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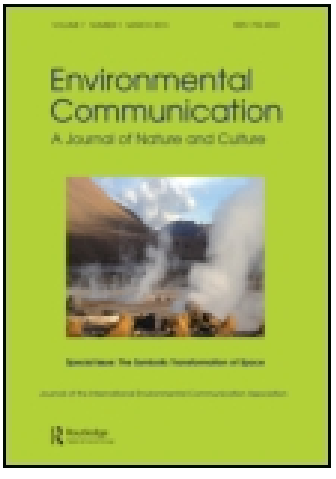

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Carbon capture and storage (CCS) has received abundant federal support in the USA as an energy technology to mitigate climate change, yet its position within the energy system remains uncertain. Because media play a significant role in shaping public conversations about science and technology, we analyzed media portrayal of CCS in newspapers from four strategically selected states. We grounded the analysis in Luhmann's theory of social functions, operationalized through the socio-political evaluation of energy deployment (SPEED) framework. Coverage emphasized economic, political/legal, and technical functions and focused on benefits, rather than risks of adoption. Although news coverage connected CCS with climate change, the connection was constrained by political/legal functions. Media responses to this constraint indicate how communication across multiple social functions may influence deployment of energy technologies.

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With increasing pressure to mitigate climate change by reducing greenhouse gas (GHG) emissions, the relationship between energy production and climate is receiving increased media attention (Brossard, Shanahan, & McComas, 2004; Carvalho & Peterson, 2009; Gordon, Deines, & Havice, 2010; Staudt, 2008; Stephens, Rand, & Melnick 2009). This relatively recent swell in coverage follows a brief peak that occurred in 1988 when the Intergovernmental Panel on Climate Change (IPCC) was established and the US Senate held hearings on climate change (Peterson & Thompson, 2009). Now, with many nations adopting climate policies and development of mitigation strategies well under way, news of climate-related activities has once again captured media attention, following the cyclical pattern typically found in independent US media (Brossard et al., 2004; Gordon et al., 2010). As a primary source of information and influence on technology and its associated risks and benefits (Maibach & Hornig Priest, 2009; Peterson & Thompson, 2009), media play an important role in public opinions of technologies that may contribute to mitigating anthropogenic climate change. Further, media coverage provides insight into emerging public conversations, which is especially important for understanding how new technologies may fit into socio-technical systems (Stephens, Rand, et al., 2009). Media representations of energy technologies are strategically important to the emerging relationships between people and those technologies. In this project, we analyzed media coverage of carbon capture and storage (CCS) to clarify the public conversation about how this technology may function within the US energy system.

As the second largest emitter of GHGs in the world, the USA will need a diverse portfolio of technologies to significantly reduce its GHG emissions. The US Department of Energy (DOE) is especially interested in including CCS in the national energy portfolio because of the technology's potential to decrease CO_2 emissions from the coal-dependent electricity sector and other stationary industrial sources, while allowing continued use of fossil fuels and established infrastructure (Stephens, 2009). With roughly 60% of global CO_2 emissions coming from fossil fuel use, and 71% of current US electricity production coming from fossil fuels, the potential impact of CCS technologies is substantial (Intergovernmental Panel on Climate Change, 2007; U.S. Energy Information Administration: Independent Statistics and Analysis, 2010). Commercial deployment, however, depends not only on the maturity of technologies for sequestering CO_2, but also on public support, both for policies that encourage reduction of GHG emissions and for local storage of CO_2 under people's back yards (Bradbury et al., 2009; Stephens, Bielicki, & Rand, 2009).

We characterize the public conversation about this emerging technology within the energy system by analyzing CCS coverage in newspapers from four strategically selected states. Our analysis identifies (1) frequency of CCS coverage and differences between newspapers as correlated with their proximity to energy production and/or political centers (includes changes over time), (2) social functions emphasized, (3) relative emphasis on risks and/or benefits, and (4) attention to climate change as

a driver for adopting CCS technologies. We first outline our theoretical framework for analyzing CCS communication and then briefly review communication research on media coverage of climate change. Third, we explain our methods. Fourth, we report our results. Finally we discuss what our findings suggest regarding how the public conversation about emerging technologies such as CCS may contribute to transforming the energy system.

Theoretical Perspective

To better understand how society conceptualizes and addresses environmental issues such as climate change, we begin with Luhmann's (1982, 1989, 1995) theory of social function systems. Luhmann posits that while society is connected to its environment, it cannot communicate directly with that environment (Peterson, 1992). Rather, as is the case with any system, society can respond to its environment only according to its own mode of operation, which, Luhmann argues, is communication (Luhmann, 1992; Peterson, 1992). Luhmann (1989) describes the subsystems of late modern society as distinct, yet related, systems that communicate with each other only when sufficiently perturbed. He argues that "only in exceptional cases (i.e., on different levels of reality, irritated by environmental factors), can it [society] start reverberating . . . This is the case we designate as resonance" (Luhmann, 1989, p. 15). Anthropogenic climate change is an environmental factor that has perturbed the social system, leading to resonance, or communication, between function systems.

