

Not In (or Under) My Backyard: Geographic Proximity and Public Acceptance of Carbon Capture and Storage Facilities

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ABSTRACT

Carbon capture and storage (CCS) is an innovative technical approach to mitigate the problem of climate change by capturing carbon dioxide emissions and injecting them underground for permanent geological storage. CCS has been perceived both positively, as an innovative approach to facilitate a more environmentally-benign use of fossil fuels while also generating local economic benefits, and negatively, as a technology that prolongs the use of carbon-intensive energy sources and burdens local communities with prohibitive costs and ecological and human health risks. This paper extends existing research on “Not In My Backyard” (NIMBY) phenomenon in a direction that explores the public acceptance of CCS. We utilize survey data collected from 1,001 residents of the coal-intensive U.S. state of Indiana. Over 80% of respondents express support for the general use of CCS technology. However, 20% of these initial supporters exhibit a NIMBY-like reaction and switch to opposition as a CCS facility is proposed close to their communities. Respondents’ world views, their beliefs about the local economic benefits that CCS will generate, and their concerns about its safety have the greatest impact increasing or decreasing the acceptance of nearby facilities. These results lend valuable insights regarding the perceived risks associated with CCS technology and the possibilities for its public acceptance at both a national and local scale. They may be extended further to provide initial insights on likely public reactions to other technologies that share a similar underground dimension, such as hydraulic fracturing.

KEY WORDS: Carbon capture and storage, NIMBY, Public acceptance

1. INTRODUCTION

Carbon capture and storage (CCS) has emerged as an innovative and important technical approach to help mitigate the problem of climate change. By capturing carbon emissions at large-volume sources, transporting compressed carbon dioxide (CO₂) via pipeline to storage sites, and injecting it underground for permanent storage in geologic formations, CCS technology has the potential to reduce significantly the volume of greenhouse gases now being released into the atmosphere. While CCS technology is proven in the context of enhanced oil recovery and small pilot projects, the feasibility of its use for commercial-scale carbon mitigation at large power plants has not been demonstrated and therefore the economics and technical requirements remain open to question. Many experts predict that, if successfully deployed, CCS technology could help society reach long-term climate protection goals.^(1,2)

CCS has been perceived both positively, as an innovative technology that will facilitate a more environmentally-benign use of fossil fuels while also generating local economic benefits, and negatively, as a technology that prolongs the use of carbon-intensive energy sources and burdens local communities with prohibitive costs and ecological and human health risks. Both of these perspectives have been expressed at the community level and have succeeded in influencing the outcome of proposed CCS facilities. For example, the FutureGen project, a joint venture between the U.S. Department of Energy (US DOE) and a consortium of industry partners, initially moved forward due in part to support from local residents in Illinois, USA who considered the project as an economic opportunity.⁽³⁾ In other cases – such as in Beeskow, Germany and Barendrecht, Netherlands – strong local opposition has resulted in the abandonment of well-established plans for CCS deployment.^(4,5) This type of resistance from local residents may reflect the influence of a classic “not in my backyard” (NIMBY) sentiment.

NIMBY in this context, however, may have an added layer of complexity: CCS facilities have several components that include an above ground facility as well as underground CO₂ storage.

The latter is not visible but is where much of the uncertainty about CCS lies. CCS thus has the potential to elicit both NIMBY and related NUMBY (not *under* my backyard) reactions.

Traditional NIMBY phenomena have been extensively researched in the context of more familiar technologies and land uses, but few scholars have closely considered NUMBY reactions associated with CCS or other underground activities.

This paper examines how the closeness of a hypothetical CCS facility to individuals' communities influences their acceptance of it. The analysis focuses on the state of Indiana, USA, where two commercial-scale CCS projects are in the planning and feasibility assessment stages^(6,7) and examines the role that demographics, homeownership status, community and regional characteristics, perception of safety risks, and cultural world views, as described by Douglas and Wildavsky, have on the acceptance of CCS as the proximity of a proposed facility's location changes.

2. LITERATURE REVIEW

2.1 NIMBY and NUMBY

Projects that yield geographically diffuse benefits but carry localized costs often result in resistance from the nearby residents who would bear the burden of these costs.⁽⁸⁾ The recent cancellations of planned CCS facilities in Germany and the Netherlands in response to community opposition have raised the specter of NIMBYism acting as an obstacle to CCS implementation. This “not in my backyard” phenomenon has been well studied in a variety of contexts since first appearing as a concept in the 1980s.⁽⁹⁾ In most research, NIMBY conflicts are

assumed to follow a simple rule that opposition increases the closer an individual is to an undesirable facility.⁽¹⁰⁾ Furthermore, opposition to socially beneficial but locally undesirable land uses is frequently tied to concerns about health and safety, decline in property values, general decline in quality of life, emotional attachments to existing local land uses, and a desire to preserve existing rural aesthetics.^(9, 11-13)

Empirical work examining the NIMBY phenomenon, however, reveals a somewhat less consistent picture. Both the nature of the land use and any benefits that may accompany it complicate the simple theoretic relationship. For example, whereas perceptions about the safety risks of prisons are found to correlate with people's proximity to a proposed prison site,⁽¹⁴⁾ recent survey research on perceptions of landfill risk finds a much weaker relationship between nearness and perceived levels of danger.⁽¹⁵⁾ An analysis of longitudinal survey data from southern New Mexico finds that support for a nuclear waste facility actually increased with proximity to the proposed site and nuclear waste transportation route.⁽¹⁶⁾ This and other studies point to citizen participation and trust in administrative decision-making as important factors in getting beyond NIMBY opposition to foster public support and achieve successful siting agreements.^(17, 18) Moreover, as was the case with the New Mexico nuclear waste facility, if residents believe a proposed land use will generate benefits that outweigh perceived risks, support for a project can be positively associated with proximity.^(16,19)

The related concept of NUMBY ("Not under my backyard") has been less frequently examined. Along with CCS, hydrological fracturing (or "fracking") – a practice of injecting highly pressurized water and chemicals into the ground in order to release natural gas stored in geologic shale formations – is the most likely activity around which a NUMBY reaction may arise.⁽²⁰⁾ No empirical studies on either CCS or fracking have systematically considered the

specific dimensions of NUMBY as distinct from NIMBY reactions. Indeed many studies treat the terms almost as synonyms, both referring back to the conventional NIMBY meaning.^(21, 22)

The motivations behind the desire to keep socially beneficial but locally undesirable land uses away from one's home or property likely are the same, regardless of whether the projects are above or below ground. However, whereas the typical subjects of NIMBY studies (e.g. prisons and landfills) are visible, those associated with NUMBY are not, which may alter how they are perceived. Because they are less visible, relevant below ground activities will not damage the existing aesthetic of an area and may be more readily overlooked or forgotten about. At the same time, however, these activities may be associated with greater uncertainty, particularly regarding how far their potentially negative effects extend underground.

