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Comparing online and offline knowledge networks of Carbon Capture and Storage

Sarah Mander[a]*, Rebecca Cunningham[a,b], Louise Lever[a], Clair Gough[a]

[a] *Tyndall Centre for Climate Change Research, University of Manchester, Manchester M13 4PL*
[b] *University of Technology Sydney, Institute for Sustainable Futures, Broadway, Ultimo, 2007 Australia*

Abstract

This paper examines the complex ecosystem of organisations involved in the proposed role out of carbon capture and storage (CCS) in the UK. Through analysis of interview and twitter data, it focuses on the flow of knowledge flows within online and offline networks, highlighting how in this case, CCS retains a niche audience, with communication and information flows concentrated with industry and stakeholder networks at a local and regional scale, as opposed to reaching broader national policy makers, and the wider publics. This brings a unique insight into the construction of networks across intersecting sectors of this critical technology and highlights how for successful implementation CCS, actors may need to reach out beyond their existing network.

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Keywords: Social network analysis; knowledge flows; twitter

1. Introduction

This paper examines the complex ecosystem of organisations involved in the proposed roll-out of carbon capture and storage (CCS) in the UK, focusing on how knowledge flows within online and offline networks. Previous research has investigated the impact of public perceptions of CCS (for example [1, 2]) and knowledge networks have been explored in a range of sectors including agriculture, science communication, climate adaptation, human resource management and beyond. There is little research, however, that seeks to understand how information about CCS flows between different social groups, and nothing that contrasts offline and online knowledge networks. This paper seeks to fill this gap and to understand existing networks and the potential for knowledge exchange within these networks which can support deployment and implementation of CCS technology.

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1.1. Social networks and the advancement of CCS

Drawing on the work of Bourdieu, a 'field' is a network, structure or set of relationships; within this field, advancing a particular position, for example communication, production or accumulation of goods, can be thought of as a battle between competing actors, all seeking to enhance their power [3]. The ability of any particular actor to successfully compete in this 'game' depends on their resources, or capital; four types of capital are identified: economic; social; information and symbolic.

- Economic capital refers to the financial resources that an organisation can spend on activities such as lobbying
- Social capital is based on the contacts and networks which can be used to promote a particular position
- Information capital is a result of understanding or ownership of data which has value within a particular field. In the case of CCS, this could be research outputs or participation in a demonstration project, for example
- Symbolic capital is a consequence of the profile or status of a particular individual or organisation, and crucially encompasses the tricky issue of public trust, or distrust of particular types of organisations.

The types and amounts of capital to which actors have access will determine how successfully they are able to compete within a particular field and how they compete. Within a particular field, actors can work together, building a network and working with that network drawing down different types of capital to achieve a common aim. Collaborative governance processes can be improved where strong networks facilitate the generation, acquisition and diffusion of different types of knowledge and information [4] and a network of individuals may be an effective channel for communication. In some settings, social networks may offer a more flexible approach for communication than many top-down strategies typically implemented by institutions due to the ways in which individuals interact on a social level [5].

Through Social Network Analysis (SNA) it is possible to qualitatively explore and quantitatively analyse interactions between entities within a network, and explore different types of ties between entities, such as similarities (e.g., group membership), social relations (e.g., works with), interactions (e.g., had advice from) or flows (e.g., resources, information) [6]. Both strong and weak ties can be beneficial depending on the type of network and the desired outcome from the activity; an introverted person who lives consciously in a small village as they enjoy the quiet life may find a small dense network effective, whereas conversely, an extroverted person may want a broad and diverse network with many weak ties and only a few strong ties. Granovetter [7] demonstrated that weak ties can often provide information that within a small dense network may become redundant. Dense social networks can also be beneficial as strong ties increase trust and thus social capital [8]. More recently, an exploration of the crossover between science and policy organisations within government by Goggin et al [9] demonstrated that there needed to be a mixture of both inter-organisation and external to organisation contacts. This study further investigated the influence of social media within the mix of knowledge exchange relationships.

