Public Support for the Development and Deployment of Low-Carbon Energy Technologies: The Influence of Economic Interests and Cultural Worldviews

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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 impedes policies to advance low-carbon technologies. It reports on a study that investigated 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 depends on the type of policy. 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.

Key Words
CCS; wind energy; public support; economic interests; cultural worldview

1. Introduction

Climate change continues to be a daunting challenge for the global community, which 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 offer the 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; Metz et al. 2005).

Public support is increasingly recognized as a significant barrier to the development and deployment of low-carbon technologies. 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 deployment of the technologies. 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, 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. Given the widespread use of both coal and wind in the U.S., we conduct a national survey of U.S. households to estimate the influence of economic interests and cultural worldviews on the public acceptability for these low-carbon technologies.[1]

The literature on public perceptions of CCS has explored the influence of knowledge and information, trust in various stakeholders, views on energy strategies, and local considerations. In general the public has relatively little knowledge about CCS, new information does not necessarily change views, and in some cases people have intuitive misconceptions about risks and benefits (Ding et al. 2011; Itaoka et al. 2012; Wallquist et al. 2010). The effect of communication on public perceptions depends on early engagement and the level of confidence in the source of information, with industry and government inspiring less confidence and researcher and NGOs inspiring more confidence (Bradbury et al. 2009; Brunsting et al. 2011; Terwel and Daamen 2012; Upham and Roberts 2011). Studies indicate that views on CCS vary across countries according to national energy issues, that the public prefers renewable energy sources to CCS, and that the public has limited expectations with regard to the future importance of CCS (Fleishman et al 2010; Kraeusel and Möst 2012; Oltra et al. 2010; Pietzner et al. 2011; Shackley and McLachlan 2006; Upham and Roberts 2011). In terms of local considerations, studies have found that compensation to local communities, risk and safety of people, and perceived community benefits are important to public perceptions (Bradbury et al. 2009; Brunsting et al. 2011; Terwel and Daamen 2012).

[1] In addition, a survey of U.S. households was appropriate because the worldview measurement instrument was constructed for U.S. social, cultural and political conditions (Kahan et al., 2011).

Wind energy is a more mature technology than CCS. Wind energy accounts for 1.8% of the global electricity supply, and in "some areas with good wind resources, the cost of wind energy is already competitive with current energy market prices" (Wiser et al. 2011). 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). Wind energy projects are often met with local resistance due to concerns over negative impacts on wildlife, degradation of landscapes, and noise, among other effects. The literature on public attitudes towards wind energy has focused on the so called 'not-in-my-backyard' (NIMBY) effect (e.g. Craig et al. 2011; Heintzelman and Tuttle 2012; Krueger et al 2010). NIMBY refers to attitudes by people expressing general support for renewable energy, in particular wind energy, while resisting deployment in their local community. This explanation has however been criticized for being too simplistic (Wolsink 2000 and 2007). 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, Wolsink 2007).

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 two different, but potentially equally important phases in the technology life cycle—development and deployment.

Economic interests are defined 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. To the extent that individual economic concerns shape acceptance of low-carbon technology, the prospects for meaningful collective action are diminished. A number of studies indicate that compensation to communities can help overcome local opposition to CCS deployment and wind farming (e.g. Bradbury et al. 2009; Craig et al. 2011; Heintzelman and Tuttle 2012) and this suggests that economic considerations are of relevance when analyzing local perceptions of energy technologies. However, questions remain about the way economic interests influence local attitudes towards low-carbon energy technologies. For instance, do these influences vary across different technologies (e.g., CCS versus wind) or development phases (e.g. development versus deployment)? In order to provide answers to these and related questions a comparative framework of analysis is required.

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. Given individuals might form perceptions of low-carbon

technologies to match existing cultural worldviews, an investigation of how cultural worldviews shape perceptions of such technologies highlights the tension between individual values and the collective action problem of climate change. By better understanding the role of cultural worldviews, decision makers can be better equipped to design and implement policies that address energy and environmental challenges.

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 U.S. households. The survey considers two technologies (CCS and wind) and two phases (development and deployment) to facilitate 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 (RDD) was used to obtain phone numbers for households located in the contiguous U.S. (including the District of Columbia). 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 (RDD) oversample of the top 100 coal-producing counties within the contiguous states. These coal-producing counties were located within 19 different states: AL, AZ, CO, IL, IN, KY, LA, MD, MS, MO, NM, ND, OH, PA, TX, UT, VA, WV, and WY. Within selected households, individuals 18 years and over were chosen at random for participation. All households and individuals who were initially unwilling to participate in the survey were contacted again in an effort to persuade them to participate. Up to six contact attempts were made at each phone number. Using formula #4 from the American Association for Public

Opinion Research (AAPOR), the response rate was 25.1 percent, which yielded 674 completed interviews. Note that this rate adjusts for the fact that many phone numbers in the list are non-eligible by considering the proportion of all cases interviewed of all eligible units ever contacted.