Because CCS has both above and below ground components, both NIMBY and NUMBY are relevant, although they are not disentangled in this study. We use "NIMBY" throughout this paper to refer to the combination of NIMBY and NUMBY sentiments.

Finally, it is important to note that in order to reflect a NIMBY (or NUMBY) phenomenon individuals have to support a project in the abstract, and oppose it only if it occurs near their place of residence. Critics contend that this dynamic is rarely witnessed and that the NIMBY concept is both an over-used and insufficient characterization of more general opposition.^(23, 24) A free-rider preference must be identified for opposition to be appropriately classified as a NIMBY reaction.⁽²³⁾

2.2 Factors influencing acceptance of CCS

A significant number of studies have been conducted that examine public attitudes towards CCS and assess the factors that enhance or diminish its likely acceptance. One major

strand of this research uses case studies to examine the social dynamics that are observed within a community during the planning or construction of CCS pilot facilities.^(4, 5, 25, 26) These studies often highlight the critical role that early and transparent communication and local trust in project developers can have in shaping community opinion.

A second strand of research, often using survey data, assesses opinions expressed towards hypothetical CCS deployment, since the technology had not yet been brought to commercial scale.⁽²⁷⁻³³⁾ A key finding from these studies is the overall lack of awareness that the public has about CCS technology: only between 4%⁽³¹⁾ and approximately 20%^(29, 32, 33) of the general public living in countries with active CCS agendas has ever heard of the technology.

Members of the public associate a relatively consistent set of risks with it, including CO₂ leakage, induced seismicity, explosions, and groundwater contamination.^(30, 34, 35) The risk perception literature makes it clear that, irrespective of probabilities, people are less likely to accept risk if it includes potentially catastrophic effects, is unfamiliar, or is involuntarily imposed.^(36, 37) Other opposition to CCS is based on the idea that it is, for a variety of reasons – including its potential to perpetuate reliance on fossil fuels and divert investment away from renewables – an inappropriate means to address climate change.^(30, 38)

As previously described, NIMBYism requires that opposition be linked to a free-rider preference, which is often identified when decreased support for a socially beneficial project accompanies its increased proximity to people's homes. Findings on NIMBY-driven reactions to CCS have been mixed, with some survey-based and quasi-experimental studies finding that the hypothetical placement of underground CO₂ storage in and away from respondents' own municipalities yield similar levels of opposition, suggesting the absence of opposition linked exclusively to location.^(22, 39) On the other hand, in a small Swiss sample, Wallquist et al. (2012)

were able to explicitly identify NIMBY-driven attitudes toward certain components of CCS facilities, namely pipelines and storage sites.⁽⁴⁰⁾ To date, no studies utilize a sufficiently large sample to support a multivariate analysis that can identify both the presence of NIMBY-based responses and the factors that predict this type of reaction.

Building on previous research, we hypothesize that owning a home, having notable concerns about perceived CCS risks (i.e. explosions, earthquakes, suffocation, and groundwater contamination), and the belief that state taxpayers or utility rate payers would absorb the additional cost burden of CCS will decrease the likelihood that respondents will support the placement of a facility near their home or community, but have less of an impact on their opinions regarding its national placement. On the other hand, we hypothesize that people who think that a CCS facility would provide an important local economic benefit are more likely to express support for CCS in their community. Additionally, we hypothesize that individuals living in rural areas or coal producing regions are less likely to exhibit a NIMBY-like response because of their greater familiarity with land-based and mining activities. The belief that climate change is a serious problem is expected to lead to a greater acceptance of CCS regardless of location.

We also consider the role that “world views” or “cultural biases” have on the acceptance of CCS. Cultural Theory has been used to predict acceptance of climate change and new technologies.^(42, 43) It proposes four “cultural types” based on people’s preferred level of group interaction and the extent to which they believe these groups should constrain individual behavior.^(42, 44) Previous research suggests that three of these cultural types – individualist, hierarchical, and egalitarian – create relevant predilections towards the acceptance of climate change and new technologies.^(42, 43) Individualists typically view technology as an opportunity for growth and are supportive as long as it is not perceived to interfere with market functioning.

Compared to other cultural types, individualists tend to perceive climate change as less of a threat.⁽⁴³⁾ Those with a hierarchical bias may view climate change as a result of growth mismanagement. They are comfortable with existing patterns of authority and tend to view technology positively if it has been recommended by experts and officials. Those with an egalitarian bias view inequality as the largest risk to society and favor actions that increase equality. Egalitarians often perceive large centralized technologies as contributing towards inequality; however, climate change is projected to have uneven effects and cause disproportionate suffering among the poor, thus increasing inequality. We hypothesize, therefore, that egalitarians will weakly support CCS and that the location of CCS facilities will not affect this support. Assuming it has the support of trusted authorities, hierarchicalists are likewise hypothesized to support CCS regardless of location. Individualists, on the other hand, are hypothesized to support CCS in the abstract, as a market-based mechanism preferable to regulations to address climate change, but will oppose it if a facility is nearby and feels forced upon them.

