TRUST

High resolution monitoring, real time visualization and reliable modeling of highly controlled, intermediate and up-scalable size pilot injection tests of underground storage of CO_2

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Executive summary

TRUST aims at conducting CO2 injection experiments at scales large enough so that the output can be extrapolated at industrial scales. It relies on four sites: the heavily instrumented sites of Heletz (Israel, main site) and Hontomin (Spain), access Miranga (Brazil) and the emerging site in the Baltic Sea region. The objectives are to: carry out CO2 injection with different strategies, displaying characteristics representative of the large scale storage and with injection volumes that will produce extrapolable reservoir responses; Develop, use and implement characterization and MMV technologies for maximized safety and minimized risks, including real time visualization of the CO2 containment and detection of possible failures; Develop optimal injection strategies that maintain realistic figures of injectivity, and capacity while simultaneously optimizing the use of energy; Detect and mitigate CO2 leakage at an abandoned well; Produce comprehensive datasets for model verification and validation; Improve the predictive capacity and performance of computational models, as well as their capability to handle uncertainty and thermo-hydro-mechanical and chemical phenomena at different scales (at the scale of the experiments) and upscaling (extrapolation to industrial scale) simulations; Address critical non-scientific issues of public acceptance, community participation, communication, dissemination, liabilities and prepare templates for the preparation and application of injection licenses and communication with regulators; Establish on-site facilities for analysis of monitoring and measurement, providing training and capacity building; Address the risk assessment in a meaningful way; Prepare a platform for the exploitation of project findings and for knowledge and information sharing with planned, large scale, CCS projects. Allow open access to sites, and seek cooperation with large scale CO2 injection projects both at the European and International levels.

Keywords	Large scale CO2 Injection, Monitoring, Model validation, Injection strategies, risk assessment, communication, extrapolation, real time visualization, open access, capacity building, training.

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1. Introduction

Carbon capture and storage (CCS) is an emerging technology to limit greenhouse-gas emissions from large-scale fossil fuel usage. It essentially consists of capturing CO_2 from large man-made emission sources, transporting it via a network of pipelines and storing in deep subsurface geological formations (i.e. depleted oil and gas reservoirs or deep saline aquifers). The International Energy Agency (IEA, 2009) suggests that CCS will play a vital role to limit global warming as one of the lowest cost greenhouse gas mitigation technologies. However, the technology still needs to be demonstrated at commercial scale and research and development (R&D) needs to continue to successfully deploy commercial-scale CCS projects (*ibid*).

Directive 2009/31/EC of the European Parliament and of the Council of 23 April 2009 on the geological storage of carbon dioxide (also named EU Carbon Capture and Storage or CCS Directive) establishes a regulatory framework for the geological disposal of CO2 within the European Union. The Directive embraces issues such as who regulates, the relevance of existing laws and their relationship with CCS, nature of incentives for CCS or gaining public acceptance. However, transposing its provisions into national laws and the implementation of CCS itself varies across Member States. Furthermore, some issues, like how to articulate communication and seek public acceptance or help ensure a robust licensing and permitting procedure, remain unresolved. On the one hand, the public is relatively unfamiliar with CCS, they have significant concerns relating to the risks involved with storing and disposing CO_2 and they lack trust in government or industry to take decisions on this technology (EC, 2011). On the other hand, aspects of CO_2 geological storage licensing are still emerging and developers and regulators will 'learn by doing' due to the current uncertainties. IPCC (2005) claims that the widespread application of CCS depends on a number of factors, such as technical maturity, costs, regulatory aspects, environmental issues and public perception, among others.

According to several studies, public opinion has not yet been formed with regards to this emergent technology (ACCSEPT, 2007; de Best et al., 2006). There have been studies in different countries on public perception and opinion surrounding the development and deployment of CCS, like in France (Ha-Duong et al., 2007; 2009; 2011), Japan (Itaoka et al., 2009), in the US (Bradbury et al., 2011), Canada (Sharp et al., 2009), the UK (Shackley et al., 2004), Netherlands (de Best et al., 2006; 2009), Germany (Pietzner et al., 2009), Switzerland (Wallquist et al., 2009) and Spain (Oltra et al., 2010). Vercelli et al. (2013) provide a very useful contribution by reviewing the studies on CCS public perception which have investigated the introduction of CCS information to the public and its interaction with public perception. They review the research published between 2007 and 2011 in Europe, United States, Australia and Japan. The authors conclude that the content characteristics of the information provided seems more important in terms of influencing perception than trying to provide 'neutral information'. In addition, the relationship within which the communication on CCS takes place is also an important factor that should be prioritised from the methodological and operational point of view.

Ashworth et al. (2013) synthesise the key findings, recommendations and challenges resulting from the investigation of social factors influencing CCS project deployment. At the risk of oversimplifying a very complex topic, their analysis reveals seven key themes (see Box 1) arising from the body of work related to CCS social science research.

Box 1. Key themes emerging from international CCS social research (adapted from Ashworth et al., 2013)

1. Framing CCS: advocating CCS as a single solution is likely to be rejected. Instead, CCS should be set in the context of a portfolio of technologies for mitigating climate change;

2. Local context: it is fundamental to understand all the aspects related to the local communities which will be potentially hosting the CCS project. Cultural considerations, socioeconomic characteristics or the community's experiences with different industries may influence positively or negatively in the perception of the CCS project;

3. Trust: it refers to the trust in the communicators and sources of information as well as on building trusting relationships with stakeholders;

4. Communication and engagement processes: it is important to communicate and engage with stakeholders and the public early on and in an inclusionary way, being flexible enough to accommodate to the concerns that may be raised by stakeholders;

5. Information: access to quality, relevant and factual information is acknowledged as a key learning, as well as multiple sources of information. Both, 'what' and 'how' to communicate are important factors to inform the knowledge and opinion of stakeholders.

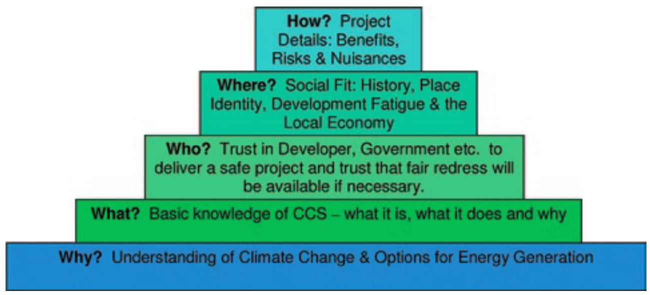
6. Risk perception: it is vital to understand how communities perceive CCS and associated risks. In addition, local concerns should be considered in the overall project risk assessment process.

7. Governance: ethical dimensions of the projects issues like procedural fairness, justice and legal and regulatory frameworks, among others, are part of addressing governance in CCS projects.

