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Policy Stakeholders' Perceptions of Carbon Capture and Storage: A Comparison of Four U.S. States

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ABSTRACT

Over the past decade, the United States (US) has demonstrated strong and evolving interest in the development of carbon capture and storage (CCS), an emerging set of technologies with potential to reduce carbon dioxide emissions from coal-fired power plants. Given the many technical, economic, and environmental uncertainties about the future of CCS, the political salience of this technology is high. In the US, states make key decisions about deploying energy technology projects, but variation in state-level energy context (both technical and socio-political) is substantial. This research assesses variation in the state-level energy context for CCS development by exploring energy policy stakeholders' perceptions of CCS in four geographically and demographically diverse states. Policy stakeholders have different degrees of familiarity with CCS, and the goal of this research is to understand and compare the perceptions of CCS among stakeholders who shape state-level energy policy. Semi-structured interviews with 84 energy policy stakeholders across government, industry, academia, and non-governmental organizations active in four different states (Massachusetts, Minnesota, Montana and Texas) were analyzed to compare perceptions of CCS risks and benefits. Negative associations of CCS were mentioned more frequently than positive attributes in each state, and technical, political and economic risks are more dominant than environmental or health and safety risks. Content analysis of the interviews provides insight on emerging sub-national discourse regarding CCS, on state-level variation in familiarity with CCS, and on sub-national variation in the socio-political context for energy technologies. The variation in state and stakeholder energy priorities and perceptions revealed in this study highlights challenges in the development and implementation of national-level energy policy and also specific challenges in the deployment of CCS.

1. Introduction

Within the past decade, carbon capture and storage (CCS) has emerged as an important technology with unique potential for reductions in carbon dioxide pollution (IPCC, 2005; Meadowcroft and Langhelle, 2009; Markusson et al., 2012). This climate mitigation technology has particular political salience as it offers the possibility of reducing carbon dioxide emissions from fossil fuel-based electricity production (IPCC, 2005; Bäckstrand et al., 2011). CCS involves integrating: (1) capture of CO_2 from coal fired power plants and other large stationary industrial sources, (2) transport of large volumes of captured CO_2 from the source to a storage location, and (3) injection and containment of the CO_2 in appropriate geologic storage locations for hundreds to thousands of years. Globally, interest and investment in CCS has grown due to the technology's potential to reduce pollution associated with society's heavy reliance on coal-fired power plants for electricity production, and because of the climate-related political relevance of advancing a new technology with substantial climate mitigation potential (Stephens, 2006, 2009; DoE, 2007). The United States (US) is among

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the countries whose government has demonstrated the strongest interest and highest level of investment in CCS over the past decade (Tjernshaugen, 2008; Meadowcroft and Langhelle, 2009; van Alphen et al., 2010).

While most other energy technologies with climate mitigation potential offer co-benefits beyond greenhouse gas emissions reduction, the only reason to consider implementing CCS is its potential to reduce carbon dioxide emissions (Meadowcroft and Langhelle, 2009). Given the high costs of an integrated CCS system, including a major additional energy requirement to capture, compress, transport and inject the CO_2 (National Energy Technology Laboratory, 2007), early opportunities to demonstrate CCS have been associated with the oil industry practice of Enhanced Oil Recovery (EOR), where CO_2 is injected into depleted oil reservoirs to mobilize and produce additional oil (Intergovernmental Panel on Climate Change, 2005; Jaramillo et al., 2009). CCS is a controversial climate mitigation technology due to many concerns including high cost, technical complexity, regulatory and liability challenges (Wilson et al., 2007), and the technology's potential role in strengthening, rather than reducing, society's reliance on fossil fuels (Wong-Parodi et al., 2008; Bradbury et al., 2009).

The extent to which CCS advances in the US will be influenced by the state policies (Pollak et al., 2011) and perceptions of CCS (Wong-Parodi et al., 2008), especially among key energy stakeholders. In the US, it is state-level processes, institutions, and organizations which shape and influence energy technology development (Rabe, 2004a). Although federal energy policies outline broad direction for the US energy system, fund research and development efforts and establish environmental regulations, states remain the main locus of influence on electricity system development. State legislatures have authority to pass statutes that shape the electric power industry, impact the relative use of different energy sources, target local economic development, set additional environmental goals, and many state legislatures have passed legislation to restructure the electric industry (Mattoon, 2002). State-level public utility commissions approve and permit the construction and expansion of power plants and transmissions lines and associated rate increases in traditionally regulated states, and—together with other agencies—monitor compliance with environmental regulations (Sautter and Twaite, 2009). A wide variety of stakeholders at the sub-national level have both formal and informal influences on state energy policy adoption (Gray, 1973; Berry and Berry, 2007) and on energy technology innovation (Jacobsson and Johnson, 2000; Bird et al., 2005; Breukers and Wolsink, 2007; Rao and Kishore, 2010).

In the absence of national-level climate policy or comprehensive energy policy in the US, state-level climate and energy policy has played a critically important role (Rabe, 2004a, 2008). The high degree of variation in climate and energy policies adopted by the states, however, reflects the diversity of sub-national contexts within which emerging energy technologies with climate mitigation potential are being considered (Bohn and Lant, 2009; Fischlein et al., 2010; Pollak et al., 2011). These sub-national socio-political contexts are complex and are influenced by multiple factors including level of commitment to greenhouse gas (GHG) reductions and differences in energy systems related to geographic, resource, and political differences (Stephens et al., 2008a). Among the states that have begun to consider regulations to govern CCS, divergent approaches are apparent and represent diversity in state-level perspectives on CCS (IOGCC, 2008; Pollak and Wilson, 2009). However, the specific state-level contexts and perceptions of key energy stakeholders remain poorly understood.

To enhance understanding of the complex socio-political contexts within which energy technology deployment occurs, Stephens et al. (2008a) have developed and applied an integrated research approach, the SPEED (Socio-Political Evaluation of Energy Deployment) framework. This framework provides a structure to analyze and explore interactions among multiple different socio-political factors (beyond technical feasibility) which influence energy technology deployment, including regulatory, legal, political, economic, and cultural factors. The SPEED framework encourages multiple approaches to exploring these socio-political factors including policy review (Wilson and Stephens, 2009a), media analysis (Stephens et al., 2009), and stakeholder interviews (Fischlein et al., 2010). The SPEED framework adapts and operationalizes Luhmann's (1989) theory of society as a system made up of self-organizing functional subsystems and incorporates a diversity of interactive influential factors including technical, political, economic, environmental, and health/safety (Luhmann, 1989, 1995).