Luhmann (1989) identifies the major function systems most relevant to science and technology as economy, law, science, politics, religion and education. Although all subsystems are closed in respect to their organization and mode of operation, all retain the ability to resonate with one another through communication. Internal resonance, or communication, enables society to respond to the complexities presented by environmental perturbations. Each operation (communicative event) of a system reproduces the system's boundary by further embedding itself into a network of future operations. System boundaries, then, lack permanence; at the same time they are nearly impossible to breach. Because every part of a system is contingent on every other part, it is difficult to predict how society will respond to environmental perturbations. Instead, each issue, as a unique phenomenon, will be communicated differently, depending on which social functions it disturbs. Despite its direct application to challenges faced by late-modern society, however, Luhmann's theory provides an exclusively macroperspective and offers little guidance for empirical research. This may account for the fact that, despite the remarkably central position Luhmann affords communication, relatively few communication and policy researchers have made use of this powerful social theory (Boswell, 2011; Calliess & Renner, 2009; Fischlein et al., 2010; Stephens, Rand, et al., 2009).

We used the socio-political evaluation of energy deployment (SPEED) framework (Stephens, Wilson, & Peterson, 2008), which offers an empirical application of Luhmann's social theory to energy policy, to guide our analysis. SPEED focuses on social dimensions of emerging energy technology deployment, particularly as related

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to risks and benefits, claiming that integration of new energy technologies into a social system relies primarily on aesthetic, economic, environmental, health/safety, political/legal, and technical functions. With the exception of the aesthetic category, SPEED categories directly complement the primary function systems identified by Luhmann (Stephens, Rand, et al., 2009). SPEED focuses Luhmann's science function system on environmental science and human health/safety, amalgamates his legal and political function systems into political/legal, and relabels Luhmann's education function system as technology. It is important to realize that, within Luhmann's theoretical framework, education refers to better/worse, as in certification (that some technologies work better than others) rather than to knowledge, which he frames within the science function system. By using SPEED to analyze media from the selected states, we identified and characterized the social functions that have been emphasized in public conversations about CCS and identified challenges the current emphases may pose for diffusion of this emerging technology into the US energy system.

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Research on Climate Change Communication

Mainstream news media play an important role in informing the public of scientific and technological findings associated with climate change and its mitigation (Carvalho, 2007; Corbett & Durfee, 2004; Nisbet, 2009). As intermediaries between the public and political and scientific elites (Manning, 2001), media frame how problems are discovered, how the public interprets problems, and public acceptance or rejection of technologies developed to remediate problems (Stephens et al., 2008; Weaver, Lively, & Bimber, 2009). For controversial issues such as climate change, news media help frame both the problem and its possible solutions, interacting with multiple sectors of society and enabling people to integrate personal experiences with political issues (Boykoff & Boykoff, 2007; Hansen, 1991; Olausson, 2009). News media therefore not only influence the flow of information, but also political agendas (Anderson, 2002; Arvai & Mascarenhas, 2001; Foust & Murphy, 2009). Because this project sought to clarify communication associated with incorporating technological innovation into the energy system using media as a proxy for public dialog on CCS, we turned to Luhmann's systemic approach to society for theoretical guidance.

Methods

We investigated news media's representation of CCS by analyzing newspapers from four states (Massachusetts, Minnesota, Montana, and Texas) with varying degrees of public acceptance and progress made toward CCS deployment. We selected this group of states for its ability to capture both high and low CCS capacity, and both strong and weak climate policy. Texas and Montana are traditional energy production states, and CCS would facilitate continued use of these resources in a carbon-constrained world. Texas and Montana also have abundant geologic and other natural capacities for CO_2 storage (Pollak and Wilson, 2009; Wilson, Stephens, Peterson, & Fischlein, 2009). In contrast, Massachusetts and Minnesota lack significant in-state

capacity to capture and store CO_2. They have, however, developed strong (by US standards) climate policies that encourage reductions in GHG emissions, while Texas and Montana have no climate policy. The four states also represent geographically and demographically diverse regions of the United States with significant variations in electricity production and cover a broad spectrum of historical relationships with energy, climate policy, and infrastructure.

We selected three newspapers from each state (Table 1), representing the (1) highest circulated newspaper in the state, (2) newspaper from the state capital covering a different geographic region in the state, and (3) newspaper covering the area closest to major energy technology activities. Articles from major newspapers were obtained using the LexisNexis™ Academic search guide. For newspapers not available on LexisNexis™, we used the newspaper's own archive system and individually sorted articles according to the same search criteria used for the LexisNexis searches. The search criteria were whether articles included the terms CCS, carbon sequestration, CCS, and/or clean coal in the title and/or lead paragraph of an article. By limiting the search to the title and/or lead paragraph, we ensured that the article focused on CCS. Search dates were from 1 January 1990—coinciding with the publication of the 1990 IPCC Assessment Report—to 15 June 2009. All types of articles were included in the analysis (i.e., news, business, editorials/ opinion pieces, etc.). Articles not strictly adhering to the search criteria were manually removed from the retrieved articles. Attributes were recorded for each article and articles were given individual identifiers. Article text was unitized at the sentence level for coding.

