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What could be in store for carbon capture?

Emerging pathways based on stakeholder perspectives

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Jag skulle vilja tacka...

My classmates for making the learning experience so fun. Yes there was lots of work and lots of complaining but my first thought is what a fun couple of years. To be surrounded by people you genuinely like and respect is a treasure.

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Ice. Cold. Riders. Forever.

Abstract

European power generators are facing a powerful suite of drivers to engage in carbon capture and storage (CCS). However, the future for CCS is uncertain. The type and level of engagement will depend on how CCS develops. This work, based heavily on primary data, collected thoughts and opinions of 37 stakeholders in Northern Europe in the CCS field today encompassing power companies, NGOs, academics, and governments. This work explored attributes of *power*, *legitimacy*, and *urgency* on achieving the *commercial applications of CCS technologies* held by these stakeholders, and gained insights from their thoughts on the CCS field. The end result of the insights gained, alongside an understanding of stakeholder relationships with achieving the *commercial application of CCS technology,* are three development paths for CCS. These three storylines describe a "fast", "slow", and "failed" commercialization of CCS technologies. This work can be built upon for use as a decision making tool by stakeholders involved in CCS to aid in understanding how to act today based on how the future may look. Strategizing in this dynamic manner can help to understand the possible ways in which stakeholders can affect or be affected by the potential development paths of CCS, one of which is the commercial applications of the technology.

Executive Summary

The European Union (EU) has long been at the forefront of international efforts to combat climate change. To limit the global average temperature increase to less than 2ºC compared to pre-industrial levels, the European Parliament has proposed an EU CO_2 reduction target of 30% for 2020 and 60-80% for 2050.

One method of achieving this target is through the reduction of emissions from the power generation sector, a significant contributor of carbon dioxide (CO_2) emissions, through carbon capture and storage (CCS). CCS is a process whereby CO_2 emissions that result from the combustion of carbon based fuels used for electricity production are captured, compressed to a liquid, and transported for underground storage in suitable aquifers about 1km underground. The EU's proposed actions related to CCS are consistent with attention to CCS in the International Energy Agency's World Energy Outlook 2006 and 2007 publications, the IPCC Fourth Assessment Report published in 2007, and the IPCC Special Report on CCS, published in 2005.

European power generators are facing a powerful suite of drivers to engage in CCS in some fashion. As of now, the technology is in the pilot phases, and the EU government has called for 10-12 demonstration plants to be operating no later than 2020. The future of CCS is riddled with uncertainty and hinges on among other things, policy, the CO_2 market, post 2012 Kyoto agreements, the efficiency of the technology, the risks and probability of leakage and acceptance of CCS by the public. Currently, many people are involved in CCS through projects, shaping the market, and forming opinions. This CCS "movement" includes but is not limited to: industry, governments, non-governmental organizations (NGOs), researchers, the public, and media.

The focus question of this work "*What pathways are emerging as the CCS movement proceeds?*" aims to bring forward potential development pathways for CCS based on inputs of those engaged in the field in Northern Europe.

This was done through the exploration and analysis of the following two research questions:

- Who are stakeholders in the CCS movement?
- How do they see the field at present and in the future?

Answering the first research question "*Who are stakeholders in the CCS movement?"* involved identifying and interviewing 37 stakeholders in the CCS field and exploring their relationship with CCS through their possession of "*power*, *legitimacy* and *urgency*". The theory used in this work stipulates that for the objective of *the commercial application of CCS technologies* to be prioritized, stakeholders must possess all three of these attributes.

As it appears in this work, no stakeholders in the CCS movement (the CCS Community) possess all three attributes of *power*, *legitimacy* and *urgency* to prioritize the *commercial application of CCS* (see Section 4). This work also indicates that it is possible that if the CCS Community stays in this stakeholder snapshot (see Figure 4-2), the claim may continue to not be prioritized. This analysis shows that one way for the *commercial applications of CCS* to be prioritized is for power companies and governments to increase attributes of *power* and *urgency*. This does however, not mean that it is possible for them to do so. Furthermore, as CCS is in an early development stage, acting urgently now requires a long-term view, and a belief of CCS in the energy future. Even if this belief and long-term view is present, cost explosions must be avoided, so the momentum of urgency may be compromised. Mapping the stakeholders in

the CCS Community provided insights into where different groups of those engaged in CCS "stand" on the prioritization of the *commercial application of CCS technologies*. It also provided insights into how they can affect, or be affected by the movements of other stakeholders. Understanding the "stance" of various stakeholders was used to provide context when analyzing their views on the current and potential future functioning dynamics of CCS (Section 5); and to provide the storylines for the development paths (Section 6). That is, by having insight into what stakeholders think and know combined with where they stand, one can then understand how they may act, or how they can act in relation to an objective *(i.e.,* the *commercial application of CCS technologies).*

Answering the second research question "*How do they see the field at present and in the future?*" involved describing the functioning dynamic of CCS as described by stakeholders through 7 functions: *knowledge development and diffusion; influence on the direction of search; entrepreneurial experimentation; market formation; legitimacy; resource mobilization;* and *free utilities*. The stakeholders have different viewpoints on the functioning dynamic of CCS based on their apparent *power*, *legitimacy* and *urgency* on achieving *commercial applications of CCS technology*. This can cause a difference in opinions and beliefs within stakeholders groups (e.g., NGOs versus power companies), but also within groups themselves (for example amongst NGOs like Greenpeace or Bellona), hinging on various attributes of *power*, *legitimacy* and *urgency* on the claim.

To answer the focus question "*What pathways are emerging as the CCS movement proceeds"* the insights, trends, and ideas gained from exploration of the CCS dynamic were then further grouped into three CCS development pathways:

1. "On a War Footing" describes rapid implementation of the commercial application of CCS technologies;

2. "Better Late than Never?" describes a slower implementation of the commercial application of CCS technologies; and

3. "Trial and Error" describes a demonstration phase that does not lead to the widespread application of CCS.

The pathways serve as a tangible starting point for further scenario building and speculation on what the future may hold for CCS. As put by Lindgren and Bandhold, scenarios can be "*a way to reduce a great and complex amount of information to a manageable format, communicate complex messages to a large and diverse audience, thereby assisting shared exploration of the future across a group of stakeholder*s". It is hoped that this work will serve as a basis for a decision making tool for stakeholders involved in CCS in guiding how to act today based on an understanding of how the future may look.

Future areas of research include exploring how stakeholders like power companies may gain "power", for example through private investment. In this case, of particular interest may be to research market actors like big banks or asset management firms to understand details surrounding favourable conditions for investment in CCS. This research did not explore how stakeholders like governments may gain "urgency". Do stakeholders believe they are acting urgently? How might urgency be influenced so that the *commercial application of CCS* may be realized? While it appears that during the time of this work, claims towards the *commercial application of CCS technologies* are not urgent "enough", further research may be applicable surrounding the concept of urgency as it relates to CCS. What criteria can be developed to regard actions as "urgent" when keeping in mind issues of time and feasibility? Finally, elements of the CCS functioning dynamic could be researched in more detail. For example

functions of market formation (what is needed for private investment to occur?); legitimacy (CCS as compared to biofuels, GMOs or nuclear waste); or influence on the direction of search (examination on what is meant by "bridging the gap") could be explored across the stakeholder map, within certain stakeholders, or amongst stakeholders not represented in this work (e.g., media, public, or market actors).

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1 Introduction

Over a decade ago, many countries signed an international treaty, the United Nations Framework Convention on Climate Change[1] (UNFCCC) to begin to consider what could be done to reduce global warming and to cope with inevitable temperature increases (UNFCCC, 2008). The Kyoto Protocol (the Protocol), adopted in 1997, and in force since 2005, is an international agreement linked to the UNFCCC where nations are legally bound to reduce their greenhouse gas (GHG) emissions over the five-year period of 2008-2012. The Protocol places a heavier burden on developed countries, recognizing that they are responsible for the current levels of GHG emissions. These reductions are to be made primarily through national measures, but also through the use of the Kyoto market based mechanisms: Joint Implementation (JI), the Clean Development Mechanism (CDM); and Emissions Trading.

The European Union (EU) has long been at the forefront of international efforts to combat climate change, playing a key role in the development of the Convention and the Protocol, and taking steps to address its own GHG emissions since 1990s through the implementation of targets into Member State (MS) policies and use of the Kyoto mechanisms including the development of the EU Emissions Trading Scheme (EU-ETS)[2].

The targets of the first commitment of the Kyoto Protocol expire in 2012. On January 10, 2007 the European Commission proposed options for keeping climate change to manageable levels through its Communication "*Limiting Global Climate Change to 2° Celsius: The way ahead for 2020 and beyond*" (European Commission, 2008). The Communication, part of a comprehensive package of measures to establish a new Energy Policy for Europe, was a major contribution to the discussion on a global agreement to combat climate change after 2012, when the Kyoto Protocol's emissions targets expire (European Commission, 2008).

The following is cited directly from the Communication (COM/2007/0002 final, 2007):

Strong scientific evidence shows that urgent action to tackle climate change is imperative. Recent studies, such as the Stern review, reaffirm the enormous costs of failure to act. These costs are economic, but also social and environmental and will especially fall on the poor, in both developing and developed countries. A failure to act will have serious local and global security implications. Most solutions are readily available, but governments must now adopt policies to implement them. Not only is the economic cost of doing so manageable, tackling climate change also brings considerable benefits in other respects.

The EU's objective is ***to limit global average temperature increase to less than 2°C*** *compared to pre-industrial levels. This will limit the impacts of climate change and the likelihood of massive and irreversible disruptions of the global ecosystem. The Council has noted that this will require atmospheric concentrations of GHG to remain well below 550 ppmv CO_2 equivalent. By stabilising long-term concentrations at around 450 ppmv CO_2 equivalent there is a 50 % chance of doing so. This will require global GHG* ***emissions to peak before 2025*** *and then* ***fall by up to 50 % by 2050 compared to 1990 levels****. The Council has agreed that developed countries will have to continue to take the lead to*

[1] The Convention on Climate Change sets an overall framework for intergovernmental efforts to tackle the challenge posed by climate change. It recognizes that the climate system is a shared resource whose stability can be affected by industrial and other emissions of carbon dioxide and other greenhouse gases. The Convention enjoys near universal membership, with 192 countries having ratified (UNFCCC, 2008).

[2] In January 2005 the EU-ETS commenced operation as the largest multi-country, multi-sector GHG emission trading scheme worldwide (European Commission, 2008a)

reduce their emissions between 15 to 30 % by 2020. ***The European Parliament has proposed an EU CO_2 reduction target of 30 % for 2020 and 60 to 80 % for 2050.***

To achieve these objectives, the Communication proposed a set of actions[3] some of which are presented below:

- improve the EU's energy efficiency by 20 % by 2020;
- increase the share of renewable energy to 20 % by 2020;
- adopt an environmentally safe **carbon capture and geological storage (CCS)** policy, including the construction of 12 large-scale demonstration plants in Europe by 2015;
- strengthen[4] the EU-ETS, including the recognition of **CCS**;
- limit transport emissions; and
- reduce GHG emissions reductions in other sectors, namely residential and commercial buildings.

The EU's proposed actions related to carbon capture and storage (CCS) are consistent with attention to CCS in the International Energy Agency's (IEA) World Energy Outlook[5] 2006 and 2007 publications, the Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report published in 2007, and the IPCC Special Report on CCS, published in 2005.

The presentation of the following work (referred to herein as the "work" or "research") explores carbon capture and storage (CCS) in the context that it is one of the methods proposed by the EU to combat climate change. The following section provides a brief background on CCS, the power plant infrastructure in Europe, and relevant happenings in the CCS field at present.

1.1 Background

Carbon capture and storage (CCS) involves capturing the carbon dioxide (CO_2) arising from the combustion of carbon containing fuels in power generation, or from the preparation of fossil fuels in natural-gas processing (IPCC, 2005). CCS can also be applied to certain industrial processes, such as the production of hydrogen, ammonia, iron and steel, or cement, and to the combustion of biomass-based fuels, the latter which has the potential to yield negative emissions.

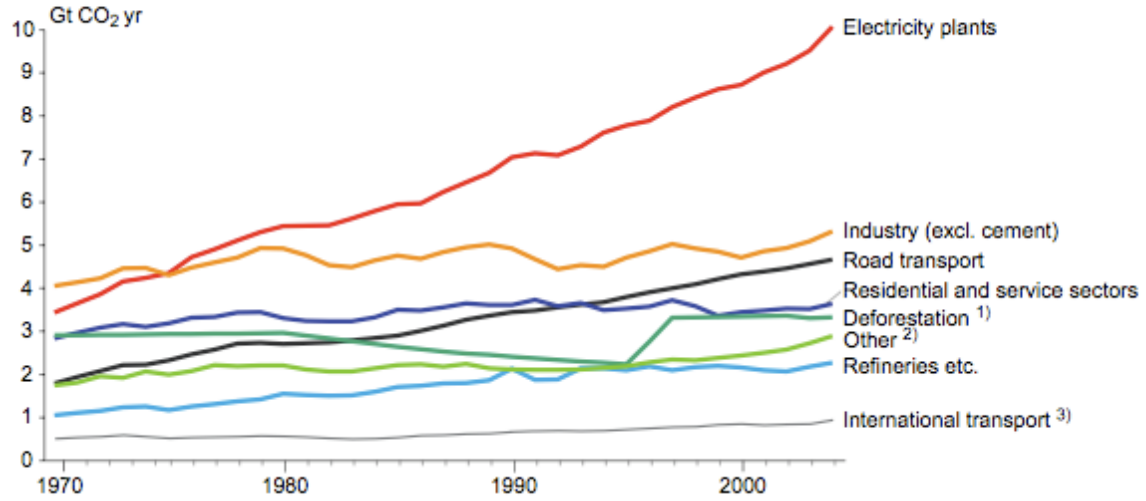
The burning of fossil fuels (oil, coal, and natural gas) in power generation accounts for approximately 60% of the nearly 50 Gt per year of GHG emissions globally (IPCC, 2007). The following figure from the IPCC's Fourth Assessment Report shows steady growth of

[3] Emissions reductions are from 1990 levels.

[4] 45 % of the EU's CO_2 emissions are covered by the EU-ETS. For a greater proportion to be covered from 2013, the following options to strengthen the role of the scheme should be considered in the review of the EU-ETS: make allocations for more than five years in order to provide predictability for long-term investment decisions; extend the scheme to other gases and sectors and recognise carbon capture and geological storage (COM/2007/0002 final, 2007)

[5] Annual publication by the International Energy Agency containing medium to long term energy analysis and projections; influential in policy objectives amongst OECD countries.

CO_2 emissions from fossil fuel emissions and that the largest single contributor to CO_2 emissions is electricity generation.



1) Including fuelwood at 10% net contribution. Including decomposition and peat fires, excluding fossil fuel fires (for complete information see reference).
2) Other domestic surface transport, non-energetic use of fuels, cement production and venting/flaring of gas from oil production.
3) Including aviation and marine transport.

Source: (IPCC, 2007)

Figure 1-1 – Sources of global CO2 emissions, 1970-2004 (only direct emissions by sector)

There are a number of advanced technologies that can mitigate emissions from electricity generation. These advanced technologies can be generalized as efficiency improvements (both generation and end-use), decarbonization and sequestration (e.g., CCS), use of renewables, and use of nuclear energy (Hoffert et al., 2002).

At the present time some of these technologies may be more desirable than others; however, achieving emissions reductions will require more than one technology (Pacala & Socolow, 2004).

1.1.1 European Power Plant Infrastructure

A newly established database from research at Chalmers University (Kjärstad & Johnsson, 2007) provides detailed information of the European power plant infrastructure for the EU25 Member states. This database registers 4700 operating power plants (of at least 10MW) covering all available technologies (except for wind), with a combined capacity of 665 GW.

The following information is presented from their paper "*The European power plant infrastructure-Presentation of the Chalmers energy infrastructure database with applications*" (2007):

- Up until the mid-1990s in the EU, coal and nuclear dominated plants built (see Figure 1-2), while natural gas fired plants have dominated investments during the last decade. Looking at planned plants and those under construction it is possible that natural gas will continue to dominate investments well into the next decade (Kjärstad & Johnsson, 2007).
- This expansion of natural gas will depend on many factors, like security of supply, post 2012 emission restrictions, nuclear phase-out, and the potential for low-carbon technologies like CCS (Kjärstad & Johnsson, 2007).

- On the other hand, Europe's proven coal and lignite reserves are almost 40 billion tons (at the end of 2005 according to British Petroleum) allowing for more than 60 years of production at current production rate (Kjärstad & Johnsson, 2007).

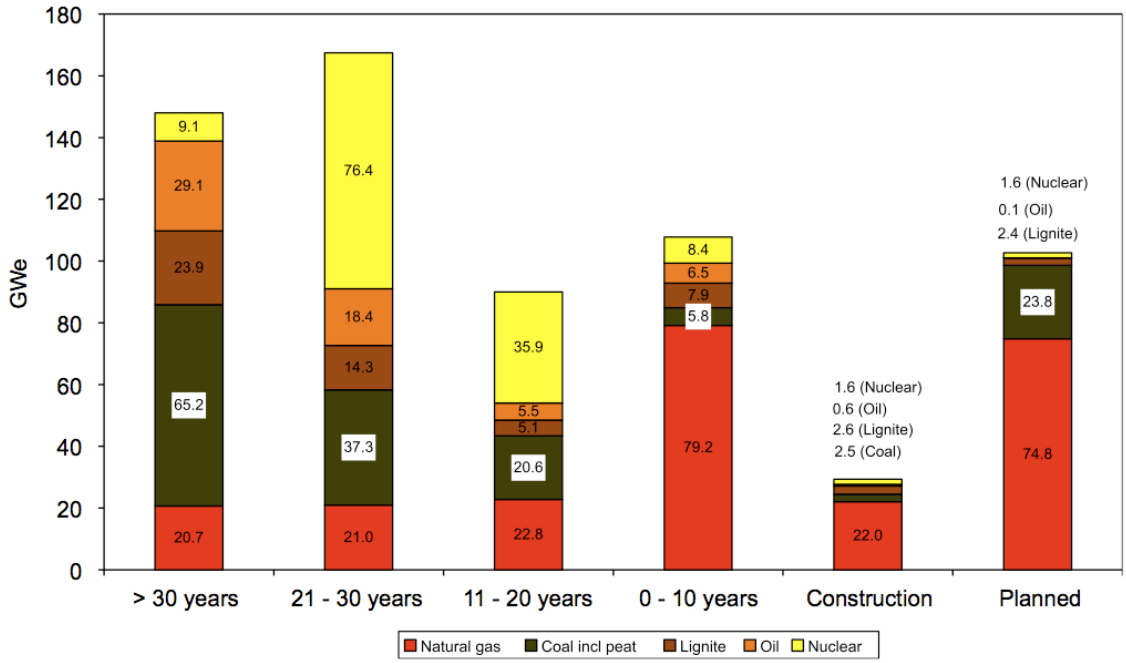


Figure 1-2 - Net capacity of thermal power plants in EU-25 in operation, under construction and planned, distributed by fuel and age and as of May 2006 (thermal plants fuelled on biomass or waste not shown). Source: (Kjärstad & Johnsson, 2007)

In the context of CCS, the match up between the locations of emission sources (power plants) and potential storage sites is important. The geographical distribution by fuel of operating thermal plants in EU-25 is presented in the Figure 1-3.