In this study, the SPEED framework is applied to assess and compare perceptions of CCS among state-level energy policy stakeholders. To do this, we define five social sub-systems to frame and categorize perceptions of CCS' risks and benefits: economic, environmental, health and safety, political, and technical. Applying and building on the SPEED framework, this paper reports on the results of 84 semi-structured interviews with energy policy stakeholders to develop a comparative evaluation of the socio-political context influencing CCS advancement in four states with very different energy contexts: Massachusetts, Minnesota, Montana and Texas. This research is based on the premise that the perceptions of stakeholders engaged in actively creating state-level energy policy play an important role in the development and deployment of new energy technologies. This study also assumes that individual stakeholder perceptions are shaped by the state context and that a diversity of factors contribute both to the state context and to individual perceptions of a technology. These factors include industrial and business interests within that state, the state-level natural resource base, current and past economic and technological challenges and opportunities in that state, and the state's energy profile. State-level energy policy stakeholders can potentially influence deployment through three primary mechanisms: (1) impacting policy decisions that may provide incentives or barriers for CCS research or deployment, (2) influencing siting of facilities, and (3) shaping general public perceptions of CCS technologies (Stephens et al., 2008a).

This analysis of perceptions of state-level energy policy stakeholders is important because understanding the complexities of stakeholders' perspectives on emerging energy technologies will help in deployment of new technologies. Studies focused on energy policy stakeholders also offer a valuable contribution social science research on energy technology innovation for climate mitigation because these critical decision-makers have strong potential to influence technological advancement. These state-level energy stakeholders are not CCS technology experts and most are not part of the growing international network of professionals focused on CCS (Stephens et al., 2011; Boyd et al. in press). They are, however, professionally involved in creating and shaping state-level energy policy development with unique perspectives on their state's energy system. This focus on perceptions of CCS among energy policy stakeholders complements other research on public perceptions of CCS (Palmgren et al., 2004; de Best-Waldhober et al., 2009; Sharp et al., 2009), that has demonstrated that public awareness about CCS technology is low compared to other climate mitigation technologies (Reiner et al., 2006; Reiner, 2008) and that many complex factors influence general public perceptions of the technology (Bradbury et al., 2008). The goal of this research is to understand the perceptions of stakeholders who actively participate in shaping energy policy and legislative processes that influence energy technology decisions at the state level (Stephens et al., 2008a).

Table 1
Description of the five frames used to code the content of the interview transcripts. The signaling words and themes included here represents a simplified version of the codebook used in the transcript analysis.

Frames	Positive (benefit)	Negative (risk)
Economic	- Market is available for technology - Financial incentives make technology feasible - Low cost - Creates jobs	- Technology is expensive - Technology is not developed to commercial scale
Environmental	- Technology will reduce GHGs or carbon emission, mitigate climate change, reduce other air pollution	- Negative environmental consequences (e.g. habitat loss, ground water contamination)
Health & Safety	- Technology may improve health and safety (i.e. reduce respiratory problems, asthma, etc.)	- Technology may pose risks for workers, worker safety - Uncertainty about how technology will impact environment
Political	- Legislation is present or being considered that would help or facilitate the technology - Technology is popular, easy to sell to public, socially acceptable, popular among the public or the community - Technology helps reputation of the state, or some other political entity	- Technology is politically sensitive or controversial - Technology deployment may be difficult due to difficult permitting or siting process - Technology difficult because of the absence of a legal framework or regulatory uncertainty
Technical	- Technology has been proven reliable in other uses - Takes advantage of existing natural resource - Technology is feasible, doable, promising and/or has potential	- Technology may not work, is unproven, or uncertain - Infrastructure does not yet exist to support technology - Technology is limited in its technical capacity

Understanding these stakeholders' perceptions has potential to enhance the effectiveness of emerging energy policies at the state-level and national levels.

2. State selection and context

We apply a comparative approach to understand the state-level socio-political context for CCS in four geographically and demographically diverse states (Table 2). Massachusetts, Minnesota, Montana and Texas vary in their energy resources, patterns of energy consumption and production, climate and energy policies, as well as their geological capabilities to store captured CO_2. Each state represents a different level of CCS potential and interest; Texas and Montana are two states with demonstrated geologic potential for CCS while Massachusetts and Minnesota have minimal geologic potential for deploying CCS. These four states were selected based on this diversity among multiple factors, but also based on research team familiarity with the energy systems and access to energy-sector actors in these states.

Texas' interest in CCS can be associated with the strong oil industry influence in that state and the potential value of integrating CCS with the common practice of injecting CO_2 underground for Enhanced Oil Recovery (EOR). Montana's interest in CCS can be connected to the economic and politically important coal industry and the state's efforts to support the industry's long-term viability. Both Montana and Texas already host CCS demonstration activities (Ragland et al., 2010). Neither Minnesota nor Massachusetts host large coal or oil industries, and coupled with a lack of appropriate geologic reservoirs for carbon storage any engagement with CCS in these states would require out-of-state coordination. Massachusetts and Minnesota are two states with GHG reduction policies in place, while Montana and Texas do not have explicit GHG reduction policies.

These four states represent a range of very different energy system contexts within the U.S. (Table 2). Exploring energy policy actors' perceptions of CCS in each of these four states offers a unique comparative perspective on the different socio-political contexts across state-level energy systems. This research also provides insights on future state-level challenges and opportunities for CCS as well as other emerging energy technologies.

Table 2
Comparison of state-level energy system characteristics.

	Texas	Montana	Minnesota	Massachusetts
EOR opportunity	X	X	–	–
Other storage sites	X	?	–	–
Climate legislation	–	–	X	X
Electricity importer	–	–	X	X
Hydrocarbon resources	X	X	–	–

3. Methods

To assess the socio-political context for CCS at the state level, we compare and analyze energy policy stakeholders' perceptions of CCS through analysis of semi-structured interviews conducted between May 2008 and December 2009. We interviewed 84 stakeholders representing industry, government, NGO's, and academia (Table 3) who have been engaged in state-level political activity related to energy technology policy and asked them about their perceptions of the risks and benefits of CCS. This diverse set of energy policy stakeholders was selected by searching the state-level databases of legislative committee testimony where energy bills were presented and discussed. Additional stakeholders were identified via snowball sampling during the first round of interviews in which we ask interviewees whom else they suggest we interview (Lincoln and Guba, 1985). Interviews with a distributed representation of individuals from government, NGOs, academia and industry was attempted in each state, however we acknowledge that our approach led to more interviews with government and NGO representatives and fewer interviews with industrial and academic stakeholders (Table 3).

The interview protocol (see Appendix A) was designed to allow policy stakeholders to share their perceptions of the risks and benefits of CCS, from their organizational perspective on how CCS is promoted or discouraged within their state's policy setting. The responses to the interview questions analyzed for this paper focused on perceptions of CCS, but each interview also included a set of questions on perceptions of the risks and benefits of wind power (results from analysis of the wind-related questions have previously been published (Wilson and Stephens, 2009a; Fischlein et al., 2010). The recorded interviews were transcribed by a professional third-party service and transcripts were loaded into QSR International's NVivo™ 8 qualitative analysis software, a text-analysis program that facilitates analysis and coding of large amounts of text.