In recent years, guidelines on good practice in communication and stakeholder engagement have been published (see for example NETL, 2009; World Resources Institute, 2010; Ashworth et al., 2011; Prangnell, 2013; Bellona, 2009) focusing mainly on how to communicate to and involve the local level in a prospective CCS facility. Kuijper (2011) describes a three-stage process as part of the communication and involvement plan regarding a CCS facility. The process starts with a careful analysis of stakeholders' concerns and influence, followed by a definition on why the local community should support the CCS facility ('the local value proposition) and finally, developing the public acceptance strategy in collaboration with stakeholders. As will be explained later on in Section 3, the SiteChar project also addresses the need to develop a 'social map' of stakeholder opinions and opinion shapers as a starting point. Similarly Desbarats et al. (2010) and Ashworth et al. (2011) also emphasise the need for an initial analysis and evaluation to identify concerns and priority issues to be addressed later on in the communication and stakeholder involvement processes.

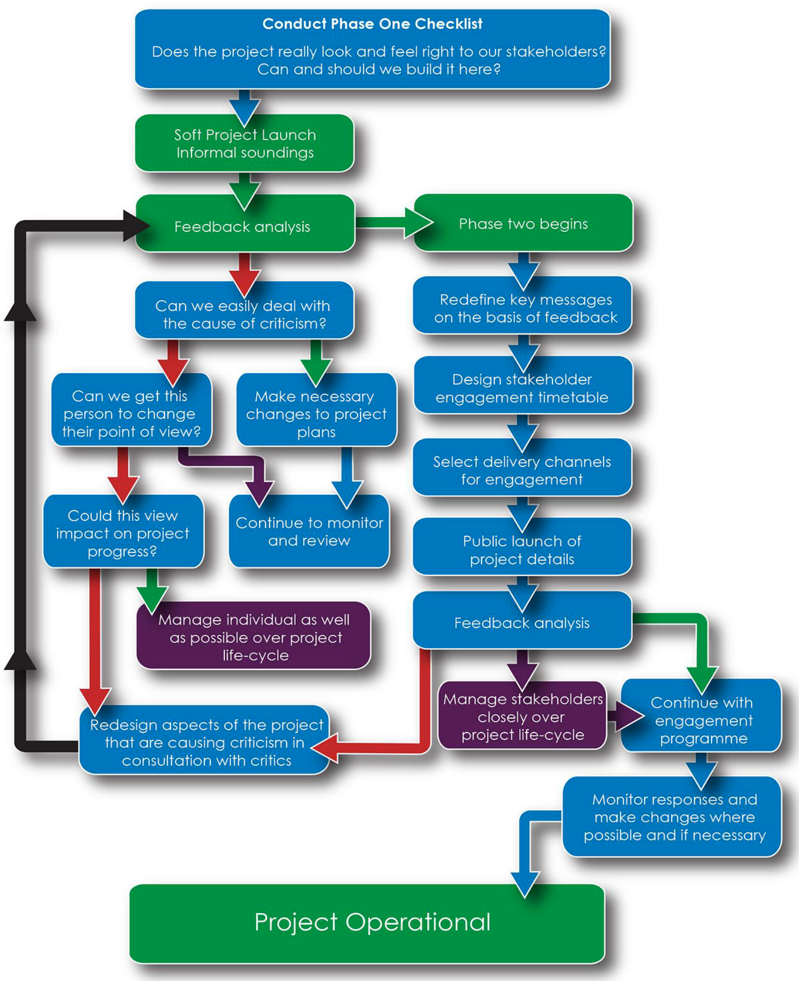
Hammond and Shackley (2010) suggest the following stepwise approach towards public acceptance of a CCS facility (Figure 1). They suggest that even if not every step may be necessary for every stakeholder group, these are the minimum aspects that an engagement campaign should take into account: why CCS, what is it, who is responsible to deliver a safe project, where it will be placed and how it will be implemented.

Figure 2. Stepwise approach to public acceptance of CCS facilities (Hammond and Shackley, 2010)



Prangnell (2013) also provides key recommendations on communication and engagement for CCS projects, based on the experience of communication strategies adopted by developers in five CCS projects. He suggests a phased approach to stakeholder management, as shown in Figure 2 below.

Figure 2. Stakeholder management flowchart (Prangnell, 2013)



Prangnell (2013) suggests a flowchart based on five basic steps:

1. Define the project

2. Explain the project

3. Respond to feedback

4. Monitor responses

5. Review regularly and frequently.

Despite the mechanistic approach to stakeholder management shown in the flowchart, Prangnell notes that implementation is an organic process and the challenge is to be flexible and respond quickly and appropriately.

In the broader literature on public participation and siting controversial projects or infrastructures, there is a widespread recognition that the traditional approach of '*decide, announce and defend'* based on the permit procedure and addressing the concerns as legally required, often ends up with increasing public opposition and the project being cancelled. A new model of approaching stakeholders in this type of projects is required. The new model '*engage, interact and co-operate*' or '*investigate, adapt, engage'* is characterized by a new dynamic of dialogue and decision making. From the very beginning, it is important to investigate all the characteristics of the potential community well, identify all stakeholders and the local benefits of the project. Then, it is important to adapt the message and the channels to the community and stakeholders. Engaging early with all concerned parties is key as part of the new decision-making context.

So far, the literature on CCS has focused very much on gaining public acceptance. However, public acceptance is linked to the traditional '*decide, announce and defend'* model. There has been a shift towards an approach based on engagement of the public and promoting ownership of the project. In the context of the CATO-2 research program[1], researchers from the University of Leiden are undertaking empirical research in areas which have not yet been addressed by social scientists in the field of CCS. For instance, ter Mors et al. (2012) have explored the role of community compensations in CCS facility siting controversies. They review the broader literature on host community compensations when siting controversial facilities and conclude that compensation may help to prevent or solve facility siting controversies.

The present report reviews and brings together the main findings from the literature on social sciences around CCS, reports from European funded governance projects, findings from national research projects and surveys and reports from CCS demonstration projects and initiatives. The objective is to capture the main lessons learned from the literature and experience so far.

[1] See www.co2-cato.org for further information on the project.

2. Public perception of CCS

Studies on public perception at EU level show generally low levels of awareness of CCS. The European Commission released in 2011 the largest survey done in Europe up to that time on knowledge and awareness on carbon capture and storage (EC, 2011). More than 13000 EU citizens from 12 Member States were interviewed to examine their understanding in issues related to climate change and their level of knowledge of CCS. The survey shows that the level of awareness of CCS in Europe is low, except for the Netherlands where 52% of the respondents said they had heard and knew what CCS was. In this section, the results of the main survey on CCS perception and awareness at EU level, the Eurobarometer, is summarised, together with the findings from social science research comparing CCS with other technologies. Later on, section 4 of the present report addresses social science research on CCS at national level.