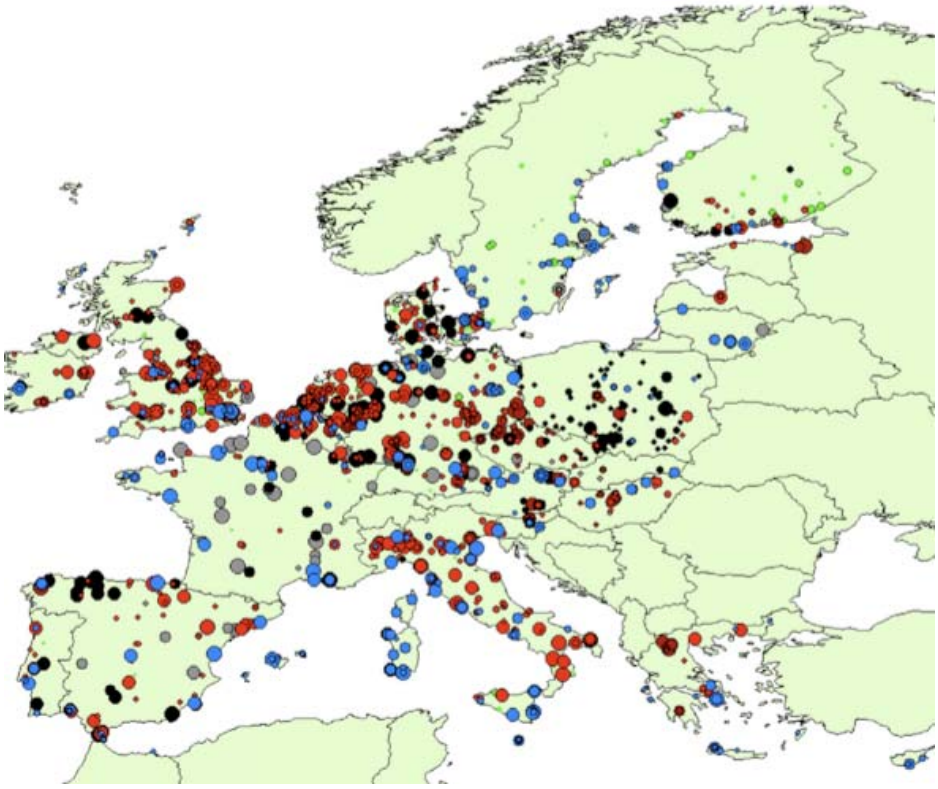


Figure 1-3 - *Geographical distribution by fuel of operating thermal plants in EU-25. Red denotes gas-fuelled plants, black denotes coal, brown denotes lignite, blue denotes oil, yellow denotes nuclear while green denotes biomass/waste plants. Source (Kjärstad & Johnsson, 2007).*

Coal and lignite presently account for around one-third of the EU's electricity production (European Commission, 2008b). Coal reserves (including lignite) are present in considerable amounts in Germany, Poland, the UK and Turkey (Euracoal, 2004). According to Kjärstad & Johnsson, the EU has well established trading of coal with non-OPEC countries like Australia, Colombia, South Africa and USA and, so far, the coal price appears more stable than the oil and gas prices (Kjärstad & Johnsson, 2007). Coal-based power generation in combination with CCS will enhance security of supply for electricity and heat through use of an indigenous energy source (i.e., coal and lignite) and through diversification of fuel, suppliers and transport routes (Kjärstad & Johnsson, 2007). The authors convey that altogether, 5 GW of coal and lignite capacity is under construction within EU25 as of May 2006 while another 26 GW is being planned (Kjärstad & Johnsson, 2007).

The current European energy system is based on a centralized concept, with large point sources and transmission networks used to distribute to end consumers. In contrast, a distributed energy system can refer to an energy system in which energy conversions units are located close to energy consumer, including the distribution of technology, the reallocation of decision-making, expertise, ownership, and responsibility in terms of energy supply (Alanne & Saari, 2006). Distributed energy systems do not fit the existing electricity market. Although distributed energy systems can be seen as disruptive, appropriate changes may allow for the potential of huge growth (Greenpeace , 2007) and a recent energy scenario document from Greenpeace predicts a high penetration of renewable energy starts from 2030 onwards (Greenpeace , 2007). This growth, and transition from a centralized to a distributed system, is likely to be slow as centralized generation is filled with sunken costs, and comparatively larger generating capacities. As such, CCS is viewed by many proponents as a "gap bridging" solution until a better alternative is viable.

1.1.2 Carbon Capture and Storage (CCS)

Carbon capture and storage (CCS) involves the capture of carbon dioxide (CO_2), compression into a liquid and transport to a suitable underground storage location.

Capturing CO_2 involves separating the CO_2 from some other gases, compressing it to reduce its volume (to occupy around 0.2% of the volume of the gas at standard temperature and pressure) for transport to a suitable geological reservoir (IPCC, 2005, 2007).

Capture techniques vary mostly among three main types: pre-combustion, post-combustion oxyfuel combustion. All of these types of capture systems currently consume large amounts of energy, resulting in decreased plant efficiencies and reduced net power outputs when compared against the same plants without capture systems (Mccoy, 2008). The associated energy penalty (loss of efficiency) is around 30%[6]. Available technology captures about 85–95% of the CO_2 processed in a capture plant. Currently, power companies and suppliers are exploring the different types of technologies. While the technologies available work today at a pilot level, it is expected that future improvements will increase efficiency and drive down costs.

Transportation can be by truck, ship, rail, or pipeline. During the early stages of the technology truck or ship may be used, while larger scale deployment will likely involve pipeline transportation[7]. Pipeline transport of CO_2 operates in a mature market in the US, where over 2,500 km of pipelines transport more than 40MtCO_2 per year (IPCC, 2005). The local risks associated with pipeline transportation could be similar to or lower than those posed by hydrocarbon pipelines already in operation (IPCC, 2005).

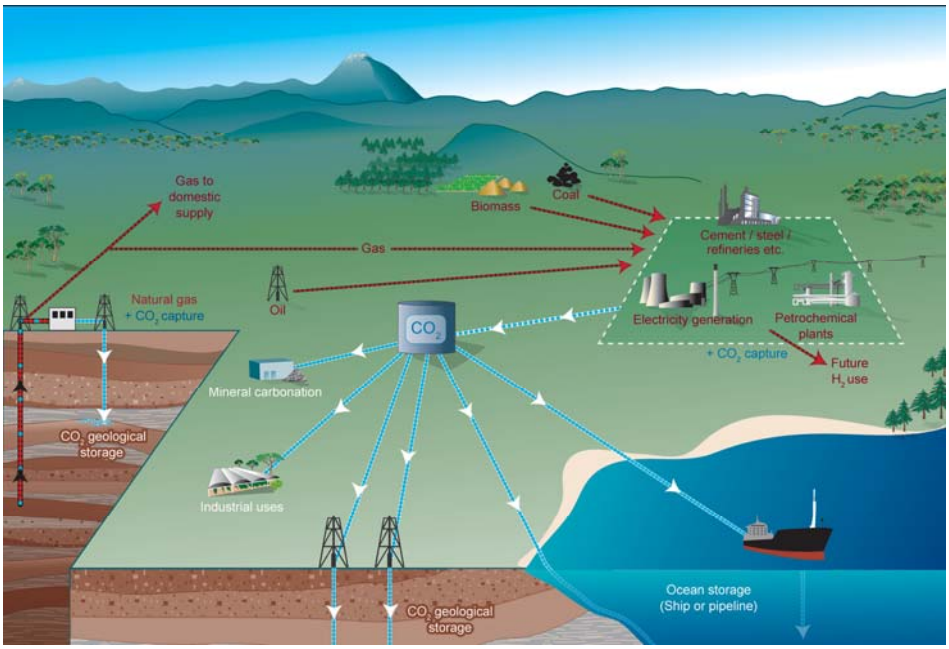


Figure 1-4 - Schematic diagram of possible CCS systems showing the sources for which CCS might be relevant, transport of CO_2 and storage options (Source (IPCC, 2005), Courtesy of CO2CRC)

[6] A power plant equipped with a CCS system (with access to geological or ocean storage) would need roughly 10–40% more energy than a plant of equivalent output without CCS, of which most is for capture and compression.

[7] Pipelines are preferred for transporting large amounts of CO_2, for distances up to 1,000 km (IPCC, 2005). Ships may be used for smaller amounts less than a million tonnes, or larger distances (IPCC, 2005).

Storage methods include geological storage in geological formations, such as oil and gas fields, and unminable coal beds. This occurs at depths around 1km, where CO_2 has a liquid like density, for an efficient use of storage space and improved storage security. At this depth, various physical and geochemical trapping mechanisms prevent it from migrating to the surface. Observations and models currently suggest that the fraction of CO_2 retained in appropriately selected and managed geological reservoirs is very likely (probability of 90-99%) to exceed 99% over 100 years, and likely (probability of 66-90%) to exceed 99% over 1000 years (IPCC, 2005). If they would arise, local health, safety and environmental concerns would be comparable to risks associated currently with natural gas storage and enhanced oil recovery (EOR) (IPCC, 2005), with both of these technologies having decades of experience of long term application. Figure 1-5 indicates identified storage sites in Europe and coal- and lignite-fuelled power plants within the EU-25 and Norway (Kjärstad & Johnsson, 2007).

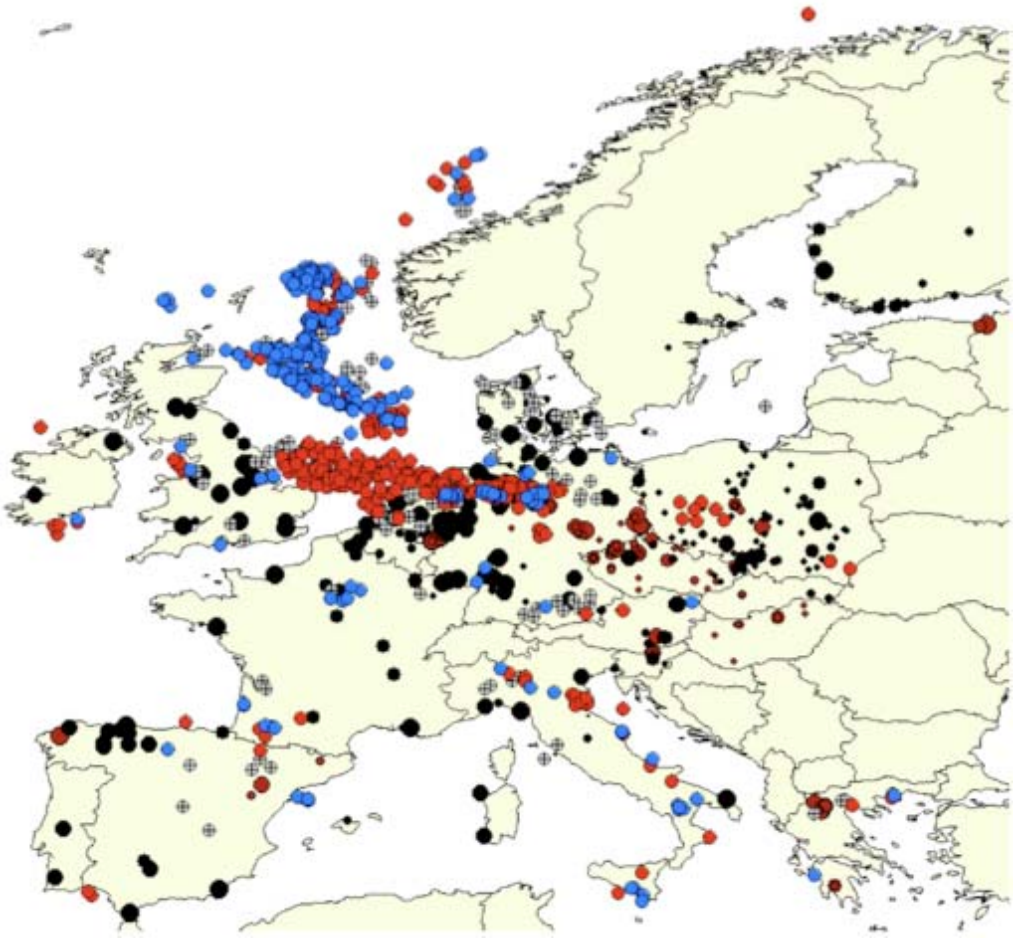


Figure 1-5 - Identified storage sites by reservoir type and coal- and lignite-fuelled power plants within the EU-25 plus Norway. Source (Kjärstad & Johnsson, 2007)

In the above figure blue circles denote oil fields, red denotes gas fields, crossed grey denotes aquifers while black and brown denotes hard coal- and lignite-fuelled power plants respectively.

As per Kjärstad and Johnsson, the bulk of storage potential is concentrated to five countries located around the North Sea; Denmark, Germany, the Netherlands, Norway and the UK, which collectively account for almost 95% of the identified trapped storage potential in Europe.

Costs for CCS are difficult to gauge as the technology is not mature, and the future uncertain. IPCC (2005) estimates an increase in electricity generation costs of 0.01-0.05 US dollars per kilowatt hour (US$/kWh), depending on fuel, technology, location, and national circumstances (IPCC, 2005). Capture costs can range from 15-75 US$/ton$CO_2$, transport, 1-8USD/ton$CO_2$, and geological storage[8] 0.5-8US$/ton$CO_2$ (IPCC, 2005).

The IEA analyses shows that CCS could play a significant role by 2050 in limiting CO_2 emissions from coal-fired power plants in rapidly growing economies with large coal reserves (IEA, 2006)[9]. CCS is also heralded by the IEA as "*one of the most promising routes for mitigating emissions in the longer term – especially in China, India and the United States, where coal use is growing fastest"*. However, this can only be the case if the technology can be demonstrated on a large scale and if adequate incentives to invest are put in place (IEA, 2007).

The most ambitious IPCC atmospheric stabilization scenario calls for CO_2 emissions to be reduced 13% lower than 2005 emissions and 12% higher than 1990 emissions. As per the IEA World Energy Outlook (2007) 450 Stabilization Scenario, this comes from the following avoided emissions in 2030 (IEA, 2007):

- over 25 % from efficiency in fossil-fuel use in industry and buildings accounts;
- 13 % from lower electricity demand, resulting from more efficient electricity use in buildings;
- 4% from switching to second-generation biofuels in transport;
- 19% from renewables in the power sector;
- 16% from increased reliance on nuclear generation; and
- 21 % CCS in power generation and industry.

This then assumes the widespread deployment (commercial application) of CCS in power generation and industry including the US, India, and China. Also 15% of fossil-fuel generating capacity would need to be retired (may be less if retrofitting with CCS is an option) between 2012 and 2030, and all new generating capacity either nuclear power, renewables based or, after 2015, fossil-based with CCS (IEA, 2007).

[8] This cost does not include potential long-term remediation and liability costs.

[9] From the IEA "Beyond the Alternative Policy Scenario" (BAPS) in the World Energy Outlook (2006): CCS in the power sector would reduce emissions by 2 Gt in 2030. Approximately 3,100 TWh of electricity would then be generated from coal and natural gas plants equipped with CCS. Some 70% of new coal-fired capacity and 35% of new gas-fired plants would be equipped with CCS over the projection period. CCS in coal plants would account for more than 80% of the captured emissions.

1.1.3 CCS in Europe

The commercial application of CCS will require the cooperation and input of many members of society, including governments, industry, NGOs and the public.

Currently, applications of CCS technologies are in the early stages. Pilot plants, (e.g., 30 MW) are being tested and demonstration plants (500 MW and up) being planned. Three industrial storage sites are currently active: the Sleipner project in an offshore saline formation in Norway, the Weyburn EOR project in Canada, and the In Salah project in a gas field in Algeria (IPCC, 2005). These storage projects operate at a commercial level (1MtCO_2/year and larger), and currently are at around 0.5% of their capacity. An up to date list of active, planned and cancelled projects is provided by Massachusetts Institute of Technology (MIT) and available online[10], indicating a high demonstration activity around 2011 and 2012 through until 2015.

Following the priority given to "zero emission power generation" in the Sixth Framework Programme[11], industrial stakeholders and the research community united to form the European Technology Platform for Zero Emission Fossil Fuel Power Plants (ZEP) (ZEP, 2007). In February of 2008, ZEP made recommendations to the European Commission (Commission) on the implementation of the 10-12 CCS plants planned for Europe - the EU Flagship Program. The goal of the EU Flagship Program is to kick start the large-scale deployment of CCS in Europe and possibly worldwide (ZEP, 2008). Key recommendations are as follows:

- the EU Flagship Programme needs co-investment from private and public sources;
- industry should carry a major portion of the costs and risks;
- 'First Mover' costs and risks should be shared between the EU and industry;
- the principles of funding support should be determined as a matter of urgency; and
- competition among sponsors for funding support is essential.

In March of 2008, the Draft Directive on the "geological storage of carbon dioxide and amending Council Directives" was introduced, to "ensure that CCS is an available mitigation option, and that is done safely and responsibly" (European Commission, 2008). The Draft Directive states that CO_2 captured and stored will be crediting as not emitted under the ETS and the surrender of emissions trading allowances for any leaked emissions (European Commission, 2008). The Directive also stipulates that access to CO_2 transport networks and storage sites could become a condition for entry into the heat or electricity market, depending on relative prices of carbon and CCS (European Commission, 2008). It also proposes that new combustion plants should have suitable space on the installation site for the equipment necessary to capture and compress CO_2, and that the availability of storage sites and transport networks, as well as the technical feasibility of retrofitting for CO_2 capture have been assessed (i.e., plants must be "capture-ready") (European Commission, 2008).

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[10] Can be found at http://sequestration.mit.edu/tools/projects/index.html

[11] Mandated to fund and promote European research and technological development for the period of 2002-2006.

Also to note briefly are the relevance of two Kyoto market mechanisms: the EU-ETS and the CDM. Currently, the EU-ETS price of CO_2 is at 23€/tonne[12]. Projections of abating 1 tonne of CO_2 with CCS are approximately €50-100 (Friends of Europe, 2008). The EU Flagship Program should offer important feedback so the cost can come down, to be in line with a carbon price of €20-30 (Friends of Europe, 2008). As such, the price of carbon and allowances allocated in the EU-ETS will be a major determinant on the success of CCS. During the second phase of the ETS (2008-2012), operators would have to explicitly enter CCS projects under the ETS (Tomescu, 2008). However, CCS will be recognized by default during the third phase of the ETS (2013-2020) as the ETS recast includes CCS explicitly (Tomescu, 2008).

As discussed briefly above, for CCS to reduce emissions on a global level, it must be deployed in China and India. Thus, the inclusion of CCS in the CDM is much talked about at present.

1.2 Research Objective and Scope

At the outset it is considered important to stress that this research does not address the question of "whether or not CCS is the right path forward with regard to the future energy mix?"[13] Rather, this work has its motivation in that Europe, and perhaps in particular European power generators are facing a powerful suite of drivers to engage in CCS in some way. The point of departure for this work has been that factors such as the significant proportion of fossil fuel fired plants in the EU, the long term availability of coal and concerns regarding energy security of supply all juxtaposed with the EU's increasing motivation to set and achieve ambitious climate change mitigation targets are creating a context where the EU must engage in CCS in some significant fashion.

CCS as an emerging technology, in an unestablished market, faces a great deal of uncertainty, and its fate is unknown. For example, it is unclear how the demonstration phase will get kickstarted, who will do this, and if this testing phase will be valid to move to full commercialization? Furthermore, what form will the market take? How will allowances be made under the EU-ETS scheme? What will the public think and will they accept CCS? What will the final regulation look like?

Moreover, this is not just a technology for Europe. The IEA World Energy Outlook 2007 predicts the following for China and India in their reference scenario[14]: *Their economies remain heavily dependent on coal, mostly produced indigenously. By the end of [2030], coal – used mainly in power stations – makes up 59% of the two countries' combined energy use, up from 57% in 2005* (IEA , 2007). In this light, other questions are also of interest. Will other countries like China or India, adopt CCS? Will Europe and other developed countries be able to prove this technology in time?

1.2.1 Knowledge Gap

European power generators are clearly facing a powerful suite of drivers to engage in CCS. The type and level of engagement will depend on the future of CCS, which is uncertain. So

[12] As of September 10, 2008.

[13] Of interest to the reader could be energy scenarios without CCS, detailing the phase out of nuclear and aggressive ramp up of renewable energy and energy efficiency measures as presented in the Greenpeace document "Energy [r]evolution" (Greenpeace, 2007).

[14] Assumes no major policy changes.

what could the future of CCS look like? This knowledge gap was indicated to the researcher by Vattenfall, a Swedish state-owned power company.

Vattenfall is Europe's fifth largest generator of electricity, with 2007 figures showing 46% of coal based electricity generation. Vattenfall recently launched a 30 MW CCS pilot plant and has plans for more pilot and demonstrations plants, leading to the commercial application of CCS technology. Vattenfall is considered to be a "first-mover" in CCS.

Currently, many people are involved in CCS through projects, shaping the market, and forming opinions. This CCS "movement" includes but is not limited to: industry, governments, non-governmental organizations (NGOs), researchers, and the public.

As active participants in this movement, Vattenfall is interested in knowing how the future of CCS may look; and how stakeholders will engage in the CCS "movement" as it proceeds. This knowledge gap is consistent to other participants in this "movement" as evidenced during the course of this work.