2. Method

2.1. Study area

The research maps the information flow of CCS in offline (Tees Valley, UK) and online (Twitter) knowledge networks. The Teesside Combined Authority covers an area of 1562 km^2 and a population of 660,000 [10]. Employment in this region is primarily heavy industries, such as petrochemicals, commodity chemicals, fertilizers and polymers. Supported by a Local Enterprise Partnership, a cluster of these energy intensive industries have come together as the Teesside Collective to create a CCS equipped industrial zone and create a hub for low carbon industry [11].

2.2 Data collection

To understand the knowledge flow of information about CCS within offline networks within the region, empirical data was collected from semi structured interviews with relevant stakeholders within the Tees Valley (N=10) between July – September 2015. Each participant was asked to name their sources of information about CCS and where they shared CCS information; the semi-structured approach ensured that common ground is covered in each interview whilst allowing participants to speak more broadly to the issues most pertinent to them. Table 1 summarises the interviewees.

Table 1. Interviewee summary

Interviewee	Number
Elected Local Government	1
MP (National Government)	1
MEP (European Government)	1
Industry	2
NGO	2
Local Government umbrella group	2
Academic	1

Online data was procured from Twitter using the Tweepy API for a discrete period immediately after the interviews were completed (Oct – Nov 2015) using search terms #CCS and variants (e.g. #Ccs, #ccs). A database of was created in neo4j and mondo.db open software, and cleaned to ensure that it only contained tweets that where #CCS linked to text that included "carbon" or "capture" or CO_2".

2.3. Data analysis

Within this study, the flow of CCS information between the offline network of stakeholders, holding both formal and informal roles, was examined to understand where it was sourced from and where it was shared. Responses from the interviews were used to create affiliation and attribute matrices for all the entities identified through the interviews (i.e. individuals, websites, media etc) that included name, gender, location, and affiliation of both the ego (a specific person being interviewed) and alters (the other entities within the network). An ego's "Get" network was drawn from the ties between the interviewee and their source of information. A "Share" network was built up from the ties between an interviewee and the information recipient. The 'ego' networks for both "Get" and "Share" were manually stacked to identify any overlap between individuals' source and dissemination networks.

When it comes to analysis, online data from Twitter data can be shaped in a variety of ways; for example, the twitter user may be the node, with the tweet being the tie between them; alternatively the hashtag may be the node, and tweets and retweets ties to users using that hashtag; these explorations may be longitudinal as t is possible to explore tweets, and retweets over time [12]. However, there is a need to keep these data sets discrete, as it has been found that hashtags can and morph over time, which can make them difficult to track in some cases; there are cases as well where an individual hashtag is used for multiple events or acronyms [13].

Both datasets were explored for any similarity; in particular identifying key persons, organisations, information sources or pathways that were utilised in both the offline and online networks. Network cohesion values were calculated that included average degree (the average number of connections attributed to each node), average distance (the number of nodes that could be reached from a particular node), closure (measure of the completeness of relational triads), components (number of cliques), density (number of ties divided by the maximum number possible), diameter (the number of nodes required to reach across the network), and fragmentation (proportion of pairs of nodes that are unreachable). The data collected for both the offline and online networks is directed (ie. gets information from, retweeted by). As such each node will have an 'out' degree measure (e.g. number of allocations

node offers to other Information source/s that inform that node) and an 'in' degree measure (e.g, number of allocations node has from others saying they receive information from that node). 'Betweenness' centrality, as defined by Borgatti et al "is a measure of how often a given node falls along the shortest path between two other nodes" [14,p174]. Higher 'betweenness' of a node allows the node to have greater influence when potentially passing information between nodes in the network.