Research has also been conducted to investigate the perception of specific stakeholder groups regarding CCS. In the US, it was found that most environmental NGOs see CCS as a better option than nuclear power and that the majority of them would accept CCS as a mitigation solution (Wong-Parodi, G. et al., 2008). Similarly, Johnsson et al. (2009) find that NGOs prefer CCS over nuclear power, but much less than renewables. As expected, NGOs have the largest share of negative positions on CCS compared to other stakeholder groups involved in CCS. Huijts et al. (2007) compares viewpoints of professionally involved actors (members of government, industry and environmental NGOs) with citizens. Acceptance of this technology will depend not only on the information provided by the different actors and their opinions, but also, and to a greater extent, on the trust that the responsible actors can build and maintain. This trust will be influenced by their perceived intentions and perceived competence. Bellona (2013) describes what different groups – independent experts, industry, non governmental organisations, politicians and the public – think about CCS. Whilst experts in general think that CCS is necessary, they also recognise the challenges related to CCS that still need to be solved. The general opinion of industry is very positive, although the costs and financial risks are pointed out as drawbacks. In the webpage, Bellona also presents the position of different NGOs, those who have a positive view on CCS (like Bellona or E3G) and those who are very negative to CCS (like Greenpeace). Other NGOs, like WWF and Friends of the Earth International, view CCS as a bridge technology to the renewable energy scenario, provided that it is proven and strongly legislated. In general, politicians are positive to CCS as a mechanism to help reduce greenhouse emissions, although a lot of work needs to be done at the political level to deploy CCS commercially. Finally, public opinion varies a lot across countries and localities. Early dialogue with all interested parties and building public confidence in the project should be addressed together with the technical aspects of the project.

The International Energy Agency (IEA) and the Carbon Sequestration Leadership Forum (CSLF) were commissioned by the G8 leaders to work together to address the barriers to public acceptability of CCS technology (CCP, 2007). They prioritise concerns and issues affecting CCS deployment according to stakeholder groups (NGOs, public, government, industry and R&D organisations). According to the authors, even if the maturity of understanding of CCS varies between regions and stakeholder groups, the main perceptions and issues affecting the deployment of CCS are: cost of deployment, scale of deployment, perceived risks (to local health and safety), lack of accessible information, supporting policies and adequacy of regulatory frameworks to address the perceived risks. In a more recent report, CCP (2012) also analyses key findings from the literature review, interviews and case studies to consider issues of concern for different stakeholder groups and how these may inform project development. Table 1 illustrates the position of different stakeholder groups regarding different issues of concern around CCS, highlighting which issues are the focus of interest and which ones are noted.

Table 1. Priority Stakeholder Issues (Chrysostomidis et al., 2012)

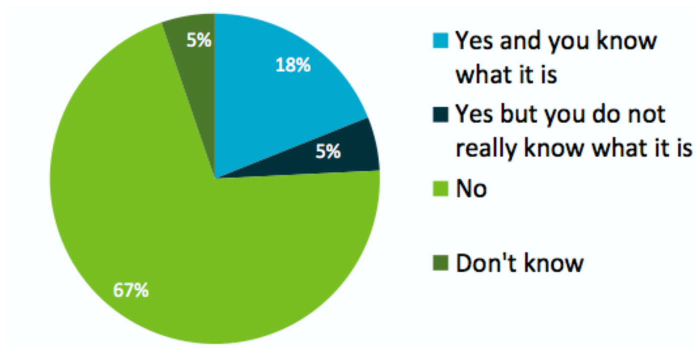
	EHS Impacts	Awareness & acceptance of CCS	Technical aspects	Commercial & local development benefits	Policy & legal issues	Diversion from renewable energy	Positive impact on climate change	Variable positions on CCS
NGOs & Leaders	✓		✓		✔	✔	✔	✔
General Public	✓	✓	✓	✓	✔	✔	✔	
Politicians & Policy makers	✓	✓	✓	✓	✔	✔	✔	✔
Industry	✓		✔	✔	✔	✓	✓	
Local Community	✔	✓	✓	✔	✓			✓
Regulators	✔	✔	✔		✓			
Investors	✓	✓		✔	✔			
Media	✓	✓	✓	✓	✓	✓	✓	✓

✔ Focus of interest ✓ Issue noted

2.1 The Eurobarometer: public awareness and acceptance of CO_2 capture and storage

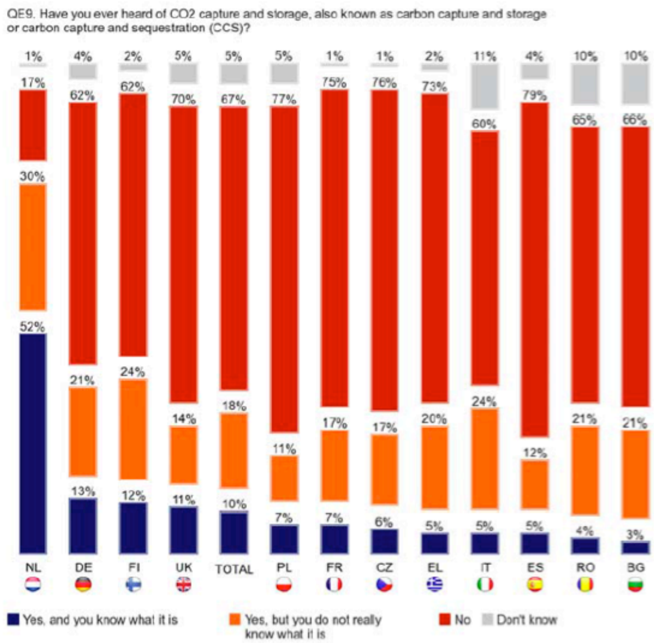
The Eurobarometer survey (2011) on public awareness and acceptance of CO2 capture and storage interviewed 13091 EU citizens in 12 Member States of the European Union. The results revealed that only one out of ten respondents had heard of CCS and knew what it was. In general, the level of awareness is low.

Figure 3. Level of information and knowledge on CCS (EC, 2011)



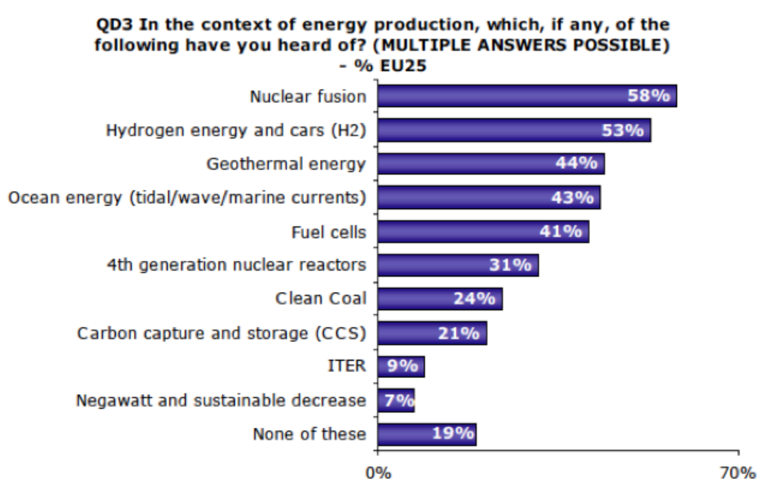
There are variations in the level of awareness and knowledge on CCS depending on the countries. The Netherlands stands out as having the highest level of awareness in Europe. The level of awareness in the Netherlands is over five times higher than in the average since 52% of the respondents had heard of CCS and knew what it was, compared to the European average, where two thirds (67%) had not heard of CCS. Germany (13%), Finland (12%) and the UK (11%) are the other three countries, after the Netherlands, with higher levels of awareness and understanding of what CCS is, compared to the rest of European countries.