Insights into how the future might look could involve for example a comparison to similar technological movements like the diffusion of combined cycle plants, or the development of natural gas networks. Another insight could be the collection and comparison of historical public perceptions to nuclear power to understand potential futures based on the storage aspect of CCS. Another useful insight could be the examination of policy funding mechanisms for CCS. Another insight could come from talking to market actors (investment companies, big banks) to see what criteria they need to feel confident in investing in CCS. Yet another insight, and that chosen for this work, could come from scenario building. A quantitative scenario may involve energy projections based on models and real costs. A qualitative scenario could create development paths based on relevant information and insights from those involved in the CCS "movement".

A recent high-level roundtable co-organized by Friends of Europe (non-profit organization promoting public debate on the future of European integration), the Bellona Foundation (an NGO) and the ZEP with the support of the Carbon Capture and Storage Association (CCSA) and the CO_2 Capture Project (an industry initiative) was held in Brussels in May, 2008. Participants ranged from governments, industry, to research institutes and NGOs. The roundtable included a discussion on who would/should have to pay for the demonstration of CCS. The conference proceedings emphasized the varied ideas, knowledge, and beliefs in the CCS field between companies and organizations.

As it appears that the field is being shaped through open dialogue and consensus building it is possible that the future of CCS depends heavily on the ideas of those engaged in the field. Listening to what people involved and engaged with CCS are saying and understanding their viewpoints could be one way to navigate through the uncertain territory of the future of CCS, and determine potential paths forward. These development pathways, herein synonymous with "scenarios" can then be used as a method of planning for the future.

1.2.1.1 Scenarios as a tool to move forward

Definitions of "scenario" are varied throughout literature with some examples shown below:

- "An internally consistent view of what the future might turn out to be — not a forecast, but one possible future outcome" (Porter, 1985)

- "A tool for ordering one's perceptions about alternative future environments in which one's decisions might be played out" (Schwartz, 1991)

- "Scenario planning is inherently a learning process that challenges the comfortable conventional wisdoms of the organization by focusing attention on how the future may be different from the present" (Thomas, 1994)

- "Scenarios are images of the future, or alternative futures. They are neither predictions nor forecasts. Rather, each scenario is one alternative image of how the future might unfold. A set of scenarios assists in the understanding of possible future developments of complex systems."(Nakicenovic &IPCC, 2000)

Advantages of scenarios as described by Lindgren & Bandhold (2003) include that they provide an effective manner in which to reduce a great and complex amount of information to a manageable format without over-simplifications; can communicate complex messages to a large and diverse audience in a transparent and understandable way; and with no "right" or "wrong" thinking the "unthinkable" is facilitated, which in turn improves the ability to foresee unusual events, assisting shared exploration of the future across a group of stakeholders (Lindgren & Bandhold, 2003).

Scenario building can be used to change thinking and create a common vision, for decision support; to manage risk and uncertainty; and to foster learning and understanding (Strupeit & Peck, 2008).

Scenarios for CCS based on complex modelling (e.g., PRIMES[15]) are both common and important in attempts to better understand all technical and economic aspects of its future. Scenarios based on the "softer" issues like public perceptions[16] are less common, but still valid insights into how the future can look, avoiding the amounts of uncertainty in complex modelling (while of course introducing new uncertainties).

In this work, scenarios are built based on the insights and opinions expressed by stakeholders in the field to better understand potential development pathways for CCS. They are to be used a tangible starting point for further scenario building and speculation on what the future may hold for CCS. As put by Lindgren and Bandhold, scenarios can be "a way to reduce a great and complex amount of information to a manageable format, communicate complex messages to a large and diverse audience, assisting shared exploration of the future across a group of stakeholders". It is hoped that this work will serve as a basis for a decision making tool for stakeholders of CCS in guiding how to act today based on an understanding of how the future may look.

[15] The model PRIMES simulates the European energy system and markets on a country-by-country basis and provides detailed results on energy balances, CO_2 emissions, investment, energy technology penetration, prices and costs by 5-years intervals over a time period from 2000 to 2030 (Capros, Mantzos, Papandreou, Tasios, & Klaassen, 2008)

[16] A survey was conducted in 2006 of European energy stakeholders (industry, government, NGOs, researchers, academics) to determine their perceptions of CCS. Results indicated that about 75% thought CCS was necessary in their own country; risks of CCS included the energy penalty and that the development of CCS would detract from investment in renewable energy technologies (Shackley , Waterman , Godfroij , & Reiner , 2007).

1.3 Focus Question

The focus question **"What pathways are emerging as the CCS movement proceeds?"** aims to bring forward potential development pathways (or qualitative scenarios) for CCS based on inputs of those engaged in the field in Europe.

This work seeks to provide insights by exploration and analysis of the following two research questions:

- Who are stakeholders in the CCS movement?
- How do they see the field at present and in the future?

This work, conducted over a four-month period, in fulfillment of a M.Sc degree in Environmental Management and Policy, was funded by Vattenfall. The geographical scope of the research is limited to Northern Europe, as the starting point for stakeholder contacts was within Vattenfall, whose main operations are in Nordic countries, Germany and Poland.

This work is intended to constitute coherent potential future development paths for CCS based primarily on Northern European perspectives. These paths are conceptual, and are the end result of the exploration of the aforementioned research questions. It should be noted that the majority of the work and analysis was in the answering of the two research questions, and that answering the final focus question was the manner in which to present the thoughts and opinions of various stakeholders in the CCS field today, as filtered through the lens of the researcher, in a suitable manner for future use.

1.4 Outline of this Report

Section 1 provides the background information needed to understand the concepts presented in the work, and the drivers for the research. The research question is explained.

Section 2 provides the methodology on how the work was carried out.

Section 3 provides the analytical framework used in the collection of data and the analysis of the work.

Section 4 provides the finding of the research question" "Who are stakeholders in the CCS movement?"

Section 5 provides the findings of the research question "How do they see the field at present and in the future?"

Section 6 provides the findings of the focus question: "What pathways are emerging as the CCS movement proceeds?"

Section 7 provides conclusions on the work and recommendations for the future.

2 Methodology

To answer the question "*What pathways are emerging as the CCS movement proceeds?"* and the research questions of *"Who are stakeholders in the future of CCS?"* and *"How do they see the field at present and in the future?"* a three (3) phased approach was used. It should be recalled that the following work is set in the context of Northern Europe.

2.1 Phase 1: Identifying Stakeholders

A stakeholder is defined in literature as "any group or individual who can affect or is affected by the achievement of the organization's objectives" (Mitchell et al., 1997). In this work, the objective is seen as *commercial application of CCS technologies*, which is the widespread deployment of CCS, pursuant to a successful demonstration phase. The "organization" can be seen as any group with a stake in the realization of this objective.

To answer the first research question *"Who are stakeholders in the future of CCS?* the following steps were taken:

1. Seek to find a representation of stakeholders who make up the CCS "Community".

2. Understand the role of these stakeholders on the c*ommercial application of CCS technologies.*

2.1.1 The CCS "Community"

At the outset of the work, the prime study subject and financial supporter of the research (Vattenfall) made it clear that objectivity was to be retained as much as possible, thus providing limited direction on finding a representation of this community. Rather, the process commenced with an "in faculty" brainstorm to identify possible groups. Attempts were made by the researcher to identify stakeholders through web searching of participants in recent conferences, and active CCS projects. The process of acquiring stakeholders developed quickly into an iterative or "snowball" process, where further identification of stakeholders occurred throughout the interview process based on upon discussions and suggestions.

During the creation of this representation, attempts were made to balance between proponents, opponents, energy companies, suppliers, non-governmental organizations, regulatory bodies, academics, industry associations, international organizations, and research institutes. A list of this representation is provided below in Table 2-1. These stakeholders, were the informants for this work, and served as the primary form of data collected. It can be noted that a majority of these informants are members of ZEP, participants in high-level roundtable discussions, panelists and speakers at conferences, contributors and authors of publications (including the IPCC special report on CCS), and high-level executives.

Table 2-1 – List of Stakeholder Interviews

Company	Name	Country	Position	Date	Interview
Alstom	Karlsson, Helena	Sweden	Communications Director	21-Jul-08	Phone
Bellona	Frisvold, Paal	Belgium	Chairman	7-Jul-08	Person
British Petroleum	Hill, Gardner	UK	Directive CCS Technology	1-Sep-08	Phone
Carbon Capture and Storage Association (CCSA)	Chapman, Jeff	UK	CEO	7-Jul-08	Phone
Carnegie Mellon	Mccoy, Sean	USA	Project Manager and coordinator for CCS Regulatory Project	3-Jul-08	Phone
Chalmers University	Johnsson, Filip	Sweden	Professor Sustainable Energy Systems	18-Aug-08	Phone
European Commission: Directorate General for the Environment	Tomescu, Mihai	Belgium	Policy Officer	7-Jul-08	Person
European Commission: Directorate General Energy and Transport	Galanis, Ioannis	Belgium	Deputy Head of Coal & Oil, Market Observatory	9-Jul-08	Person
E3G Third Generation Environmentalism	Johnston, Mark	Belgium	Associate	6-Jul-08	Person
Energy Research Centre (ECN) Netherlands	de Coninck, Helen	Netherlands	Group Manager, International Climate and Energy Issues	7-Aug-08	Phone
European Environment Agency (EEA)	Barkman, Andreas	Denmark	Project Manager Greenhouse gas emissions and emissions trading	5-Aug-08	Phone
E.ON	Sjunnesson, Lars	Sweden	Head of R&D	1-Jul-08	Person
E.ON	Moller, Bjorn	Sweden	R&D, Strategy	2-Jul-08	Person
Environmental Resources Management (ERM)	Chrysostomidis, Ioannis	UK	Energy and Climate Change	21-Jul-08	Phone
Fortum	Lindman, Eva-Katrin	Sweden	Head of R&D	8-Aug-08	Phone
German Federal Environmental Agency	Boehringer, Alex	Germany	n/a	29-Aug-08	Phone
Greenpeace	Kruger, Martina	Sweden	Energy and climate campaign	26-Jun-08	Person
Greenpeace	von Goerne, Gabriela	Germany	Climate/Energy Unit	15-Aug-08	Phone
Linköping University	Hansson, Anders	Sweden	PhD, Dept of Technology and Social Change	11-Aug-08	Person
International Energy Agency	Gale, John	UK	General Manager, IEA Greenhouse Gas R&D Programme	1-Aug-08	Phone
Lund University	Thörnqvist, Lennart	Sweden	PhD Energivetenskaper, LTH	7-Aug-08	Person
Liberal Democrat Member of European Parliament, North-West England	Davies, Chris	UK	Rapporteur for CCS Draft Directive	18-Jul-08	Phone
Rio Tinto	Zapantis, Alex	Australia	Manager, Energy and Sustainable Development	5-Aug-08	Phone
RWE Power AG	Hiethoff, Johannes	Germany	Head of R&D	5-Aug-08	Phone
Schlumberger Carbon Services	Booer, Tony	UK	Business Development Manager	1-Aug-08	Phone
Swedish Environmental Protection Agency	Ohlander, Thea	Sweden	Climate Unit	26-Jun-08	Person
Swedish Ministry of Environment	Mjureke, David	Sweden	Departmentssekretare	1-Jul-08	Phone
Vattenfall	Görtz, Staffan	Sweden	CCS Project Head of Communication; Senior Advisor Energy Strategy	2-Jul-08	Person
Vattenfall	Bilfalk, Lennart	Sweden	Semi-retired, Senior Vice President	26-Jun-08	Phone
Vattenfall	Lindgren, Goran	Sweden	R&D; CCS Program Manager	3-Jul-08	Phone
Vattenfall	Bernstone, Christian	Sweden	R&D; Geologist, Demonstrations	26-Jun-08	Person
Vattenfall	Christensen, Niels Peter	Denmark	Lead of CO_2 Storage, Former Geological Survey of Denmark	10-Jul-08	Person
Vattenfall	Ekström, Clas	Sweden	Vattenfall Research and Development AB	27-Jun-08	Person
Vattenfall	Liljemark, Stefan	Sweden	Vattenfall Power Consultant AB, CCS Transport	12-Aug-08	Person
World Coal Institute	Warren, Luke	UK	Policy Manager	23-Jun-08	Person
World Energy Council	Nekhaev, Elena	UK	Director of Programmes	13-Aug-08	Phone
Wuppertal Institute for Climate, Environment and Energy	Viebahn, Peter	Germany	Project Co-ordinator	21-Jul-08	Phone

2.1.2 Role of Stakeholders in CCS

Upon establishment of a representative CCS "Community", it was sought to understand the role that these stakeholders have on the *commercial application of CCS technologies*. This 'stakeholder mapping' was done by use of the analytical framework described in Section 3.1, where stakeholders were classified by the possession of attributes of power, legitimacy and urgency. Classification was based on interview questions aimed at understanding incentives for entry into the "CCS Community", views on the goal of CCS, and understanding how much time and resources is put towards CCS within an organization. The mapping exercise was completed to understand the role played currently by each stakeholder and gain insight into what type they can conceivably become in realizing the *commercial application of CCS technologies.*

2.2 Phase 2: Understanding the Dynamics of the CCS field

The second research question: *How do stakeholders see the CCS field at present and in the future?*, involved seeking to understand the dynamics of the CCS field through the collection of primary data from stakeholders listed in Table 2-1, in a three series approach. This approach was based on the exploratory nature of the research, and the need to gain an understanding of the field in a short timeframe. Roughly one-third of stakeholders were put into each series.

The first series of interviews was to explore potential interview themes. These were then tested in the subsequent interviews throughout the first phase.

During this first series, it was not deemed logical to have a pre-determined list of set questions given the varying standpoints of actors. As such a semi-structured, open question approach was taken. Flexibility[17] was exercised in each interview, depending on where the informant chose to develop the conversation. Moreover, the researcher gave prompts for discussion based on findings from other interviews, while the first interviews were based on recent readings. Examples of some prompt questions are as follows:

- Do you feel the development of CCS puts a brake[18] on the development of other technologies? How, why, or why not?
- Discuss incentives for moving towards CCS and barriers that may be / are being encountered?
- What are your thoughts on transportation of CO_2? Is it a major barrier[19]?
- Regarding the finance, who should pay for the demonstration projects? How can full scale CCS be financed?
- Do you see this technology analogous to others? Which ones and how so?

[17] This methodological choice was borne out of experiences while researching.

[18] The question steered a topic which is debated frequently in the CCS field.

[19] This second leading question was asked most of the time, as barriers in transportation did not arise as much as hypothisized.

- How do you view the CCS community?

The second series of interviews involved grouping the information into a more structured framework, by use of an innovation analytical framework described in Section 3.2. In these interviews, stakeholders were asked to comment on certain "functions" (as described in Section 3.2), to understand the stakeholder perceptions of the dynamic of the CCS field. Some of these "functions" fostered discussion, and others did not. In these interactions, if the use of the framework was not proving to be fruitful, the discussion reverted to topics discussed in the first series of interviews.

The third series of interviews involved more focused discussions on potential futures for CCS. Here, qualitative discussions on the probability of developments and the confirmation of emerging themes (through leading questions) from all previous research were discussed. Example discussion topics are presented below:

- Do you see a chance of failure in the demonstration phase? How, when?

- Can you comment on the possibility of CCS operating in a niche market?

- Others have commented on or used the term bridging the gap. How long is this bridge? What is it bridging to?

During all stages of interviews, secondary data was collected, including company or organizational material, and relevant and recommended academic papers. The majority of this research is based on the primary data, with secondary data supplementing where possible and deemed necessary.

2.3 Phase 3: Development Pathways

When looking at how one might answer the focus question through the use of scenarios, a backcasting or forecasting method could have been suitable. The latter method might involve studying actors and technologies, analyzing their capabilities in achieving certain CCS futures, and coming up with a semi-prescient description based on a number of assumptions. This normatively-driven approach would identify leverage points in achieving a certain future but would also cause various possibilities to be "dropped". Conversely, a backcasting approach allows for the creation of a plausible story or vision of what could constitute a success or a failure based on real stakeholders. As previously mentioned, listening to what people involved and engaged with CCS are saying and understanding their viewpoints to determine paths forward could be one way to navigate through the uncertain territory of the future of CCS. As such a backcasting approach was used.

Further explanation on guidance used to build the emerging pathways is presented in Section 3.3.

2.4 Methodological Limitations

This work was completed in a four-month timeframe during the summer of 2008. This work is lacking an exhaustive literature review on the theories used in the analytical framework (stakeholder salience, innovation theory, and scenario building), and on publications surrounding CCS, whether that be on current issues, or on comparisons made to other

technologies (e.g., natural gas pipelines, nuclear energy, etc.). There simply was not enough time to do both and it was decided that the work would remain heavily dependant on primary data.

The "snowball" approach of finding the stakeholders assumes that other informants are aware of additional informants in the system in question, and may also cause the practical limitation of the study to be exceeded (Carlsson, 2002). Despite limitations, this method was used to accommodate an extremely short research period, and deemed representative of a snapshot of the CCS "Community", given its close-knit attributes and relative newness. Difficulty was experienced in locating opposition groups to CCS. Perhaps such groups exist on a more individual level, or the newness and scientific nature of the problem has not facilitated a favourable environment for opponent groups. The absence of a community of doubters may place limitations on the information collected, particularly on the variety of information collected.

Furthermore, given the circumstance, the researcher made efforts to maintain and objective standpoint. While often agreeing with, or rather, understanding viewpoints of various actors, the analysis of the gathered information was done with a lens outside of the CCS Community. As put by Peter Schwartz, a leading futurist: "Flexibility of perspective is critical, [the scenario builder] must simultaneously focus on questions that matter to [them], and keep [their] awareness open for the unexpected" (Schwartz, 1991). Nevertheless, it is possible that leading, or loaded questions were asked during the interview process.

Finally, the series approach of interviews meant that stakeholders were asked different questions, prompting different discussions. Attempts were made to ensure that each "grouping" of stakeholder (e.g., NGOs, power companies, academics) were present in each series of interviews, but this was of course limited to stakeholder availability over the course of the interview period (May 2008 – September 2008).

Given the potential large-scale application of CCS, and its uncertain future, the CCS Community as a whole could involve a variety of stakeholders, only some of which are represented in this work. If large-scale applications of CCS occurs, new stakeholders would emerge for example, the owner and operator of liquid CO_2 pipelines, end users of CO_2, and a host of specialists in a number of areas. Furthermore, in using a representation to understand how the CCS field could look like in the future; stakeholders who offer differing viewpoints and point to the unexpected (those outside the immediate community, without a stake involved), and opponents are also of value. Stakeholders representing these viewpoints in this work are limited.

If this work were to be repeated, it could yield different results, as the potential stakeholders that can be interviewed is limitless. To this end, the results of this work (stakeholder map and their insights on the CCS field) are a reflection of the CCS field at current. Similar work done at a different time, with different stakeholders could yield different insights. However, the process in which the data is gathered and analyzed, that is, the concept of stakeholder mapping, understanding the functioning dynamic of the CCS field, and finally, the presentation of the work into three tangible scenarios can be repeated, and improved upon.

3 Analytical Framework

The following section details the analytical framework used in this research. It is provided to give the reader an overview of the theoretical approaches used to provide guidance in the gathering and analyzing of data. The analytical framework was largely inspired by the following papers:

- "Toward a Theory of Stakeholder Identification and Salience: Defining the Principle of Who and What Really Counts" (Mitchell, Agle, & Wood, 1997)

- "Analyzing the functional dynamics of technological innovation systems: A scheme of analysis" (Bergek et. al, 2008)

This literature was used to analyze the data collected in Phase 1 (Identifying Stakeholders) and Phase 2 (Understanding the Dynamics of the CCS Field) respectively.

The construction of the emerging pathways is presentation of stakeholder perceptions on the dynamics of the CCS field, in a time context. These pathways are qualitative scenarios, and did not heavily rely on the use an analytical framework. The justification on the performance of this task did hinge on an understanding of the contribution and relevance of scenario building to answering the research question, as briefly discussed in Section 1.2 and again in Section 3.3.

The use of frameworks to analyze data mostly sought to maintain a consistency of approach in answering the research questions.

3.1 Stakeholder Attributes and Classes

The following framework was used in Phase 1 of the methodology – "Identifying Stakeholders".

A stakeholder can be defined as:

- one who "can affect or is affected by the achievement of an organization's objectives"(Freeman, 1984);

- those that "have a stake or a claim on the firm" (Evan & Freeman, 1988);

- "participants in the human process of joint value creation" (Freeman, 1994); and

- those who "interact with the firm and thus make its operation possible" (Näsi, 1995).

