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Socio-political dimensions of CCS deployment through the lens of social network analysis

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Abstract

The Socio-Political Evaluation of Energy Deployment (SPEED) framework was proposed to improve understanding of energy technology deployment. It was intended to help energy policy-makers develop and implement more effective strategies to accelerate the deployment of emerging energy technologies. The theoretical underpinnings lie in the fields of sustainability science, political science, and risk perception. Part of the objectives of the SPEED framework are to identify the dominant socio-political influences on energy technology decisions and examine how policy can facilitate a societal response to climate change by contributing insights to stakeholders. The focus is at the state level because it is at the state level that emergent energy technologies are sited, permitted, and built. The purpose of this study was to examine the structure of communication about carbon capture and storage (CCS) technology from the perspective of individuals actively involved in decisions that affect deployment and diffusion. We use density of function-system networks to examine differences between states and categories stakeholders. The information is used to inform the discussion of the current structure of communication and how it might present either barriers or opportunities for CCS innovation. Five function systems are used, each divided into benefits (positive) or risks (negative) associated with CCS: economic benefit (ECP), economic risk (ECN), environmental benefit (ENP), environmental risk (ENN), health and safety benefit (HLP), health and safety risk (HLN), political benefit (POP), political risk (PON), technical benefit (TEP), and technical risk (TEN). An additional category of CCS statements that could not be definitively assigned to one of these categories was included as an ‘other’ category (OTP and OTN). Networks were constructed for all stakeholders, each state, and each stakeholder type based on ties of shared intensity of communication about the particular frame. From these networks, density measurements were calculated and reported. In the case studies presented here, technical risk dominates communication about CCS at the state level. The economic, technical, and political system functions appear to present the greatest barrier due to largely negative communication. This study focuses on how the development of shared meaning creates ties between individuals in a CCS policy network.

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1. Introduction

Carbon capture and storage (CCS) is one of many proposed methods for mitigating anthropogenic climate change. The United States is the second largest emitter of greenhouse gas (GHG) emissions in the world, representing 20 % of the global total [1]. Touted as an interim measure to reduce GHG emissions, CCS would allow the utilization of substantial coal reserves to meet current energy demands in the next decades [2].

The Socio-political Evaluation of Energy Deployment (SPEED) framework was developed to improve understanding of energy technology deployment so that energy policy-makers could develop and implement more effective strategies to accelerate the deployment of emerging energy technologies. The theoretical underpinnings lie in the fields of sustainability science, political science, and risk perception. Part of the objectives of SPEED are to identify the dominant socio-political influences on energy technology decisions at the state level and examine how policy can facilitate a societal response to climate change by contributing insights to stakeholders. Although CCS deployment is influenced by policy decisions taken at the national level, most energy policy in the USA relies on state-level statutes and regulations. Thus, despite numerous federally supported research and development projects at pilot scales, CCS technology transfer and deployment at a commercial scale depend on support from state-based networks. Further, it is at the state level that emergent energy technologies are sited, permitted, and built [3].

1. Theoretical Framework

Luhmann's theory that human society is defined as a function of its communication [4-6] is a major influence on the SPEED framework. Luhmann [4, 6] views society as an autopoietic system of self-organizing function systems that influence each other through resonance. In fact, they "recognize each other's existence only through reliance on intra- and inter-system communication or resonance" [4, 7], and it is this information sharing to create mutually recognized meaning that leads to integrated knowledge [8]. Because meaning is actualized through communication, how people communicate about CCS reflects the likelihood of positive movement towards successful deployment. The research method employed in this study involves analysis of semi-structured interviews of energy policy stakeholders in four states: Massachusetts, Minnesota, Montana, and Texas. The stakeholders potentially influence energy technology deployment through three primary mechanisms: impact on policy decisions that provide barriers or incentives to deployment, influencing siting of new facilities, and/or influencing consumer demand for the new technology [3]. Understanding stakeholder perceptions of risks and benefits through examination of their communication about CCS technology provides insight into how further deployment might proceed. The interviews were analyzed according to six function systems: technical, political, economic, environmental, health and safety, and aesthetic. Each of these frames was further divided into benefits (positive) or risks (negative) to society.

The network perspective lends added dimensionality to the analysis of these structured interviews. People influence each other through exchange of ideas as well as material flow. It is not just the elements of a conversation, but how they are put together in terms of position (nodes) and relationships (ties) [9-11]. Network analysis elaborates beyond descriptive analysis and characterizes the structure of communication. This study determines relationship through ties based on shared perception as revealed through similar communication. It is not a who-knows-whom affiliation network, but a relational network that illuminates how network actors, or energy policy stakeholders, communicate about CCS. Often, social research on communities focuses on objects such as organization and populations that comprise the communities and neglects the links that tie these communities together [12]. Network analysis allows us to focus on both ties and nodal attributes. The difference between conventional and network data is that the former focuses on actors and attributes whereas network data focuses on actors and relations [10].