Figure 4. Level of awareness of CCS in European countries (EC, 2011)



Similar results where found in 2006, when the European Commission carried out a survey to assess public perception, level of knowledge and attitudes towards energy issues and energy technologies (EC, 2007). In this Eurobarometer published in 2007, 24815 European citizens were interviewed concerning different energy related issues. In general, only 21% of the respondents claimed to have hard of carbon capture and storage. In the Netherlands, more than four out of ten respondents (45%) had heard of this technology, followed by Finland (33%) and Denmark (33%).

Figure 5. Knowledge of energy production technologies (EC, 2007)

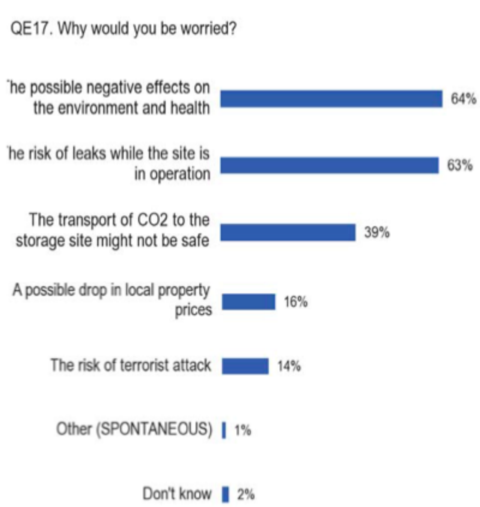


The level of knowledge of CCS in the countries where CCS projects are co-financed from the European Energy Programme for Recovery (EEPR) as part of the European Recovery Plan is also low. Thus, in the Netherlands, the UK, Italy, Spain, Germany and Poland only one is nine has heard about CCS. In countries where there are EU co-financed CCS projects, the level of awareness is low, except for the Netherlands. When asking specifically to the people in the regions where CCS projects are sited, in Poland (Lodzkie), Spain (Castilla-León) and Germany (Brandenburg) more people had heard about the CCS project than respondents in other regions of those countries. In the UK, Italy and the Netherlands the level of awareness of CCS project is similar across the different regions. In addition, in Germany, Spain and the UK, the respondents cited job creation as one of the perceived local benefits of CCS.

Regarding information provision about CO_2 storage, the results indicate that for 45% of the EU respondents, universities and research institutions, followed by NGOs and journalists, are the most trusted whereas governments, industry and developers tend to be mistrusted. In addition, there are national differences with regards to whom citizens trust most to give them information about CCS. The countries where respondents have the highest levels of trust in universities and research institutions are the Netherlands (68%), Finland (67%) and Greece (66%). The lowest levels of trust amongst respondents are found in Poland (34%) and Romania (35%). These are also the two countries showing lower levels of trust in NGOs (Romania, 16% and Poland, 20%). On the contrary, the proportion of respondents who trusted NGOs was highest in France (43%), Germany (42%) and Greece (38%).

Respondents were asked about their opinion and concerns regarding the location of a CO2 storage site close to their home (within 5 km of their home). Overall, six out of ten people (61%) said they would be concerned about the safety of CO2 storage and under a quarter (24%) would be 'very concerned'. The respondents in the Netherlands expressed the lowest level of concern (43% said they would not be concerned). The two main concerns people had about CO2 storage were 'effects on the environment and health' and the 'risk of leaks while the site was in operation' (see Figure 5). This results are similar to the ones shown by Johnsson et al. (2009) where the most common concern is the risk of leakage from reservoirs (about 40% in total), followed by seismic activity (25%) and risks associated with transport and handling (around 20%).

Figure 6. Concerns about CO2 storage (EC, 2011)



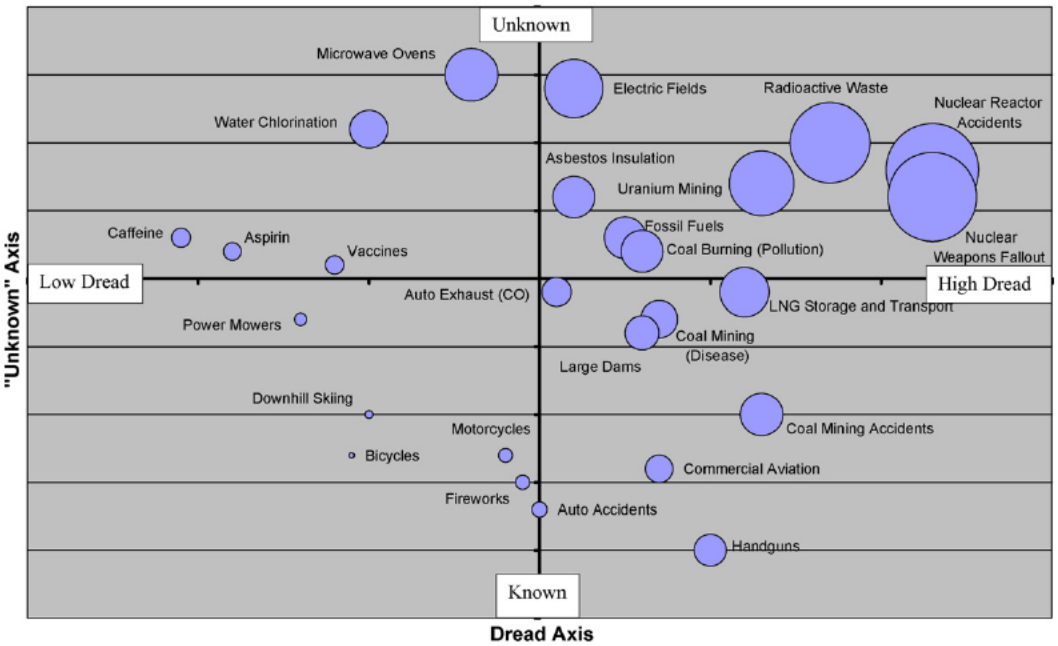
2.2 Public perception of CCS compared to other technologies

There is not much literature comparing public perception of CCS technology with other types of technologies, such as radioactive waste disposal. Although some claim that geological disposal and CCS are far apart, others attempt to compare and draw lessons learnt from radioactive waste to be applied to developing technologies like CCS (Chapman et al., 2011; Reiner and Nuttall, 2011). Some of the points in common are the challenge of communicating highly technical issues to different audiences as well as the related 'not in backyard syndrome' (NIMBY). Whilst risk communication in radioactive waste disposal is extensive, the area of CCS communication is yet poorly studied and there are few examples of good practice in CCS communication. De Best and Daamen (2006) investigated the choices of the general public regarding six CCS options after having received and evaluated expert information on the consequences of these choices. They found that public opinion is not stable (changed within twelve minutes), depends on the mood of the respondent and is affected by information beyond the expert information provided.