To gain comparative insights on stakeholder perceptions of CCS, we used content analysis of the transcribed interviews. Content analysis helps identify patterns of meaning in non-quantified data

Table 3
Distribution of different categories of policy stakeholders interviewed in each of the four states.

Policy stakeholder categories	Description	MA	MN	MT	TX	Total
Government-Elected	Individuals serving as elected officials within the state government, primarily legislators	2	2	5	2	11
Government-Non Elected	Individuals working in appointed or competitive employment positions state or local government offices	4	1	2	7	14
NGO-Environmental	Non-profit organizations focused primarily on environmental, scientific, or related subjects	7	7	5	6	25
Academic	Researchers and scholars engaged in either wind or CCS research	1	3	2	1	**7**
Industry		5	1	3	2	**7**
- NGO	Non-profit trade associations, lobbying organizations, or chambers of commerce					
- Utility	For-profit municipal or investor-owned electric or natural gas utilities					
- Wind Developer	For-profit organizations focused solely on the development of wind generation either for utilities or distributed generation					
- Other	For-profit organizations focused on power development projects not related to a single specific technology. Involved in process through financing, consulting, legal representation, etc.					
Total		19	23	20	22	84

and is a common tool in qualitative analysis (Holsti, 1969; Krippendorf, 1980). We employed *a priori* coding (Creswell, 1998), meaning that our coding categories were developed from a theoretical foundation as opposed to emerging from the material (Stemler, 2001). In this approach, codes are initially structured from theory and then, during the coding process, coding criteria are refined to ensure mutual exclusiveness of coding categories (Weber, 1990).

The codebook was developed based on five social function frames: economic, environmental, health and safety, political, and technical (Table 1) derived from the research team's previous work (Stephens et al., 2008a; Stephens et al., 2009) which adapted Luhmann's (1989) social theory to provide a systematic framework for analyzing stakeholder perceptions of energy technology deployment (Luhmann, 1989). The economic frame includes references to costs, jobs, and all financial incentives and disincentives. The environmental frame includes references to potential impacts of CCS on the natural environment, while the health-and-safety frame includes any mentions of impact to human health. The political frame includes discussion associated with legislation, regulations, permitting, legal issues, and reputation, and the technical frame includes all mentions of reliability, infrastructure integration, and capacity (Table 1). The codebook was designed to identify and categorize references to both perceived risks and benefits of CCS in these five categories. Risk perception of key energy policy actors in each state provides a valuable frame for evaluating state-level discourse of CCS technology, and helps to differentiate patterns of negative and positive evaluations in each state context.

After the codebook was finalized, a team of three researchers analyzed each interview transcript by coding the interview texts. The unit of analysis was an "utterance"—a complete unit of spoken language—into which interviews were segmented as proposed by Hruschka et al. (2004). Because utterances do not have an equivalent in written language (Kurasaki, 2000), we used sentences as the proxy unit of analysis when coding interviews. Due to the complexity of both the codebook and the analyzed material, each interview was coded by two coders, who then compared their work to reconcile the interview into a single set of codes. This practice of reconciliation offers several advantages over a more conventional approach of individual coding that aims to achieve, but does not always attain high inter-coder reliability. We attained nearly 100 percent (minus the corrections for chance agreement) coder agreement on the fit of each utterance because we discussed the meaning of each utterance coded. In addition, through the process of discussing all codes and divergences, the quality of the codebook was continually strengthened. Although more time consuming, this reconciliation approach also helped overcome human error. By revisiting disagreements in coding, both coding errors and different interpretations of the codebook were identified, discussed, and resolved. Reconciliation of codes also improved the cohesion among coders as time in conversation enhanced learning, as well as the consistent application and interpretation of the codes. The iterative processes of reconciliation and codebook refinement resulted in both increased reliability and validity of this study, with validity defined not only as appropriate decision making according to the codebook, but as the degree to which the codebook and its theoretical foundation apply to the real world (Potter and Levine-Donnerstein, 1999). Once the interviews were coded, the results were analyzed quantitatively by comparing the number of utterances in each frame and also qualitatively by reviewing the specific details of the content within the coded text.

4. Results and discussion

The quantitative results of the coding of interview transcripts demonstrate that in all 4 states negative utterances of CCS technology are more prevalent than positive utterances, where interviewees mentioned the risks of CCS technology more frequently than benefits of CCS (Fig. 1). This result suggests an overall negative discourse surrounding CCS. The dominant mentions of risks rather than benefits may reflect the multiple complex uncertainties associated with CCS and its future, and the distant connection that most of the energy policy stakeholders interviewed may have with CCS technology. Massachusetts demonstrates the highest percentage of negative utterances while Texas demonstrates the least (Fig. 1); these differences are likely to reflect more positive perceptions of economic opportunities associated with CCS connected to EOR in Texas and a higher degree of skepticism about the technology in Massachusetts.

With regard to the framing of CCS in each state, the percentage of utterances coded in each of the five different categories (technical, political, economic, environmental, and health/safety)

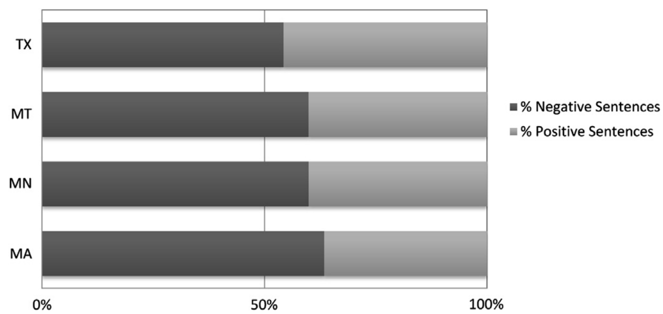

Fig. 1. Percentage of total positive and negative utterances in each of the four states (compiling results of the five different frames).

demonstrates a similar distribution in all 4 states (Fig. 2). In each of the four states the technical frame, which includes all mentions of reliability, infrastructure integration, and capacity, dominates the interview content. Next most frequent is content categorized within the political/legal frame, which includes mentions of legislation, regulations, permitting, legal issues, and political reputation. Third is the economic frame, which includes references to costs, jobs, and all financial incentives and disincentives. Content within the environmental frame, which includes references to potential impacts of CCS on the natural environment, is infrequent, but not as infrequent as the least mentioned frame which is health and safety which includes any mentions of impact to human health (Fig. 2). A similar pattern is observed when all interviews from all 4 states is compiled; technical framing is most frequent, followed by political, economic, environmental and lastly health and safety, and negative utterances within each of these frames are more frequent than positive ones (Fig. 3).