3. DATA AND SAMPLE

3.1 Indiana Sample

Data for this study were collected from 1,001 Indiana residents in late 2011 using the Indiana University Energy, Climate, and Environment Survey. Indiana is a coal-intensive state, which we operationally define as one with significant mining activity and a majority of electric power production from coal. We oversampled residents from coal mining ($n=300$) and agricultural ($n=304$) regions of the state to ensure adequate representation. Residents from urban areas account for 397 of the observations. Weights are used on age, race, sex, education, region,

cell phone ownership, and the number of adults in each household to make the sample representative of the Indiana state population.

Kentucky, Illinois, Ohio, Texas, Pennsylvania, West Virginia, and Wyoming also meet our criteria as coal intensive states. Public acceptance and potential NIMBYism in coal-intensive states is of particular interest because they are common venues for early planned CCS deployment activities and the public debate and opinion formation that will take place within them may influence the future of CCS.⁽²⁹⁾ Indiana was selected as the focus of this study because it is home to two locations where commercial-scale CCS projects are currently being considered. Moreover, socially and politically, Indiana makes an interesting case study: in a number of ways it is a “typical” U.S. state, falling near the middle of national rankings on measures of income, poverty, and population growth.⁽⁴⁵⁾ Politically, it tends to be conservative, but currently has a U.S. Senator from each party and was a swing state in the 2008 presidential election. At the same time, Indiana presents an unwelcoming atmosphere for climate protection initiatives. It is among the minority of states that have not participated in any climate-related initiatives;⁽⁴⁶⁾ its popular former governor took a strong stand against federal climate legislation;⁽⁴⁷⁾ its economy is heavily dependent on manufacturing;⁽⁴⁵⁾ and its renewable energy potential is among the lowest in the country.⁽⁴⁸⁾ The state’s reluctance to take action on climate protection, coupled with its reliance on coal and subsequent desire to keep it a viable energy source, has the potential to create a particularly interesting dynamic surrounding the acceptance of CCS.

3.2 Survey Design

The survey instrument employed in this study utilized a three-part telephone-mail-telephone design. The first stage secured participation and asked background questions about demographics

and general environmental attitudes. It did not specifically mention CCS. The response rate in the first phase was 24.3%. The mailing stage involved the dissemination of a CCS diagram and factsheet, with a request that participants view these materials prior to the second telephone interview. The factsheet and diagram were designed to provide limited educational information about CCS, without any detail on possible costs, risks, local advantages or disadvantages (See Appendix 1 for factsheet). It was reviewed by several policy and technical CCS experts for accuracy. This factsheet served as the only source of CCS information for a majority of respondents, who were previously unfamiliar with the emerging technology. The final stage of the survey asked the respondents a series of questions about CCS designed to assess: (1) their impressions and associated concerns about the technology; (2) the extent of their agreement with a series of asserted advantages and disadvantages of CCS; (3) their impressions as to whether CCS is a good approach to protecting the environment; (4) whether they would support CCS being located in the U.S., Indiana, and near their own community; and (5) who they think will and should pay for the added costs of CCS. The second interview had a response rate of 75.3 percent. The 1,001 respondents used in this analysis completed all three waves of the survey.

3.3 Dependent Variable

Survey participants described their level of support for the construction and operation of a CCS facility using various geographic points of reference. Specifically, they were asked: “If experts determine there is a suitable site for underground CO₂ storage, would you strongly support, somewhat support, somewhat oppose, or strongly oppose the operation of a Carbon Capture facility *somewhere in the U.S.*?” The same question was later repeated, but the reference location was changed to “*near your home or community.*” Of the respondents, 80% had never

heard of CCS prior to this survey and the majority answered questions about their support for CCS with the less committal responses of “somewhat support” or “somewhat oppose” over their more decisive variations. We condense the categories reflecting gradients of support and opposition into just two categories: support and oppose. This decreases the amount of variation in the dependent variable, but is done because our respondents’ opinions about CCS are relatively uninformed and reflect initial reactions. The resulting dichotomous variables serve as dependent variables in the analysis.

3.4 Independent Variables

Independent variables in the analysis are described in Table 1 and include respondents’ demographic characteristics, characteristics about the community or region in which they live, and their level of concern over the expense of CCS and the various safety risks that are frequently associated with the practice. It also includes variables representing respondents’ cultural world views, as described by Douglas and Wildavsky.⁽⁴¹⁾ Cultural types were measured by assessing the level of agreement with two statements associated with each viewpoint. All of these statements have been used and vetted in previous research.⁽⁴⁹⁾ Answers were used to create three eight-point scales that show the relative strength of each cultural bias on an individual’s outlook.