We developed a codebook grounded in the SPEED (Stephens et al., 2008) framework. In addition to the categories drawn from SPEED (esthetic economic, environmental, health/safety, political/legal, and technical), we included an "other" category for statements that were too vague to categorize, but still described CCS. We also differentiated benefits and risks associated with each potential function. Criteria for the six function systems along with respective benefits and risks of the technology were outlined in the codebook (Fischlein et al., 2010). All coders used QSR International's NVivo 8.0™ qualitative software to code articles, first individually and then as a team so that all articles were independently coded by at least two people and then corroborated by those individuals to ensure complete coding consensus. To enhance fidelity to the coding protocol and norms, we distributed articles so that each coder shared a certain number of articles with each of the other three coders. We

Table 1. Newspapers included in the news media analysis.

Newspaper type	Massachusetts	Minnesota	Montana	Texas
Highest circulation	*Boston Globe*	*Minneapolis Star Tribune*	*Billings Gazette*	*Houston Chronicle*
State capital or different region	*Springfield Republican*	*St. Paul Pioneer Press*	*Missoulian*	*Austin American-Statesman*
Closest to energy technologies	*Cape Cod Times*	*Duluth News Tribune*	*Bozeman Daily Chronicle*	*Midland Reporter Telegram*

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ran queries addressing the frequency of function systems employed over time to delineate salient patterns. We also used SPSS Statistics 17.0™ software to run General Linear Models with Levene's Test for Equality of Error Variance and the Dunn-Sidak method for pairwise comparisons to determine whether CCS was discussed differently across the four states. To examine change over time within each state, we conducted a Poisson regression and examined the likelihood ratio for significance. It should be noted that only years with CCS coverage were included in this analysis.

Finally, we determined the presence/absence of the term "climate change" and its variants as well as the term "emissions," within the articles focused on CCS. We included "emissions" because we discovered that many stories used reducing emissions as an indirect way to reference the climate mitigation potential of CCS. We used presence/absence to establish whether or not the article connected CCS with climate change.

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Results

Only 9 of the 12 regional newspapers reported on CCS technologies over the 19-year period, resulting in a total of 216 articles. Of those nine newspapers, all three newspapers in Montana and Texas, one Massachusetts newspaper (*Boston Globe*), and two Minnesota newspapers (*Minneapolis Star Tribune* and *St. Paul Pioneer Press*) published on CCS. Newspapers in Texas (119) and Montana (68) had the highest frequency of articles on CCS in comparison with Massachusetts (19) and Minnesota (10). Differences also existed within states, where the majority of CCS stories appeared in regional newspapers distributed near commercial energy production sites or CCS research sites (i.e., *Midland Reporter Telegram* and *Bozeman Daily Chronicle*). Regional newspapers closer to project sites focused on their local project [i.e., the *Bozeman Daily Chronicle's* focus on activities of the Big Sky Carbon Sequestration Partnership (BSCSP) or the *Midland Reporter Telegram's* heavy coverage of FutureGen, billed as the world's first coal-fueled near-zero emissions power plant].

We found minimal and highly sporadic reporting of CCS between 1990 and 2001 (Figure 1). More consistent reporting started in 2003 and began to increase in frequency in 2005 with a peak in 2007. Montana and Texas demonstrated the highest rates of reporting from 2005 to 2009.

Function systems

The political/legal function system dominated the coverage from all four states, with the highest rate in Montana, where 51% of coded material presented CCS as a political/legal issue (Figure 2). Montana's governor figured prominently throughout the articles as a proponent of using coal-to-liquids technology to reduce GHG emissions. Although the political/legal function system dominated in all states, there were statistically significant differences between the states, with Montana ($P = 0.000$) and Texas ($P = 0.003$) CCS articles demonstrating significantly more emphasis on political/legal functions than Massachusetts articles. The majority of these articles focused on states' attempts to preempt national legislation by developing state-level

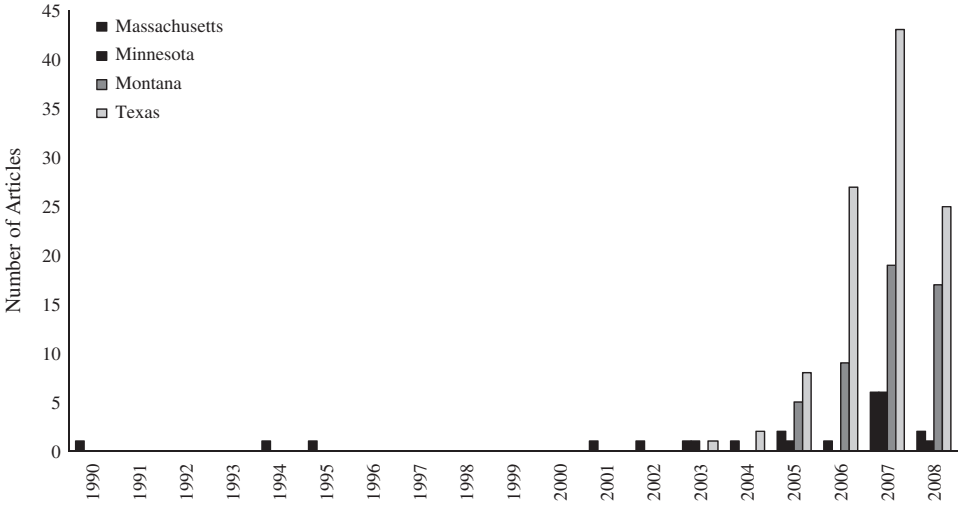

Figure 1. Number of articles reporting on CCS from 1 January 1990 to 31 December 2008 by state.

standards. Political/legal statements also described challenges associated with navigating the siting and permitting process, often connecting back to states' attempts at legislated incentives and other actions to encourage technology implementation. Texas newspapers exhibited an especially high level of reporting on siting and permitting (47% of coded utterances).