The survey consisted of five sections, each one consisting of a battery of questions. After an initial 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 individual and household characteristics, such as age, education, income, etc.[2] The survey's three remaining sections provide the primary basis to investigate the research questions and include 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 on two issues that face public scrutiny for the 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. Therefore, each low-carbon technology—CCS or wind—was presented as a group and respondents were randomly presented either CCS or wind first. The following text was read to individuals prior to asking questions related to CCS:

> *"CCS is one of many energy technologies that are being developed to reduce CO_2 emissions in electricity generation. CCS is a technology where carbon dioxide is captured from the exhaust of coal-fired power plants, transported in a pipeline, and injected into the bedrock*

[2] Responses to these questions reveal that the economy was overwhelmingly viewed as the "most important issue facing the country today" (64.2%), while most believed that energy independence should be "the top priority in the government's energy policy" (29.8%). Regarding knowledge of CCS and wind technologies, 37.9 percent of respondents indicated they "understand coal-fired power with CCS" somewhat or very well, while 76.5 percent said they 'understand wind energy" somewhat or very well. Respondents had an average age of 54 years and were mostly married (61.9%) and white (85.3%). Thirty-seven percent of respondents had a four-year college degree.

for permanent storage. This solution means that coal can be burned in power plants with only minor emissions of CO_2. At the moment there are a handful of demonstration projects around the world that show that this technology can be used. The cost of power-fired plants with CCS is high at the moment, but costs can be reduced through further research and development."

And the following text was read to individuals prior to asking questions related to wind energy:

"Wind is one of many energy technologies that are being developed to reduce CO_2 emissions in electricity generation. Wind energy is harnessed and transformed into electricity by wind turbines that are connected to the electric power transmission network. Wind energy is a renewable source of energy that generates zero CO_2 emissions. Several wind energy projects have been deployed in the US and other countries. However the production costs of wind energy remain relatively high but they can be reduced through further research and development."

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 defined as 'strongly support' and 'support' while non-support was all other responses. 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 (up to five) and stronger disagreement receiving less points (down to one). Aggregating the responses from the four questions in each dimension yields a cultural worldview measure ranging from four to 20. More 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.

3. Results and Discussion

Table 2 defines the variables used in the analysis and reports the mean values for the sample. 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 CO2 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 CO2 emissions (78.3%). Most respondents did not believe either technology would have a negative impact on the local environment where 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.

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:

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

where S_i denotes whether the i^{th} 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 variables to control for perceptions related socio-economic 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 energy technology, we examine the support for deploying the technology and support for government funding development of the technology.[3]

Table 3 reports the estimates from the four models. 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 research and development of the technology. Also, the respondents that think the technology will harm the environment are significantly less likely to indicate support. These findings follow expectations and provide some confidence about the internal validity of the survey data.

We now turn to the results that inform our research questions concerning the influence of *economic interests* and *cultural worldviews*. From Table 1, the estimates indicate that economic interests have the expected influence on the support for deployment. When there is an economic

[3] Results were robust when the estimation used a Probit specification.

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. Results are a bit 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, as expected, 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 people might not consider the potential indirect threat to economic interests from alternative technologies.

Moving to the influence of cultural worldviews, estimates find that cultural worldviews do not have a role in the support for the deployment of the energy technologies. This finding arises for both cultural worldview dimensions, with neither having a significant effect on an individual's likelihood of supporting the deployment of CCS and wind energy technologies. However, cultural worldviews did matter in whether people supported government funding for research and development. For the hierarchy-egalitarianism dimension, 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.

Consistent with our 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 will lower support. These findings are unsurprising and appear to generalize across energy technologies. The more interesting results concern the influence of economic interests and cultural worldviews, and in particular the divergent effects on the different phases for the technologies. Results show that economic interests consistently influence support for the deployment of specific technologies, while individual cultural worldviews have no significant effect on support for deployment. Worldviews only influence support for government funded research of the technologies. It is worth noting that, despite the divergent perceptions of CCS and wind, the role of economic interests and cultural worldviews is quite consistent across both low-carbon energy technologies.

4. Conclusion and Policy Implications

Large scale deployment of low-carbon technologies is crucial to mitigating climate change. Public support is a key barrier to publicly funded development and deployment of low-carbon technologies. We focus on two technologies that differ considerably with respect to maturity and public awareness: CCS and wind energy. Using survey methods, we extend the existing literature on understanding 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.

Results reveal a surprisingly clear distinction: economic self-interests influence public support for deployment, whereas cultural worldviews only influence support for publicly funded research and development. Our finding that economic interest influence local support for the use of low-carbon energy technologies are consistent with previous studies that suggest that local opposition to technology deployment eases when compensation mechanisms are in place (e.g. Craig et al 2012 and Heintzelman and Tuttle 2012). However, while these studies frame compensation in monetary terms, we find that more general local economic interests help shape local perceptions. More striking, results provide strong evidence that cultural worldviews have a significant role in determining support for CCS and wind energy technologies. The finding is strong for both worldview dimensions considered. We find that individuals that are more hierarchical (less egalitarian) and more individualistic (less communitarian) expressed significantly less support for government funding of both CCS and wind energy research. The potential implication is that opposition to publicly funded research and development is determined, in part, by cultural and social factors that are unrelated to the technology. Therefore, the challenge of gaining public acceptance might be particularly difficult, especially for the less mature CCS that requires more government research funding than wind.

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