Table I: Description of Independent Variables with Means and Standard Errors

| Variable | Description | Mean | SE ¹ |
|---|---|--------|-----------------|
| Gender | A dichotomous variable coded as 1 if the respondents' gender is male and 0 if female. | 0.497 | 0.0263 |
| Race | A dichotomous variable coded 1 if the respondents' described their race as non-Hispanic White and 0 for any other description of race. | 0.890 | 0.0174 |
| Age | Respondents' age in years. | 48.804 | 0.875 |
| Income | An ordinal variable indicating whether respondents' annual family income is less than \$25k, \$25-\$50k, \$50-\$75k, \$75-\$100k or over \$100k. | 2.510 | 0.0672 |
| Home-ownership | A dichotomous variable coded as 1 if respondents own their home and 0 if they do not. | 0.762 | 0.0236 |
| Education | A dichotomous variable coded 1 if respondents have a college education or higher and 0 if respondents have less than a college education. | 0.242 | 0.0209 |
| Liberal | A dichotomous variable coded 1 if respondents self-identify as politically liberal. | 0.198 | 0.0211 |
| Coal region | A dichotomous variable coded 1 if respondents live in counties where coal is actively mined. | 0.116 | 0.0113 |
| Rural area | A dichotomous variable coded 1 if respondents self-identify as living in a rural area. | 0.165 | 0.0195 |
| Climate change | An ordinal variable indicating whether respondent strongly agrees, agrees, disagrees or strongly disagrees that climate change is a problem. | 2.989 | 0.0579 |
| Effectiveness concern | An ordinal variable indicating whether respondents have a large, moderate, small or no concern that CCS will not be effective in permanently storing CO ₂ and helping to minimize climate change as intended. | 3.174 | 0.0479 |
| Expense concern | An ordinal variable indicating whether respondents have a large, moderate, small or no concern that "CCS is a very expensive technology." | 3.156 | 0.0448 |
| Safety index ($\alpha = 0.878$; IIC = 0.787) | <p>An additive index indicating how many of 4 possible CCS risks respondents express a "large concern" about.</p> <p>Respondents were asked: As with all technologies, storing carbon dioxide underground has the potential to result in negative events. I am going to read a list of four concerns that some people have about CCS. If a CCS facility was constructed on a suitable site in the United States, please tell me if the following would be a large concern, a moderate concern, a small concern or no concern to you?</p> <p>a. Ground water contamination resulting from CO₂ that is stored underground</p> <p>b. Suffocation resulting from CO₂ leaking out of the ground into people's houses and basements</p> <p>c. Earthquakes may be caused by the injection of CO₂ into the ground</p> <p>d. Explosions caused by the CO₂ stored underground</p> | 1.742 | 0.0895 |
| Economic benefit | An ordinal variable indicating whether respondents think CCS would provide an important, somewhat important, little, or no economic benefit to the surrounding community. | 3.318 | 0.0480 |
| CCS payment | A dichotomous variable coded as 1 if respondents think Indiana tax or rate payers will bear the cost burden of any CCS facility built in the state. | 0.711 | 0.0246 |
| Individualistic ($\alpha = 0.508$; IIC = 0.337) | <p>An 8 point index indicating the strength of respondents individualistic world view. The index is based on whether strongly disagree, disagree, agree, or strongly agree with each of the following 2 statements:</p> <p>a. Competitive markets are almost always the best way to supply people with the things they need.</p> <p>b. Society would be better off if there was much less government regulation of business.</p> | 5.954 | 0.0792 |
| Hierarchical ($\alpha = 0.498$; IIC = 0.343) | <p>An 8 point index indicating the strength of respondents hierarchical world view. The index is based on whether strongly disagree, disagree, agree, or strongly agree with each of the following 2 statements:</p> <p>a. Society works best when people strictly obey all rules and regulations.</p> <p>b. One of the problems with people today is that they challenge authority too often.</p> | 5.684 | 0.0882 |
| Egalitarian ($\alpha = 0.471$; IIC = 0.374) | <p>An 8 point index indicating the strength of respondents egalitarian world view. The index is based on whether strongly disagree, disagree, agree, or strongly agree with each of the following 2 statements:</p> <p>a. We need to dramatically reduce inequalities in society, such as between whites and people of color.</p> <p>b. The world would be a better place if its wealth were divided more equally among nations.</p> | 5.478 | 0.0931 |

¹ Linearized standard errors; ^a Chronbach's alpha; ^{IIC} Average inter-item covariance for items in the index variables.

4. METHODS AND RESULTS

Separate logistic regressions are run on dependent variables indicating respondents' level of support (or opposition) for a hypothetical CCS facility located "somewhere in the United States" and "near respondents' homes or communities." Their results are compared to assess how the factors that predict support change as the project location nears individuals' residences. Table 2 shows the empirical results of the factors that predict support in the US in the form of logistic coefficients and marginal effects. Table 3 shows similar results for CCS projects located near respondents' homes or communities.

The results suggest that the factors associated with support for proposed CCS facilities located "somewhere in the United States" are different from those related to the support of such facilities closer to respondents' homes. Only two factors in the analysis significantly influence support for the proposed CCS facility located in an unspecified location somewhere in the country. All else equal, the belief that CCS will provide an economic benefit predicts increased support and greater concern about safety risks, as measured by the consolidated safety index, is associated with decreased support. These influences remain when the proposed facility moves near one's home or community and others additionally become significant. The magnitude of the opposition related to concern about risk is also notably larger when respondents consider a nearby facility: For a one-unit increase in the safety index variable (which represents an additional risk for which a respondent expresses a large concern), the likelihood that the respondent supports a CCS facility somewhere in the USA decreases by 3.6 percent while the likelihood of support for a nearby facility decreases by 8.3 percent. Finally, the egalitarian cultural type is insignificant when considering CCS in the USA but becomes significant when it

moves closer to respondents' communities; individuals that display a stronger egalitarian worldview are more likely than others to support nearby CCS facilities, all else equal.

Table II: Logistic Assessment of the Factors that Predict Support for CCS Facilities “Somewhere” in the USA

| | Coefficients | | Marginal Effects | |
|---|---|---------|------------------|---------|
| Male | 0.158 | (0.355) | 0.016 | (0.035) |
| Race | 0.427 | (0.599) | 0.049 | (0.077) |
| Age | -0.009 | (0.008) | -0.001 | (0.001) |
| Income | -0.129 | (0.172) | -0.013 | (0.018) |
| Own home | -0.696 | (0.671) | -0.061 | (0.046) |
| Education | 0.429 | (0.415) | 0.040 | (0.036) |
| Liberal | -0.709 | (0.494) | -0.084 | (0.066) |
| Coal region | 0.227 | (0.315) | 0.021 | (0.029) |
| Rural | -0.056 | (0.413) | -0.006 | (0.043) |
| Climate problem | 0.280 | (0.196) | 0.028 | (0.019) |
| Expense concern | 0.062 | (0.216) | 0.006 | (0.022) |
| Effectiveness concern | 0.323 | (0.225) | 0.033 | (0.023) |
| Safety index | -0.354** | (0.122) | -0.036** | (0.013) |
| Economic benefit | 1.099** | (0.160) | 0.111** | (0.019) |
| CCS payment | 0.390 | (0.445) | 0.042 | (0.050) |
| Hierarchical | 0.031 | (0.112) | 0.003 | (0.011) |
| Egalitarian | 0.144 | (0.151) | 0.015 | (0.014) |
| Individualist | -0.103 | (0.134) | -0.010 | (0.014) |
| Constant | -2.826 | (2.361) | -- | |
| | $n = 757$ $F = 5.33$ (0.000) $McFadden's\ Adj\ R^2 = 0.267$ | | --- | |
| Standard errors are in parentheses. The survey-weighted model correctly predicts support 86.4% of the time. 82.4% of the weighted, non-missing sample falls in the modal category of CCS support. ** $p < 0.001$, * $p < 0.05$ | | | | |

Table III: Logistic Assessment of the Factors that Predict Support for CCS Facilities Near Respondents' Homes or Communities

| | Coefficients | Marginal Effects |
|--|---|------------------|
| Male | 0.489 (0.288) | 0.098 (0.056) |
| Race | 0.557 (0.407) | 0.121 (0.094) |
| Age | 0.002 (0.008) | 0.000 (0.002) |
| Income | 0.064 (0.112) | 0.013 (0.022) |
| Own home | 0.131 (0.395) | 0.027 (0.081) |
| Education | 0.260 (0.356) | 0.050 (0.066) |
| Liberal | 0.115 (0.378) | 0.023 (0.073) |
| Coal region | 0.272 (0.276) | 0.052 (0.051) |
| Rural | 0.116 (0.328) | 0.023 (0.063) |
| Climate problem | 0.203 (0.157) | 0.041 (0.031) |
| Expense concern | 0.099 (0.185) | 0.020 (0.037) |
| Effectiveness concern | 0.110 (0.177) | 0.022 (0.035) |
| Safety index | -0.413** (0.102) | -0.083** (0.020) |
| Economic benefit | 1.200** (0.159) | 0.240** (0.033) |
| CCS payment | -0.078 (0.329) | -0.015 (0.065) |
| Hierarchical | -0.065 (0.090) | -0.013 (0.018) |
| Egalitarian | 0.185* (0.088) | 0.037* (0.018) |
| Individualist | 0.178 (0.094) | 0.036 (0.018) |
| Constant | -6.429** (1.671) | --- |
| | $n = 748$ $F = 5.53 (0.000)$ $McFadden's Adj R^2 = 0.248$ | |
| Standard errors are in parentheses. The survey-weighted model correctly predicts outcomes 79.2% of the time. 67.8% of the weighted, non-missing sample falls in the modal category of CCS support. ** $p < 0.001$, * $p < 0.05$ | | |

As described previously, a NIMBY effect is witnessed when people show a free-rider preference by supporting a project in the abstract, and opposing it only if it occurs near their home.⁽⁵⁰⁾ The data reveal a modest free-rider preference for CCS: 779 of the respondents to this survey stated that they would support or strongly support the operation of a CCS facility on a geologically suitable site “somewhere in the U.S.” Of these respondents, 166 switch from support at the national level to opposition when the proposed site shifts to “near your home or community,” a 21.3% reduction in support. As table 4 shows, 174 respondents oppose CCS in

both locations. However, it is only the former group—those who switched from support to opposition—that display a NIMBY-like reaction.

Table IV: Distribution of Support for CCS at Various Locations

| | Support CCS near home | | |
|---------------------------------|------------------------------|------------|--------------|
| Support CCS in the US | NO | YES | Total |
| NO | 174 | 10 | 184 |
| Yes | 166* | 613 | 779 |
| Total | 340 | 623 | 963 |
| * Display a NIMBY-like reaction | | | |

Whereas the results in Tables 2 and 3 separately show the factors that predict support for the operation of CCS facilities “somewhere” in the United States and near respondents’ homes or communities, Table 5 presents the results of a third logistic regression that focuses on the factors that influence individuals to *switch* from support to opposition as a proposed facility moves closer to their residence. Observations in this model are restricted to the respondents who expressed support for CCS in the U.S., and the dichotomous dependent variable is coded one for the subset of those who displayed a NIMBY-like response. The individuals who express opposition to CCS anywhere in the U.S. are excluded from this analysis because it eliminates the possibility of displaying a NIMBY pattern.

The results suggest that being male, liberal, believing CCS will benefit the community economically, and having an individualistic world view is associated with a reduced likelihood of displaying a NIMBY response, all else equal. On the other hand, respondents with a greater concern about safety risks are associated with a higher likelihood of switching to opposition when the proposed location of a CCS facility nears.

Table V: Logistic Assessment of the Factors that Predict a NIMBY Reaction

| | Coefficient | Marginal Effects |
|---|---|------------------|
| Male | -0.695* (0.351) | -0.081* (0.039) |
| Race | -0.369 (0.441) | -0.047 (0.061) |
| Age | -0.006 (0.010) | -0.001 (0.001) |
| Income | -0.102 (0.149) | -0.012 (0.018) |
| Own home | -0.562 (0.447) | -0.071 (0.062) |
| Education | -0.402 (0.492) | -0.043 (0.047) |
| Liberal | -0.889 (0.480) | -0.085* (0.039) |
| Coal region | -0.402 (0.359) | -0.041 (0.035) |
| Rural | -0.123 (0.438) | -0.014 (0.048) |
| Climate problem | -0.092 (0.171) | -0.011 (0.019) |
| Expense concern | 0.053 (0.198) | 0.006 (0.023) |
| Effectiveness concern | -0.136 (0.200) | -0.016 (0.024) |
| Safety index | 0.439** (0.107) | 0.051** (0.012) |
| Economic benefit | -0.954** (0.228) | -0.110** (0.025) |
| CCS payment | 0.738 (0.405) | 0.077 (0.036) |
| Hierarchical | 0.018 (0.096) | 0.002 (0.011) |
| Egalitarian | -0.065 (0.093) | -0.007 (0.011) |
| Individualist | -0.307** (0.100) | -0.035** (0.012) |
| Constant | 4.862** (1.653) | -- |
| | <i>n</i> = 612 <i>F</i> = 3.13 (0.000) <i>McFadden's Adj R</i> ² = 0.201 | -- |
| Standard errors are in parentheses. The survey-weighted model correctly predicts outcomes 84.2% of the time. 80.6% of the weighted, non-missing sample falls in the modal category of non-NIMBY reactions. ** <i>p</i> < 0.001, * <i>p</i> < 0.05 | | |

5. DISCUSSION

Carbon capture and storage has the potential to serve as a bridging technology, enabling the continued use of fossil fuels – without adding to the build-up of greenhouse gases in the atmosphere – until clean energy technologies advance sufficiently. This global benefit, however, is accompanied by local costs; namely, the risks and uncertainties that some communities will have to bear. Such scenarios of shared benefits and localized costs provide fertile ground for

NIMBY-like reactions where opposition to local placement can stall or stop project development. Indeed, this has already happened at several planned CCS locations in Europe.^(4,5)

A significant difference, though, between planned CCS operations and the deployments of other large-scale industrial technologies is that, exclusive of several specialized examples of CCS operating in conjunction with the existing developed oil and gas fields (e.g. Weyburn Field, Saskatchewan), there have been no actual experiences with CCS for the public to observe and react to. Because attitudes about CCS are based on concepts and perceptions rather than information about actual past events or situations, the ability to make direct comparisons of NIMBY-like responses to other energy-related industrial developments such as wind farms or oil refineries is limited.

Similar to the members of the public who have participated in previous other studies about CCS, our sample of Indiana residents were largely unaware of the technology prior to the survey.^(4, 32, 33) After being presented with a basic explanation of its purpose and function, however, over 80% expressed general support for CCS. This high level of initial support may be linked to the state's coal intensive history, which could result both in an economic interest favoring the continued use of coal as well as greater familiarity with underground coal-related activities.

A modest but notable NIMBY-like reaction was observed, with over a fifth of the initial supporters changing to opposition when the hypothetical facility moved from "somewhere in the United States" to "near" respondents' homes or communities. Neither living in a rural area nor a coal producing area significantly influences support for CCS, suggesting that this switch to opposition is not a result of a more general sentiment that CO₂ storage should not occur near more densely populated areas.^(22, 50) However, because these views reflect relatively uninformed

preferences, they are likely highly malleable and could be influenced, either positively or negatively, by image-building campaigns.

Respondents' world views, or cultural biases, emerge as predictors of CCS support and NIMBY-like reactions, although not always in the manner predicted. Egalitarians are associated with an increased likelihood of support for nearby facilities. This is consistent with the high value they place on fairness: not accepting to personally take on the risks that they would bestow on others may be viewed as counter to this value. Respondents holding a strong individualistic world view are significantly less likely to display a NIMBY sentiment and more likely to support CCS near their homes or communities, all else equal. This is counter to our hypothesis that because individualists place a high value on personal freedoms they would be less willing to accept a nearby facility if it felt "imposed" on their locale. However, this reaction does assume a feeling of imposition that is unlikely to occur when asking about a hypothetical facility. Moreover, individualists may view CCS positively as a market-based response to climate change. The hierarchical world view is not significantly associated with support or opposition towards CCS in either location.

Overall, demographic variables have a small impact on respondents' attitudes towards CCS. However, being male, white, and politically liberal is associated with increased support of nearby CCS facilities and reduced NIMBYism, all else equal. The modest impact shown by fundamental demographic characteristics reflects the findings of other energy-orientated NIMBY studies.⁽⁵¹⁾

The above findings relating worldviews and demographics with CCS acceptance may prove practically useful when conducting social site characterizations for potential CCS facilities. However, respondents' perceptions about CCS's economic benefits and safety provide

the more functional policy levers and communication “hooks.” The strongest and most consistent predictor of support for CCS is individuals’ belief that it will generate economic development. This belief increases support for facility placement both in the U.S. as a whole and near respondents’ communities. It also reduces the likelihood that a NIMBY sentiment will be expressed. Indeed, when offsetting local benefits (e.g. jobs, tax revenue, economic stimulus) accompany undesirable land uses, they are often able to shift the majority position to favor local acceptance.⁽¹⁹⁾ This suggests that if CCS proponents can ensure and communicate the incidence of local economic benefits, local acceptance will become more likely.

Previous studies find that members of the public associate a relatively consistent set of safety risks with CCS; namely CO₂ leakage, induced seismicity, explosions, and groundwater contamination.^(30, 34, 35) This research likewise finds that higher levels of concern about these risks significantly reduces respondents’ likelihood to support CCS development. The significant role such concerns play in shaping respondents’ CCS acceptance has several implications for CCS and related technologies. For instance, proponents of CCS will need to adequately communicate expected risks to a concerned public in order to garner and maintain support for the technology. It is important to point out that the questions used to generate the dependent variables that quantify CCS support in this study begin with the phrase “If experts determine there is a suitable site for underground CO₂ storage...” Thus, some degree of testing and safety is already implied in the question itself. Despite this, larger concerns about perceived risks consistently and significantly reduce the support expressed for local CCS facilities and are associated with an increased likelihood of a NIMBY-like reaction.

This study examining the influence of proximity on Indiana residents’ acceptance of CCS facilities has several limitations which point to avenues for future research. First, given the

sampling of just one U.S. state, the ability to extrapolate results to other states or regions nationally and globally is limited. There exists the potential that the results could be representative of attitudes of the region in general, but they may also specifically reflect the thoughts of individuals living in this coal-intensive and industrialized state. Second, the lack of familiarity most respondents had with CCS implies that the results presented here represent a baseline assessment of Indiana residents' acceptance of CCS facilities. As people learn more about the technology, support may move above or below this baseline. Third, we utilize qualitative descriptions of proximity, which capture the construct but likely result in some variation in the specific distances interpreted. Future researchers interested in assessing the geographic range of NIMBYism may choose to ask about individuals' acceptance of facilities at a number of specific distances. Finally, while we recognize that NIMBY and NUMBY attitudes both come into play with CCS, our analysis does systematically differentiate between them. An additional avenue for future research is to more fully explore the nuances between NIMBY and NUMBY, particularly the relative importance of each in support for or opposition to various projects that involve both above and below ground processes.

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REFERENCES

1. Intergovernmental Panel on Climate Change (IPCC). Climate Change 2007: Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, 2007.
2. National Research Council. Advancing the Science of Climate Change. Washington D.C.: National Academy Press; 2010.
3. Hund G, Greenberg S E. Dual-track CCS stakeholder engagement: Lessons learned from FutureGen in Illinois. *Energy Procedia*. 2011; 4:6218-25.
4. Dütschke E. What drives local public acceptance – comparing two cases from Germany. *Energy Procedia*. 2011; 4:6234-40.
5. Brunsting S, de Best-Waldhober M, Feenstra CFJ, Mikunda T. 2011a, Stakeholder participation practices and onshore CCS: Lessons from the Dutch CCS Case Barendrecht. *Energy Procedia*. 2011a; 4:6376–83.
6. Global CCS Institute [Internet]. Canberra, Australia: Global CCS Institute. Indiana Gasification; [cited 2012 Aug 12]. Available from: www.globalccsinstitute.com/projects/12431
7. Indiana Office of Energy Development [Internet]. Indianapolis: State of Indiana; Indiana CCS Summit: Conference Proceedings and Recommendations for Next Steps; 2008 [cited 2012 Aug 12]. Available from: www.in.gov/oed/files/ccs-summit-print.pdf.
8. Davis CE, Lester JP. Dimensions of Hazardous Waste Politics and Policy. New York: Greenwood Press. 1988.
9. Schively C. Understanding the NIMBY and LULU phenomena: Reassessing

our knowledge base and informing future research. *Journal of Planning Literature*. 2007; 21:255-66.

10. Dear M. Understanding and Overcoming the NIMBY Syndrome. *Journal of the American Planning Association*. 1992; 58(2): 288-300.
11. van der Horst D. NIMBY or Not? Exploring the Relevance of Location and the Politics of Voiced Opinions in Renewable Energy Siting Controversies. *Energy Policy*. 2007; 35: 2705-14.
12. Devine-Wright P. Rethinking NIMBYism: The Role of Place Attachment and Place Identity in Explaining Place-Protective Action. *Journal of Community and Applied Social Psychology*. 2009;19:426-41.
13. Devine-Wright P. Place attachment and public acceptance of renewable energy: A tidal case study. *Journal of Environmental Psychology*. 2011;31(4):336-43.
14. Martin R, Myers, DL. Public Response to Prison Siting: Perceptions of Impact on Crime and Safety. *Criminal Justice and Behavior*. 2005; 32(2):143-71.
15. Johnson RJ, Scicchitano MJ. Don't Call Me NIMBY: Public Attitudes Towards Solid Waste Facilities. *Environment and Behavior*. 2012; 44(3): 410-26.
16. Jenkins-Smith HC, Silva CL, Nowlin MC, Delozier G. Reversing nuclear opposition: Evolving public acceptance of a permanent nuclear waste disposal facility. *Risk Analysis*. 2011; 31(4):629-44.
17. Kraft ME, Clary BB. Citizen Participation and the Nimby Syndrome: Public Response to Radioactive Waste Disposal. *The Western Political Quarterly*. 1991; 44(2): 299-328.
18. Rabe BG. Beyond NIMBY: Hazardous waste siting in Canada and the United States. Washington, DC: Brookings Institution; 1994.

19. Jenkins-Smith H, Kunreuther H. Mitigation and Benefits Measures as Policy Tools for Siting Potentially Hazardous Facilities: Determinants of Effectiveness and Appropriateness. *Risk Analysis*. 2001; 21(2): 371-382.
20. Kerr RA. Natural Gas From Shale Bursts Onto the Scene. *Science*. 2010; 328(5986): 1624-1626.
21. Curry T, Reiner D, Ansolabehere S, Herzog H. How aware is the public of carbon capture and storage? in E. Rubin, D. Keith and C. Gilboy (eds), *Proceedings of 7th International Conference on Greenhouse Gas Control Technologies. Volume 1: Peer-Reviewed Papers and Plenary Presentations*, IEA Greenhouse Gas Programme, Cheltenham, UK. 2004.
22. Huijts NMA, Midden CJH, Meijnders, AL. Social acceptance of carbon dioxide storage. *Energy policy*. 2007; 35(5): 2780-2789.
23. Wolsink M. Wind power and the NIMBY-myth: Institutional capacity and the limited significance of public support. *Renewable Energy*. 2000;21(1):49-64.
24. Aitken M. Why we still don't understand the social aspects of wind power: A critique of key assumptions within the literature. *Energy Policy*. 2010;38(4):1834-41.
25. Brunsting S, Desbarats J, de Best-Waldhober M, Duetschke E, Oltra C, Upham P, Riesch H. The Public and CCS: The importance of communication and participation in the context of local realities. *Energy Procedia*. 2011;4:6241-7.
26. Ashworth P, Bradbury J, Wade S, Feenstra Y, Greenberg S, Hund G, Mikunda T. What's in Store: Lessons from Implementing CCS. *International Journal of Greenhouse Gas Control*. 2012;9:402-9.
27. Parfomak PW [Internet]. Washington DC: CRS Report for Congress; Community Acceptance of Carbon Capture and Sequestration Infrastructure: Siting Challenges.

2008; [cited 2012 May 1] Available from:

www.nationalaglawcenter.org/assets/crs/RL34601.pdf.

28. Bielicki JM, Stephens JC [Internet]. Public Perception of Carbon Capture and Storage

Technology. 2008 June 2-3. [cited 2012 May 1] Available from:

http://belfercenter.ksg.harvard.edu/files/CCS_Public_Perception_Workshop_Report.pdf

29. Carley SR, Krause RM, Warren DC, Rupp JA, Graham JD. Early Public Impressions of

Terrestrial Carbon Capture and Storage in a Coal-Intensive State. *Environmental*

Science and Technology. 2012;46(13):7086-93.

30. Shackley S, McLachlan C, Gough C. The public perception of carbon dioxide capture

and storage in the UK: results from focus groups and a survey. *Climate Policy*. 2005;4:

377-98.

31. Curry TE, Ansolabehere S, Herzog H. A survey of public attitudes towards climate

change and climate change mitigation technologies in the united states: Analyses of

2006 results. Cambridge (MA): Laboratory for Energy and the Environment,

Massachusetts Institute of Technology; 2007 April. Report No.: LFEE 2007-01 WP.

32. Itaoka K, Okuda Y, Saito A, Akai M. Influential information and factors for social

acceptance of CCS: the 2nd round survey of public opinion in Japan. *Energy Procedia*.

2009;1:4803-10.

33. Miller E, Summerville J, Buys L, Bell L. Initial public perceptions of carbon

geosequestration: implications for engagement and environmental risk communication

strategies. *International Journal of Global Environmental Issues*. 2008;8(1):147-64.

34. Wallquist L, Visschers VHM, Siegrist M. Lay concepts on CCS deployment in Switzerland based on qualitative interviews. *Int. J. Greenhouse Gas Control*. 2009;3(5): 652–7.
35. Wallquist L, Visschers VHM, Siegrist M. Impact of Knowledge and Misconceptions on Benefit and Risk Perceptions of CCS. *Environmental Science and Technology*. 2010;44: 6557-62.
36. Slovic P. Perception of Risk. *Science*. 1987;236:280-5.
37. Starr C. Social Benefit vs. Technical Risk: What is our Society Willing to Pay for Safety? *Science*. 1969;165:1232-8.
38. Palmgren C R, Morgan GM, Bruine de Bruin W, Keith DW. Initial public perceptions of deep geological and oceanic disposal of Carbon Dioxide. *Environ. Sci. Technol*. 2004; 38 (24):6441–50.
39. Terwel BW, Daamen DDL. Initial public reactions to carbon capture and storage (CCS): differentiating general and local views. *Climate Policy*. 2012;12(3):288-300.
40. Wallquist L, L'Orange Seigo S, Visschers VHM, Siegrist M. Public Acceptance of CCS System Elements: A Conjoint Measurement. *International Journal of Greenhouse Gas Control*. 2012; 6:77-83.
41. Douglas M, Wildavsky A. *Risk and Culture*. Berkeley (CA): University of California Press. 1982.
42. Wildavsky A, Dake K. Theories of Risk Perception: Who Fears What and Why? *Daedalus*. 1990; 119(4):41-60.
43. Jones MD. Leading the Way to Compromise? Cultural Theory and Climate Change Opinion. *PS Political Science and Politics*. 2011;44(4):720-725

44. Thompson M, Ellis R, Wildavsky A. Cultural theory. Westview Press. 1990.
45. U.S. Census Bureau. [Internet]The 2009 Statisitcal Abstract: State Rankings. 2009;
[cited 2012 May 1] Available from: www.census.gov/compendia/statab/rankings.html
46. Pew Center on Global Climate Change. [Internet] U.S. Climate Policy Maps. 2009;
[cited 2012 May 1] Available from:
www.pewclimate.org/what_s_being_done/in_the_states/state_action_maps.cfm
47. Daniels M. Indiana Says 'No Thanks' to Cap and Trade. The Wall Street Journal. 2009.
15 May, page A11
48. Energy Information Administration, 2005, "Renewable Potential Maps,"
www.eia.doe.gov/emeu/reps/rpmap/rp_contents.html
49. Ellis R, Thompson F. Culture and environment in the Pacific Northwest. American
Political Science Review. 1997;91(4):885-897.
50. Wolsink M. Invalid theory impedes our understanding: A critique on the
persistence of the language of NIMBY. Transactions of the Institute of British
Geographers. 2006; 31(1):85-91.
51. Ansolabehere, S, Konisky, DM. Public attitudes toward construction of new power
plants. Public Opinion Quarterly. 2009; 73(3), 566-577.

Appendix 1: CCS Survey Factsheet

Thank you for participating in the _____ survey about energy and the environment. As a token of our appreciation, we have included a five dollar bill with this mailing. You will receive another five dollars for participating in a shorter follow-up interview in the coming days. Before that interview, please take a moment to read this brief fact sheet about a new energy technology.

Carbon Capture and Storage (CCS) Fact Sheet

What is Coal?

Coal is a fuel that is burned to produce energy. Coal is comprised of many common elements like carbon, hydrogen, sulfur, and oxygen. When coal is burned for electricity, these elements are released into the atmosphere in the form of carbon dioxide (CO₂).

What is CO₂?

Carbon dioxide, or CO₂, is a gas that is found naturally in the Earth's atmosphere. All living things produce carbon dioxide. Plants, trees, and the ocean absorb CO₂ from the air. Carbon dioxide emissions have been increasing as people around the world burn more coal, oil, and natural gas.

CO₂ is considered a "greenhouse gas". Greenhouse gases, or GHGs, allow sunlight to enter the Earth's atmosphere, where they then trap the heat that is created. This helps to keep the Earth's temperature warm and seasonally constant. High levels of greenhouse gases, like CO₂, in the Earth's atmosphere can produce an increase in the Earth's temperature. This result is called "global warming" or "climate change". Climate change is characterized by an overall warming of the earth and can lead to more extreme weather events. This change in climate can affect the ocean, crops, animals, and people.

What is CCS?

Carbon capture and storage, or CCS, is a technology in which carbon dioxide (CO₂) emissions are captured from industrial processes which burn fuels, such as electricity production. The captured CO₂ is transported by pipeline and is injected into rock formations deep underground for permanent storage or disposal (see diagram).

What is the purpose of CCS?

Carbon capture and storage is designed to reduce the amount of CO₂ released into the atmosphere. Storing CO₂ underground prevents it from going into the atmosphere and may reduce some of the problems associated with climate change.

Where is CCS currently being used?

Several small facilities around the world are currently in operation and are demonstrating carbon capture and storage for research purposes. A few large, commercial-scale projects are currently under construction. CCS has not yet been used to capture CO₂ from large coal-powered electricity generation facilities.

Example CCS Facility