Johnson et al. (2009) asked different stakeholder groups, including electric utilities, oil & gas companies, CO2-intensive industries and NGOs in US, Europe and Japan, about their preferences over technologies. There were small differences across regions and between different stakeholder groups. In general, renewable energy was preferred over CCS. In almost all groups, wind power was preferred over CCS. On the other hand, electricity companies and NGOs preferred CCS over nuclear power. The challenge of reducing emissions using only current technologies is believed to be severe by all.

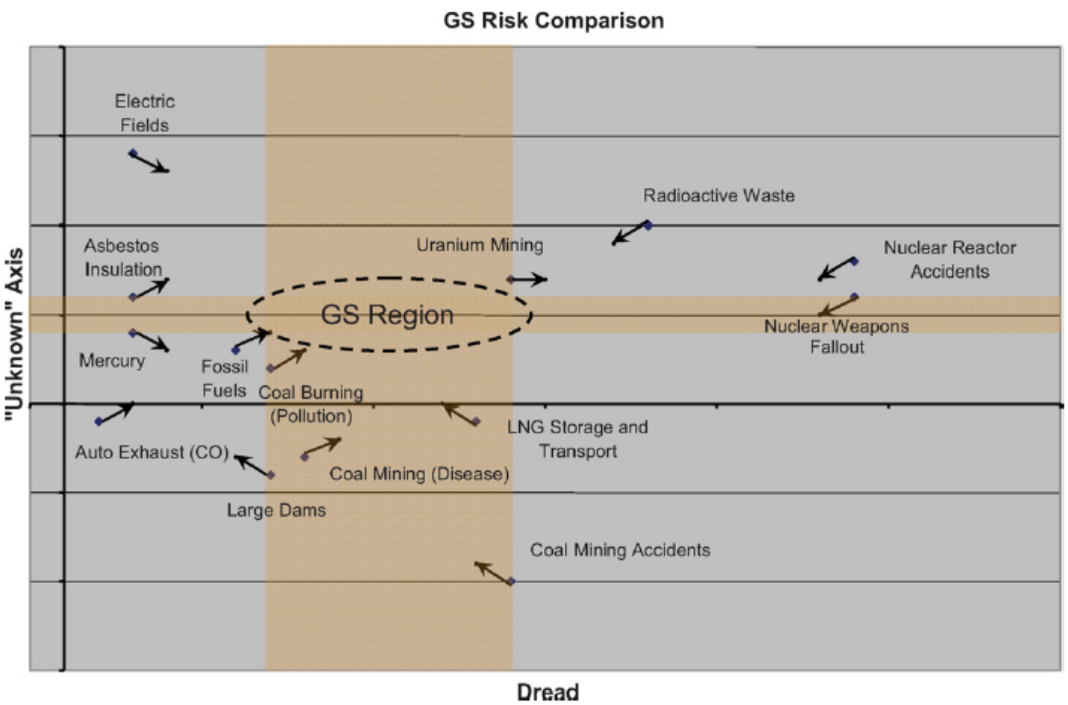
Singleton (2009) tries to infer likely responses from the public to the geological storage technology by comparing CCS with existing studies on different technological hazards. The analysis takes the psychometric model of public risk perception, developed by Slovic (1987) as a starting point (see Figure 6). The psychometric model evaluates subjective risk perception using two criteria: "dread" (a measure of the extent to which the public perceives risk as involuntary, that has a potential to be catastrophic, that presents a high risk for future generations or that is difficult to mitigate) and "unknown" (a measure of the extent to which the public perceives risk as hidden, unusual, poorly known and with long-term effects). Singleton et al. (2009) try to compare geological storage to other technologies, based on these characteristics.

Figure 7. Psychometric plot of various hazards (Slovic, 1987)



The authors suggest that geological storage will be perceived to have less risk than nuclear technologies, but would be perceived as riskier compared to fossil fuels, coal burning pollution and other widely accepted technological hazards. There is yet insufficient data to conclusively affirm whether CCS is safe or unsafe and therefore, the initial perception regarding CCS can be theoretically improved. They conclude that to facilitate CCS acceptance, tests and field demonstrations would need to be implemented in order to increase awareness on CCS and improve best technologies to mitigate the potential risks of this technology.

Figure 8. Overall plot of geological storage compared to other hazards. Only the upper right quadrant of Slovic's psychometric framework is shown. The shaded region in the dashed circle illustrats where geological storage is likely to be plotted (Singleton, 2009)



3. European research projects on governance and CCS

A growing body of literature has emerged over the last years in European social science research focusing on CCS. In this section, we review the main findings from European funded research projects on governance of CO2 capture and storage, such as ACCSEPT, nearCO2 and SiteChar, in order to depict the main lessons learned.

3.1 ACCSEPT

ACCSEPT was funded under the FP6 (2005-2007) and it aimed to contribute to measure CCS social acceptance and establish recommendations for the timely and responsible application of CCS. The project identified, analysed and provided recommendations on the following factors as influencing the emergence of CCS within the EU: legal, regulatory, economic, social acceptability and cross-cutting issues (ACCSEPT, 2007). There were three main focuses of the project: a European wide survey to assess opinions over CCS; stakeholder consultation through two workshops and research into the economics, regulation, legal and social aspects of CCS[2].

ACCSEPT conducted a survey during 2006, in which they asked 512 stakeholders from across Europe their opinion on CCS in the energy future. In general, the majority of the respondents were moderately supportive of CCS and perceived the risks as moderate or non-existent. They believed CCS had a role to play in their country's plans to mitigate carbon emissions. Environmental NGOs were more concerned about the risks of CCS and the implications for renewable energy compared with energy industry and governmental representatives. Shackley et al. (2009) conclude that perception of CCS is influenced by factors such as the level of concern over energy security, climate change and electricity prices as well as by how it is perceived in relation with other generation technologies. Furthermore, CCS shows some disadvantages from the point of view of public perception in the field of energy and climate change: it is related to fossil fuels, it involves waste disposal, it is costly, new and not fully understood (Anderson, et al., 2009).

3.2 NearCO2

The main purpose of the FP7 European project NearCO2 (2009 – 2011) was to develop effective strategies to convey to stakeholders and the public at large the risks and advantages of CCS and to involve them in local decision-making on CCS projects. In order to do this, the project investigated European public perceptions of CCS via case studies, surveys and focus groups[3]. The results of NEARCO2 showed that the general public is relatively unfamiliar with CCS and climate change mitigation. In general, the general public prefers renewable energy over CCS. The project also pointed out to the concerns relating to the risks involved with storing CO2 and the lack of trust in government and industry to make the right decisions.

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[2] See www.accsept.org for further information.