This network analysis of structured interviews of key state energy policy stakeholders in four case study states builds on descriptive analysis [13]. We use network analysis to look at the relationships of communication interaction. This is especially useful to address the question of how relations are developed and revealed through different societal functions. This paper assumes that resonance, in a luhmannian sense, occurs when two policy stakeholders talk about CCS in a similar manner, more specifically when they frame their communication in terms of one of the pre-defined function systems of the codebook. This paper attempts to begin to elucidate the 'resonance' that Luhmann [4] described within communication structure. The measure used to establish a tie or linkage between two individuals involves a shared communication score and an intensity of function score. Together, these represent resonance as "shared intensity" of communication between two individuals.

The purpose of the study is to examine the structure of communication about CCS technology from the perspective of actors involved in decisions that affect CCS technology deployment and diffusion. This analysis, taken in the context of state and actor level differences in deployment, informs us as to how communication reflects the likelihood of successful deployment. The information is used to inform the discourse regarding the current structure of communication and areas that might present either barriers or opportunities for CCS innovation.

2. Context of Case Studies

The differences in the states in relation to CCS deployment can be characterized according to their energy production situation, state specific climate and energy policies, capabilities in storing CO₂, and natural carbon resources. Key points are that Massachusetts and Minnesota are net energy importers while Montana and Texas are net energy exporters. Further, Massachusetts and Minnesota are states which have GHG policies in place, even though they are not net production states. These and other energy related differences are presented in Table 1 [14].

Table1 Comparison of state level differences, especially as relates to energy policy enactment.

Parameter	Massachusetts	Minnesota	Montana	Texas
Population, 2009 (in millions)	6.6	5.3	1.0	24.8
Person per square mile, 2000	809.8	61.8	6.2	79.6
Energy consumption per person, 2006 (million Btu)	229.9	353.5	453.2	501.7
Electricity produced from coal, 2008 (MWh)	10,628,688	31,755,253	18,331,532	147,131,841
Electricity produced from petroleum, 2008 (MWh)	2,107,999	231,617	419,150	1,033,520
Electricity produced from natural gas, 2008 (MWh)	21,514,434	2,865,846	65,659	193,247,078
Net electricity imported, 1999 (TWh)	12	14	--	--
Net electricity exported, 1999 (TWh)	--	--	14	19
CO ₂ stationary source emissions (million metric tons per year)	24.6	65.6	45.5	364.8
Storage capacity in un-minable coal seams (million metric tons)	0	0	293	18,538 to 26,469
Storage capacity in oil and gas reservoirs (million metric tons)	--	0	1,262	47,761
Storage capacity in deep saline formations (million metric tons)	6 to 25	--	265,407 to 988,831	533,600 to 2,133,300
State GHG policies in place	Yes	Yes	No	No

3. Methods

The data analyzed in this study are derived from open-ended interviews to assess differences in perceptions of risks and benefits for deployment and diffusion of emergent energy technology. Initial policy stakeholder selection was of individuals identified through their participation in energy policy testimony at the state level. Additional stakeholders were identified through snowball sampling during the first round of sampling [15]. The interview protocol was designed to allow stakeholders to a) reflect on their institutional and organizational perspective, b) consider to what extent their state's energy policy is motivated by climate change, c) share their general perceptions of emergent energy technology, d) reflect on how the technology is promoted or discouraged within their state, e) share their opinion of the media coverage of the technology, and f) identify other influential stakeholders within their state [13, 16]. The interviews involved questions about both wind and CCS technology, but the data presented

in this analysis focuses only on the CCS related responses. A research team of three coded the interviews using QSR International's NVivo™8 qualitative analysis software; a program that facilitates coding large amounts of text and fosters inter-coder reliability and reconciliation. The codebook was constructed *a priori* [17] examining six social subsystem frames and their respective risks and benefits, namely: political, technical, environmental, aesthetic, health, and economic [16]. The unit of analysis is the utterance, defined as individual sentences, where each sentence could either be coded or not, and with the possibility that multiple codes could apply to individual sentences. The number of occurrences for each codebook category were extracted from the data set, and presented as a percent of all CCS coded utterances for this analysis.

For the final analysis, five function systems were used, each further subdivided according to benefits (positive) or risks (negative) associated with CCS: economic benefits (ECP), economic risks (ECN), environmental benefits (ENP), environmental risks (ENN), health and safety benefits (HLP), health and safety risks (HLN), political benefits (POP), political risks (PON), technical benefits (TEP), and technical risks (TEN). An additional category of CCS statements that could not be definitively assigned to one of the categories was included as an 'other' category (OTP and OTN). The aesthetic category was not included because no statements pertaining to this subsystem were made in relation to CCS. Networks were constructed for all actors, each state, and each policy stakeholder type. From these networks, density measurements were calculated and reported.

The density of valued networks is the total of all values or ties divided by the number of possible ties. Key to the meaning of the network relationships and thus the density measurement is the way that the ties between individuals are established. For this analysis, the tie between a pair of individuals represents shared intensity of communication within that frame. In order to account for both the 'shared' component and the 'intensity' component of resonance, as well as exclude individuals that did not communicate risk or benefit for a function system, the ties were calculated according to the following formula.

Shared Intensity or Resonance =

$$(1 - |\text{proportion}_A - \text{proportion}_B|)(\text{proportion}_A + \text{proportion}_B)(\text{re-coded matrix}) \quad (1)$$

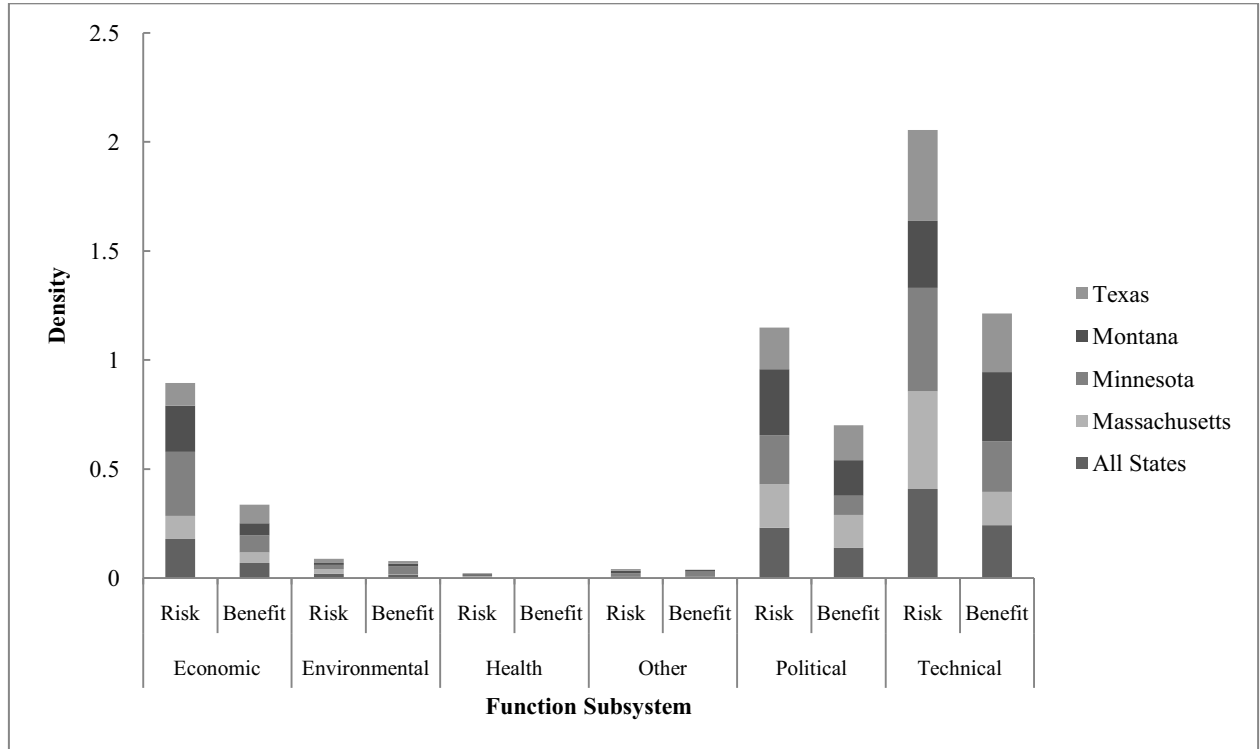
Each parenthesis in equation (1) specifies a separate matrix of pair wise comparisons of all network actors. The first matrix is a score of the proportion of shared communication about CCS in a particular context (benefit or risk, respectively positive or negative) for a particular subsystem (for instance, as a political benefit unit). The second measure reflects the additive proportion that the two actors added to the robustness of this function system, i.e. how much they talked about this particular category. The third measure is a binary matrix that, when included, eliminates those ties that involve an actor that did not communicate about this category at all. It is constructed as a product matrix of the two proportions that is then re-coded into a binary matrix of one's (they talked about this frame) or zero's (at least one person in the tie did not talk about this frame). The three matrices are multiplied cell-wise to obtain a final matrix reflecting resonance. Density is calculated for the product matrix which illustrates the overall resonance of this particular frame in the overall picture of communication. The possible range of density measurements based on this matrix formulation is between a value of zero and two.