The analysis by Mitchell et al. (1997) begins with Freeman's widely accepted definition of a stakeholder as "any group or individual who can affect or is affected by the achievement of the organization's objectives". The authors then identify a need for a clearer method of stakeholder identification that can separate stakeholders from nonstakeholders, and propose a dynamic model for identifying stakeholder salience ("who or what really counts" or rather who should be paid attention to in relation to achieving an objective). Mitchell et al. identify that different classes of stakeholders can be identified by the possession and interaction of three attributes:

- the stakeholder's *power* to influence the organization or issue at hand;
- the *legitimacy* of the stakeholder's relationship with the organization or issues at hand; and
- the *urgency* of the stakeholder's claim on the organization or issue at hand.

To illustrate with an example, a power company like Vattenfall could be a stakeholder having the objective of *the commercial application of CCS technologies*. Potential stakeholders who can affect or be affected by the achievement of this objective could be NGOs, the general public, governments, and so on. This includes stakeholders who are in support of and oppose the objective.

Figure 3-1 depicts stakeholder attributes and classes as posited by Mitchell et al., adapted to provide some examples.

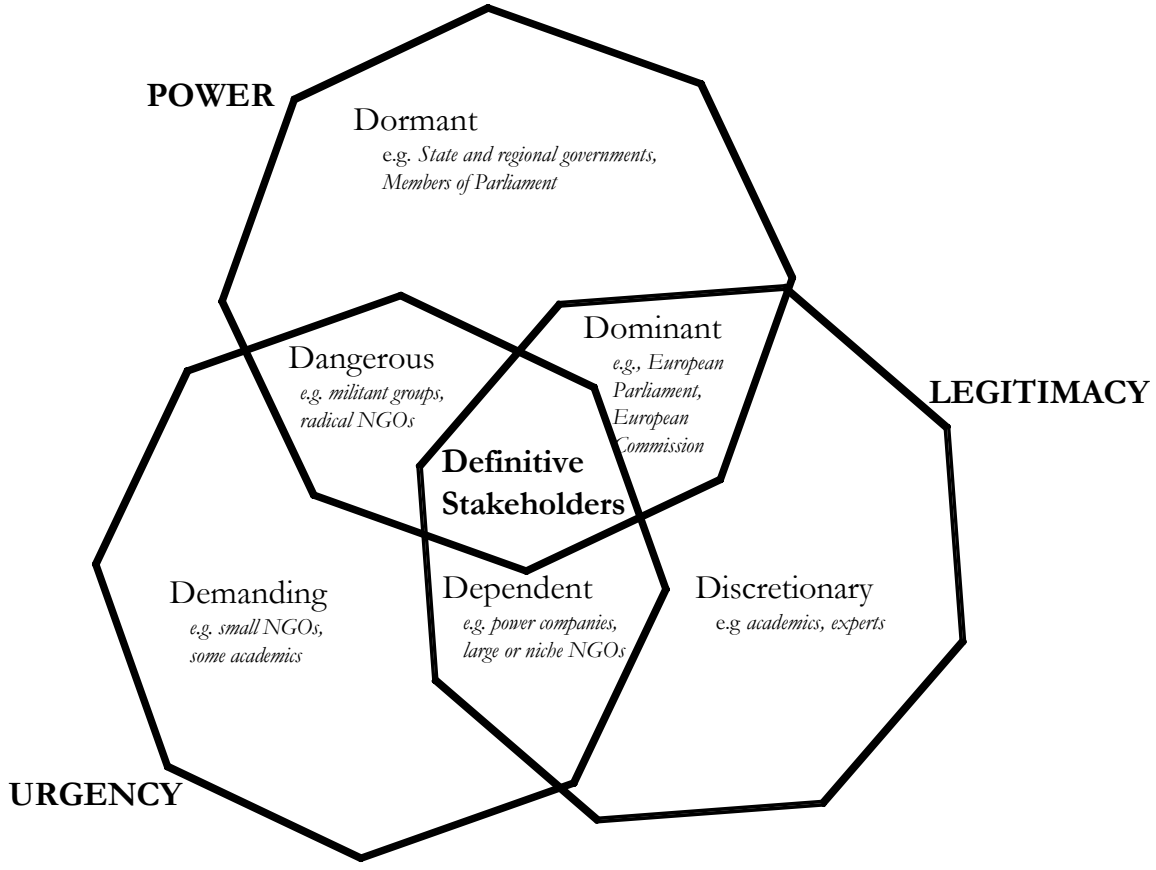

Figure 3-1 - Stakeholder Typology (adapted from by Mitchell et al. (1997))

Power is defined as the ability of those who possess power to bring about the outcomes they desire (Mitchell et al., 1997). The access can be both acquired and lost.

Urgency is defined as the degree to which stakeholder claims call for immediate attention (Mitchell et al., 1997). The attribute of urgency moves the model from static to dynamic, and

exists when two conditions are met: when a relationship or claim is of a time-sensitive nature; and when that relationship or claim is important or critical to the stakeholder (Mitchell et al., 1997).

Legitimacy is defined by Suchman (1995) as a "generalized perception or assumption that the actions of an entity are desirable, proper, or appropriate within some socially constructed system of norms, values, beliefs and definitions". This definition implies that legitimacy is a desirable social good, something larger and more shared than a mere self-perception, and that it may be defined and negotiated differently at various levels of social organization (Mitchell et al., 1997).

These attributes are further discussed in the context of this work in Section 4. Stakeholder classes are explained in Table 3-1 with examples in the context of this work given in italics.

Table 3-1 – Stakeholder Classes and Descriptions (Adapted from Mitchell et al., 1997)

Stakeholder Class	Description
Dormant Stakeholders *State and regional governments, Members of Parliament*	The relevant attribute is power, possessed to impose their will, but by not having legitimate or urgent claim, their power remains unused.
Discretionary Stakeholders *Academics, experts*	The relevant attribute is legitimacy, but power and urgency are absent, thus there is often little pressure to engage in an active relationship with such a stakeholder.
Demanding Stakeholders *Small NGOs, Some academics*	The relevant attribute is urgency. Demanding stakeholders are likened to "mosquitoes buzzing in the ears", irksome but not dangerous. If these stakeholders do not acquire power or legitimacy to move their claim to a more salient status, the "noise" of urgency is inadequate in being heard.
Dominant Stakeholders *European Commission, European Parliament, possibly Power Companies*	Possession of both power and legitimacy assures influence. A formal mechanism may be in place that acknowledges this influence and importance of relation with the claim.
Dependent Stakeholders *Power Companies, Larger NGOs, Niche NGOs*	These stakeholders, lacking power but possessing urgent, legitimate claims, depend on others for the power required to carry out their will. Urgent, legitimate claims adopted by dominants stakeholders can move the once dependent stakeholder into the most salient class.
Dangerous Stakeholders	A stakeholder with urgency, power, but no legitimacy is classified as dangerous, possibly violent.
Definitive Stakeholders	When a stakeholder exhibits power, legitimacy, and urgency, the claim is prioritized.
Nonstakeholder	Stakeholder does not possess power, legitimacy or urgency.

The main points to understand from this framework is that a definitive's stakeholder's claim will be prioritized, and that stakeholders can shift between classes on a time or issue basis, requiring varying degrees of attention depending on their possession of power, legitimacy and urgency, as depicted in Figure 3-2.

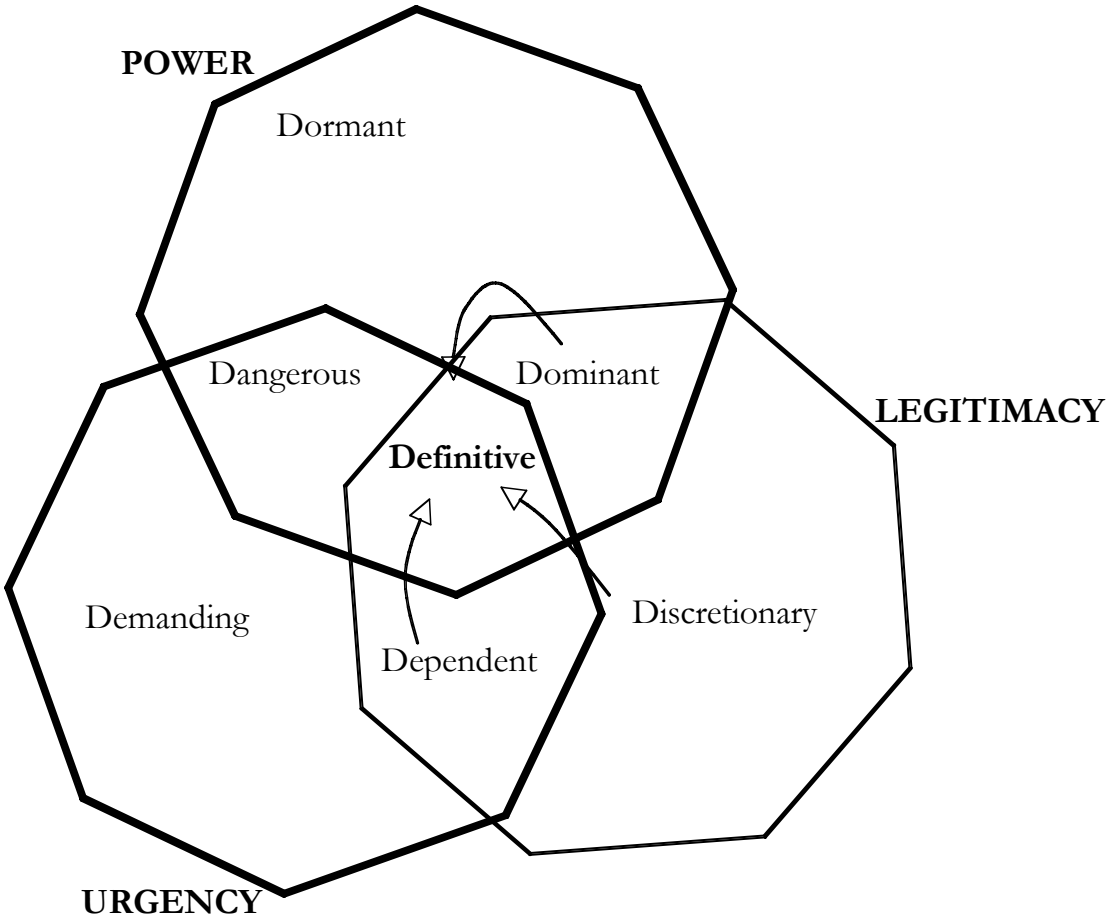

Figure 3-2 – Example pathways towards becoming a Definitive Stakeholder (adapted from by Mitchell et al. (1997))

In this figure:

- discretionary stakeholders acquire urgency, and power to become definitive stakeholders;
- dependent stakeholders (e.g., Vattenfall), gains power to become a definitive stakeholders; and
- dominant stakeholders (e.g., the European Commission) gain urgency, to become definitive stakeholders.

Charting the positioning of stakeholders in relation to an objective, can help to understand if a claim will be prioritized, and the consequence of stakeholder class shifts. It should be noted that just because there is a *possibility* to shift classes, does mean that stakeholder *can* do this. For example, a discretionary stakeholder, say an academic, has the possibility to gain urgency

which could happen, but also can gain power, which is maybe less feasible and thus less likely to happen.

3.2 Dynamics of an Innovation System

The following framework was used in Phase 2 of the methodology, during the gathering of and analysis of primary data to understand how stakeholders perceive the field to be CCS now and in the future.

As technological change is a dynamic process, requiring a transformation of the innovation system in which changes take place, a dynamic innovation system approach helps to understand and guide its direction (Hekkert et al., 2007).

In this work, the basis for analytical framework (Bergek, et. al, 2008), was not used a result of a detailed examination of innovation theory. Furthermore, the concept of CCS and its potential implementation as an innovation system is not explored. Indeed, it is perhaps debatable whether the components of CCS are truly innovative; however, the application of the aforementioned framework in this research assumes the concept of CCS "as a whole" as an emerging technological innovation system (TIS).

The method of analysis given by Bergek et al. (2008) is depicted in Figure 3-3.

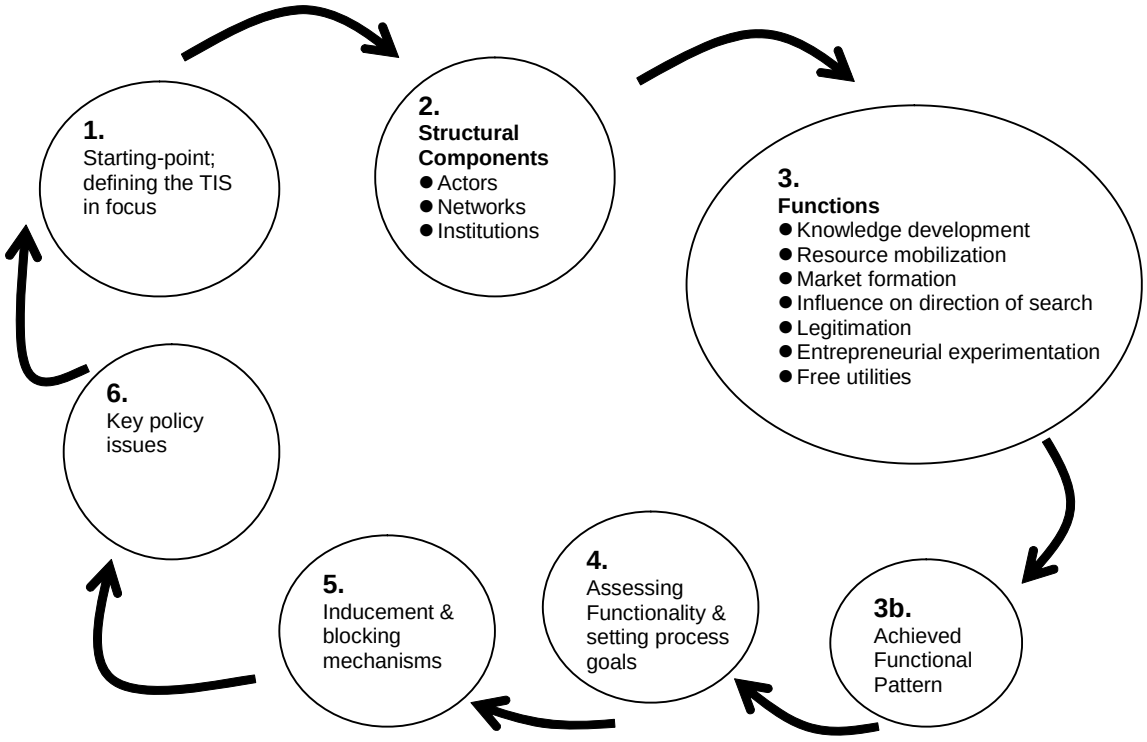

Figure 3-3 – The scheme of analysis (adapted from Bergek et al., 2008)

Essentially, the concept is as such: the TIS is defined (Step 1), its structure identified (Step 2) and functional pattern described (Step 3a) to come up with an achieved functional pattern (Step 3b). How well the functions are being performed (Step 4) is then examined to identify

blocking mechanisms (Step 5), thereby identifying policy issues (Step 6) to be addressed that can feed back into the scheme to drive the TIS forward (Bergek et al., 2008). Elements of identifying the "structural components" of CCS as a TIS were used in Phase 1 of this work.

Given that in the case of CCS, the use of a particular energy source (e.g., coal) is influenced by policy (Step 6), and the influence of firm behaviour (actors, networks or institutions – Step 2), this framework was considered suitable to describe the functional pattern of CCS.

The dynamics of the TIS can be described by the fulfillment of the seven (7) "functions": knowledge development and diffusion; influence on the direction of search; entrepreneurial experimentation; market formation; legitimacy; resource mobility; and the development of positive externalities or "free utilities". These functions provided by Bergek et al. (2008) and further described in Table 3-2, are derived through a scrutiny of similar work to date, with the analysis aiming to ascertain how the TIS is behaving in terms of a set of key processes.

Table 3-2 – TIS Dynamic Functions (adapted from Bergek et al., 2008)

Function	Description
Knowledge development and diffusion	Knowledge base of the TIS globally and locally. Captures breadth and depth and how well knowledge is diffused and combined. Knowledge can vary by type and source.
Influence on the direction of search	For a TIS to develop, a range of actors need to enter, requiring incentives or pressures to do so. Their visions, expectations, and belief in growth potential; perceptions on of relevance of different types of knowledge; technical bottlenecks; and crisis in current business combine to form the strength of this function.
Entrepreneurial experimentation	A TIS often evolves under uncertainties with respect to technologies, applications, and markets. This uncertainty is a fundamental feature of development and is not limited to the initial phases of development. One way of handling uncertainty is to ensure entrepreneurial experimentation and allow for a social learning process, bringing different knowledge and perspectives to the industry. On the contrary, a TIS without vibrant experimentation may stagnate.
Market fomation	For an emerging TIS, markets can range from underdeveloped to mature, or not exist. Customers may have not articulated demand or may not have the competence to do so, price and performance of new technology may be poor, and standards are often required (institutional change). Market phases can often take several decades to mature.
Legitimation	In this context, it is taken to be the "social acceptance" of the TIS, which must be compliant with relevant institutions. New technology must be considered appropriate and d desirable by relevant actors for resource mobilization, to form demand, and for actors in a new TIS to gain political strength. Furthermore, legitimacy is not given, however it is formed through conscious actions by various organizations/individuals Considerable time is needed to create legitimacy, and it often complicated by competition from adversaries defending an existing TIS.
Resource mobilization	As a TIS evolves, a range of different sources need to be mobilized (technical, scientific, financial and complimentary resources). The extent of ability to mobilize can be examined by gaining an understanding of human capital through education and complimentary assets (products, services, network infrastructure).
Development of positive externalities or "free utilities"	As markets move beyond first niches, the space for an emerging TIS to evolve and for functions to be strengthened enlarges. Central to this process is entry of firms as they strengthen all other functions. By resolving uncertainties and improving legitimacy new entrants essential offer "free utilities" or positive externalities for established firms or new entrants.

Although not explicitly described, it should be understood that these functions are intertwined with one another and can work separately or in combination with each other. The functional pattern does not show whether the TIS is well functioning or not, as a weakness in one function does not necessarily constitute a problem, and vice versa for a strength.

3.3 Constructing the Pathways

The following guidance was used in Phase 3 of the methodology – "Development Pathways".

The use of "functions" enabled the researcher to group stakeholder perceptions and knowledge of the CCS field at current and into the future to construct development paths (scenarios) based on stakeholder perspectives.

When creating the pathways, the following was kept in mind:

1. A method of presenting the work so it may be used by stakeholders as a tangible starting point for further scenario building and speculation on what the future may hold for CCS.

2. A main advantage of this research is the independent "lens" by which to explore the thoughts and opinions of the stakeholders interviewed. That is, information from all stakeholders was used, not just trends.

3. What can actually be said, given the breadth and depth of information collected?

Finally, the number of pathways chosen was based on time, resources and guidance from Schwartz (1991): 'Scenarios often (but not always) seem to fall into three groups: more of the same, but better; worse (decay and depression); and different but better (fundamental change). While this is not painted by Schwartz as the best option for building scenarios, it is consistent with his knowledge of scenarios, as a leading global futurist.

3.4 Analytical Limitations

Stakeholders were classified to understand how they affect or are affected by the claim. This classification was done based on secondary data (e.g., number of employees to reflect power, or activity in CCS project to reflect urgency) and primary data collected during interviews (e.g., belief in the claim, strategy for the future).

With the exception of a few energy companies and one NGO interviewed, this meant that one stakeholder represented their organization. Furthermore, it was difficult to distinguish personal opinions and values from organizational ones. While attempts were made by the researcher during interviews to clarify the difference, it appeared for the most part, that visions on the future were personal opinions, but ones that are discussed in organizational circles.

The analysis of the functioning dynamic of the CCS field, now and into the future was dependent on the degree of participation[20] from stakeholders. The analysis also involved grouping the discussion into the system "functions" and stringing together the thoughts of stakeholders. This was done by grouping information by stakeholder class and then

[20] Involved drawing insights from informants and testing on subsequent informants.

presenting it as one collective thought. This method, again, assumes that the informants are adequate proxies for their stakeholder classes. Furthermore, if the reader does not agree with the initial stakeholder grouping the manner in which the analysis is presented may prove less insightful. If this is the case, the reader is urged to ignore the stakeholder groupings, and absorb the findings as information and perceptions from the stakeholders as a collective community.

The use of an analytical framework (categorizing, and grouping) can cause information to get polarized, perhaps making opinions or knowledge seem stronger or more certain than they are in actuality.

Finally, the emerging pathways of CCS are not compared to other energy types. The assumption is made that the volumetric supply of renewable energies at costs comparable to CCS are too uncertain and not available in the timeframes needed.