Technical and economic function systems were next in level of coverage and exhibited no statistical difference across states. These two functions were often discussed within the same articles as political/legal functions, indicating the close

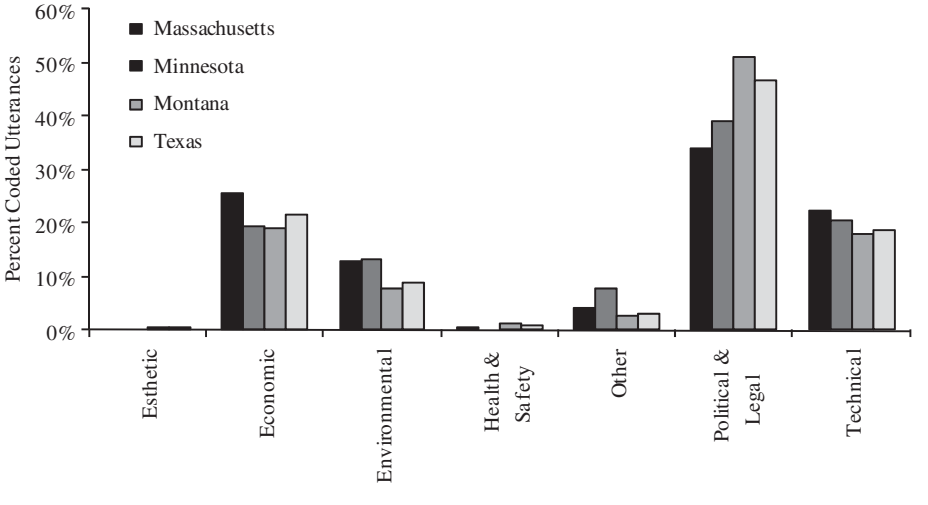

Figure 2. Comparative breakdown of function systems by state, reported as percent of coded utterances.

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relationship between economic development, project planning, and the need for a legal framework to guide deployment. Most articles promised the creation of jobs in the communities where CCS projects were proposed. In Montana and Texas, economic incentives to move forward in project development included taking advantage of the states' fossil fuel resources such as coal in Montana and oil and gas in Texas. These states have large capacities for CO_2 storage with Texas particularly interested in the availability of cheap CO_2 for enhanced oil recovery (EOR), a process for recovering oil from nearly depleted oil fields. Few articles reported on risks associated with such projects other than financial risks to industry or US tax payers (i.e., for government-funded projects) if the project hit "road bumps" such as poor market demand, a fluctuating economy, problems with permitting, or failure to receive government incentives. Articles noted that CO_2-capturing technology decreases the efficiency of energy production, thus raising energy costs to consumers. A few articles expressed doubts regarding the readiness of CCS for commercial deployment, and some described the technology as experimental. For example, in an interview with the *Midland Reporter Telegram* on the viability of CO_2 storage:

> Senior research engineer and associate director of New Mexico Tech's Petroleum Research and Recovery Center at New Mexico Tech, Reid Grigg, said the project is Phase III of a decade-long project to discover if CO_2 can be permanently stored in coal seams . . . If we're going to sequester CO_2, we have to prove that we not only [know] where it's going but that it's going to stay there. (McEwen, 2008)

Characterization of the technology varied, with some reports featuring aspects of the technology that are well proven such as coal gasification for the production of liquid fuels mentioned in an associated press article in the *Houston Chronicle*: "The process of converting coal to gas or liquid fuel was developed in Germany and helped power the Nazi war machine during World War II" (MacPherson, 2007). Out of all the states, Texas newspapers presented the technology most positively, with the others portraying CCS as still in the research and development phase.

Newspaper coverage in all four states rarely focused on environmental, health/safety, or aesthetic functions associated with CCS. The few statements about the environmental benefits of CCS emphasized its potential to reduce GHG emissions. The majority of environmentally oriented statements highlighted the reduction of CO_2 emissions that could be achieved by adopting CCS. They also included statements about environmental quality problems caused by "old" and "dirty" coal-fired power plants, touting improved quality through the construction of CCS-ready facilities. Though the amount of coverage that described CCS as an environmental benefit was generally consistent between states (Table 2), there was a significant difference between Minnesota, with the highest, and Montana with the lowest level of coverage regarding environmental functions ($P = 0.042$).

The health/safety function system received minimal attention in all states. When articles mentioned health/safety they focused on either (1) the possibility of the release of toxic chemicals from a plant failure, CO_2 leaks, earthquakes, water contamination and impacts to property rights, and/or the safety measures put in

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Table 2. Statistically significant risk/benefit differences between states by function system using General Linear Models with Levene's test for equality of error variance and the Dunn-Sidak method for pairwise comparisons.