3 See www.communicationnearco2.eu for further information.

The analysis of eight case studies of public involvement in energy infrastructure projects revealed that there are other factors, apart from communication approaches, that have an influence on public perception of CCS. These factors include: understanding the local contingencies (e.g. local industrial history or social capital); two-way open dialogue and early interaction (e.g. informal processes); the importance of high quality communications material (e.g. different formats, wide range of material) and the need to build up trust in the project developer (e.g. through involving experts who are perceived as independent).

As part of the project, a multimedia 15 minute DVD was produced on climate change, CO2 and CCS. The DVD was shown in focus groups in Spain, Germany, Belgium, UK, Netherlands and Poland to assess their change of attitude towards CCS after having seen and discussed the contents of the DVD. However, the results of the focus groups showed that first, providing information does not result in more positive attitudes by itself and second, building trust requires other factors beyond providing information.

On the role of local communities living near CCS projects, it was found that those living closer to the storage site were less supportive than those living further. Regarding jobs and potential benefits from CCS projects, support from local communities diminishes with distance to the capture site.

3.3 SiteChar

SiteChar is an FP7 Collaborative Research Project (2011-2013) that examines the entire site characterisation chain, from the initial feasibility studies through to the final stage of application for a storage licence based on the criteria defined by the relevant European legislation: storage capacities, geological modelling at basin or reservoir scale, injection scenarios, risk assessment, development of the site monitoring plan, technical and economic analysis (assessment of all the costs related to storage), public awareness, etc. Technical, economic and societal requirements for suitable underground storage of CO2 are investigated in five sites in different European areas.

Although SiteChar is not a social science research project like the previous ones, one of its objectives is to identify and develop appropriate methods for involving the local population in the process of a CCS project development. The research method used to develop public participation activities is the Social Site Characterisation. For this, two potential storage sites were chosen: the North Sea off shore multi-store site (the North Sea Outer Moray Firth site) in Scotland and the onshore oil and gas field (Zlecze & Zuchlow site) in Poland. Both sites have been 'socially' studied, including levels of local awareness, knowledge, perceptions, issues affecting local well-being, as well as trusted media, institutions, and public representatives. One of the preliminary tasks in the WP dedicated to advancing public awareness, was to create a 'social map' of stakeholder opinions and opinion shapers. In addition, in both sites, community representatives and the local public were informed about the research and involved in discussions about CCS by a focus conference and an information meeting.

3.4 R&Dialogue

R&Dialogue[4] is a European research action project (2012 – 2016) on dialogue science-society in energy transitions in ten participating countries (Czech Republic, France, Germany, Greece, Italy, the Netherlands, Norway, Portugal, Spain and the UK). The partners include research organisations, NGOs and consultancies from the field of energy. The project aims to develop national action plans and a European vision towards a low-carbon society through organising a dialogue between R&D organisations and civil society organisations. Among other low carbon technologies, like wind, biomass, solar power, tidal or geothermal energy, R&Dialogue considers CCS. The project website includes the following examples of sustainable energy projects with this specific technology: the Rotterdam Capture and Storage Demonstration project (ROAD) which is a joint project by EON Benelux and GDF Suez Energie Netherlands, starting in 2015; and Ardmucknish Bay QICS project (Quantifying and monitoring potential ecosystem Impacts of geological Carbon Storage) which took place in summer 2012.

4. National CCS projects and initiatives

This report presents some of the commercial or experimental projects on carbon capture and storage in the USA, Australia and Europe. The intention is not to revisit all the projects in detail because much has already been written on the different experiences. Several organisations around the world gather information on the specific CCS projects. The Massachussets Institute of Technology (MIT) has a database with CCS projects worldwide, including announced projects, cancelled and inactive[5]. Similarly, the Global CCS Institute provides information on large scale integrated CCS projects around the world[6]. Specifically on communication and engagement, the Commonweath Scientific and Industrial Research Organisation (CSIRO) has undertaken a series of case study reports as part of an international comparison of communication and engagement practices surrounding carbon dioxide capture and storage projects[7].

This section summarises some of the key aspects of each case and briefly highlights the lessons learned as reported in the reviewed literature. It should be emphasized that the social response to a specific project is complex and is a combination of different factors. It is therefore difficult to explain why a certain project was cancelled or supported based only in one factor.

The cases described below are summarized in Table 1.

[4] See http://www.rndialogue.eu for further information.
5 Further information at sequestration.mit.edu/tools/projects/index.html.
6 See www.globalccsinstitute.com.
[7] The reports are available at www.csiro.au

Table 1. Comparing CCS projects

Case study	Project type	Site selection	Community characteristics	Communication and engagement tools used	Project outcome
Barendretch (Netherlands)	Permitting procedure for commercial storage (CCS at an oil refinery (0.3 million tCO2/year)	Private industry selection, supplemented by grant award	Urban area, densely populated residential area above storage sites. Major infrastructural changes. Heavily industrialized area.	Top down approach; no engagement in project design; reactive to opposition. Formal hearings as part of impact assessments. Information center at shopping mall. Websites and informational flyers. Personal visits by national ministers.	Project cancelled by the Government due to extensive delays and complete lack of local support. Negative media coverage.
Beeskow (Germany)	Explore suitability to store CO2 on a commercial scale	Private industry selection, supplemented by subsidies by the EU	Rural area, residents living above storage site. Strong local appreciation for nature, rural area, no significant industry.	Information to community representatives. Internet site Brochures Free telephone hotline. Press conference. Information office Information to schools, clubs, etc.	Project cancelled
Laq-Rousse (France)	Demonstration onshore CCS.	Private industry selection.	Semi-urban or rural area. Low history of industry. Familiarity with the type of industry.	Consultation charter Q&A hotline Quarterly information bulletin Public hearings Scientific follow-up committee (with government support) Open days Local Information and Monitoring Commission (CLIS)	Began operation in 2010. Local support.
FutureGen (US)	Research-oriented IGCC with CCS (1 million tCO2/year)	Competitive process using extensive siting criteria to select from interested	Rural area.	Public-private partnership Interviews and focus groups, stakeholder meetings; Economic development perspective emphasized Educational demonstrations and meetings with local residents	Strong community support. Stakeholder meetings led to better designed site plan for the facility.

		potential host communities		Public hearings	
Ketzin (Germany)	Small scale R&D (CO2Sink research project to observe and analyse effects of CO2 injection into a reservoir).	Funded and managed by research institute and public sector	Rural area, no people living above storage site. History of local industrial development and gas storage, renewable energy (wind, biomass).	Officials and the public informed and involved during the planning stage (meetings). Website. Tours of the site. Press conferences. Newspapers. Affected municipalities invited to make statements, although not compulsory.	Strong support from the community.
Otway Basin Pilot Project (Australia)	Demonstration program, pilot research project, set up by CO2CRC Pilot project Ltd	CO2CRC (Cooperative Research Centre for Greenhouse Gas Technologies)	Rural districts with dairy farms and associated milk processing.	Community reference group; community liaison; visits; events, informative website, newsletters; educational resources to local schools, fact sheets and brochures.	Completed first phase of injection. Second CCS trial successfully completed in March 2012. Monitoring to continue up to 2015.
Compostilla project (Spain)	Pilot and full scale demonstration project	Alliance CIUDEN, Endesa and Foster Wheeler	Hontomín is a small village (84 inhabitants in 2011) in the municipality of Merindad del Rio Ubierna (1433 inhabitants). Previous mining activities. Economic collapse in the 1980s.	Collaboration agreement between CIUDEN and local administrations to articulate short and medium term objectives. Guided tours, interviews, meetings, social characterisation, videos. Economic and social development perspective.	Completed first phase in October 2013. Second phase ongoing.