4 The CCS Community

The "CCS Community" is the term coined during this research as the representation of stakeholders (any group with a stake in the realization of the "*commercial application of CCS technologies*"). The "Community" is a representation of the larger CCS community, which encompasses proponents and opponents within power companies/public utilities, oil and gas industries, academics, non-governmental organizations (NGOs, which include non-profit organizations and environmental organizations), government, coal mining industry, industry associations, research institutes, service companies, environmental agencies, intergovernmental/international organizations, "other" heavy emitting CO_2 industry players (e.g., petroleum, cement industry), market actors (banks, investment management), the public and the media.

In this work, the stakeholders presented in Table 4-1 (by organization and grouping) are the representation of the Community.

Absent from this representation are members of the public, the media, "other" industry players and market actors, the latter who were unavailable for interview. Stakeholders in this representative community are considered to be proxies for their "grouping". For example, collectively, Greenpeace, Bellona, and E3G represent NGOs, while British Petroleum (BP) represents the oil and gas industry.

To understand the role played by these stakeholders on the *commercial application of CCS technologies;* they are classified in the following section.

Table 4-1 – CCS Community Representation

Stakeholder	Proxies
Power Companies	
Companies range from big (E.ON) to small (Fortum), including vertical integrated utilities (RWE, E.ON), and state-owned companies (Vattenfall). Other active companies include Dong Energy and Enel, the former was not available for interview.	Vattenfall
	E.ON
	RWE Power
	Fortum
Oil and Gas	
BP is a leading multinational oil company and an original leader in CCS. Statoil, a major player in CCS were not available for interview. Shell and Total are also active companies.	British Petroleum (BP)
Suppliers/Service Companies	
Companies range from leading suppliers of power plant equipment (Alstom), to leading oilfield services provider involved in storage applications (Schlumberger) and consulting companies (ERM) specializing in knowledge of various aspects of CCS. Other active suppliers include Siemens and General Electric.	Alstom
	Schlumberger Carbon Services
	Environmental Resources Management (ERM)
Environmental Agencies	
Government agents on a European and national level, tasked to provide sound, independent information on the environment.	European Environmental Agency (EEA)
	Swedish Environmental Protection Agency
	German Environmental Protection Agency
Research Institutes	
Non-profit applied sustainability research focusing on energy (Wuppertal) and independently funded (mostly government) knowledge research centre (ECN).	Wuppertal Institute
	Energy Research Centre Netherlands (ECN)
Mining (Coal)	
Large Australian based mining company (coal, uranium, iron ore)	Rio Tinto
Industry Associations	
Representing members, mostly from industry. Other active associations are Euracoal, and Eurelectric both whom were not available for interviews.	World Coal Institute (WCI)
	Carbon Capture and Storage Association (CCSA)
International/Intergovernmental Organizations	
Worldwide energy policy advisor (IEA), and a registered charity offering programs, services, reports to member countries (WEC).	International Energy Agency (IEA)
	World Energy Council (WEC)
NGOs	
Environmental organizations, industry funded (Bellona - a non-profit foundation, with its Europe division seeking "to influence the making of EU legislation through alliances with other NGOs, industry, academics and progressive politicians, particularly members of the European Parliament"), member funded (Greenpeace), and non-profit niche consulting group (E3G). World Wildlife Fund (WWF) and Friends of the Earth were not available for interviews.	Bellona
	Greenpeace
	E3G Third Generation Environmentalism (E3G)
Academics	
The academic field is growing for CCS. To note, research is being done out of Massachusetts Institute of Technology (MIT), University College of London *(UCL), and Imperial College, the latter two not available for interviews.*	Carnegie Mellon
	Linköping University
	Lund University
	Chalmers University
Regulatory	
The European Parliament (EuroParl) plays an active role in drafting legislation and also has joint power with the Council over the annual budget of the European Union. DG Env defines new environmental legislation, and DG TREN is concerned with the development of community transport and energy policies for the EU. The Swedish MOE have the overall responsibility for coordinating the Government's work on sustainable development. The similar body in Germany was not available for interview.	European Parliament
	European Commission: Directorate General for the Environment (DG Env)
	European Commission: Directorate General Energy and Transport (DG TREN)
	Swedish Ministry of the Environment (MOE)

To understand the relationship these stakeholders have with the commercial application of CCS technologies, the reader is reminded of the stakeholder classifications by use of the following figure:

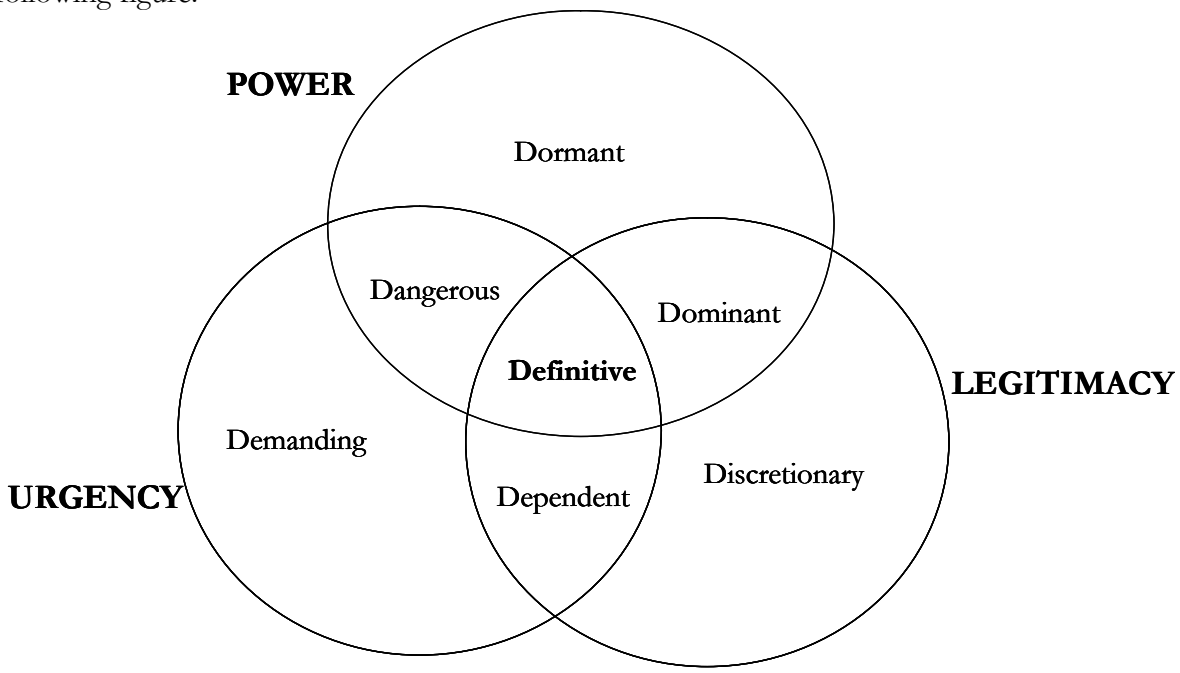

Figure 4-1 – Stakeholder Typology (adapted from Mitchell et al., 1997)

4.1 Who is Who?

In this work, the objective is seen as *commercial application of CCS technologies*[21]. To understand the claim stakeholders have on the objective, they are mapped by their possession of attributes of power, legitimacy and urgency (as explained in detail in Section 3.1 with reference to Mitchell et al.). More explicitly, the use of the framework in this research is discussed below.

Power refers to the stakeholder's **ability** to impose their will so as to ensure the *commercial application of CCS technologies*. In this research, the attribute of power is deemed to include items such as:

- the stakeholder's political influence through its size (number of people it employs or represents)
- money as amount available to invest towards the objective.

A stakeholder's power can be linked to its importance to the national economy.

Urgency refers to how **immediate** the stakeholder's claims are regarding the *commercial application of CCS technologies*. Urgency can be thought of driven by tangible needs or "feelings" as opposed to power, which is seen as "ability". Urgency is the degree of interest the

[21] This is of course just one objective of what is at stake when looking at development paths of CCS. For example, local air pollution, global warming, the price of electricity, social equity, company reputation, or the development of renewables energy sources, are also at "stake" and could be seen as an objective. Depending on the claim, stakeholder attributes can change.

stakeholder has in achieving its objective. The word "immediate" can be linked to risk in the following ways:

- money: how does monetary risk influence an organizations degree of interest in achieving an objective?
- reputation: how does reputational risk influence an organizations degree of interest in achieving an objective? and
- strategy: how much does the organization's degree of interest fit with strategic direction?

Legitimacy is viewed in two ways:

- Stakeholder view: how desirable, proper and appropriate within dominating institutional norms[22] are the **actions** by the organizations in focus to bring about or prevent the *commercial application of CCS* technologies within dominating institutional norms.
- Issue view: how desirable, proper and appropriate within dominating norms is the *commercial application of CCS technologies* and more explicitly *the long-term use of coal.*

In this research, the stakeholder view of legitimacy is measured by how well an organization's actions are understood, how much are these actions "taken for granted", and how well are these actions accepted (how "right" are these actions) by both the public and politicians. The issue view of legitimacy is measured by how well is the long-term use of coal and CCS understood, how much is it accepted, and how much is it taken for granted by both the public and politicians.

The application of Mitchell et al.'s framework requires exploring the stakeholder view of legitimacy, and is discussed across the varying stakeholders in the following sections.

The issue view of legitimacy emerged as a reoccurring theme during the collection of primary data. How well understood and how well accepted the long-term use of coal and CCS is further discussed in the function of "legitimacy" in Section 5.5. Issue legitimacy as "taken for granted", is seen to be in a current state of flux between dominating institutional norms, and what is currently deemed desirable, proper, and appropriate. Indeed it appears that sources of energy are no longer taken for granted, as illustrated by concepts of differentiated electricity between not only conventional sources versus renewables but also within these classes as well. For example, within renewable energy, distinctions are made between off-shore and on-shore wind, or between generations of biofuels. In conventional sources, clean coal once meant low emissions of sulphur dioxide, or nitrogen oxides and is now being referred to as low or zero carbon dioxide emissions. The drivers behind this flux are not discussed or explored in this research, although as indicated in Section 1, there are clear links to fossil fuel use and concerns of climate change. What is noted here is that this flux state of legitimacy can influence urgency.

The following figure depicts the results of the stakeholder mapping analysis.

[22] Dominating institutional norms refers to (for example) public opinion, what is taught in schools, what is proposed by governments, and customary behaviour.

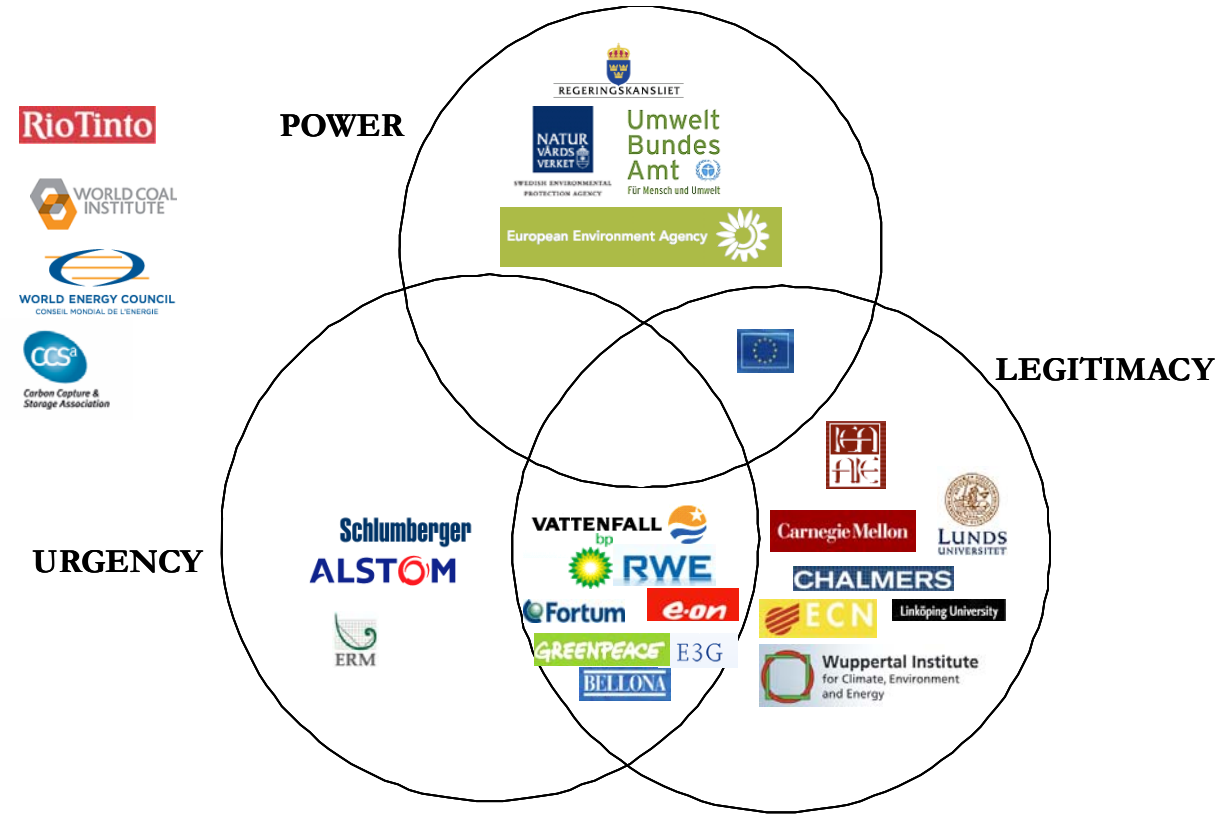

Figure 4-2 – Stakeholder Classifications on the "Commercial Application of CCS"

Stakeholders of Rio Tinto and WEC are not included in this analysis, as they were not deemed to be adequate proxies of their bigger stakeholders groups. Industry associations (WCI and CCSA) are not as easily classified in this analysis as they represent other present stakeholders. As such, they are recognized as consortiums that can influence (strengthen and weaken) all three attributes through knowledge transfer and consensus building. The non-profit organization E3G is not explicitly referred to in this analysis as it is more the informant[23] from this organization that is actively engaged in CCS.

Although not an established part of the CCS community, members of the public are also stakeholders, as is the media. These stakeholders are not discussed in detail but it is hypothesized that they could be dormant stakeholders, possessing power but little urgency, or legitimacy (due to lack of knowledge in the CCS arena or sensationalistic attitudes).

Information collected from all stakeholders was taken into consideration and is presented in the analyses in Sections 5 and 6.

During the process of acquiring informants, the researcher was more often referred to an individual as opposed to an organization. This is not unexpected as CCS is an emerging industry and many organizations (with the exception of engaged power companies for example) have only few staff dedicated to the topic. This should not discredit from the purpose of mapping stakeholders to see where they as a collective stand on the claim.

[23] The informant keeps an up to date blog covers the debate the on-going development of CCS in Europe, particularly in the EU institutions (http://ccswire.blogactiv.eu/)

Furthermore, as previously discussed, it appeared for the most part, that individual visions on the future were personal opinions, but ones that are discussed in organizational circles.

4.1.1 Dominant Stakeholders

From this work, it appears that the European Parliament (EuroParl), the Directorate General Energy and Transport (DG TREN), and the Directorate General for the Environment (DG Env) are *dominant* stakeholders, possessing legitimacy, and power, but lacking urgency. Some degree of urgency exists, not enough is present to push these stakeholders into the *definitive* category.

4.1.1.1 Power

For the period 2004-2009, EuroParl has 785 MEPs, representing the EUs 492 million citizens. EuroParl plays an active role in drafting legislation and also has joint power with the Council over the annual budget of the European Union. The proposed budget for 2009 is €134.4 billion (European Commission, 2008c).[24] In the course of this budgetary procedure the Parliament makes changes and amendments to the draft budget proposed by the Council and the Commission (European Parliament, 2001). The budget cannot be implemented until it has been signed by the President of the European Parliament.[25]

The main role of DG Env is to define new environmental legislation and ensure that agreed measures are put into practice in the EU Member States (European Commission, 2008a). DG Env, based in Brussels has around 700 staff. The main role of DG TREN is the development of community transport and energy policies, including dealing with State Aid, and managing the financial support programmes for the trans-European networks, technological development and innovation (European Commission, 2008b). DG TREN has a staff of over 1,000 in ten Directorates located in Brussels and Luxembourg. While these government stakeholders possess political influence, EuroParl has the most power out of these stakeholders, through both numbers and money, followed by DG Env, DG TREN, based on their defined roles.

4.1.1.2 Urgency

These roles also have an affect on urgency as there is monetary risk in investing or allocating money to CCS as its success is uncertain; and reputational and strategic risk in promoting a technology with an uncertain future. In this analysis, the proxies for government appear to lack urgency. This could be in part due to the fact that they are accountable to the public (their shareholders), making competing claims inevitable. For example, within DG TREN, CCS issues compete with State Aid issues (Galanis, 2008). With respect to pushing CCS forward, a lack of urgency is illustrated by the lack of financial commitment by the EU to fund

[24] The financial framework for 2007-2013 allocates spending in six different areas (sustainable growth – 44%; preservation and management of natural resources – 43%; citizenship, freedom, security and justice – 1%; the European Union as a global player - 6%; administration – 6%; and compensations - <1%). http://ec.europa.eu/budget/prior_future/fin_framework_en.htm

[25] In the case of 'compulsory expenditure' (e.g. agricultural expenditure and expenditure linked to international agreements) it is the Council that has the last word. In the case of 'non-compulsory expenditure' (other expenditure) Parliament decides in close collaboration with the Council.

demonstration plants, each requiring outside investment of a couple of billion Euros[26]. With respect to urgency regarding climate change, there are a "lack of legislative hurdles" to prevent coal from being used (Davies, 2008). This is not to say that efforts are not being made on the government front. DG Env is working on the legal aspects of enabling CCS, which emerged as a necessity from the IPCC Special Report (as detailed in Section 1). The proposed CCS Draft Directive is intended to be adopted before 2009, which requires fast and close cooperation between the Parliament and the Council, de facto a first reading agreement (Tomescu, 2008).

4.1.1.3 Legitimacy

The issue view of legitimacy rests heavily on governments. The *commercial application of CCS technologies* and more explicitly *the long-term use of coal* is legitimate if deemed desirable, proper and appropriate within dominating norms. These norms can evolve through influence of governments through applying necessary legislation (e.g., mandatory CCS on all new installed coal-fired capacity). Within the stakeholder view, legitimacy is not questioned, that is that governments have a legitimate claim on the *commercial application of CCS*. It is assumed that as elected by the people, government's actions (although not liked by everyone), are understood, accepted, and taken for granted.

4.1.2 Dependant Stakeholders

Power companies, oil and gas companies, and NGOs are *dependent* stakeholders, possessing legitimacy, and urgency, but lacking power. Some degree of power exists, not enough is present to push these stakeholders into the *definitive* category.

4.1.2.1 Power Companies and Oil and Gas Companies

Attributes of urgency and legitimacy are more notable than power (the ability to act towards the objective) when compared to the power held by governments. The attribute of urgency is growing but is still considered to be deficient, as all commitments made by companies are still dependant on financial and technical feasibility, as such, it is arguably just as important to "hold back" as it is to proceed. The attributes are discussed below, based on both primary and secondary data. These stakeholders are depicted on Figure 4-2. It should be noted that the exact placement of these stakeholders in relation to each other is an example, and to adequately decide if for example Vattenfall has more urgency than RWE, would require more research.

Urgency

All efforts to date on CCS have been made without the applicable legislation in place. While progress has been made on the legislative front the sheer fact that businesses have engaged in this technology without a certain future is a sign of some form of urgency. To further examine this, stakeholder involvement in active and cancelled CCS projects is used. This is assumed to describe the degree of interest as influenced by monetary risk.

Vattenfall recently unveiled its 30 MW pilot plant, Schwarze pump in Brandenberg, Germany. Vattenfall plans to scale up to a 250 MW demonstration plant, and have a commercial concept available by 2020. Vattenfall has plans for three additional demonstration plants, inclusive of

[26] Range required for the EU Flagship Program is 6-16 billion Euros (ZEP, 2008a)

storage and transport to be built by around 2014. BP was a clear pioneer in CCS at the beginning but has faced cancelled projects recently. It can be argued that this does not necessarily constitute a lack of urgency rather that considerable efforts have met with unfavourable conditions. Furthermore, BP and Rio Tinto formed Hydrogen Energy, which will develop alternative energy solutions in the form of decarbonised energy projects. E.ON and Fortum have plans for pilot plants, and RWE has plans for a demonstration plant to be operated by 2013.