While the quantitative results above reveal subtle differences among the four states, qualitative analysis of the content and substance of the interview transcripts reveals distinct state-level differences. For example, although technical framing is equally dominant – representing about 42–43% of the discussion in both the Massachusetts and Texas interviews (Fig. 2) – additional analysis reveals that very different issues are being raised in the different state contexts. The remainder of this section reports on state-specific details that emerged from qualitative analysis of the interview transcripts. This qualitative analysis demonstrating state-level differences in socio-political discourse on CCS complements previous research focused on state-level differences in policy related to geologic storage for CCS (Pollak et al., 2009; Pollak et al., 2011). This comparative analysis of discourse among energy sector stakeholders helps to understand both factors contributing to state-level CCS policy differences and the impact of state-level CCS policy differences on actors' perceptions.

4.1. Massachusetts

In Massachusetts, analysis of the 19 stakeholder interviews revealed 63% of all CCS coded utterances focused on the perceived risks of CCS, with the discussion often related to the uncertainty about whether or how CCS would develop in the state. Within the technical frame, stakeholders in Massachusetts focused on two aspects of the CCS technology. First, its minimal applicability to the state was mentioned, given the state's lack of capacity for geologic storage: "there's no place to sequester it [CCS]" (MA01) and "we don't have the land and we probably don't have deposits where you could dump it [CO2]" (MA03). Secondly, more general concern about the technological readiness of CCS was mentioned by several stakeholders: "it's a technology that may have potential but. … will have to be explored much further before we plunge headlong down the path of building plants (MA13)."

One Massachusetts energy industry consultant spoke of a "willingness" (showing social and public acceptance) to welcome CCS technology into the state to reduce greenhouse gas emissions:

> "If [CCS] becomes proven, if it's cost effective, and the pressure will mount for us to meet the goals of the Global Warming Act that just got passed, then certainly we'll be involved in it and how it's structured and so forth" (MA15).

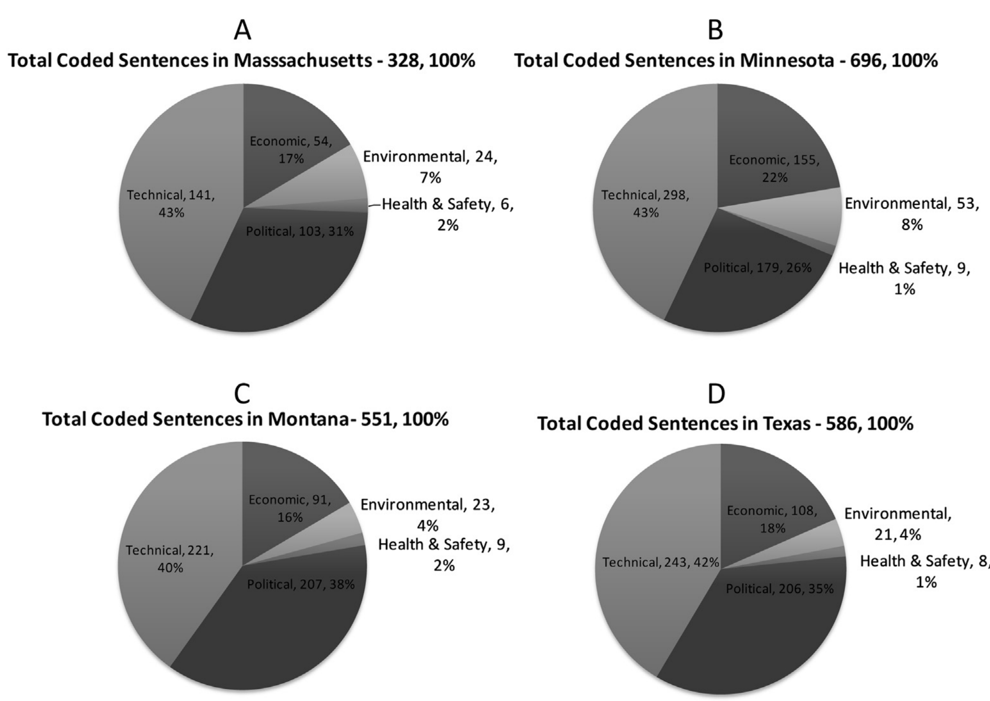

Fig. 2. Percent of coded utterances (absolute numbers listed before percentage) in each of the five frames in the interview transcripts in each state. 1a – Massachusetts, 1b – Minnesota, 1c – Montana, and 1d – Texas.

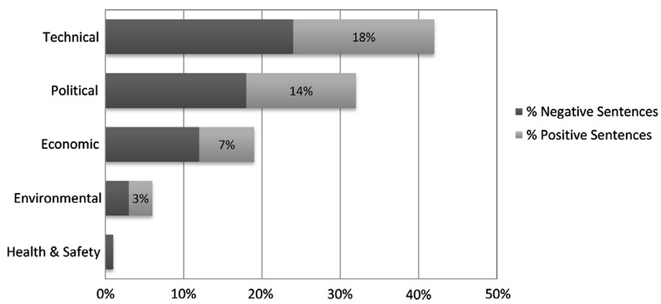

Fig. 3. Total distribution of positive and negative framing in each of the five frames when results of all four states are compiled.

On the political front, CCS is already included in Massachusetts legislation: As one interviewee mentioned "[CCS was included] in the Green Communities Act .... [where] there was a GHG emissions standard set for it" (MA03). Despite the political support for including CCS into policies the state level, one stakeholder highlighted that Massachusetts with its limited geological storage capacities to store CO_2 could be better off "pay[ing] for somebody else's capture of carbon in another state, perhaps they could get credit for that" (MA02). This apparent disconnect between adopted policies to promote CCS and the technical realities of actually deploying CCS highlight an important difference between adopted policies and the socio-political context for deployment.

Several MA stakeholders also mentioned local resistance and liability issues as important obstacles to CCS development in the state: "the law has not yet evolved to the point where it knows exactly how to handle underground storage of carbon"(MA03). Limited public awareness and the potential of negative public reactions were also identified as issues in Massachusetts.

> "I think it's an opportunity that a lot of people don't necessarily know about, so I think you're gonna have a hurdle from the general public when they hear carbon sinkholes or …. capturing the carbon and burying it" (MA06).