Source: adapted from World Resources Institute (2010).

4.1 Barendretch (Netherlands)

As shown above, Netherlands has the highest levels of public awareness of CCS in Europe, where more than 50% of the population have heard of this technology and knows what it means. However, high level of knowledge at national level does not necessarily mean that the level of support to this technology is also high at the local level, when a community is selected to host a storage facility, as in the case of Barendrecht. It should also be noted that interestingly the Eurobarometer survey shows that the Netherlands had the second lowest proportion of respondents who thought that CCS would be beneficial (EC, 2011).

Barendrecht is a small densely populated residential village in the Netherlands (46000 hab.), close to Rotterdam. The onshore storage facility project promoted by Shell started in 2007 when Shell proposed two depleted gas fields in the area. The project originally received support by the Dutch government and was eligible for government funding provided the necessary permits were obtained. However, the Dutch government cancelled the project by the end of 2010 due to opposition from the local population and local politicians. Since then, on-shore storage is not authorized in the Netherlands although there are off shore projects under way. A detailed analysis on the Barendrecht project can be found in Feenstra et al. (2010); Kuijper (2011) and Brunsting et al. (2011). In addition different surveys have been conducted to examine the level of public awareness, attitudes and beliefs concerning the CCS project before and after the decision to cancel the project (Ter Mors et al., 2011; Terwel et al., 2012).

Based on the literature mentioned above and at risk of simplifying, some of the lessons learned from the experience in Barendretch and the factors that went wrong are summarized below:

- The lack of a discussion and justification about CCS in the larger context of climate change and of alternative solutions, before any specific details of any CCS demonstration project starts;
- The values, needs and opinions of stakeholders should be investigated and taken into account in the project design, being flexible enough to seek compromises and adapt;
- The project was presented to the community as a final plan and this also led to a lack of trust in the proponents, as there seemed to be no room for discussion. Both project developers and the national government were not trusted by the local community. Furthermore, distrust in the national government increased because of the gradually withdrawal of executive decision-making abilities from the municipal government by the national government (without prior announcement).
- The debate only took place via formal procedures, like media, press releases or via the BCO2 (administrative consultation groups). No direct contact existed between the project developers and opponents.
- Prangnell (2013) points out at specific ways in which the content information was presented. The simplified schema of underground storage describing the depth of the storage strata and not drawn to scale, made people feel that the CO2 was beneath their feet and could seep into their houses at any moment.

4.2 Beeskow and Ketzin (Germany)

In the framework of the NearCO2 project, Dütschke (2011) analyses and compares two CO2 underground storage projects in the region of Brandenburg in Germany: a) the CO2Sink research project at Ketzin, which started to inject CO2 in 2008 and has been well accepted by local politicians and the local public and b) the project initiated by Vattenfall at Beeskow which met strong local opposition. The former was part of the CO2Sink demonstration project coordinated by GFZ German Research Centre for Geosciences in collaboration with the site manager Verbundnetz Gas (VNG) whilst the latter was part of a commercial strategy by the Swedish company Vattenfall. Although in both cases communication with the public took place at an early stage and using different channels, in Ketzin community representatives were involved before any activities had started whereas in the case of Beeskow, the affected communities learned about the project when it was already decided to go for an exploration permit. Local action environmental groups organised themselves and opposed to the project until it was stopped in 2010.

Dütschke (2011) found out that other factors like the scale of the project and the level of industrialization in the area also played a role. The dimension of the project was an important factor influencing acceptance (in the case of Ketzin because of the small scale) or resistance (in the case of Beeskow, as the project has a commercial size). The industrial history of the community might have helped in the level of acceptance. Ketzin had a storage of natural gas before whereas Beeskow is a rural area with almost none industries. The case of Ketzin also illustrates the importance of having academic institutes as leaders of the project, because these are considered impartial and are trusted organisations by the public. In general, trust in industrial energy providers is limited. The debate around radioactive waste disposal also contributed to enhance distrust by the general public.

4.3 Laq (France)

Ha-Duong et al. (2013) extensively describe the different phases through which the project of Total went with regards to the social aspects: before and after the permit request and operations. Total's Lacq plant is the first end-to-end carbon capture, transportation and storage demonstration facility in Europe. This commercial scale demonstration project began injecting CO2 in January 2010. It included a comprehensive monitoring program to verify that no gas is leaking from the storage site and that the environment is not being impacted by the injection of carbon. In 2007, Total launched a consultation process involving all stakeholders in the areas around Lacq and Rousse to discuss the context of climate change, the potential of CO2 capture and storage, the reasons for choosing the Lacq Basin, the project details and impacts and the spin-off for the surrounding area[8]. Total organised three information sessions open to all interested parties. Early informal engagement with approximately 40 local people prepared for these meetings. In addition, the developer published a 'consultation charter' to guarantee a meaningful dialogue with all stakeholders as well as an information brochure will all details of the project context and operation, among others. Transparency and trust were recognized by Total as key aspects to gain approval from the community. High-level employees from Total attended the meetings, showing the importance of considering the community seriously in the process. In addition, a Local Information and Monitoring Commission (CLIS) was set up to continue dialogue between Total and local stakeholders. The CLIS is constituted of 4 State representatives, 9 locally elected, 2 from unions, 4 from associations, 5 experts and 4 from Total. It has legal power to ask the developer to provide further evidence or investigations on certain topics and makes public their independent assessment of the project.

Ha-Duong et al. (2013) recognize Total's attention to social aspects by engaging early with the public and investing human and economic resources to take into account social needs and concerns. However, more people could have taken part in the meetings if the process would have run for a longer period or had reached a wider audience.

[8] Information from Total at: http://total.com/en/society-environment/environment/climate-carbon/carbon-capture-storage/lacq-pilot-project/discussion-consensus-building

4.4 Otway (Australia)

The CO2CRC Otway project is the first demonstration CCS project in Australia which aims to demonstrate that CCS is technically and environmentally safe and meets the expectations of government and the community. The project includes a comprehensive monitoring programme. Actions have been undertaken at the community level, such as establishing the Otway Project community reference group constituted of local landowners, regulators, local government representatives and community groups. This group allows stakeholders to be regularly updated of project progress and share opinions and ideas. In addition, a former school teacher was appointed as community liaison officer to ensure local contact with landholders, researchers, visitors and the local community. The liaison officer also runs events such as Open Days and regular tours of the project.