The influence of reputational risk and strategic direction on urgency is examined through primary data surrounding incentives for entering the CCS market and the inclusion of CCS in future strategy. Urgency is linked to immediacy, which is tricky in the energy business as "short-term" strategy can encompass decades due to the scale of investments and planning. This concept of "time" and urgency is further elaborate in Section 4.4.2.

From a strategic viewpoint, power companies are engaged in CCS for a number of reasons. Primary data points to diversification of risk (can we "wait" for renewable energy technologies?), policy objectives to reduce GHG emissions by 50-80% by 2050, staying competitive with current business trends, continuation of existing industry, energy security, a "license to operate"[27] with coal, belief in CCS as a business opportunity, and gaining a first-mover advantage. Companies are bound to their shareholder interests. A state-owned company like Vattenfall can take the longer view, and perhaps has a different reputation to uphold than privately-owned E.ON, or a smaller company like Fortum. Furthermore, a vertically integrated company like RWE, E.ON, or BP will likely be subject to the benefits or pitfalls of riskier investment, and their strategy will reflect this. Company strategies and core business are related to urgency.

Table 4-2 – Core Business of Stakeholders[28]

Company	Core Business
BP	Exploration, extraction, transport of oil and gas, making and selling fuels, generating low carbon energy
E.ON	Power and natural gas *36% coal, 29% natural gas and oil, 21% nuclear, 14% renewables*
RWE	Electricity, gas, water & wastewater, waste disposal & recycling *Nuclear, lignite, hard coal, gas, hydro*
Vattenfall	Electricity and heat *Fossil fuel 45%, nuclear 33%, hydro 21%, other 1%*
Fortum	Electricity and heat *Nuclear 46%, hydro 37%, coal 10%, biomass 3%, peat 2%, other 2%*

[27] This term is used throughout this work. It is intended to mean that the use of coal may be seen as illegitimate or not in line with social values. The use of CCS may be seen as helping to increase the legitimacy of coal, as global warming causing emissions are largely avoided from entering the atmosphere through the capture and storage process.

[28] The information is extracted from the following company websites:
http://www.bp.com/extendedsectiongenericarticle.do?categoryId=5&contentId=7044157
http://www.eon.com/en/unternehmen/23422.jsp
http://www.vattenfall.com/www/vf_com/vf_com/365787ourxc/366203opera/555848newpo/index.jsp
http://www.fortum.com/dropdown_document.asp?path=14022;14024;14026;14043;14070;14071;28379
http://www.rwe.com/generator.aspx/produkte/language=en/id=498/products-services-home.html

When looking at core business as presented in the above table, Vattenfall, RWE, and E.ON may be more dependent on the continued use of coal, exhibiting a higher degree of urgency on CCS is it becomes a "license to operate". Further integration of CCS will depend on what happens with core business, for example the future of the oil and gas market for BP. At present Fortum has the least urgent claim in this group of stakeholders with a low amount of coal as an energy source and low involvement in CCS comparatively. However, if their share of biomass increases and CCS is a feasible technology for this source, it is possible that they could yield net negative CO_2 emissions and depending on the price of carbon and the EU-ETS, CCS could become an integral part of their business strategy.

It is of course, difficult to assess urgency from what companies "say" they are doing or what they plan to do, as CCS projects take time. Nevertheless, communicating this information publically does carry some weight and perhaps increases legitimacy as discussed below.

Legitimacy

To review, legitimacy in this research refers to how well an organization's **actions** are understood, how much are these actions "taken for granted", and how well such actions are accepted (how "right" are these actions) by both the public and politicians.

In this attribute, companies are discussed collectively based on primary data, as research did not include a detailed analysis of legitimacy (which would entail amongst other things, collecting data on social perceptions[16]). Companies are communicating the main concepts of CCS and their commitment towards it. In general however, CCS is not a well-understood topic by the public or politicians (further discussed in Section 4.2). Primary data indicated that CCS feels like a "forced hand", where norms and legitimacy surrounding coal are in the process of change. One emerging worry for the power industry regarding this commitment to CCS is that it is something that may be seen as "right" in the eyes of the public, while there is still uncertainty on its financial and technical viabilities still remains. If these uncertainties are unresolved, what will these companies do then? Will they continue to use coal without CCS? Will this be "wrong"? As far as being taken granted, CCS is at an early stage of development, so perhaps a large portion of the public are not engaged in the issue. To increase legitimacy on their involvement in the claim, some power companies are self-financing pilot projects and planning for demonstration projects without a financial aid scheme in place.

4.1.2.2 NGOs

At this current time, this analysis indicates that NGOs (similar to power companies and oil and gas companies) are dependent stakeholders, possessing legitimacy, and urgency, but lacking power. Some degree of power exists but not enough is present to push these stakeholders into the definitive category. They depend on others for the power required to carry out their will. Urgent, legitimate claims adopted by dominants stakeholders can move the once dependent stakeholder into the most salient class (Mitchell et al., 1997). Conversely, if these organizations lose legitimacy, for example in the public eye due to funding mechanisms, or political or industry eye due to a lack of credibility surrounding sound knowledge of CCS, they can move towards to demanding stakeholders. While still being subject to change, it appears that the role played by NGOs is moving towards one with gained legitimacy.

Generally speaking NGOs are non-profit, lean organizations. The attribute of power is not present outright in these organizations but strength in numbers can be acquired through

gaining and affecting the public interest. Furthermore, in Europe, the European Commission has control of national subsidies so NGOs have access to power by leveraging in Brussels (Johnston, 2008).

The attribute of urgency is interesting when dealing with NGOs. Monetary risk can be thought of as money spent more effectively on a different campaign or objective, which then links to strategy in determining where efforts will be concentrated. Greenpeace spends roughly 80% of their funding on campaigning, with priority on the climate and energy campaign (Greenpeace, 2007). Publications within the last two years include their "Energy [R]evolution" a comprehensive scenario document, and "False Hope" questioning among other things, the cost, timeliness, and risk of CCS. It appears that despite being an international organization with divided concerns across various environmental mandates, Greenpeace is attaching urgency to the commercial application of CCS. Bellona focuses primarily on energy with publications within the last couple of years focused on climate change and CCS, namely "The Bellona Scenario", which advocates CCS as part of the solution to combating global warming.

Reputational risk is a prominent influencer on urgency for NGOs who have a role to play in society. As representatives of civil society, a non-homogenous mix of values, this role is not fixed, and no one is privileged to say what that representation should be (Frisvold, 2008). This role of NGOs has been and is continuing to change as they work more closely with government and even industry. That is to say, in this context of analysis they are gaining legitimacy as their reputation moves from "pesky" to informed stakeholders with legitimate claims.

Similar to companies, NGOs are bound to the interest of their shareholders. In understanding the "rightness" or their actions, one can point to industry funding for Bellona, versus member funding for Greenpeace, the latter whom have more carefully protected their status of objective analysts/commentators and thus maintained higher credibility. This can be seen as measures to gain legitimacy.

4.1.3 Discretionary Stakeholders

With discretionary stakeholders, the relevant attribute is legitimacy, and both power and urgency are deficient.

At this current time, this work indicates that the actions of academia and research institutes are taken for granted and considered more "right" than actions say from a mining company. They do not directly posses attributes of power and urgency, but can affect them through their influence on the CCS community, the public, and politicians through delivering the "facts", in the most objective, transparent way possible. On the stakeholder map in Figure 4-2, the IEA is placed apart from the other discretionary stakeholders. During the course of this work, it was viewed that the IEA has more power to drive policy than the other stakeholders in this grouping.

4.1.4 Demanding Stakeholders

Service companies like Alstom, ERM, and Schlumberger provide services to the private and public sectors. For example, Schlumberger is involved in major CCS projects[29] worldwide

[29] Involvment in all three large-scale commercial storage projects: InSalah, Weyburn, Sleipner.

(Booer, 2008), and Alstom provides equipment/services for seven active CCS projects[30] worldwide. It is possible that as these companies become entrenched in CCS as their core business, their urgency will increase (as tied with reputational, strategic and monetary risk). In this analysis they are classified as demanding stakeholders, possessing urgency, but lacking power and legitimacy. These stakeholders see a business opportunity tied to the actions of dominant and dependant stakeholders, which may make money if CCS is successful and the opposite if it is not. This compromises legitimacy.

4.1.5 Dormant Stakeholders

This analysis indicates that the Swedish MOE and environmental agencies (Swedish and German national environmental protection agencies and the EEA) are dormant stakeholders. They possess power by their influence on governments and the public through their provision of independent information, but at this time lack a legitimate or urgent relationship with the commercial applications of CCS technologies. This is due to their role as a provider of sound, independent information. For example, they cannot be seen as supporters of CCS until it has been made clear to them that it is an urgent, legitimate claim. It can be noted that the informant from the Germany agency seemed more engaged in CCS possibly due to a different role outlined for them from a national perspective.

It is likely that the role of these stakeholders will shift as the CCS movement proceeds, and uncertainty on the technology and its potential for success or failure begins to be resolved.

4.2 Who is Who Revisited

The stakeholder mapping of the "CCS Community" indicates that none of the stakeholders really appear to possess all three attributes of power, legitimacy and urgency. This indicates that the "commercial application of CCS" is not yet prioritized. This work also indicates that it is possible that if the community stays in this stakeholder snapshot, the claim may continue to not be prioritized.

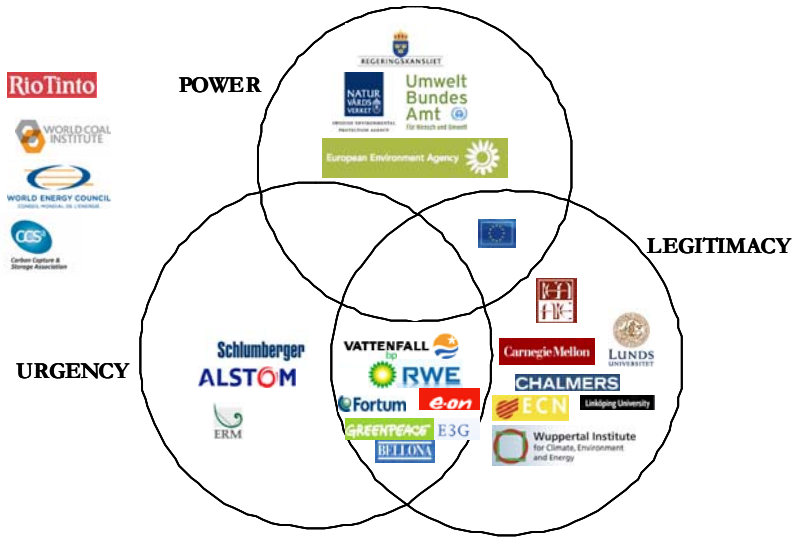

Figure 4-3 – Stakeholder classifications on the "Commercial Application of CCS"

[30] Mountaineer and Northeastern (US), Karlshamn (Sweden), Mongstad (Norway), Lacq (France), Schwarze Pump (Germany), and recent partnership with TransAlta (Canada)

This void of a definitive stakeholder is perhaps favourable to opposition groups, as it could mean that the commercial application of CCS is not reached. However this strategy is unlikely for opponent groups, as it means that money and resources that could be spent elsewhere are tied up in a claim that may never be fulfilled. For proponents, this begs the questions: who will prioritize it the *commercial application of CCS technologies*?

According the stakeholder map, this could happen in five situations: if dependant stakeholders (power/oil and gas companies or NGOs) gain power; if dominant stakeholders (governments) gain urgency; if discretionary stakeholders (academics) gain both power and urgency; if demanding stakeholders (services) gain power and legitimacy, and/or if dormant stakeholders (environmental agencies, some national governments) gain legitimacy and urgency. For simplicity in this work, the former two options are assumed probable and are discussed further below.

4.2.1 Gaining Power

This work shows that in order for dependant stakeholders (e.g., power companies) to become definitive stakeholders they must gain power. This could happen for example if the CO_2 price was favourable to CCS, or if a consortium of power companies joined forces and charged more for "value-added" CO_2 free electricity, the latter being unlikely, due to amongst other things the time lag and capital required to provide such electricity, or the question of equity and fairness in such a pricing scheme. This could also come in the form of money, through public and/or private investment. This research did not explore how dependant stakeholders may gain power, but it may an area of interest for further research. Of particular interest may be to research market actors like big banks or asset management firms to understand details surrounding favourable conditions for investment in CCS.

For the time being, it appears that dependant stakeholders are likely to remain dependant on strengthening the attribute of urgency both within themselves and upon dominant stakeholders (e.g., governments). That is to say, power companies demonstrating urgency like self-financing demonstrating plants, or NGOs gaining public opinion (thereby gaining also power and legitimacy while demonstrating urgency) may strengthen the urgency amongst dominant stakeholders (e.g., governments).

4.2.2 Gaining Urgency

This work shows that one way for the claim of the commercial application of CCS to be prioritized it to strengthen the attribute of urgency within dominant stakeholder groups (e.g., governments).

As previously mentioned, this could be shown by government giving a clear political signal like a ban on non-CCS operating coal plants, or an unlocking of public money to CCS demonstration plants. This research did not explore how dominant stakeholders may gain urgency, but it may an area of interest for further research. Might urgency be gained from accelerated weather crises, or a strong commitment to CCS by the United States? Do stakeholders believe they are acting urgently? How might urgency be influenced so that the commercial application of CCS may be realized?

It is unfair to discuss the attribute of urgency and determine that governments, companies, or organizations do not possess urgent "enough" claims without reflecting on the time dimension. With respect to the government, they are in the process of drafting a legislation, which takes time. Companies are building pilot plants, and working on feasibility studies of

demonstration plants. They are "doing" things for the long-term which doesn't always show in the short term (Sjunnesson, 2008). But all of this takes considerable time, making it perhaps seem less urgent. While such activities are necessary, and must be undertaken, the risk exists that one is seen to be moving slowly, and momentum of any sort of CCS "movement" can be lost among stakeholders.

It takes time to build confidence, to build capacity, for governments to feel that need to act, to demonstrate flagship programs (Hill, 2008). The time dimension make is difficult for [stakeholders] to do the right thing, as [for example] then may not want to spend money to support deployment, when other [matters] are more immediate (Hill, 2008). People recognize the challenge but [underestimate] time, as they are not offsetting the cost of inaction and adaptation (Hill, 2008). Furthermore, rapid movements cost more and technology is not mature when it reaches the market. Economic rationale demands a "reasonable" pace, to avoid cost explosions.

The incompatibility of the time dimension is a common thread throughout sustainability, applicable to corporate mandates, political terms, and even perceptions or trends in the public. This research does not offer answers to this relationship between time and urgency, but puts forward the concept as one that should be kept in mind when understanding a stakeholder's relationship to the commercial application of CCS technologies. That is, the concept of urgency in this work relates to immediacy, which is difficult to see by the actions of any stakeholders on the map. While it appears that during the time of this work, claims towards the commercial application of CCS technologies are not urgent "enough", further research may be applicable surrounding the concept of urgency as it relates to CCS.

5 Exploring the Functional Dynamic of CCS

The following analysis is based almost entirely on primary data collected during interviews with stakeholders. As previously mentioned, it is important to keep in mind that the stakeholders as discussed here are being treated as a proxy for their larger groupings (e.g., NGOs) and stakeholder classification groups (e.g., dominant, dependant, discretionary). Citations are presented where appropriate as anonymity was requested during some interviews. The information was grouped in two ways. The primary data collected by interviews was grouped loosely into the seven innovation functions explained in Section 3.2 (knowledge development and diffusion, influence on the direction of search, entrepreneurial experimentation, market formation, legitimacy, resource mobilization, and free utilities) to show how stakeholders assess the functionality of CCS both currently and into the future. This information is further grouped by stakeholder classifications to allow the reader to see "who" thinks "what" and in some cases still preserve anonymity. It is recognized that the reader may not "agree" with the classifications of stakeholders. It is then an option for the reader to interpret the data under the larger grouping of functions.

It is not the intent of the researcher to polarize the data by categorizing. Information was not prioritized or weighted by "who" it came from. Furthermore, less information from some stakeholders on issues could be attributed to the types of questions asked by the researcher (as interviews were conducted in a three phases). However, this can also give some indications of what was urgent by the stakeholder, or what they felt comfortable talking about as most interviews were kept open (as discussed in Section 2.2). It is important to realize that all of the information presented in this Section has been cited or paraphrased from primary data. Reflections made by the researcher are only presented in Section 5.8.

This method of analysis and presenting of data is intended to make it easier for the reader to understand how stakeholders view the functioning dynamic of CCS, for use in developing potential pathways provided in Section 6.

To remind the reader, the stakeholder typology is presented again:

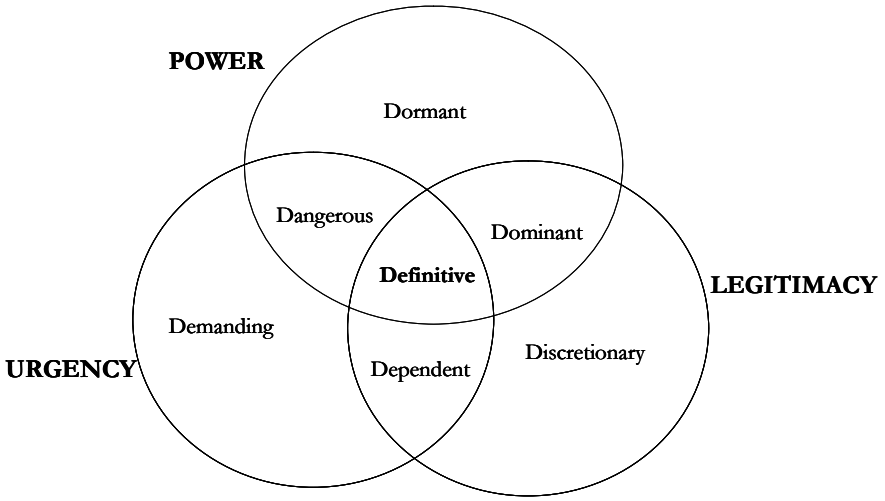

Figure 5-1 – Stakeholder typology as per Mitchell et al. (1997)

Dominant stakeholders within this discussion have been deemed to encompass the EU government; dependant stakeholders encompass power/oil and gas companies and NGOs; discretionary stakeholders encompass research institutes and academics; demanding stakeholders encompass service companies; and dormant stakeholders encompass environmental agencies and the Swedish MOE. Information from all other stakeholders have still been taken into consideration and placed where it seems to best-fit with other stakeholder insights and viewpoints. If stakeholder groups are missing in the analysis it is because they were somewhat silent on issues. Furthermore, the information collected from dormant stakeholders (environmental agencies and the Swedish MOE) was limited and not opinion-heavy. This information was placed in the discussion where it fit in with other stakeholder opinions.

5.1 Knowledge Development and Diffusion

This section concerns how well stakeholders think knowledge is developed and diffused within the CCS Community and amongst the general public. The reader is reminded that the presented discussion represents the data gathered from the stakeholders referenced where possible and appropriate.

5.1.1 Dominant Stakeholders

In this analysis, EU governments appear to possess power and legitimacy but lack urgency towards achieving the commercial application of CCS technologies.

The field of CCS involves expensive technology and it is expensive to gain skills and experience in the application of technologies to achieve CCS. There is thus an inherent selection of who has the ability to gain or access this knowledge in relation to their financial resources (Tomescu, 2008). The CCS Community consists of the same faces, shown over and over again so amongst these faces, knowledge is well diffused but not necessarily developed.[31] Knowledge is not well diffused amongst politicians or the general public (Davies, 2008).

For CCS to commercialize knowledge development must be rapid; this includes having the right incentives for technology to get on the market so information is exchanged. This is essential to overcome general existing skepticism, which may linger until commercial CCS projects are developed. During the demonstration phase and the 10-12 plants planned for Europe, an iterative process should diffuse and develop knowledge and deliver clear results.

Thus far, knowledge gaps are being filled as a continuous process. It is important to keep up momentum, as there is a risk in waiting to acquire knowledge to ensure success (Galanis, 2008). There is a possible knowledge gap in the large-scale storage that will be required during the demonstration phase. There is a chance that the demonstration phase will be insufficient, as it is being done to test the technology and system as a whole.

5.1.2 Dependant Stakeholders

In this analysis, power companies, oil and gas companies, and NGOs appear to possess urgency and legitimacy but lack the power to carry out their will towards the commercial applications of CCS technologies.

[31] This is not to imply that this repetition of faces in the CCS community is either positive or negative, rather it is an observation made by dominant stakeholders.