In the economic frame, Massachusetts' stakeholders' perceptions of CCS were mostly negative and based on lessons learned from other states and in other parts of the world. One interviewee expressed his concern about the expense of CCS projects, citing the example of "the ill-fated FutureGen… [that] had so much so overruns that [it] became not feasible" (MA01).[1] Moreover, another stakeholder highlighted the complex and costly system needed to deploy CCS in "places like New England that do not have appropriate storage sites [where they] would have to be pumping CO_2 vast distances or finding a way to transport it safely, which [would be] very expensive" (MA05). There were also worries that funding CCS would divert funds from other technologies: "it's a slippery slope because once funding starts going to storage, it'll start incentivizing that technology and move us away from renewables" (MA05).

All mentions of the environmental and health and safety frames in Massachusetts were negative; often highlighting that CCS technology alone falls short in providing a complete solution to many environmental problems:

> "If you're just doing carbon capture and it doesn't address the other air emission issues that [affect] human health.… like sulfur dioxide and nitrogen oxide" (MA 18).

4.2. Minnesota

In Minnesota, we interviewed twenty three energy technology stakeholders (Table 3). Awareness about Minnesota's coal-intensive electric sector shaped stakeholder perceptions of CCS. "We support converting old coal plants because we know we need a deep reduction in CO_2 emissions" (MN04). Nevertheless, like in Massachusetts, the technical discourse in Minnesota also focused on the lack of geologic storage capacity within the state, with frequent statements like: "Minnesota is uniquely poorly suited for this [CCS]" (MN08).

Despite the lack of geological storage capacity in Minnesota there are several pieces of legislation that focus on broad GHG reduction strategies, including the 2007 Next Generation Energy Act, which set a target of 30% emission reduction by 2025 and 80% by 2050 (2005 baseline), though none explicitly mention CCS (Boies et al., 2008). Furthermore, the state was exploring the use of coal IGCC (Integrated Gasification Combined Cycle) technology as a clean energy technology and has passed incentive regulation supporting a proposal for a merchant-power IGCC plant (Wilson et al., 2009).

> "[Excelsior Energy is] an energy development company and our sole mission right now is to commercialize IGCC and then CCS technologies. […] lots of federal benefits have been awarded to the project [Mesaba Energy Project[2]] because […] IGCC needed to be commercialized" (MN11).

In 2007, the Minnesota legislature granted $90,000 to the state Geological Survey to study if Minnesota has suitable geologic formations to sequester CO_2 (Wilson et al., 2009). While no sequestration resources were located in the state boundaries, there are opportunities regionally. One interviewee referred to other opportunities in nearby states: "Minnesota doesn't have the types of resources.… but the Dakotas do" (MN20). Additionally, the state is a participant in the U.S. Department of Energy's (DOE's) Plains CO_2 Regional (PCOR) Partnership, so the state could consider sequestering captured CO_2 in regional sedimentary basins within that partnership (Thorleifson, 2008). One stakeholder pointed out that:

> "There are oil fields in North Dakota that aren't that far from the power plants as well as [in] Alberta, Canada where Basin Electric is already transporting carbon from its synfuels plant into.… Weyburn oil field" (MN01).

In Minnesota, the scale of potential CO_2 storage operations was also a concern: "How much carbon we're talking about? How much of a land area .… we're talking about [for CO_2 storage]?" (MN04). The reliability of storing CO_2 permanently underground was also mentioned, which according to one environmental advocate is "not dissimilar to storing nuclear waste" (MN05).

The technical aspects of CCS played a significant role for Minnesota interviewees, with stakeholders expressing doubts about the near-term commercial availability and readiness of CCS: "We're very skeptical of coal plants that want to be built on the understanding that someday, [CCS] will happen and when it does they are just going to automatically have their plant ready for it" (MN18).

[1] FutureGen, a large-scale CCS demonstration project, was initially announced by the Bush administration in 2003 to be the world's first zero-emissions power plant. This project had significant industry support and involvement with initial plans including construction of a new 275 MW coal gasification plant with underground injection and storage of CO_2. Government plans for this project have been restructured several times throughout the past 8–9 years, and the current scope of the project is significantly reduced from its initial conception.

[2] Excelsior Energy proposes to license, construct, own and operate the Mesaba Energy Project, an Integrated Gasification Combined Cycle (IGCC) electric power generating station. Reference: Smith (2006) Clean Coal: Clean Coal Technology Is Not an Oxymoron. Coal Power Magazine.

The overall efficiency of deploying CCS was another important technical issue stakeholders felt should be addressed:

> “To capture it and compress the gas it takes about 30 MW, so you’ve got kind of a conflict between capturing it, which is a good thing, and storing it, which is a good thing, but you’re going to have to produce more energy to make the system work, which would tend to reduce the efficiency” (MN01).

Like Massachusetts, Minnesota has adopted GHG reduction policies, and this was reflected in some stakeholders’ supportive comments about CCS and its GHG mitigation benefits, for example, “climate-friendly technologies [like CCS] are the major focus of our efforts these days” (MN17). Nevertheless, there was still no connection made as to how significant a role CCS will play in meeting state’s GHG reduction targets. Stakeholders also thought that: “there’re still a lot of unknowns in terms of the regulatory framework of how are you going to do it [CCS]? And what permits you need to do it? And what the legal requirements are for doing it?” (MN21). The lack of regulatory frameworks related to liability and pore space ownership was felt to pose further resistance to CCS development in Minnesota as indicated by one stakeholder:

> “Who owns the pore spaces underground? …. And how many landowners would you need to get to agree to store the carbon? What are the legal costs of making that happen?” (MN04)

In Minnesota within the economic frame, several stakeholders saw CCS as an extension of the existing energy system and emphasized the need to account for environmental cost associated with the continued use of cheap energy sources like coal: “we’re realizing that it’s only cheap because we failed to account for or pay for all of the costs” (MN23). Discussions on the cost of carbon storage and the potential increase in electricity price were also quite frequent:

> “The proposed plant on the Iron Range [Mesaba Energy Project] is looking.... to take 30% of their CO_2 and pipe it to North Dakota for oil extraction and that’s promising but it’s not enough to justify the building of the plant in my opinion because there’ll still be a big increase in carbon emissions and at great cost” (MN02)

Within the environmental frame, Minnesota stakeholders did mention some positive aspects of CCS; this quote demonstrates an explicit connection being made between environmental benefits and CCS technology deployment.

> “[CCS is] certainly not our preferred option, but when you are in as much trouble as we are in terms of global warming, you can’t afford to get rid of anything that has the potential to be part of the solution” (MN08)

The health and safety risks discussed in Minnesota arising from CO_2 leaks and possibly resulting in the destruction of ecosystem and human life were also mentioned: “CCS is not yet a proven technology, … there are concerns about its potential stability, the health impacts and so on, ... there are problems with ….whether CO_2 actually will stay in the ground and not come back out” (MN19).