Function system	States	Mean difference	Standard error	*P*-value
Economic risk	MN vs. MT		0.024	0.027*
Environmental risk	MA vs. MT	0.034	0.010	0.007*
Environmental risk	MA vs. TX	0.037	0.010	0.002*
Environmental risk	MN vs. MT	0.030	0.010	0.016*
Environmental risk	MN vs. TX	0.033	0.010	0.004*
Other risk	MN vs. MT	0.056	0.012	0.000**
Other risk	MN vs. TX	0.058	0.011	0.000**
Political and legal benefit	MA vs. MT	0.192	0.046	0.000**
Political and legal benefit	MA vs. TX	0.194	0.044	0.000**
Political and legal benefit	MN vs. MT	0.134	0.045	0.017*
Political and legal benefit	MN vs. TX	0.136	0.043	0.008*
Technical risk	MA vs. MT	0.116	0.021	0.000**
Technical risk	MA vs. TX	0.136	0.020	0.000**
Technical risk	MN vs. TX	0.066	0.019	0.003*
Technical benefit	MA vs. TX	0.091	0.034	0.044*

*$P < 0.05$; **$P < 0.001$.

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place to prevent such occurrences, or (2) the purported ability of CCS to improve air quality. Assurances of safety often came from recognized experts who also described ongoing research. For instance, the *Bozeman Daily Chronicle* reported that, "in its first regulations on the burial of carbon dioxide underground, the EPA on Tuesday unveiled measure to project [sic] drinking water from the gas behind the bubbles in carbonated beverages" (Bozeman Daily Chronicle Staff, 2008). Finally, aesthetic functions of CCS were mentioned in only four sentences throughout all 216 articles.

Risks and benefits

A breakdown of risks vs. benefits by state shows a mixture of reactions about the deployment of CCS (Table 3). Though all four states focused more on benefits than on risks, Montana and Texas newspapers were the most positive. Massachusetts newspapers generally focused on risks when describing technology. Montana and Texas articles were significantly more likely than Massachusetts articles to focus on technological benefits ($P = 0.000$ for both comparisons), and Minnesota articles were significantly more likely than Texas articles to focus on technological risks ($P = 0.003$). Minnesota articles made more general references to risk than did Montana and Texas ($P = 0.000$ for both comparisons). In addition to their focus on technological benefits, Montana and Texas articles focused on political/legal benefits more often than Massachusetts and Minnesota articles, whereas all states focused on political/legal risks at relatively equal rates. Massachusetts and Minnesota articles focused more on environmental risks than did Montana and Texas articles. The difference in coverage between Minnesota and Montana demonstrated the only

Table 3. Comparative breakdown of risks and benefits by state, reported as percent of coded utterances of each category.

	Massachusetts		Minnesota		Montana		Texas	
	Risks (%)	Benefits (%)	Risks (%)	Benefits (%)	Risks (%)	Benefits (%)	Risks (%)	Benefits (%)
Aesthetic	0	0	0	0	0	0	0	0
Economic	9	17	10	9	4	8	6	16
Environmental	4	9	4	10	1	5	1	9
Health and safety	0	1	0	0	1	0	1	0
Other	3	1	7	2	0	1	2	1
Political and legal	14	20	15	23	11	58	9	31
Technical	14	8	8	12	3	8	5	17

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significant difference regarding economic risks and benefits, with Minnesota coverage more likely to focus on economic risks.

Changes over time

We were able to detect some state variation in coverage over the nearly 20 years of data analyzed. In Massachusetts, only coverage of the political/legal (peaks in 1995, 2001, and 2007) and technical (peaks in 2002 and 2007) functions fluctuated significantly over time ($P = 0.000$ and $P = 0.000$, respectively). In Montana, coverage of the economic, political/legal, and technical function systems showed significant changes over time, beginning in 2005 ($P = 0.000$ for all three systems). From that point, coverage of political/legal functions steadily increased throughout the remaining years analyzed, with coverage of technical functions peaking in 2007 and coverage of economic functions peaking in 2008. In Texas, coverage of all but aesthetic functions showed significant change over time. Both economic ($P = 0.000$) and environmental ($P = 0.013$) functions began receiving coverage in 2005 with mild growth thereafter, whereas coverage of political/legal functions ($P = 0.021$) showed a stronger increase. Health/safety functions ($P = 0.000$) received coverage only in 2007, and coverage of technical functions ($P = 0.000$) began in 2004, with a peak in 2007. Minnesota was the only state that experienced no significant changes over time in coverage of these function systems.

Connecting climate change with CCS

The CCS articles in all four states were more likely than not to mention the issue of climate change. Terminology and presentation of the issue within CCS articles varied by state however (Table 4), with direct use of the terms "climate change" or "global warming" in 71% of the Minnesota articles, 66% of the Montana articles, 63% of the Massachusetts articles, and 58% of the Texas articles. Articles sometimes referred to climate change less directly by use of the term "emission/s." Massachusetts articles referred to climate change and control of emissions in equal proportion (63% presence for both). Montana articles also referred to climate change (67% presence) and emission control (62% presence) in relatively equal proportions. Minnesota and

Table 4. Percent presence of the terms climate change and its variants and emissions within CCS articles (*The Missoulian* was excluded from analysis due to a small sample size).