Power Companies

The amount of knowledge amongst the fields of capture, transport and storage is not consistent. The technology is perceived to be sound amongst all three areas, however planning and consent may be difficult.[32] The timeliness of transport regulations and the deficiency of the amount of people looking at transport are considered to be a problem. For example, if ships are required for transport (a possibility for transportation before infrastructure is in place, or while pipeline regulations are in the making) a certain type of large, low-pressure ships are required. These ships, need around 20,000 tonnes carrying capacity, and are not yet readily available[33] (Liljemark, 2008).

Outside of the CCS community knowledge is low. This large percentage of people if informed in a manner that is not based on proper knowledge may have ill-conceived notions of CCS. In a sense the information delivered thus far by companies and governments towards the public has missed the proper target as the need for CCS is largely linked to electricity consumption (Möller, 2008).

Currently, CCS is leaving R&D desk studies and moving towards demonstration. Although energy companies may have enough capital to build competence it is still difficult to build wide and deep knowledge in an uncertain field. Furthermore, companies that have the capability and competence in areas of transportation and storage (e.g., refineries or Norwegian natural gas companies) are not the main players (Christiansen, 2008). This is a technical barrier for power companies that are entering a world with different risks, and incompatible knowledge spheres.[34] The Draft Directive should fill gaps in uncertainty, or promote that these gaps be filled.

There seems to be a lack of influential or strong opposition groups against CCS. This can be viewed as poor knowledge diffusion, as different perceptions and opinions are essential inputs for dependant stakeholders as they attempt to shape the industry.

NGOs

The challenge of developing and diffusing knowledge is particularly large, as it involves thinking far in to the future, and executives who have such visions are being told by experts that there are barriers in each step. There is a lack of knowledge in the storage aspect of CCS, and all sites are unique, and leakage is a possibility. Some storage experts are openly communicating this, while others are not so transparent. It seems as if there is some blind faith in CCS.

5.1.3 Discretionary Stakeholders

In this analysis, research institutes and academics have a legitimate place in the CCS debate but perhaps have no real urgency or power to push it forward.

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[32] For example, while the knowledge to build a pipeline exists, it is the part of the value chain that passes through people's land. Local problems are likely when "real" projects are underway.

[33] It was expressed by this stakeholder that IM Skaugen (http://www.skaugen.com/) is somewhat prepared for an early new fleet.

[34] The example here was that geologist and engineers have very different views of "certainty". The former talk about 1-2 degrees of steel, while the latter discusses an 80% chance of finding sand in a formation (Christiansen, 2008).

While awareness of CCS has grown tremendously, the knowledge thus far in the field is dependant on a limited number of sources[35] (Hansson, 2008). Knowledge quickly moves out of date making market predictions difficult. For example, for transportation pipelines, the cost of steel has been extremely volatile, making old figures irrelevant.

The development of knowledge of dependant stakeholders, in particular NGOs, is gaining respect as it is moving from being focused on easier targets of "leakage" to general energy supply discussions.

The academic community seems to be aware of these uncertainties; however this is not necessarily reflected through research papers, possibly due to their scientific nature.[36]

5.2 Influence on the Direction of Search

This theme covers the incentives for entering into the CCS Community and the visions, expectations and belief in CCSs potential for growth (e.g., CCS as a gap bridging solution). The reader is reminded that the presented discussion represents the data gathered from the stakeholders referenced where possible and appropriate.

5.2.1 Dominant Stakeholders

In this analysis, EU governments appear to possess power and legitimacy but lack urgency towards achieving the commercial application of CCS technologies.

The stimulation and financing of demonstrations plants will influence the direction and growth of CCS. At current, there is no money in the EU budget for this. Compulsory methods of "influencing the direction" could be the ban of non-CCS coal plants. This is not foreseen as the moment, as it is difficult to increase pressure with unfavourable economics. It is possible however, that public pressure will change over the next couple of years, and CCS will gain more political support. This could even coincide with a legislative proposal to forbid conventional power plants. In this situation, funding mechanisms[37] would be put into place for demonstration projects. The incentive to enter into CCS, hinges on a legal framework that will provide a clear signal that CCS constitutes the only real way to maintain "a license to operate" with coal. At the moment, there is not a clear incentive to become engaged in CCS.

The belief in the potential for CCS can be linked to its perception as a "gap bridging" solution. This was expressed by the proxy for the European Parliament[38] as:

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[35] A recent (2008) Ph.D completed by Anders Hansson from Linköping University, Sweden (available in Swedish "Kolets återkomst") looked at CCS in scenario building. Findings indicated that in most cases, these scenarios are based on high energy consumption, and an optimistic technological learning rate. Furthermore, the economics of CCS presented by the IPCC Special Report on CCS are largely in reference to Massachusetts Institute of Technology (MIT), and the International Energy Agency (IEA). The relevance of scenarios in CCS is questioned with the limited knowledge sources used and uncertainties this can cause. Furthermore, most scenarios with CCS are compared to non-CCS options, further promoting CCS. (Hansson, 2008)

[36] It was noted here by Hansson that during research, written papers and scenarios appeared more convincing than when talking in person with authors (Hansson, 2008).

[37] The interview with this stakeholder was quick, and this point was not further elaborated. It is assumed that "funding" is from public money, to coincide with the banning of conventional coal use.

[38] Paraphrased from (Davies, 2008)

There is a limit to the amount of storage sites, and amount of coal, but there is no clear defined date on when that will be. The arrival of a truly sustainable technology, which fulfills electricity needs, will allow for the halted need of CCS, as it will cease to make financial sense. In a time sense, perhaps this is post 2050. However, this is rarely discussed, especially in practical investment circles, wherein 2030 is also somewhat regarded in the realms of fantasy.

5.2.2 Dependant Stakeholders

In this analysis, power companies, oil and gas companies, and NGOs appear to possess urgency and legitimacy but lack the power to carry out their will towards the commercial applications of CCS technologies.

Power Companies

"*One company takes the lead, and then in one week there are others there*", is how one stakeholder described the creation of the vision of CCS. Strategy and the urgency within an organization will influence the direction of CCS. The power or scope of energy companies was questioned by one stakeholder, and further discussed that it is only within the ability of power companies to know what choices to make at the right time. It is then speculated by the researcher that this could indicate a slow deployment of CCS.

Although it varies from one country to the next, the approach to coal, greenhouse gas emissions and climate change has moved from passive to factual. It is very possibly that soon it will be socially and legally unacceptable to use coal in the manner it is used now.

"Bridging the gap" means continuing to use oil and coal until there is a better alternative, and currently there are not that many alternatives (Christiansen, 2008). If we build one generation of power plants with CCS, each will live for about 40 years; it is difficult to see further that that (Ekström, 2008).

Unavoidably, a focus on CCS will pull resources away from other technologies, but these resources are not a fixed amount, and climate issues are gaining attention and investment. Within power companies, programs are getting funding; the difference is that normally it would be a slower progression. So it is not necessarily that CCS is pulling R&D funding from other sources of energy, just that efforts are increasing rapidly on R&D in absolute terms (Lidgren, 2008). One common view of multiple stakeholders was that while money can be spent on a number of technologies, none are capable of delivering the volume that CCS can. Moreover, this is viewed to be occurring in parallel to the development of other energy technologies, not competing with it. The talk that there is some intrinsic danger that CCS will compete for attention or resources in terms of development of support policy with renewables energy is based on the presumption that they are the best possible technologies (Chapman, 2008). It can be conversely viewed that renewable energies are set to be a drain on CCS, as seen by the EUs commitment to 20% renewable energy by 2020 - this commitment means that Member States are committed to spending money on renewable energy, and not on CCS (Chapman, 2008).

To change direction would require a clear political signal, and at the current time, signals are positive for CCS. For the most part barriers are viewed as challenges that can be overcome.[39] The ultimate direction is dependant on how consistent the EU is in their determination to take the lead on climate change issue and how affordable the EU regards this issue (Görtz, 2008). Affordability is a result of how the rest of the world will act, but waiting and a decreased urgency on the deployment of CCS is also a risk (Görtz, 2008).

[39] The example provided here was that recommendations from the ZEP are well received and implemented by government.

It is easy to focus on the early phase of CCS and deployment. Strategizing past the demonstration phase, and planning for major infrastructure will be more difficult. How will competition and cooperation interact with each other to influence direction? Most people are focusing on the 10-12 demonstration plants, but there will be a big gap after. A clear direction and plan for the demonstration phase is required. If, for example, funding is made available, what will be the direction to take?

Technical bottlenecks in the future may be that in the case of the first projects, there will be a high infrastructure burden (e.g., big pipeline, small project), so others can "piggyback" provided there is proper planning in place. There is a danger of haphazard construction of projects, so it is important to have a view of sinks, sources, and how to connect in the future.

CCS runs a small risk that it will be a self-fulfilling prophecy, and not occur due to reasons that are not necessarily justified technically, but are based on perceptions[40].

NGOs

The vision amongst the CCS community is varied, as industry is looking for incentives, and some NGOs are looking for the government to pressures industry; the solution lies with a mix of both (Johnston, 2008). Influence on the direction of CCS will come politically which is closely linked to national perspectives and issues of energy security[41].

Amongst NGOs, the view on funding of the demonstration plants varies. There is a strong general position from industry that renewable energies are not currently strong enough to make a big change, and that CCS can. If this is the thinking, then it is up to industry to prove this, without the use of public money (von Goerne, 2008). Another opinion is that the demonstration phase should be deserving of funding and the directional search should be aided by a "kickstart fund", as cost discovery should be a sharing of intellectual property (Johnston, 2008).

Some groups feel that the development of CCS is hindering the development of renewable energies. Another opinion, echoing the sentiments of some stakeholders from power companies is that the diversion of public money towards CCS is dangerous, with respect to the development of renewables energy and energy efficiency, however all technologies are required to meet energy demand.

On "bridging the gap", the following comments were made (von Goerne, 2008; Johnston, 2008; Krüger, 2008):

What actually is the gap? It can be argued that although renewable energies require a new distributed infrastructure, so does CCS, for example transportation networks. Essentially, the debate from the industry viewpoint comes to the discussion of alternatives, do we risk minor leakage from the CCS, or do we heat the planet? It is unfair to say "bridging the gap", as it is unlikely that such a large scale investment will be left,

[40] The analogy was then made to nuclear power, where the waste is not dealt with as a result of political reasons, as opposed to technical reasons.

[41] The example given here was that Europe imports roughly 1/3 of coal, and the closure of domestic subsidies could mean that ½ or more of the coal in Europe could be imported.

once a "gap" is crossed. CCS will be a transitional technology but will be around for most of the century.[42] *The term bridging may divert from long-term thinking. For policymakers, targets are set for 2020, which possibly diverts attention from the long-term issue of only being halfway to the goal of 80% emission cuts in the developed world by 2050.*[43]

With respect to predicted energy consumption, the concept of direction of search can be viewed to a self-fulfilling prophecy (Krüger, 2008).[44] Furthermore, the direction of search and the choice that is made now, involves money that can only be spent once (von Goerne, 2008).

5.2.3 Discretionary Stakeholders

In this analysis, research institutes and academics have a legitimate place in the CCS debate but perhaps have no real urgency or power to push it forward.

Looking briefly at other sources of energy, the last decade showed a transformation in the natural gas sector. Infrastructure has developed from the formation of simple local contracts between producer and consumer to complex global contracts In the EU, there was a tremendous diffusion of combined cycle plants, illustrating high efficiency at low cost (Johnsson, 2008). So it is possible that even if the price of natural gas goes up, the trend will continue in the order of 50-60 years, of course depending on cost (Johnsson, 2008). Nuclear power on the other hand, depends on the country, but it is clear that it is making resurgence, even in Germany with polarized opposition (Johnsson, 2008). With available coal reserves, CCS can play a significant role, but perhaps the faith is too large. However, to meet emission targets set by the IPCC for 2050, we are long past the time when we can choose which way to go, we need absolutely everything.

There are no technologies today that are sustainable; a bridging system can take us there. In this sense, *a good definition of a bridging system is one that we can use until we get to another system, but this latter system, we have no idea what it looks like* (Johnsson, 2008). So when do we get out? Even in 2100, unless radical new concepts come on board, the gap will not be bridged. This bridging concept has come up from people predicting the widespread use of hydrogen as an energy source. If we delay CCS, we must realize that we still need CCS, and one can hesitate to call it an interim solution.

The atmosphere within the CCS Community is generally optimistic. Everyone acknowledges the technical and financing difficulties, but remains positive in resolving issues, largely in part due to the political support. It is unknown how long this political momentum will last, and to what extent the market will step in.

Finding the right incentive for CCS is a challenge. Explicitly, this could be a tax or permit price, a higher carbon price (not just the ETS which may not be stable or high enough) or subsidies. Implicitly this could be a carbon performance standard[45]. Will incentives come fast

[42] The conversation continued here to discuss the current EU-ETS proposal: "the zero-cap will reach an automatic cap which is implicitly imposed in the legal proposal. When this happens, and CCS is only capturing 90% of emissions, how will one acquire permits for the remaining 10% still emitted?" (Johnston, 2008)

[43] As briefly discussed in Section 1, in 2005, the EU Council (25 Heads of Government of the European Union) agreed that with a view to achieving the ultimate objective of the UNFCCC, the global annual mean surface temperature increase should not exceed 2°C above pre-industrial levels (Council of the European Union, 2005).

[44] The self-fulfilling prophecy is, in the beginning, a false definition of the situation evoking a new behaviour which makes the original false conception come 'true'. (Merton, 1968)

[45] Essentially a limit on the amount of CO_2 emitted per kWh

enough to drive investment and keep the momentum? There may be a stronger belief in the realization of CCS if the EU would release a press release that they are dedicating some 10 billion Euros for demonstration (de Coninck, 2008). After that, the market may be able to work. In general it seems like no one is really moving, and there is a chance that demonstrations either won't happen, or will occur insufficiently.

One benefit of the vision of CCS is that it makes the fossil fuel industry part of the solution to climate change. In a sense, it allows a "powerful enemy" to join the battle on ones own side, but is also involves the fuel source that many wish to get rid of. There are different views in the research community, where many claim that CCS raises the energy cost of coal, so the marginal cost of renewables are more competitive. For major utilities, CCS is perhaps a result of a more convenient technology as it fits into their culture, which is large scale centralized energy production.

This vision of CCS is a result of the climate change "hype" and is a "spirit of the times", a combination of industry interests and political ideas (Thörnqvist, 2008). Energy planning is filled with all types of contradictions and uncertainties; it should only "look" as it is, not as how we want it to be, as eventually, it will right itself in the marketplace or through a crisis (Thörnqvist, 2008). Primary focus should instead be directed on local environmental effects for they are more certain. So while we have a moral obligation to abstain when we can, at what cost do we do this (Thörnqvist, 2008)?

5.2.4 Demanding Stakeholders

In this analysis, demanding stakeholders are service companies and suppliers who have an urgent interest in CCS but appear to lack power or legitimacy in achieving its commercial application.

Skepticism exists on if CCS, particularly storage, will work[46]. How much work is necessary to have a convincing storage site, without going through the expense of actually developing it (Booer, 2008)? Apart from the storage, the investment cost and the energy penalties on the capture methods must decrease to ensure it can be competitive with other technologies. As far as an exit strategy, oil and gas are closer to needing it than coal. There is talk of peak oil, and other strategies, but it is possible that oil and gas are not ready to switch their business.

5.3 Entrepreneurial Experimentation

This function covers how uncertainty is handled or is envisioned to be handled within the CCS field, and largely focuses on the demonstration phase. Within this theme, almost all data stems from discussion with power companies, thus information is not grouped into stakeholder classes.

The reader is reminded that the presented discussion represent the data gathered from the stakeholders and is referenced where possible and appropriate.

Some companies have chosen to develop a particular technology, but it is a risk to dismiss other technologies. Within R&D, steps cannot be taken in series; rather technologies must be investigated in parallel, to meet requirements as quickly as possible. It could have been hoped

[46] The term "works" here refers to no CO_2 leakage from storage operations

for an earlier start of true competition, that is the full attention from suppliers, but this is improving (Lindgren, 2008).

Entrepreneurs find it difficult to get into this area; a role could be to sell proven technology to bigger companies. But for the most part, CCS technology deals with huge sums of money that entrepreneurs and small to medium establishments (SMEs) do not have access to (Chapman, 2008). There does seem to be plenty of large equipment suppliers with the motivation to develop technology on all fronts. One issue here is that suppliers tend to get comfortable with certain technologies. For example, power companies can get comfortable with something they are used to, potentially stifling experimentation.

The demonstrations must be done well and safely. To handle this uncertainty, valid conclusions must be drawn from the demonstration plants. This will require public investment from the EU, and pluralism (e.g., a range of technologies, in different countries) in thinking to ensure adequate testing. It is hoped that there will be an open proposals to build on different applications, preferably a quiet objective evaluation of proposals. In this evaluation, there is a risk of anti-competitive behaviour, where a candidate will come along having good faith of gaining support through the flagship program, and another candidate would have taken their "spot" (Chapman, 2008). It is important during the demonstration phase that there is competition both within technologies and amongst technologies.

The storage aspect of CCS is particularly tricky, as just because one site works, does not mean another will. In this sense, economies of scale may not be achieved with storage (von Goerne, 2008). How will the experiments and testing account for this?

5.4 Market Formation

Presently, the CCS market has not been created. The data collected and presented below surrounds what may be needed for a functioning market during the early (pilot phase), bridging (demonstration phase) and mature (commercial) phases[47] of CCS. The discussion centered on Europe but also extended globally, mostly to China through the inclusion of CCS in the CDM.

The reader is reminded that the presented discussion represent the data gathered from the stakeholder referenced where possible and appropriate.

5.4.1 Dominant Stakeholders

In this analysis, EU governments appear to possess power and legitimacy but lack urgency towards achieving the commercial application of CCS technologies.

The market (early or mature) will not form if Member States do not prioritize CCS, or operators fail to invest in demonstrations, or those that invest are not transparent enough to share the knowledge. If operators worked as a network, one advantage of a common identity could be State Aid[48] clearance.

[48] DG TREN covers State Aid controls of coal and transport, more information on EU State Aid can be found at http://ec.europa.eu/comm/competition/state_aid/overview/index_en.cfm

On an international level, China can replicate the technology, possibly at a lower cost as compared to the EU. This could certainly be an incentive for cooperation in an international arena. Of course it will mean a raise in local costs and price, but it is possible that China will act for environmental concerns.

As proposed, the EU-ETS allowances will be tendered and bought for power generators. This mechanism works to favour abatement only when CO_2 prices are high enough. It is not clear when this will be. Currently, discussions are underway in Parliament for the scheme to include 2 emission allowances for each tonne of CO_2 stored. This would favour CCS technology in the marketplace.

5.4.2 Dependant Stakeholders

In this analysis, power companies, oil and gas companies, and NGOs appear to possess urgency and legitimacy but lack the power to carry out their will towards the commercial applications of CCS technologies.

The following discussion on market formation is based entirely on input from representatives of power companies.

The formation of the market will be one of the biggest barriers to full-scale commercialization. This market cannot squash incentives, that is, if "how to invest" takes too long, or if poor criteria are made for this, a functioning CCS market will not be achieved (Görtz, 2008).

In this regard, the power sector considers that the carbon market is totally in the hands of the regulators, as they will essentially decide how the market is kept[49](Chapman, 2008). In principle the ETS creates a situation where demand exceeds supply to favour abatement. In practice, there is risk and timescale associated with this. People don't move as rapidly to invest (Chapman, 2008). Furthermore, when will the EU-ETS merge with emission trading schemes in other countries, and when will other sectors enter into the ETS? Will the ETS apply to the whole CCS value chain, where in the end, permits will end up in the storage, and then if you leak, you pay. There is an expectation that allowances will be auctioned in 2011, for the ETS but this market mechanism is based on speculation. This is a big if, on what the allowances will be.

Many informants foresee the market price of electricity increasing. This amount[50] paid by the consumer, could be a tax and the revenue recycled back into the CCS system (Möller, 2008).

The less mature CCS technology is when it reaches the market, the more external funding will be required (Lidgren, 2008). If this is done before the legal framework, then a lot of external funding will be required (Lidgren, 2008). Power companies are counting on this framework, and the funding, and there should be a public coverage of risks for implementing the technology (Lidgren, 2008).