Both the offline ("Get" and "Share" networks) and online (twitter #CCS) were visualized. The offline networks were visualised through SNA visualization tool NETDRAW and the output sociograms are related directly to the UCInet analysis with the layout of the figures being constrained by Euclidian distance; as such, the central nodes are located in the centre of the visualisation [15]. The online data was visualised using ORA [16].

3. Results

3.1. Offline networks

Table 2. Visualization key and network summary

Location or scale of node	Symbol	"Get" nwork	"Share"nwork	Category of node	Colour
Local	○	27	42	Local government umbrella group	
National	□	43	22	Elected Local Government	
International	△	8	4	Government dissemination	
Online	◇	3	8	Media	
				Academic	
Various	▽	14	1	Partnership organisation	
		N=95	**N=77**		

Analysis of the "Get" network for CCS (fig.1.) highlights a number of important actors within this network. #2, a locally elected representative (yellow circle in the lower left quadrant) has many key connections, including a local council umbrella group (#7) and an academic (#3). Both academic information (magenta) and government information (taupe) are closely linked. Within the "Share" network, there is a dense cluster of local nodes (yellow), with far more online sources shared (diamonds). As illustrated in Table 2, the "Share" network is smaller than the "Get" network, with the 10 interviewees reporting 95 sources from which they sought information about CCS, and they shared CCS information with 77 others. Participants tended to get their information from national sources and share through local sources. Both academic and local council umbrella groups were at the centre of the "Get" network, while information was more widely distributed through media outlets.