A respondent at a non-profit energy consultancy provided one perspective on a potential blueprint for developing CCS projects in Minnesota:

> “[F]inding partners to … map out all of the pieces that would be required for a [CCS] project … would .... probably be the very beginning challenge, ... making sure the technology works, … selling the whole thing to a regulatory commission or to an independent party that would finance such a project and then getting the public to accept that kind of build-out is in their best interest” (MN20).

4.3. Montana

In Montana, 20 stakeholders were interviewed (Table 3). For Montana, a state with Department of Energy funded CCS technology pilot project experience as well as significant experience with natural resource extraction, the discourse within the technical frame was still more negative than positive. However, rather than focusing on concerns about storage potential, participant comments in Montana focused more on doubts about the commercial readiness of the technology and the ability for the technology to be implemented on large scale. “I’m troubled that it’s never been proven out on the scale that will be necessary” (MT11).

Within the technical frame in Montana, while several stakeholders agreed that CCS is a “very interesting idea and [that they are] all for trying to emulate nature [as] nature has stored carbon for a long time” (MT 11), skepticism about the capacity to store CO_2 was expressed by several interviewees. In the words of one energy developer:

> “What I’ve read in the Intergovernmental Panel on Climate Change report on carbon sequestration is … that worldwide, we would have about enough geological formations for about 60 years of sequestration. So sequestration is a finite resource as well” (MT 04).

One Montana stakeholder also mentioned the advantage that Montana has with respect to potential storage locations and the mapping of these locations: “Montana is unique in that it has a number of geological reservoirs available that have been mapped and characterized by the Big Sky Carbon Sequestration partnership” (MT20).

Doubts about the readiness of the technology for commercial deployment were also mentioned in Montana: one stakeholder said that despite “an awful lot of research [The Big Sky Carbon Sequestration Group] came up with the big fat nada” (MT 07).

In Montana, the future use of the vast coal deposits has become a critical agenda item for Montana’s political leadership, as represented in this stakeholder’s comments:

> “The governor is fixated with clean coal, and … that’s probably why he has a 70 percent approval rating in the state of Montana because Montana’s got … a quarter of the nation’s coal.” (MT11)

The importance of coal mining to this state’s current and future economic development may explain the strong focus on CCS as an enabling technology for continued coal use. “When Governor Schweitzer was first elected in 2004, there was a lot of talk about how [he was] going to be doing coal projects, [if he was] gonna be capturing the carbon in some way” (MT13). In December 2005, the Governor established the Climate Change Advisory Committee (CCAC), tasked to evaluate state-level GHG reduction opportunities in various sectors of economy. The recommendations made by the committee were designed to reduce statewide GHG emissions to 1990 levels by 2020, and to find further opportunities for decreasing reliance on imported fossil fuels, and establishing Montana as a leader in developing new technologies to produce cleaner burning fuels while sequestrating CO_2 (Peterson et al. 2007). Hence CCS became “one of the Governor’s … pet projects or pet issues” (MT19).

The concerns and perceived requirements for effective advancement of CCS expressed by one Montana stakeholder from an environmental non-governmental organization are representative of similar comments by several other Montana stakeholders:

> "We need to get the regulations in place that guarantee that we will have very good site analysis prior to anything going into the ground …. That we have really excellent verification and monitoring requirements, and that … the industry remains liable for at least a hundred years to make sure that in … ten years things don't go wrong" (MT 07).

In Montana, additional concerns about the influence of industry on proposed legislation for a regulatory framework for underground CO_2 storage including the designation of liability and ownership rights (i.e. surface vs. pore space vs. mineral) were also frequently mentioned "one of the things that the utilities were requiring is a government guarantee of no liability if they sequester carbon" (MT 04), other stakeholders felt that: "the industry, when they started talking about how to deal with … subsurface ownership, or … just clarifying surface ownership … don't want these issues clarified. … It's not in their interest to clarify these issues" (MT 07).

Discussion on the economic frame in Montana often included comments on the advantage of CCS for development of local coal resources and job creation. These were however outweighed by concerns about the relative cost of electricity production with CCS with stakeholders indicating that: "to clean up the dirty electrons, you'd be paying five and a half cents more …, [or even] more, so let's just figure what you're getting in addition to what you're actually paying for the dirty electrons" (MT04).

The environmental frame received minimal attention from Montana stakeholders. The majority of statements attributed to this frame highlighted the current state of environmental quality resulting from coal power plans and the amount of emissions that could be reduced from the adoption of CCS. There were also some explicit connections made between climate change and the adoption of CCS energy in Montana.

> "In order to solve the climate crisis we have to use [CCS] as a bridge to the future because we do have a heavy coal dependence" (MT07).

In Montana like most states in the study, minimal attention was given to the effects of CCS on public health and safety. The few when mentioned, these risks were associated with the failure of underground storage sites due to earthquakes or other geological disturbances, resulting in CO_2 leaks, water contamination, and possible destruction of ecosystem and human life. In the words of one stakeholder,

> "And then we find out in a few years that it .... contaminated ground water, or you've had some leaks in somebody's field, and all the plants are dead or worst case scenario .... people die" (MT 07).

In 2003, Montana State University, was awarded one of the DOE's seven Phase I regional carbon sequestration partnerships, making "Montana State right here in Bozeman …. home of the Big Sky Carbon Sequestration Project" (MT11). This joint government-industry partnership has engaged key stakeholders in the research and development of CCS and linked Montana to a nationwide network of CCS research.

Skepticism of the technology's development was also expressed in another way, when one interviewee from a prominent environmental non-profit mentioned that delays in commercial-scale development of CCS technology could be a strategic tactic used by the industry.

> "Industry is more content being able to argue that this is a possible technology down the road, than they are actually making it work. They're only going to make it work if carbon costs something. They just want to keep this debate alive so they can keep saying that, you know coal can be clean" (MT 07).

4.4. Texas

Even with the opportunities for EOR with CCS in Texas, negative comments were still in the majority in the twenty-two stakeholder interviews, although the portrayal of CCS in Texas was less negative than in the other states. Within the technical frame, on the positive side, Texan stakeholders frequently showed confidence in the operational success of the technology for injecting CO_2 with EOR: "the technology has been used successfully in Texas for approximately 30 years … in the Permian Basin" (TX 04). In addition, examples of available infrastructure for successful implementation of CCS projects in the state were often mentioned. A state government official indicated that Texans: "have a huge system of pipelines, so I think we're probably in a pretty good place …., to be able to gear up to transport the CO_2 quickly" (TX 05).

In Texas the political frame was explicitly focused on the legal and regulatory feasibility for CCS: "We know enough to design an effective regulatory framework and an effective regulatory framework is currently within sight" (TX08). Comments within the political frame included some different issues than those raised in the other three states. For example, Texas has established important regional carbon sequestration linkages by becoming the CCS project center for DOE's programs Southeast Regional Carbon Sequestration Partnership (SECARB) and Southwest Partnership (SWP). These partnerships have helped the state assess state-specific approaches and potential for capturing and permanently storing CO_2. Texas was also a finalist in the proposed FutureGen site selection process.[3] In its attempt to create a viable policy environment for the project, Texas decreed in 2006 that it will take ownership of the CO_2 sequestrated and relinquish the operators from any liability in the case of an accidental escape of carbon.

> "If the state steps in and says, "No, that's our liability, not yours," that makes … a carbon sequestration project much more attractive" (TX 07).

Within the political frame, stakeholders' indicated that as the largest domestic oil production state, Texas could benefit substantially from federal climate policy or the creation of Texas greenhouse gas reduction target policies to promote CCS technology.

> "The biggest challenge is probably lack of a market signal to overcome the high cost. And that, in turn, translates into the challenge of needing to pass climate legislation. So the biggest single challenge to CCS is the challenge of passing cap and trade legislation in Washington" (TX 8)

In Texas, several of the policy stakeholders interviewed also showed concerns about the lack of regulations in place for protecting landowner rights and clarification on liability issues. A lawyer in an environmental non-profit pointed out concerns with pore-space ownership:

> "There's a big question with even figuring out who owns the property rights. … You have to figure it out for every separate jurisdiction and there is no clear-cut decision anywhere" (TX08).

The economic frame in Texas incorporated discussions about moving forward with CCS deployment to take advantage of oil and gas production and to create jobs. Stakeholders also noted that the negative implications of such projects could include financial risks to the companies or tax payers in an event the project fails due to poor market demand, a fluctuating economy, permitting problems,

[3] The proposed FutureGen project was eventually awarded to Mattoon, Illinois before it was subsequently was canceled.

failure to receive government incentives, and other issues. From the consumer perspective, a respondent commented on the high level of financial risk associated with CCS.

> "It's a zero sum gain if we put all of our public dollars into CCS research and development, and it doesn't work out. We're screwed. …, so yeah, we see it as a distraction at best, big sink hole at worst" (TX 10).

Within the environmental frame in Texas, a few stakeholders positively associated CCS deployment and climate change: "carbon sequestration, … we hope, will have an impact on global climate change" (TX05). Others focused on reducing CO_2 emissions from coal: "we're gonna have coal for a long time, and probably it's prudent to look at technologies that could meet those mandates of not producing any more CO_2, just to tide us over" (TX 15). Negative references within this frame were highlighted by statements about CCS encouraging continued use of coal resources which one environmental advocate indicated would involve: "ripping up large swaths of the world to mine coal … it is imperfect and it's just stupid" (TX01). Other interviewees raised concerns about the potential environmental degradation from sequestration: "[CO_2] leaching into water supplies, leaching into ground water, coming out in springs and rivers and stuff, would be a concern; … subsidence, which … changes the terrain near the top of the ground [is also a concern]" (TX03).

In Texas, the few statements coded into the health and safety frame were negative; the majority of stakeholders voiced concerns about the possibility of CO_2 leakage from a plant failure, water contamination and stressed the need to enact safety measures for prevention:

> "You wanna encourage people to … capture, transport and sequester CO_2, but you also wanna protect ground water and public safety and, … wanna make sure that it's […] stor[ed] permanently underground rather than leaking somewhere" (TX 05)

Overall, stakeholders acknowledged that the favorable support for the development and deployment of CCS gives Texas some unique opportunities:

> "There is probably better awareness and more realization that the train is coming. The state can take one of two approaches. … we can either stand in front of it and be in the denial phase but as the largest carbon emitter in the country …, probably the better thing to do would be to jump on the train and help steer it and say, "How can we be part of the solution? How can we utilize our expertise in oil and gas and reservoir management and all of these things to basically lead the country in carbon capture here?" So … I think things are turning slowly from denial to more acceptance" (TX 07).

The multiple opportunities for capturing CO_2 in Texas were mentioned by several interviewees: "As a large carbon emitter from very large point sources, like refineries and petrochemical plants and utilities, … [Texas has] a lot of incentive to reduce … carbon emission, so we have a lot of reasons why we might like CCS" (TX 17). The unique position that the state of Texas is in with regard to using captured CO_2 in EOR was also mentioned by several stakeholders: "the most immediate opportunity is not necessarily the storage but the utilization of carbon for EOR" (TX 07). "Right now, [the state can] basically buy and ship naturally occurring CO_2 from Colorado and pipe it into the Permian basin for EOR" (TX 07). The extensive opportunity for CCS implementation and economic benefits associated with using CO_2 for EOR operations in nearly depleted oil fields were also indicated: "We are supportive of a series of incentives to be able to develop the technology to compress CO_2 and use it for tertiary [EOR] recovery" (TX 01).

Despite these opportunities some respondents indicated that "[CCS is] not a silver bullet" (TX08), and acknowledged many economic, political, and environmental obstacles:

> "What we lack, it's not the knowledge of how to do it, but an economic incentive to make people want to do it and a regulatory framework that provides certainty to the developers …, and certainty to the public that they'll be able to do this in a safe manner that protects the environment" (TX08).

The Texas legislature, unlike Minnesota and Massachusetts, has not yet adopted any GHG reduction policy; on the likelihood of Texas passing any climate-related legislation one environmental non-profit manager said:

> "Texas would probably be the last or certainly one of the last states to voluntarily embrace something like a cap and trade program. You won't get that kind of a program in Texas till it's adopted nationally" (TX 08)."

4.5. Integrated discussion of state comparisons

Differences in CCS discourse among energy sector actors in these four states reflect how political and cultural factors are influencing (and are influenced by) development of emerging technologies. While a strong commitment to GHG reductions in Massachusetts and Minnesota resulted in some positive perceptions of the potential value of CCS, this was coupled with a practical wariness of CCS due to the lack of potential storage locations in those regions, even though CCS had been explicitly mentioned in some policy documents. On the other hand, the on-the-ground experiences and opportunities associated with demonstration projects in Montana and Texas resulted in more positive discourse in those states.

These results complement research on state-level CCS policy differences (Pollak et al., 2009; Pollak et al., 2011) by providing a more nuanced analysis of the socio-political context for policy development. This research goes beyond policy analysis by providing crucial details shaping the risk and benefit framing of key stakeholders active in creating energy policy. There are important relationships between state-level CCS policy and the stakeholder discourse analyzed here. In addition to creating policy which can support or thwart new technologies like CCS, energy policy stakeholders can also influence facility siting and shape public perceptions of emerging technologies. While some of the actors interviewed in this study may have been directly involved in CCS policy or technology, most were not directly involved or engaged in CCS-related work. Thus this subset of influential actors who are engaged in creating policy and shaping public opinion is particularly important for understanding the context of CCS development.