It will be a big challenge to build up the market and the necessary infrastructure (Liljemark, 2008). It is unclear what role oil and gas will play in CCS (Christiansen, 2008). Perhaps space will be a commodity. Transportation is existent and proven, so there will not be technical barriers, but it will take permitting and time, is lacking regulation, and implementation will be

[49] The stakeholder also mentioned that this not totally different to oil and gas where it is controlled by OPEC.

[50] Two indications were given at 1.5-2.5 □c/kWh and 3-4 □c/kWh.

hard (Möller, 2008). For example, to take CO_2 to the North Sea, you need several oil companies to operate oil fields (a lot of CO_2 in a short time), and the opposite is required with power plants (moderate amount of CO_2 in say 30 years) (Christiansen, 2008). The business will need time to mature. With respect to risk sharing, oil companies are used to this, but power companies have no tradition for this (Christiansen, 2008). If European companies joined up, it might seem intimidating for politicians. However, joint transport and storage, the latter riddled with intellectual license issues, is a possibility (Christiansen, 2008).

Transport will likely be via pipeline, which will take a long time for investments and agreements to materialize (e.g., the EU is more densely populated compared to the US where transportation already exists) (Liljemark, 2008). Who will make the brave decision to oversize the first projects for the sake of market formation (Liljemark, 2008)? It makes sense for governments to invest in things not commercially viable, to own the asset, and then sell to the private sector when viable (Zapantis, 2008). This is similar to the formation of railroads, or electricity markets (Zapantis, 2008). The first several CCS projects will not operating at a profit, so the return on investment must come from government.

5.4.3 Discretionary Stakeholders and Demanding Stakeholders

In this analysis, these are stakeholders who appear to lack a combination of power and urgency (academics, research institutes), and those who lack power and legitimacy (suppliers, services). They are grouped together as the information collected from these groups was similar.

At the moment, carbon funds, traders, and banks are not interested in the demonstration phase, as it is as yet, not permissible in the CDM or ETS, and the scale of investment is too large. It would be unexpected if traditional investors were involved, so a guaranteed framework[51] is necessary to secure revenue streams (Chrysostomidis, 2008). Ideally, this is how the CCS value chain should work, a competitive market, where pipeline operators are separate upstream and downstream. In this sense, depending on the security of the revenue stream, CCS can be financed commercially. So the main issue then becomes, securing a revenue stream, which requires a safe environment, which based on oil and gas could be a payback period of 10 years (Chrysostomidis, 2008). Financing to bring CCS from an early to mature market is however, necessary. Transportation pipelines for example, are capital intense, and at the moment, filled with risk due to an uncertain market.

In a mature market, with an international carbon trading system is in place, it is likely that commercial plants will still need funding (Gale, 2008). This gap could be closed through institutional funding (major banks or World Bank) in parallel with industry cost reduction achieved through economies of scale.

The CCS Directive proposes that Member States are responsible for the infrastructure build up after the demonstration phase. As it is planned, there is no "super authority" entitled to do this, so each country will start its own planning (Viebahn, 2008). This will be a barrier for infrastructure, as pipelines will cross borders (Viebahn, 2008).

The role of enhanced oil recovery (EOR) on the market is doubtful due to technical mismatch between the requirement for EOR, and the supply continuity demand that power stations

[51] A framework would help to overcome the difficulties in determining costs. Factoring local market conditions are also extremely important in determining costs. All future prices are estimations, which will only work under certain conditions, at an exact location (e.g., estimations for 20€/ton may work at one location, but will not be an average representative cost).

need (Booer, 2008). Alternatively, promoting the CCS market may involve coming up with a commodity use for CO_2 (Mccoy, 2008).

A fully mature market depends on what happens globally with CCS and the global price of CO_2. Developing countries, China for example, may be able to quickly ramp up based on knowledge diffusion and political pressures, even though it will be fairly costly to retrofit and plants now are not "capture ready" (Johnsson, 2008). Furthermore, the polarized[52] debate surrounding the inclusion of CDM in CCS in developing countries may lead to little or slower market penetration. CCS in the CDM was assumed by developed countries to be met readily by developing countries, while much of the opposite has occurred. Part of this resistance is amplified by the stance from developed countries, who imply that poor governance and underdeveloped institutions in CDM host countries will not be able to sufficiently address the complex technical and legislative issues around CCS (de Coninck, 2007).[53]

5.5 Legitimacy

At current, there are no fixed norms[54] surrounding CCS. The framework by Bergek et al., (2008) predicts that in an emerging innovation system, legitimacy will have to be created.

When discussed during interviews, this function of legitimacy was defined as the social acceptance of CCS (referred to as issue legitimacy in Section 4.1). This included discussion surrounding the creation of legitimacy through communication and a successful demonstration phase, analogies to other energy sources, and stakeholder perception on what it means.

The reader is reminded that the presented discussion represent the data gathered from the informants, not the opinion of the researcher, referenced where possible and appropriate.

5.5.1 Dominant Stakeholders

In this analysis, EU governments appear to possess power and legitimacy but lack urgency towards achieving the commercial application of CCS technologies.

The creation of legitimacy will take considerable efforts, and responsibility must be demonstrated by all parties involved. Ultimately, however, the State will have to accept the long-term risks. The demonstration phase will be important for the creation of legitimacy. If something goes wrong in the demonstration phase, the public opinion may turn against CCS.

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[52] Differs from a constructive debate, where debaters reconcile their position with their opponents. A polarized debate one or more parties involved do not look for the middle ground, because they cannot reconcile the overall topic of discussion with their own norms and conviction (de Coninck, 2007).

[53] For reflections on allowing CCS in the CDM see "Trojan horse or horn of plenty?" (de Coninck, 2007). The interview with the author yielded the following brief world outlook: China seems to be interested, but doesn't want to pay, their position on CCS can be seen parallel to their position on climate policy. That is, emissions have been rising, now on the same level as an average world per capita, enforcing a moral obligation. India and Brazil are vehemently opposed to CCS in the CDM, similar to their stance on emission reductions and future commitments to targets. African countries, with the exception of South Africa (who has been active and constructive on agreements), display considerable skcepticism, so capacity building will be crucial. The Middle East is a strong proponent; Saudi Arabia has been talking of mitigation, and BP is planning demonstrations (de Coninck, 2008).

[54] Norms refers to (loosely for example) "that which is expected or taken for granted" and can be shown via public opinion, what is taught in schools, what is proposed by governments and so forth.

There are, and will be concerns on the morality of burying CO_2. One counter argument to this is that there is nothing more immoral than emitting CO_2 into the atmosphere.

Nuclear energy should be used cautiously as a comparative analogy for CCS. They differ in terms of long-term liability, and the monitoring and reporting framework will be better developed. The timeline of storage is different, and there is a better overview of risks.

The term "capture-ready" as proposed by the Directive is weak, but was used as not to exclude other technologies.

5.5.2 Dependant Stakeholders

In this analysis, power companies, oil and gas companies, and NGOs appear to possess urgency and legitimacy but lack the power to carry out their will towards the commercial applications of CCS technologies.

Power Companies

It is unclear how much power is held in the public sphere. That is to say that the public may or may not be a "show-stopper" for commercial applications of CCS.

The task here is on creating legitimacy and building acceptance. One question brought forth here, is on what is seen as legitimate. Unlimited liability will not happen, so how to monitor the storage afterwards, and when do both parties (e.g., a power company and the State) agree on what is good enough[55] (Christensen, 2008)? The credibility of energy companies is low to begin with, and the larger the company the lower the credibility. If members of society or the public cannot relate to an issue, then it is viewed as an absolute risk (Görtz, 2008). Some people (public, politicians, and environmental organizations) do not see CCS as a pragmatic approach, rather as a method by companies to hold on to existing business. CCS should be seen as in line with societal values; an action to mitigate climate change. Who is the polluter here? Is it the owner of CO_2, or the user of "value-added" electricity? Will the public be willing to pay for more for these values? Experiences to date with green electricity price differentiation shows that this is likely not to happen (Görtz, 2008).

Analogies to nuclear energy are considered reasonable in some aspects, but some big differences are that you can't keep the waste on site for storage, nor is the waste or activity as dangerous as nuclear. Extreme caution should be used when comparing CCS to nuclear. CCS must be more open and transparent than nuclear power, and avoid the bad salesmanship that occurred to "sell" the technology to the public.

There does not seem to be unified opposition to CCS, as most NGOs have taken a stance that while not liking CCS, they are accepting[56] with clauses and getting involved with the topic.

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[55] For example, oerhaps there will be small leaks, but if they are handled properly and not harmful, is that ok?

[56] A recent joint statement made by World Wildlife Fund (WWF), Friends of the Earth (FOE), Greenpeace, and the Royal Society for the Protection of Birds (RSBP) on CCS indicates that CCS "may have a role in future to deliver the deep emission reductions that are needed to avoid climate chaos. However, CCS technology has not yet been proven at scale. Any demonstration plant should be established solely for the purpose of exploring technical feasibility and full price discovery at an appropriate scale, and should be fully equipped with CCS abatement. It should also form part of clear European strategy to assess the viability of the different technical options for CCS (including pre- and post-combustion capture)." They also call on the government to introduce strong legislation on CO2 storage and transport (Greenpeace UK, 2008).

There is reluctance for some politicians to enter into the CCS arena for fear of backlash. For example, will CCS be seen as similar to supporting nuclear power, biofuels, or genetically modified organisms (GMOs)[57]? The EU has not been seen as successful in communicating CCS. Perhaps it is not them who should be communicating this. CCS is business driven, and politicians should not be endorsing a particular technology that is still uncertain.

It will hurt all parties involved if there are problems (e.g., a leak) during the demonstration phase. Communication needs to involve cooperation amongst power companies, with a unified message to the public.

NGOs

The current energy system was largely built around oil and coal, without knowing or recognizing there would be a problem. Now, legitimacy of energy sources is questioned. CCS would perhaps be deemed more legitimate if senior politicians talked more about it.

The term capture-ready, as proposed by the Directive, should not be used to increase legitimacy of actions. As of now the public knows very little of CCS, so social perceptions will likely involve comparing to other technologies (e.g., nuclear power or natural gas).

5.5.3 Discretionary Stakeholders

In this analysis, research institutes and academics have a legitimate place in the CCS debate but perhaps have no real urgency or power to push it forward.

Climate change represents a tragedy of the commons[58]. The atmosphere is a public good[59], so CCS and getting away from CO_2 emissions is clearly in the public interest (Mccoy, 2008). In the near to medium term, a balancing act needs to be performed if CCS is to happen. That is, at some level the public should cover some of the CCS costs, as it is in their interest to preserve the public good of the atmosphere. Before this can happen, subsidies or a tax break is necessary.

Society demands electricity. However, the traditional techniques for electricity generation are increasingly associated with an 'environmental bad'. So who should pay? One can say simply that it should be energy companies. This logic fails when you ask this of a vertically integrated utility charged with maintaining the grid, and providing power in exchange for fair rates. In this case, the public does bear some responsibility (Mccoy, 2008).

Public perception does not necessarily have to be a big barrier, but at the moment is being a bit neglected, despite warnings from previous industry (e.g., nuclear). This communication

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[57]The analogies of biofuels and GMO are not explored in detail. Both concepts especially the former came up during the collection of primary data. In this instance, the controversies are referred to in general: biofuels - diverting farmland for energy production in detriment of the food supply on a global scale; and GMOs - meddling with biological states or processes that have naturally evolved to enhance food production.

[58] Multiple individuals acting independently in their own self-interest can ultimately destroy a shared resource even where it is clear that it is not in anyone's long term interest for this to happen (Hardin, 1968).

[59] That is, up until now, people are not effectively excluded from using the atmosphere, and the use of the atmosphere does not make it less available to anyone else. This makes it a public good, but one that is economically trivial, as the atmosphere is a free good.

effort needs to be more than just "lip service"[60]. Meaning, that companies are still taking the strategy that the public is important, but are going about this similar to nuclear energy, where experts are telling the public they "have all the answers", and not to worry (de Coninck, 2008). Early involvement of the public in all stages of CCS and involvement of opponents is critical to overcome this barrier.

The only way to limit coal is not to put faith into CCS, as it will lead to the increased speed of carbon use. Rhetorical words like "natural" and "sequestration" should not be used to describe any aspect of CCS in attempts to gain legitimacy, as they imply something positive (Hansson, 2008), and this is not necessarily true.

5.6 Resource Mobilization

For CCS to evolve (to commercial applications), technical, scientific, and financial resources must be mobilized. The reader is reminded that the presented discussion represents the data gathered from stakeholders, referenced where possible and appropriate.

5.6.1 Dominant Stakeholders

In this analysis, EU governments appear to possess power and legitimacy but lack urgency towards achieving the commercial application of CCS technologies.

When the time comes, who has the resources to deal with large-scale storage? If there is to be an option to buy a turnkey solution, built in experience is necessary. The total cost of a commercial sized plant that operates reliably is not known (the cost of steel, the unsure technology, maintenance costs), so a quick expansion of production capacity will be difficult.

5.6.2 Dependant Stakeholders

In this analysis, power companies, oil and gas companies, and NGOs appear to possess urgency and legitimacy but lack the power to carry out their will towards the commercial applications of CCS technologies.

There seems to be a growth in the CCS "discipline", filled with academics, policy makers, and industry experts, yet there still seems to be a lack of resources, knowledge and experience in all three areas of capture, transport and storage. There is competition on engineering and manufacturing resources between power companies, but also from oil and gas companies. There is competition for supplier attention with the Asian market, where conventional power plant components are in demand. On a system level, how quickly can the deployment of technology occur if all goes well in demonstration phase? There will likely be a lag for resources.

5.6.3 Discretionary and Demanding Stakeholders

In this analysis, these are stakeholders who lack a combination of power and urgency (academics, research institutes), and those who lack power and legitimacy (suppliers, services). They are grouped together as the information collected contained similar viewpoints.

[60] An expression of agreement that is not supported by real conviction.

The mobilization of resources or "ramp up" will be a challenge with respect to skills and material. A recent publication[61] from Chalmers University (Odenberger et al., 2008) concludes that in the EU25, as much as 39Gt[62] CO_2 may be captured over the period 2020-2025 implying a steep ramp-up, where most CCS capacity is added during the first two decades after 2020 (when it is assumed to be commercially available). This steep ramp assumes among other things, the establishment of legal framework, inclusion of captured CO_2 in the ETS and fuel market/supply accommodations for an increased use of coal.

There is a lack of expertise in the storage aspect with a majority of the skilled workforce in the oil and gas sector retiring. As such, it is difficult to find skilled workers. The asset of experienced workers is of course their years, but they are soon retiring and this type of work is not attracting the youth (Karlsson, 2008).

5.7 Free Utilities

As the CCS market matures, the entry of new firms essentially strengthens the functioning dynamic. Most discussions surrounded the topic of new entrants in the transportation aspect of CCS, as prompted by the researcher. The reader is reminded that the presented discussion represent the data gathered from the informants, referenced where possible and appropriate.

5.7.1 Dominant Stakeholders

In this analysis, EU governments appear to possess power and legitimacy but lack urgency towards achieving the commercial application of CCS technologies.

The discussion is ongoing for transport. The role could be filled by the oil and gas companies looking for diversification or joint ventures. It is likely that the Commission will not invest in pipelines. It is improbable that the required CO_2 pipeline infrastructure can be financed from EU sources. While the TEN-E guidelines (Guidelines on Trans European Energy Network) will be revised and are likely to include the future CO_2 infrastructure, it should be noted that the financing opportunities for the CO_2 network from the TEN-E budget are limited and that the TEN-E budget has mainly been used to fund feasibility studies (Tomescu, 2008).

5.7.2 Dependant Stakeholders

In this analysis, power companies, oil and gas companies, and NGOs appear to possess urgency and legitimacy but lack the power to carry out their will towards the commercial applications of CCS technologies.

If CCS goes through to full realization, there will be public private partnerships. The value chain seems to be covered well, with the exception of a clear specialist in transportation, and a lack of research and information on who could be end users of CO_2. While there is much speculation, it is not certain that the oil and gas industry will be active in transport and storage.

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[61] Article in Press: "Ramp-up of CO_2 capture and storage within Europe". The numbers presented here should be taken into account with the clauses and assumptions presented in the article, and are shown here to provide the reader with some sort of understanding on timeframes discussed in academic circles.

[62] IEA projections are that emissions will reach 40.4 GtCO2 in 2030 (IPCC, 2007)

Transportation could involve trucks, but then on a larger scale, a joint venture between power companies. Perhaps a new player will enter but this will only happen if there is proven success with the technology, or a stable pricing on carbon. There are no apparent signals that transport/storage actors will not emerge.

5.7.3 Discretionary and Demanding Stakeholders

In this analysis, these are stakeholders who lack a combination of power and urgency (academics, research institutes), and those who lack power and legitimacy (suppliers, services). They are grouped together as the information collected contained similar viewpoints.

There is no decision on who will operate transportation pipelines. This could be a private company, the State, the same people that operate storage, the oil and gas industry, divided amongst the utilities, vertically integrated like the natural gas industry, or consortiums of companies. Perhaps companies are keeping this information confidential? There is nobody for example in the German government that is planning transport. It all seems completely unclear. It is unlikely that there will be one company (e.g., a power company) operating the whole CCS chain.

5.8 Reflections on the Functioning Dynamic

A considerable amount of information presented by stakeholders was presented in the above analysis. This presentation is both a collection of themes, trends, and ideas that emerged from discussions with stakeholders.

The stakeholders have different viewpoints on the functioning dynamic of CCS based on their apparent power, legitimacy and urgency on achieving commercial applications of CCS technology. This can cause a difference in opinions and beliefs within stakeholders groups (e.g., NGOs versus power companies), but also within groups themselves (Greenpeace versus Bellona), hinging on various attributes of power, legitimacy and urgency on the claim. Of the stakeholders interviewed, power companies were the most represented group, were the most active participants in discussions, likely due to their relationship with the commercial application of CCS technologies and as the group with the biggest proxy. The information from discretionary stakeholders (academics, research institutions) brought up interesting points that were used to foster discussions amongst all stakeholders. This is possibly due to outside of the "insulated" CCS Community.

Functions of knowledge development and diffusion, influence on the direction of search, and market formation were readily discussed by most stakeholders. The function of legitimacy usually needed further clarification (this was expected) and seemed to provoke the most thought. Functions of entrepreneurial experimentation, resource mobilization and free utilities were discussed the least, most likely because they come later in the development of a functioning CCS system.

The timeframe required to carry out this work was limited. In order to answer the focus question based on a snapshot of CCS as viewed by stakeholders at current a broad understanding of the functioning dynamic was gained. Future or additional research could be to examine one or two of the functions in more detail, for example functions of market formation and legitimacy could be explored across the stakeholder map, within certain

stakeholders, or amongst stakeholders not represented in this work (e.g., media, public, or market actors).

6 Emerging Paths of CCS

The section explicitly answers the focus question: "What pathways are emerging as the CCS movement proceeds?" through the presentation of three potential development paths for CCS. The exploration, insights and analysis of the research questions used to reveal these paths: "Who are stakeholders in the CCS movement?" and "How do they see the field at present and in the future?" were discussed in Section 4 and 5 respectively. As mentioned in the introductory sections of this work, these paths are conceptual, and are the end result of the exploration of the aforementioned research questions. It should be noted that the majority of the work and analysis was in the answering of the two research questions, and that answering the final focus question was the manner in which to present the thoughts and opinions of various stakeholders in the CCS field today, as filtered through the lens of the researcher, in a suitable manner for future use.

To reiterate, further grouping of the acquired information and analysis of the stakeholder mapping of the CCS Community and their views on the functioning dynamic into three paths was done to produce tangible results, for further use as a decision making support tool by engaged stakeholders.

Primary data from several stakeholders indicated that one problem with scenario use in predicting futures of CCS, is that data quickly becomes outdated. Furthermore, data used to build scenarios is based a limited amount of sources (Hansson, 2008). It was also pointed by Hansson[35] that social issues are likely to get bigger when implementation starts, and will be more problematic than politicians and scientists believe (Hansson, 2008).

There are some basic assumptions used in these development paths presented in this section, provided as follows:

- commercial applications of CCS is seen by the IPCC as a method of achieving no more than a 2°C temperature rise above pre-industrial levels, including 50-80% emission reductions in the developed world by 2050;
- some form of the current Draft Directive is adopted;
- the demonstration phase is initiated; and
- continued use and availability of coal.

The paths extend until roughly 2050 and is not discussed what could happen after the development of CCS, or what the technology "bridges" toward. The occurrences of unforeseen events (the emergence of water related issues, a large scale war, or the breakthrough of revolutionary energy technologies), which are outside the scope of this work are not discussed. