definitions and means.

Variable	Definition	Mean
CCS		
Support for technology deployment	Indicate support the use of CCS technology (=1 if 'strongly support' or 'support'; =0 otherwise)	63.9
Support for research funding	Indicate support for government funding to develop CCS technology (=1 if 'strongly support' or 'support'; =0 otherwise)	57.3
Optimistic for success	Indicate belief that CCS will be successful and economically viable (=1 if 'very successful' or 'somewhat successful'; =0 otherwise)	54.8
Strategically important	Indicate belief that CCS should be an important energy strategy to lower CO_2 emissions (=1 if 'very important' or 'important'; =0 otherwise)	69.3
Harm the environment	Indicate belief that CCS will have a negative impact on the local environment where facilities are built (=1 if 'very negative' or 'somewhat negative'; =0 otherwise)	32.6
Wind energy		
Support for technology deployment	Indicate support the use of wind energy technology (=1 if 'strongly support' or 'support'; =0 otherwise)	83.0
Support for research funding	Indicate support for government funding to develop wind energy technology (=1 if 'strongly support' or 'support'; =0 otherwise)	65.8
Optimistic for success	Indicate belief that wind energy will be successful and economically viable (=1 if 'very successful' or 'somewhat successful'; =0 otherwise)	70.1
Strategically important	Indicate belief that wind energy should be an important energy strategy to lower CO_2 emissions (=1 if 'very important' or 'important'; =0 otherwise)	78.3
Harm the environment	Indicate belief that wind energy will have a negative impact on the local environment where facilities are built (=1 if 'very negative' or 'somewhat negative'; =0 otherwise)	26.1
Economic		
Coal interest	Indicate that coal is important to local economy (=1 if 'very important' or 'somewhat important'; =0 otherwise)	65.6
Wind Interest	Indicate that wind energy is important to local economy (=1 if 'very important' or 'somewhat important'; =0 otherwise)	31.5
Cultural worldview		
Hierarchical	Score on hierarchy-egalitarian spectrum (4 to 20; higher (lower) implies more hierarchical (egalitarian) worldview	13.5
Individualistic	Score on individualistic-communitarian spectrum (4 to 20; higher (lower) implies more individualistic (communitarian) worldview)	11.8

We estimate the influence of economic interests and cultural worldviews on public support for energy technology by estimating the following linear probability model of individual support:

$$S_i = \alpha_i + \beta' T_i + \theta' E_i + \psi' W_i + \delta' X_i + \varepsilon_i \qquad i = 1, 2....N$$

where S_i denotes whether the ith individual is supportive of the energy technology (1 if support; 0 otherwise); T_i is a vector that contains perceptions of the technology for respondent i; E_i includes measures of the respondent's economic interest; W_i contains measures of individual cultural worldviews; and X_i contains socio-economic control variables. The disturbance terms are assumed to follow a normal distribution with zero mean and constant variance. We estimate four models. For both CCS and wind, we examine the support for deploying the technology and the support for government funding for technology development. [5] Table 3 reports the results.

Table 3. Linear probability model: determinants of support for deployment of technology and public funded research.

	CCS		Wind	
	Technology deployment	Research funding	Technology deployment	Research funding
Constant	0.137	0.596	0.505	0.711
	(0.039)	(0.000)	(0.000)	(0.000)
Technology perceptions				
Optimistic for Success	0.235	0.205	0.272	0.190
	(0.000)	(0.000)	(0.000)	(0.000)
Strategically Important	0.371	0.282	0.235	0.267
	(0.000)	(0.000)	(0.000)	(0.000)
Harm the Environment	−0.066	−0.080	−0.089	−0.087
	(0.058)	(0.031)	(0.001)	(0.012)
Economic interests				
Coal Important	0.081	0.054	0.009	0.026
	(0.019)	(0.138)	(0.715)	(0.423)
Wind Important	0.033	0.019	0.065	0.077
	(0.355)	(0.607)	(0.014)	(0.020)
Cultural worldview				
Hierarchical	−0.001	−0.023	−0.007	−0.022
	(0.805)	(0.000)	(0.079)	(0.000)
Individualistic	0.009	−0.017	−0.001	−0.028
	(0.110)	(0.006)	(0.762)	(0.000)
Control variables				
Male	0.061	0.049	0.068	0.036
	(0.068)	(0.165)	(0.005)	(0.233)
College	−0.029	−0.047	−0.012	0.002
	(0.383)	(0.179)	(0.629)	(0.954)
F	28.49	23.37	41.18	44.55
	(0.000)	(0.0000)	(0.0000)	(0.0000)
N	656	657	658	658

Note: dependent variable is support (=1 if support or strongly support; 0 otherwise); *p*-values are reported in parentheses.

We first consider how perceptions affect the likelihood of support for CCS and wind energy technologies. In all cases, the results follow a priori expectations. Respondents that indicate the technology is promising and strategically important are significantly more likely to support using the technology and investing public funds to develop the technology. Also, the respondents that think the technology will harm the environment are significantly less likely to indicate support. These findings provide some confidence about the internal validity of the survey data.

We now turn to the results that inform our research questions on the influence of *economic interests* and *cultural worldviews*. From Table 3, the estimates indicate that economic interests have the expected influence on the support for deployment. When there is an economic interest in coal, respondents are significantly more likely to support the use of CCS technology. Similarly, support for wind energy technology is significantly more likely if wind energy is viewed as important to the local economy. [6] Results are mixed concerning the influence of economic interests on the support for government funded research and development. Estimates indicate that economic interests in wind energy positively influences the likelihood of supporting government funding, but the influence of economic interests in coal is marginally insignificant in the case of CCS (p=0.138). Generally, the estimated coefficients indicate the extent that economic interests influence support is similar across the technologies considered. The remaining estimates find that economic interests in one technology does not affect the likelihood of support for the other—e.g., economic reliance on coal does not significantly affect the likelihood of support for wind. This finding suggests that support is not influenced by the potential indirect economic threat from alternative technologies.

Moving to the influence of cultural worldviews, estimates find that cultural worldviews do not significantly influence support for the deployment of the energy technologies. This finding arises for both worldview dimensions. However, cultural worldviews did affect whether people supported government funding for research and development. Respondents that have a more hierarchical (less egalitarian) cultural worldview are significantly less likely to support government-funded research for both CCS and wind energy technologies. And for the individualism-communitarianism dimension, support is diminished if the respondent possesses a more individualistic (less communitarian) cultural worldview. This finding is consistent with the notion that people with more individualistic worldviews tend to possess general resistance to government intervention. Estimated coefficients indicate the relative influence on support for government funding is similar across technologies.

4. Discussion and policy implications

Large-scale deployment of low-carbon technologies is crucial to mitigating climate change. Public support is a key barrier to the development and deployment of low-carbon technologies. Using survey methods, we extend the existing literature on individual perceptions of CCS and wind energy by investigating the role of economic interests and cultural worldviews in determining individual support for the development and deployment of the technologies.

Consistent with expectations, perceptions that a technology is promising or strategically important significantly increases the likelihood of support for the development and deployment of the technology, while perceptions that a technology will harm the environment lowers support. The more interesting results concern the influence of economic interests and cultural worldviews. We find that economic interests affect the level of support for the deployment of related energy technologies but not for public funding of development. Households that had an economic reliance on coal supported

the deployment of CCS technology but not wind technology, while households that relied on wind resources supported the deployment of wind energy technology but not CCS technology. The split result across two technologies offers unusually strong evidence that economic interests are significant factors in determining public support for low-carbon energy technologies.

Results concerning cultural worldviews tell a different story with individual worldviews affecting the level of support for public funded development but not for deployment. People with more hierarchical and individualistic worldviews exhibit significantly less support for development. The result is not technology-specific, which is consistent with a more general relationship between worldviews and public funding of research and development. The policy implication is that support for low-carbon energy policies can be influenced by cultural and social factors that are unrelated to the merits of the technology, which complicates the challenge of building public support for policies aimed at advancing low-carbon energy technologies.

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