4. Results

Density is generally used to measure integration and network cohesion [18]. It is therefore interesting that the density or resonance measures for the entire network (all states or all actors) reflects risk communication about CCS for all function systems (see Figures 1 and 2, below), and especially as concerns the technical frame. For the state data networks (Figure 1), all frames are overwhelmingly negative except communication about environmental risks and benefits. For this function system, Massachusetts and Texas remain negative, but Minnesota and Montana are more positive than negative. The implication is that there is more ambiguity in the way environmental issues associated with CCS are perceived by energy policy stakeholders.

Technical risk dominates communication about CCS at the state level. The function systems form internal clusters (similar resonance measures or close rankings for comparisons within states), indicating that there is integrity in the importance placed on each function by the stakeholders. This suggests that technical, political, economic and possibly environmental are function systems that add meaning to the structure of CCS communication.

Figure 1 Density measurements, by state.

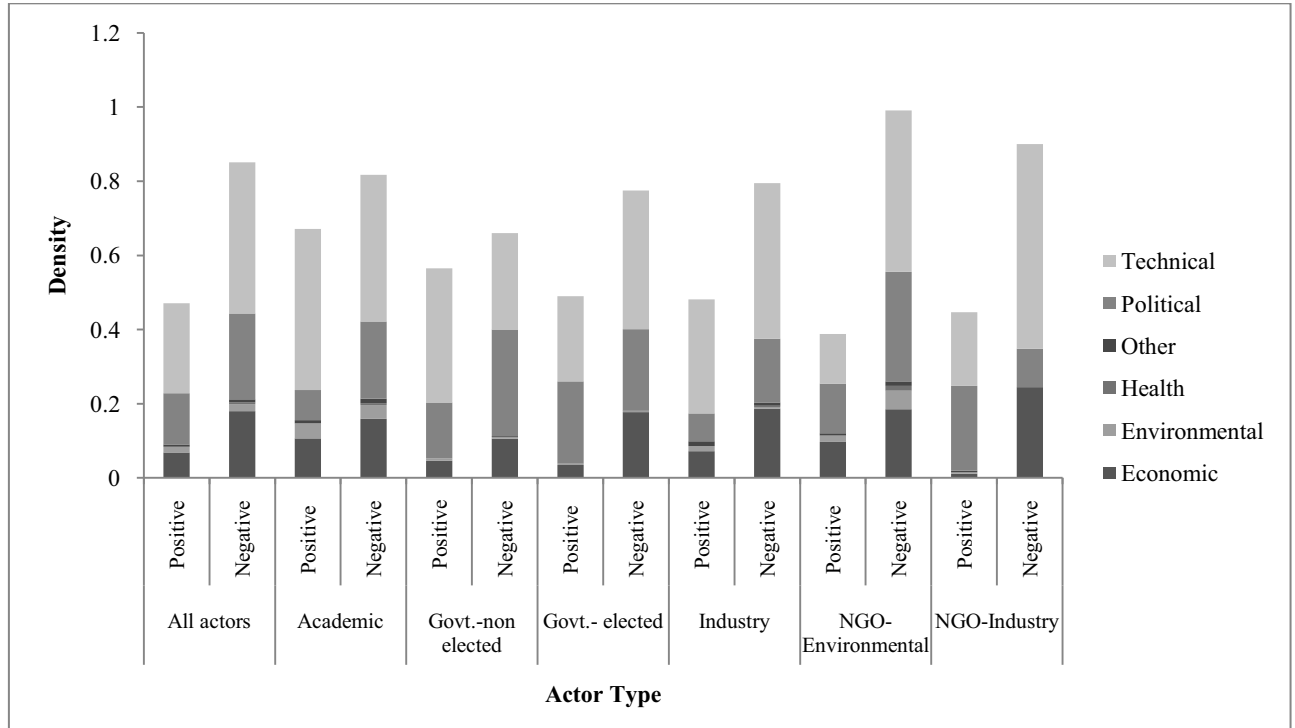


Communication in Massachusetts is dominated by technical risk. This is also true of Minnesota. In Montana, where there is active research about carbon sequestration, the technical frame leans more towards benefits. This is not the case in Texas, despite a strong initiative regarding carbon sequestration coupled to oil recovery [13]. Neither Texas nor Massachusetts actors definitively show that they perceive the political function of CCS as a risk or benefit. There is no health benefit perceived in any of the networks examined, and neither health nor the 'other' category is a strong component of communication about CCS technology.

The results of resonance measurements at the network actor (policy stakeholder) level are more clouded. (Stakeholder categories are described fully in Fischlein et al. [16].) In general, most of the communication within function systems is negative. This is true for the economic and health functions. Again, the environmental function shows greatest variation, this time with academic and non-elected government, and NGO-industry stakeholders tending towards a positive reflection where the industry and NGO-environmental stakeholders view this function in a negative lens. The density for the environmental frame for elected government officials is equal. Additionally, there is greater perception of benefit within the technical and political frames at the policy stakeholder level.

The technical and political function systems remain the most robust at the actor level as was seen at the state level. Additionally, within stakeholder groups, there are distinctive patterns of communication. The NGO-environmental stakeholders are the only group that communicates risk for all function systems. The industry and NGO-industry stakeholders show a similar pattern of benefit and risk for all functions except political where the NGO-industry lean towards benefit. This is reasonable, given that much of their activity is involved in political outreach regarding energy development. The academic and non-elected government categories also grouped together in their pattern of communication. These two stakeholder groups are the only ones that view the technical function as a benefit. Elected government officials do not cluster with any other stakeholder group. They are similar to the academic/non-elected government cohort for economic and political functions, but technical risks as are the industry related cohort.

Figure 2 Density measurements, by policy stakeholder.



As with state level differences, there is little information that can be garnered from the health and safety function because there was little communication regarding this function.

5. Policy implications and conclusions

In this paper we characterize the resonance between societal function systems as a reflection of the structure of communication about CCS technology. Grant et al. found that increased resonance among function systems was a good indicator of environmental action[7]. They simulated societal response to environmental stimuli and demonstrated that society's "understanding of the world is filtered through human language, how that understanding is reformulated by the terms available within function systems, and how understanding finally is converted into environmental action"[7]. Given that resonance among functions enables society to respond to environmental stimuli, then the tendency to discuss CCS as a risk (rather than a benefit) may be a barrier to deployment. As a system, society cannot respond directly to environmental cues, but only after those cues have been reinterpreted according to codes that make sense within the function systems of society. And, even then, response requires internal resonance across multiple function systems. Therefore, if concern about GHG is a contributing factor to CCS deployment, then an increase in resonance between function systems regarding GHG should lead to an increased sensitivity to this environmental stimulus [7].

The density measurement is used to illustrate integration and network cohesion among network actors [18-19]. Assuming that the density measure is based on ties which are reflective of resonance, this measure becomes an indicator of cohesion between function systems. Further, network density may give us insights into such phenomena as the speed at which information diffuses among the nodes, and the extent to which policy stakeholders have high levels of social capital and/or social constraint [10]. The density measurements from this analysis imply that the strong relative densities for technical risks present a significant barrier to deployment with the exception of Montana, where we can identify greater resonance regarding technical benefit. This is consistent with other studies on CCS deployment that suggest economic and technical system functions should be emphasized in order to make progress in commercial deployment[20]. Further, our results suggest that the political function is crucial and largely

undeveloped. In the case studies presented here, the economic, technical, and political system functions present the greatest barrier.

All stakeholders interviewed for this analysis are involved in policy decisions at the state level. The actor analysis provides specific information about how particular sets of stakeholders communicate their perceptions about CCS technology. Compston [21] examines climate policy from a network perspective. He postulates that increased interaction among actors leading to actual resource exchange leads to enhanced action. It is clear that the environmental NGO stakeholders should be a key area of interest if the general structure of energy policy communication regarding CCS is to change towards a more positive framework. The primary areas of concern regarding CCS perceptions are in the economic and health and safety risk frames. The industry might best be served to address concerns within its own ranks regarding perceptions of political and technical risk.

In addition to establishing ties between individuals that can be represented as shared intensity, communication also increases the possibility for joint action and enhanced development of knowledge and understanding [22]. This study focuses on shared meaning as a means of creating meaningful ties between individuals in a CCS policy network. Social network analysis suggests a flexible framework for applying this method to other energy technologies and in other locations. Social networks evolve over time and what may begin as informal ties that facilitate communication may become the means to determine common norms and values. Social network analysis lends perspective to understanding ways in which outcome success is dependent on communication linkages.

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