According to Ashworth et al. (2010) the appointment of the community liaison officer from the local community was a key factor in a well structured communications plan for a successful development of the project. Other positive initiatives that helped the project were the community reference group, the open days or the visits from the head of CO2CRC to the area. Some incidents regarding seismic surveys and the relationship with a landowner were the least successful aspects of community engagement. In general though, informal face to face meetings with landholders and stakeholders were an important factor for building trust between CO2CRC and the community.

4.5 Compostilla project (Spain)

The Endesa's Compostilla Plant is one of the six CCS projects selected by the European Commission to receive up to 180€ million from the EU European Energy Programme for Recovery. The main aim is to validate CCS technology. The project has been divided into two phases: technological development (2009-2012) and construction of the demonstration project infrastructure (2013-2015). The project involves the development of a pilot plant to capture CO2 in Compostilla (Ponferrada, León), the experimental underground storage in Hontomín (Burgos) and the commercial underground storage in Sahagún (León). The Foundation CIUDEN was established in 2006 by the Government to develop CCS in Spain. Apart from driving CCS forward, the objective of CIUDEN is also to contribute to the economic and social development of the Bierzo area, after the decline of the local mining industry in the 1980s. CIUDEN also built a National Energy Museum to disseminate knowledge about the science around energy.

During phase one of the project, consisting of testing injection and monitoring techniques at Hontomín, CIUDEN set up a communications panel with communication specialists of CIUDEN, academics and journalists and emphasized the advantages of the facility for improving local economy. The fact that CIUDEN is not an energy company and the project has research purpose, facilitated engagement with the local population. Different events were organized, like an Open day, with an informative conference for adults and an activity for children.

During phase two of the project, in Sahagún, Endesa was leading the activities and technical works to assess the suitability of the deep saline aquifer started before any engagement activities had been undertaken. The project encountered problems to get permit applications from land owners. A public engagement and communication plan was developed to respond to the new situation, based on organizing site visits, educational activities for children and meetings.

After the national elections in November 2011 and the change of government, a new management board is in charge of CIUDEN. The reduction in R&D has also affected the structure, philosophy and project of CIUDEN. Román (2012) explains that the territorial development approach and the communication plans have been abandoned. CIUDEN is now focusing only in explaining the actions and the project is closed to local participation. The consequences of this changes will have to be followed to evaluate the extent to which this will affect the development of the project.

4.6 FutureGen (US)

FutureGen was a government project to construct a near zero-emissions coal-fueled power plant to produce hydrogen and electricity while capturing and storing CO2 underground. Site selection for the FutureGen facility was based on a competitive tendering process. Twelve sites were proposed in seven states and four sites in two states were semi-finalists. Mattoon was the selected site but after determining that the costs would be too high, DoE withdrew support and the project was reconfigured in 2010. Hund and Greenberg (2010) provide a retrospective view of the FutureGen project initiated in 2006 through 2010. The new phase of the project, FutureGen 2.0, aims to upgrade an existing power plant with oxy-combustion technology to capture approximately 90% of the plant's carbon emissions. The CO2 will be transported and stored underground at a nearby storage site. DoE awarded one billion dollar funding to the FutureGen Industrial Alliance to build FutureGen 2.0.

The FutureGEn Industrial Alliance issued a 'Guidance for Prospective Site Oferrors' which provided the description of the site selection process and schedule, selection criteria and documentation to be provided by applicants. One of the criteria for the site selection was local community support for the CO2 storage site. The applicants were asked to provide evidence of this support, through for example letters from local community leaders or neighbours[9]. Four locations were short-listed. On 28 February 2011 the Alliance selected a storage site in Morgan County, Illinois, due to the high quality geology and close proximity to Meredosia power plant, which simplifies pipeline routing and reduces the overall cost of the project (Hayhow, 2011). Thus, the activities of FutureGen 2.0 are divided into two distinct but related projects: Meredosia Oxy-Combustion Power plant project and CO2 pipeline and storage project. Before commencing full-scale operations, the storage site has been the subject of an extensive draft Environmental Impact Statement conducted by DoE for public review, public hearing and comments. The final Environmental Impact Statement was issued in October 2013. It is estimated that the project will be a major economic driver and job creator.

5. Lessons learnt

For the general public CCS is still a relatively new topic. Several studies at national and international levels show that in many countries, knowledge levels of CCS are still relatively low compared to other energy-related technologies. Thus, the public is confronted with a new technology that aims to dramatically reduce CO2 emissions, but which is currently surrounded by scientific, technical, economic and political uncertainties. A crucial factor for its success or failure is how CCS is embedded in the local socio-political context. Furthermore, it is important that the national, regional and local contexts are coordinated and that an appropriate regulatory framework is in place for a CCS project to progress. According to the European Academies Science Advisory Council, the EU demonstration projects play an important role to ground the debate and build public familiarity with, and understanding of what CCS is

[9] http://www.futuregenalliance.org/resources/siting-faqs/

in practice. Furthermore, there is a role of the demonstration plants to build experience of public engagement approaches at the local level (EASAC, 2013).

This report has identified the following areas where lessons can be learnt with regards to communication and engagement around CCS activities:

- There are many factors that influence the development of a CCS project in a specific context: the project characteristics, the promoter, the perception of risk, the willingness and level of commitment towards the local community, the role of local politicians and local actors, etc. It has been shown that an R&D project which establishes strong links with the local community from the beginning, in a rural area with specific needs to diversify the local economy and previous experience with industrial activities seems more likely to get the approval of the community. However, one should be cautious about the extent to which experience from other project is transferred to different contexts.
- The communication and engagement strategy should be adjusted to the local context. The local context must be well characterized before any communication and involvement activities are considered. The familiarity of the population with industrial activities, the perception of risk, the economic and political context, etc are factors that need to be taken into account as they will influence the public response to the project. The project should also fit the local context.
- Proactive engagement should start at an early stage of the project and be a two way dialogue, involving transparent and frequent communication with the different stakeholders. It is crucial to explain the rationale for CCS, justify the different alternatives and situate the debate in the wider context of climate change, alternative technologies, policy choices, uncertainties, priorities and social values. Technical aspects will also be a part of the debate. It is important to be willing to discuss openly the different issues and concerns.
- Trust is a critical factor. In general, the level of trust in the developers or the communicators from the energy sector is low. Involving third parties, like experts or local community leaders may be a mechanism to build confidence.
- Objective, balanced and transparent information is a first step towards informing the public and developing an informed public debate on the issue. Information is most positively perceived if it comes from multiple sources with different interests. It should be recognized however that there are many factors other than knowledge shaping opinions about technology.

Taken together, the research on CCS and the different projects undertaken across the world underscore the need to further advance the social science research agenda on CCS. Research in social sciences does not only have a role in analyzing governance processes, understanding risk perception or building comparative analysis across technologies and countries, but it may have a role in informing different actors, including policy makers, about decision-making processes on controversial technologies. Within the framework of the TRUST project, we will continue to follow the evolving experience in communication and engagement processes in different CCS initiatives.

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