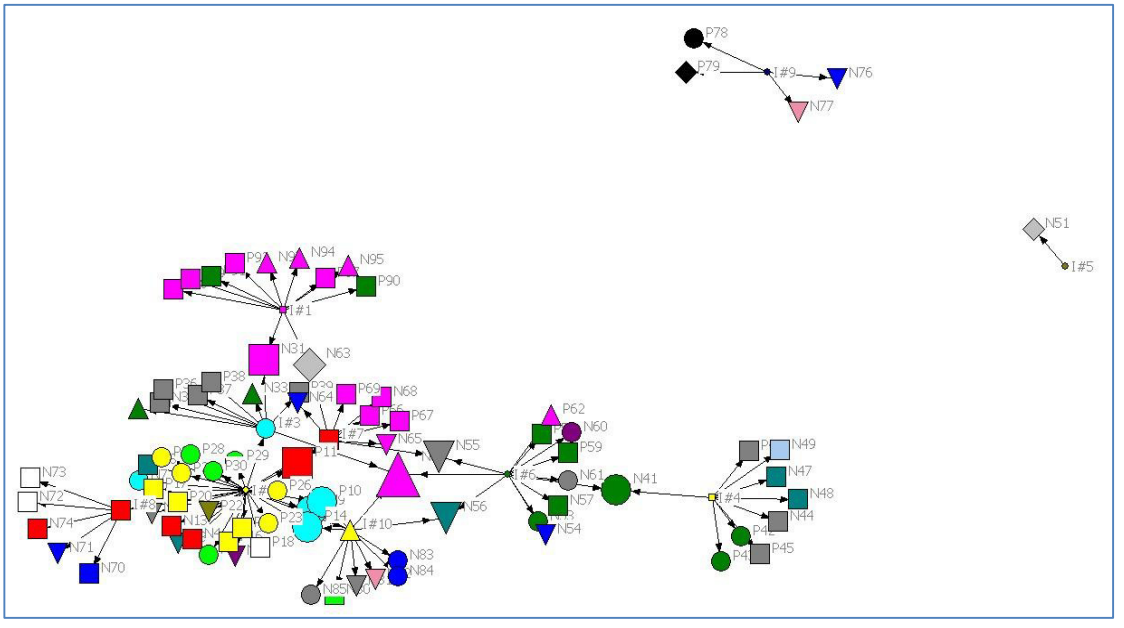

Fig. 1. “Get” network for CCS

Fig. 2. “Share” network for CCS

3.2. Online networks

A database of 68,256 tweets was initially created in neo4j and mondo.db open software. #CCS was found to refer to a music festival in Caracas so once the tweets had been cleaned to only include #CCS with relation to carbon capture and storage a total of 930 original distinct tweets were collected during the study period. 386 of these were retweeted at least once, resulting in a total retweet count of 1363. The most influential tweet during the selected period of October - November 2015 was from a media source, announcing the cancellation of the £1bn carbon capture and storage competition in the UK. This information source was retweeted 118 times. The second most retweeted tweet was from the BBC. In addition to media outlets, politicians, industry representatives and research institutions were in the top retweeted tweets. From the 386 retweeted tweets, only 12 were retweeted more than 10 times (3.08% of n386). In the context of big data, utilizing the Twitter API which in itself has limitations and biases [17], this dataset demonstrates that the #CCS network is currently a small network

There is a burgeoning field within the SNA which looks specifically at online networks, such as those found in social media [18, 19]. The online networks also need to be bound, and also are not free of sampling bias – for example on twitter there are biases towards a sector of the population who are users, then there are biases inherent to the more popular users (those with a larger number of followers) and to those influential users who tweet more frequently [21]. The audience of twitter further contains biases, as people use this online communication for various functions, and it has been found to have very different outcomes to other forms of communication, such as face-to-face conversation. Further, there are different hashtags that generate a different sensibility and a 'stickiness' that depends on the sector. For example, different hashtags on different topics have a different audience and different reach, for example, a study undertaken by Romero et al [22] demonstrated that topics such as music, celebrity and politics tended to have a higher influence than technology, movies and sports.

When it comes to analysis, Twitter data can be shaped in a variety of ways; with this analysis, the hashtag is the node, and tweets and retweets ties to users using that hashtag. This exploration is longitudinal as it is possible to explore tweets, and retweets over time [23]. However, there is a need to keep these data sets discrete, as it has been found that hashtags can and morph over time, which can make them difficult to track in some cases, as can cases as in this analysis where an individual hashtag (#CCS) is used for multiple events or acronyms [24].

4. Conclusions

This work offers insights into the relationships that have emerged between CCS actors, and the flows of information within the offline CCS network in Teesside. These findings are useful for actors both looking to enhance CCS focused communication and dissemination within this region, but also for them to consider how this social network could be strengthened in order to better support their fight to deploy CCS within the region and more widely.

Both the offline and online information networks from this case study demonstrated that CCS retains a niche audience. Findings from the offline case study highlighted that participants tended to get their information from national sources and share through local sources. Both academic and local council umbrella groups were at the centre of the "Get" network active in the offline network, while information was more widely distributed through media outlets. Elected representatives, local government umbrella groups and academics all provided a positive flow of information. The offline network was reasonably connected; however, the networks did not reach more broadly into the community, and remained more bound within industry, academia and local government. For implementation of a new technology such as CCS, where policy support and incentives are required from national government to support the work of local and regional government, a social network that is concentrated at the local and regional scale may not reach the seat of power. Although information and social capital exists within the network, is it being used effectively to reach those that matter and is the social capital that may be transferred within this network and beyond optimised? This niche knowledge network could result in a lack of policy pressure and lobbying power required to build a CCS coalition to push forward the technology.

In the online networks, it was national media outlets that held greater sway, however the social media (i.e. Twitter) analysis highlighted that CCS has yet to reach the general public, as even policy announcements and issues

with local impacts, affecting jobs for example, don't "stick" in the Twitter imagination. Awareness of CCS amongst the general public remains low, and social media has yet to emerge as a vehicle for raising that awareness. Whilst public awareness does not necessarily translate into successful deployment and implementation, familiarity can serve to inform the context within which broader discussions and debate can take place.

Bringing together both the data on offline and online knowledge networks, this research suggests a need for those looking to deploy and further CCS to reach outside their existing networks into wider communities, and in the case of social media, consider how CCS can be made unique.

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