This comparative analysis of discourse among energy sector stakeholders also highlights variation in technical understanding of CCS technologies, which is sometimes limited. This analysis helps to explain the complexity of factors contributing to state-level CCS policy differences and shaping the larger discourse surrounding CCS. This research highlights both large and small differences shaping CCS discourse between stakeholders and states and provides a nuanced view into the conversations shaping policy making and CCS development.

5. Conclusions

This analysis of energy policy stakeholders' perceptions of CCS reveals a diversity of perspectives on the potential benefits and risks of this technology and offers a nuanced view into the insights shaping the salience of CCS within different state contexts. This research complements earlier policy studies and further demonstrates how the emerging technology of CCS has different representations and raises a broad spectrum of issues for different actors in different states. This research contributes broadly to environmental management by highlighting the variation of and nuance in stakeholder's perspectives on emerging climate mitigating energy technologies. It also highlights how energy stakeholder understanding of emerging technologies is often limited and is shaped by the local political context, sometimes more than the physical system constraints. The state-level variation in energy priorities and perceptions revealed in this study also reflects inherent challenges in the development and implementation of national-level energy policy.

By exploring stakeholder perceptions of CCS in each of these four states, and categorizing their interview responses in five frames, different patterns of state-level discourse emerge. In all four states, stakeholders' mentions of CCS risks were more frequent than mentions of the benefits of CCS. This result is different than similar work on wind technology, where the risks and benefits were more balanced in energy stakeholder discourse (Fischlein et al., 2010). The prevalence of negative framing of CCS, primarily as a risk, may signal serious concerns that could lead to a lack of motivation for further development. A commonality across all states was that technical, political/legal and economic frames dominated stakeholders concerns, with intermediate attention given to environmental frames and minimal mention of health/safety concerns.

The infrequency with which CCS is discussed in relation to its potential to reduce greenhouse gas emissions, in the environmental frame, is particularly interesting. Although reducing CO_2 emissions is the major rationale for pursuing CCS projects, this was not frequently mentioned by the interviewees. Perhaps this absence represents an accepted assumption of this environmental benefit, so individuals did not feel that it was necessary to talk about it. Conversely, perhaps this lack of a frequent connection represents the fact that stakeholders do not consider the environmental benefits of CCS to be a dominant driver or prominent issue when they consider CCS. Rather CCS may be seen as an additional fossil-fuel perpetuating technology with connections, benefits, and early opportunities associated with Enhanced Oil Recovery (EOR). The lack of discourse connecting CCS with its climate mitigating potential could suggest a perceived distant and indirect climate benefit of the technology.

Overall, stakeholders across all states suggested that CCS deployment will be dependent on a favorable economic environment, coupled with suitable regulatory measures, and a legislative framework to manage long-term risks. A broad spectrum of technical understanding about CCS technology is apparent among the energy policy stakeholders interviewed. Some appear to know very little about CCS technology, while others seem to have a strong grasp of the technical details. This observation is an important reminder that those involved in policy-processes often have limited technical understanding of the technologies that they may support or oppose and that adopted policies may not always reflect technologic realities.

Despite some similarities among the four states, the comparison reveals important state-level differences in how stakeholders perceive and frame CCS that suggest direct linkages with each state's economic interests as well as the states' geology and policy environment. These subtle differences in discourse highlight profoundly different energy policy debates. Stakeholders in Minnesota and Massachusetts, who both have policies explicitly targeting GHG emissions but lack geological CO_2 storage capacity, reveal in their interviews some level of understanding that CCS deployment for these states would depend on storing captured CO_2 elsewhere. In contrast, explicit economic and political opportunities associated with CCS in Montana (strong coal reliance) and Texas (EOR) are reflected in a more positive discourse about the technology in those states. In Montana, some stakeholders see CCS as a "trump card" used by political leadership as an attempt to secure a future for Montana's vast coal resources. Texas bids for FutureGen and other near-zero emissions power plants project show the state's willingness to explore significant economic opportunity and take advantage of captured CO_2 through use in EOR operations. In Texas and Montana it seems evident that the main interest in CCS is driven by economic and political forces beyond reducing GHG emissions and that the greenhouse gas reduction association is secondary.

The socio-political context for CCS is rapidly changing in each of these four states, and the landscape is also changing at the national and international levels. The results of this research, therefore, provide an important snapshot of this evolving socio-political context highlighting conditions during the time period when the interviews were conducted. It should be noted that these interviews were conducted in 2008 and 2009 which could be considered to be at the cusp of a waning in support for and interest in CCS that has since become more widely evident (Shackley and Evar, 2012). While the energy policy/technology landscape is dynamic, some of the important subtleties and interactions associated with the state-specific context highlighted here are persistent and slow to change, so insights from this study have relevance beyond narrow considerations of the future of CCS in these four US states.

As the US struggles to create national-level energy and GHG reduction policies, policy makers and energy planners at the state-level clearly have a diversity of perspectives on the potential and challenges of CCS, as well as other energy technologies. These actors make decisions that influence their states' energy future and the potential for CCS to play a role in that future, so characterization of the emerging discourse and analysis of the variation in these energy stakeholders' perspectives is valuable to considering the socio-political state-level context within which energy technologies develop.

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Appendix A

Interview protocol

(all questions included in the larger study as they relate to wind technology, CCS technology, and climate change are listed below).

1. Tell me about your Organization/Industry/Agency.
2. What are the major issues that influence your organization?
3. How, if at all, has climate change influenced your organization?
4. How do you see your organization responding to climate change in the future?

5. What energy technologies do you expect to be most important in the future? Can you describe what about these technologies lead you to think they will be important?
6. Which of these technologies are most relevant to your organization?

Wind technology

7. We are particularly interested in two technologies, wind and CCS. Tell us what you think about wind energy?
8. Tell me how your organization has been involved in wind energy? How do you see yourselves being involved in the future?
9. What do you see as the challenges and opportunities for wind?
10. How do these issues play out in [Massachusetts/Minnesota/Montana/Texas]?

CCS technology

11. We are particularly interested in two technologies, wind and CCS. (interviewees are given an option to be read CCS definition, see Appendix B) Tell us what you think about CCS?
12. Tell me how your organization has been involved in CCS? How do you see yourselves being involved in the future?
13. What do you see as the risks and benefits for CCS?
14. How do these issues play out in [Massachusetts/Minnesota/Montana/Texas]?

Appendix B

Carbon capture and storage definition

(interviewees had an option to be read the following definition before questions about CCS technology were posed).

Carbon sequestration is the capture and long-term storage of CO_2. *Geologic carbon sequestration* captures CO_2 from power plants, oil refineries, and other industrial facilities (point sources) and stores it in underground geologic formations such as deep saline formations, depleted oil and natural gas reservoirs, and unmineable coal seams.

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