		Climate change and variants (%)	Emissions (%)
Massachusetts	*Boston Globe*	63	63
Minnesota	*Minneapolis Star Tribune*	75	75
	St. Paul Pioneer Press	67	83
Montana	*Billings Gazette*	80	80
	Bozeman Daily Chronicle	53	44
Texas	*Houston Chronicle*	76	94
	Austin American-Statesman	64	82
	Midland Reporter Telegram	30	65

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Texas articles were more prone to discuss the benefits of CCS as a means to control emissions rather than referring directly to climate change mitigation, with 80% of the Texas articles and 79% of the Minnesota articles describing CCS as a means to control emissions. The *Midland Reporter Telegram* showed the largest disparity between the use of climate change (30% presence) and emissions (65% presence). The word frequency analysis of CCS articles supported the conclusion that media in all four states connected climate change with CCS. It also revealed further differences in emphasis among the four states. Searching for the terms climate, warming, and emissions, we found that the word "climate" ranked 19th in Massachusetts and 41st in Montana; "warming" ranked 42nd in Minnesota and 80th in Texas. Unlike "climate" and "warming," "emissions" was among the top 20 most frequently used words in the newspaper articles in three of the four states: Massachusetts (ranked 12th), Minnesota (ranked 12th), and Texas (ranked 19th). For purposes of comparison, the most frequently used words (all ranking in the top 20) across all states included carbon, coal, energy, and names of states or specific projects.

Discussion

Our analysis enabled us to clarify the relative salience of CCS in the public realm, to explore which social functions were emphasized, and to investigate connections made (or not) between anthropogenic climate change and CCS as a strategy for its mitigation.

Salience

Most of the individual technologies that make up a CCS system are well established and have been commercially used (Stephens, 2006; Wilson, Johnson, & Keith, 2003). Gasification of coal was used to make fuel during World War II, and the oil industry has injected CO_2 into geologic formations for EOR since the 1980s. The possibility of combining existing technologies to form a CCS system to mitigate climate change was publically introduced in the early 1990s (the First International Conference on Carbon Dioxide Removal was in 1992; Herzog, 2001), but it took over a decade before CCS emerged as a newsworthy topic. This delay may represent lack of public concern with climate change, lag time between scientific exploration and public

interest in new technologies, and/or the fact that neither government nor industry had invested significant resources in developing the technology for climate change mitigation. Demonstration projects such as those sponsored by the DOE appear to have spurred coverage, including discussions of regulatory frameworks needed to facilitate proposed projects. Our results showed that steady reporting on CCS began in 2003 and coincided with the launch of the DOE's regional carbon sequestration partnerships. Other peaks coincided with proposals for clean coal plants and the bidding war over FutureGen.

We found significant differences between our four study states, partially related to regional attributes, needs, and the perceived appropriateness of CCS. Extensive opportunities for both capture and storage of CO_2 in Montana and Texas, along with collateral benefits such as making CO_2 available for EOR operations in Texas and potential for expanding the market for coal in Montana may explain why media in these states devoted more attention to the topic. For example, the *Bozeman Daily Chronicle* reported that, "Montana's governor is keenly interested in capturing carbon so the state can develop its vast coal deposits" (Schontzler, 2008). Both Texas and Montana also host pilot sites for large government–industry partnerships that DOE's National Energy Technology Laboratory has charged with the characterization, validation, and deployment of carbon sequestration technologies (US Department of Energy, 2008). Montana State University repeatedly received positive media coverage as the lead university in the BSCSP. The positive tone and high level of CCS reporting in Texas may reflect the state's participation in the competition for FutureGen and other near-zero emission power plants that have been proposed.

In Massachusetts and Minnesota, however, where there are limited opportunities for CCS deployment, coverage was thin. Both states lack geologic storage capacity, thus essentially removing their involvement from a basic component of operations (Wilson et al., 2009), and neither have received large DOE-funded projects. Massachusetts' minimal interest in CCS may emerge from the fact that it has the lowest amount of stationary CO_2 source emissions of all four states and would have to transport CO_2 long distances to states with more suitable storage sites. Its interest in the technology, therefore, is limited to CO_2 capture as a potential part of a broader alternative energy portfolio. Minnesota, however, produces triple the stationary source emissions of Massachusetts and is more dependent on coal, lending a policy push for clean coal plants with the possibility of transporting the CO_2 to a neighboring state with storage capacity. Thus, overall discussion about CCS in these two states remained either abstract for Massachusetts, or, for Minnesota, focused on required cooperation with other states to carry out storage of any captured CO_2.

Our finding that newspapers near current and proposed CCS projects focused on their particular project is both consistent with and different from the literature on public perceptions of CCS. The CCS public perception literature, which relies primarily on individual responses to questionnaires and participation in focus groups, tends to break out publics into two broad categories—(1) the general public and (2) the public living in communities that are potential sites for CCS projects (i.e., Johnsson, Reiner, Itaoka, & Herzog, 2009; Wong-Parodi & Ray, 2009), and these two

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publics tend to perceive CCS very differently. The general public demonstrates relative ignorance and expresses lack of interest in the topic, whereas the public facing a possibility of having a CCS project sited in their community still not only demonstrates relative ignorance, but also expresses active opposition (Bradbury et al., 2009; Feldpausch-Parker, 2010; Wong-Parodi & Ray, 2009). By using state-level newspaper coverage, we have by design constrained our view of public perception to discourse that circulates freely in the public sphere. Our results indirectly support the distinction between the two different publics, but suggest a more complex picture of perceptions and knowledge of people living in likely sites for CCS projects. We found that newspapers located near proposed CCS projects covered the technology more, and generally focused on benefits. Building on Kahlor and Rosenthal's (2009) finding that exposure to information increases people's knowledge about climate change, and the more diverse their information sources, the more they learn, further research might examine the relationship between media coverage of low carbon technologies such as CCS and individual knowledge, motivation, and engagement. From the perspective of CCS project developers, newspaper coverage may provide a window that illuminates different, but equally relevant, aspects of public perception than those obtained from individual questionnaires.

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Function systems

Most of the articles portrayed CCS as a political/legal issue, with economic and technical systems coming in second and third. Although the articles connected all social functions to some degree, we found the most resonance between these three. Statements about how CCS might enable expansion beyond current limitations permeated discourse about economics. In states with economies largely dependent on fossil fuel production (Texas and Montana), CCS was portrayed as a means to transcend limitations by protecting and expanding the fossil fuel industry because it enabled reducing carbon emissions without reducing use of fossil fuels. Luhmann (1989, pp. 51–52) claims that the concept of limitation is central to "the immense internal complexity of a monetarily integrated system" and, "limitation, therefore, is the condition of [an economic function system's] expansion." Articles in Texas and Montana newspapers presented CCS as a means for transcending limitations by supporting continued production and marketability of their dominant commodities. The *Bozeman Daily Chronicle*, for example, explained how CCS could transcend political limitations by quoting a state Senator who argued that, "The reason this bill [supporting CCS] is necessary is that in order to sell that coal (energy) back east or to California, they want green lemonade" (Person, 2009). The *Midland Reporter Telegram* enthused about how citing FutureGen in Texas would expand the state's economy by transcending both biophyscial and political limitations:

> FutureGen . . . will not only help meet strict environmental standards . . . but the applied technology will capture CO_2 that can be used to produce more Permian Basin oil ("green oil"). It will produce more jobs, generate more State and local revenue and reduce our country's dependence on foreign oil. I like to think of it as the "Greening of the Oil Patch." (Midland Reporter Telegram Staffer, 2006)

Luhmann (1989, p. 63) also argues that "whatever the economy does not bring about on its own has to be accomplished by politics with the help of its legal instrument [political/legal system]." As noted above, the economic and political/legal systems were tightly intertwined, especially in articles discussing proposed projects. The political/legal perspective was especially dominant in Montana and Texas, representing almost half of the coded statements. Without an appropriate legal framework in place to address permitting, rights, and liability, many of the proposed projects cannot move forward, thus preventing the acquisition of jobs and other economic promises. Current regulatory structures for injecting CO_2 involve a mixture of agencies and regulatory authorities at both the state and national levels (Wilson et al., 2003). Although this structure begins to address the risks and uncertainties associated with CCS, it is not sufficiently refined and likely requires additional legislation (Wilson, Friedmann, & Pollak, 2007; Wilson et al., 2008). Newspapers from all four states discussed the need for additional legislation extensively.

In addition to economic justification, political actors also turn to science to support and justify their decisions. Because science deals with truth and falsity in the form of theoretical paradigms and methodologies (Luhmann, 1989), its overarching drive is the acquisition of knowledge. Society turns to science when it senses the need for knowledge. In the case of CCS stories, the science focuses on environmental and human health/safety. This is consistent with Luhmann's claim that, if science is sufficiently integrated with other function systems, it has the potential to alert society to environmental problems (e.g., anthropogenic climate change) and to support development of technologies for responding to those problems (e.g., CCS).

Changes over time

Our analysis of change over time demonstrated that the importance of the CCS story fluctuated in all states. Discussion of the political/legal function system continued to grow over the entire time period. Coverage of the technical and economic functions, on the other hand, plateaued after a brief period of growth. This was especially evident in Texas, where CCS has been used as an adjunct in the oil industry for decades. One explanation for this phenomenon is that, once technical readiness has been established, public interest in the technology wanes and thus warrants only brief mention. Economic claims, which primarily relate to job creation and project costs, also become repetitive. These shifts in economic and technological coverage also are consistent with Brossard's et al. (2004) research on issue cycles. The emergent status of CCS explains why political and legal functions remain in the public eye. As states continue to debate the appropriate regulatory framework, political and legal social functions have become the focus of the public conversation about CCS.

Connecting CCS with climate change

Although CCS articles rarely referred explicitly to climate science, they did make loose connections between CCS and climate change. State, regional, and local politics played a large role in the extent to which climate change was cited as justification for

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implementing CCS technologies. Journalists/editors in Texas—a state whose residents predominately elect conservative political candidates and whose legislature contains numerous climate skeptics—focused more on the value of CCS for reducing emissions than on mitigating anthropogenic climate change. They relied on the vaguely perceived connection between emissions and air pollution to construct a more politically acceptable justification for CCS than the potential to mitigate anthropogenic climate change. By connecting CCS with emission reduction, rather than climate change mitigation, Texas articles encouraged the (erroneous) perception that CCS has the potential to immediately improve human health. Needless to say, they did not focus on the fact that the only emission reduced by CCS is CO_2, which is only problematic as a GHG. This response to a political exigency illustrates how news media use existing patterns of resonance (in this case, resonance between human health and politics) to develop new patterns that link a technology system designed to mitigate climate change with potentially hostile political and economic ideologies. This creative use of social resonance enabled the Texas media to introduce a novel energy technology that might otherwise have been summarily rejected because of its close connection with an ideologically unpalatable phenomenon (climate change). Although further discussion will certainly lead to questions about the connection between CCS and human health, the fact remains that CCS has been introduced into the public realm. By reinterpreting the concern for climate change as a concern for pollution, the Texas media have made it acceptable to consider implementation of CCS and have temporarily sidestepped a contentious political issue.

Linkages between climate change and CO_2 emissions in newspaper articles from the other three states were also impacted by politics, though not to the same extent or tenor as Texas. Montana—also considered a "red state" —used climate change as a rallying cry for enhancing its coal industry in a carbon-constrained world, embracing the science instead of rejecting it. Minnesota and Massachusetts were less constrained by ideological opposition to climate science and were therefore able to make more direct connections between climate change mitigation and CCS. These linkages were most evident in the use of environmental science to outline the problem and justify CCS as a possible solution. Rather than debating the validity of anthropogenic climate change, they moved the argument into the realm of how best to reduce GHG emissions. As with the Texas examples, these articles built on resonance between multiple function systems. Some, for example, noted that a new state legislation was required to facilitate economically efficient deployment of a technology that would improve human health and safety by mitigating climate change. Although this argument enabled a direct link between CCS and climate change, it did not necessarily lead to positive evaluations of CCS. Rather, it led to a variety of evaluations, ranging from outright opposition to limited support in Massachusetts and Minnesota.

Newspaper articles also produced a disjointed discussion of the technologies themselves. Articles that attempted to use CCS to justify construction of new coal-fired electrical plants claimed it was ready to deploy, whereas articles that opposed including CCS in the portfolio of technologies designed to reduce GHG emissions labeled it experimental. Both advocates and opponents connected economic

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incentives to statements about the technological readiness of CCS, claiming these incentives dictated whether or not companies would incur the expense associated with adding CCS to their systems. As might be expected with a developing technology, articles published at the end of the 20 years of coverage were more likely than those published at the beginning, to present CCS as commercially viable. A significant break in this linear progression, however, further illustrates the importance of resonance between social functions. Texas coverage of CCS portrayed the technology as ready for commercial deployment throughout the FutureGen competition. When the project was awarded to Illinois (subsequently canceled, then revived with a more limited scope), however, the story changed. The previously "shovel ready" technology suddenly became experimental. Although nothing suggests the debacle over FutureGen was driven by political and economic, rather than technological concerns, resonance with society's political and economic functions led to a dramatic re-presentation of technological readiness in Texas news coverage.

Overall, we found significant resonance/communication between the function systems Luhmann identifies as most important to late modern society. This opens possibilities for CCS deployment while also highlighting challenges. The public conversations in all four states illustrate the importance of resonance across multiple function systems. As Luhmann argues, this resonance is a necessary (but not sufficient) condition for society to even consider acting in response to an environmental perturbation—in this case, through deployment of a novel technology.

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Conclusion

Science and technology become part of the public conversation when they encroach on other social functions such as politics and economics. Especially when it comes to politically incendiary issues such as climate change, news media simultaneously frame and reflect public discourse. Our analysis of 20 years of CCS coverage from newspapers in four US states with varying degrees of public acceptance and progress in the diffusion of CCS technologies provides a window into the public conversation occurring in these and other states. The results demonstrate both similarities and differences in the portrayal of climate change in general and CCS technology in particular. Media in all states emphasized political/legal, economic, and technical social functions. They gave moderate attention to science and minimal attention to aesthetics. They also emphasized benefits, rather than risks associated with CCS, indicating a positive perception toward CCS and its future implementation. Not surprisingly, newspapers located closest to potential CCS projects published substantially more articles on CCS than did other newspapers. They also emphasized benefits more strongly than other newspapers. This was especially apparent in Montana and Texas, with extremely high levels of reporting from the *Bozeman Daily Chronicle* and *Midland Reporter Telegram*, regional newspapers in energy production communities of their states.

Although the need to mitigate anthropogenic climate change provides the fundamental justification for implementing CCS, this connection was not uniformly

emphasized in news coverage. News stories often mentioned climate change, but tended to emphasize more temporally and spatially immediate benefits such as reduction of emissions and creation of new jobs. Unlike wind and other renewable energy sources, CCS only makes sense in a world with deep constraints on CO_2 emissions. This may pose a problem for deployment of the technology, because CCS requires political/legal support (i.e., legislation) to make economic sense, and that political/legal support is contingent on broad public awareness of anthropogenic climate change and motivation to mitigate it.

While CCS takes advantage of existing infrastructure, regulations, social norms, and legal experience with the fossil fuel industry, integration challenges remain. With more projects coming on-line, however, it is reasonable to assume that media coverage of CCS activities will continue to increase. The rich resonance between function systems that we found highlights the potential for using CCS as a tool to mitigate climate change. Perhaps by focusing on technologies such as CCS, rather than directly on climate science, the media can harness society's technological optimism and belief in progress, thus encouraging members of the public to press for policies that encourage climate change mitigation.

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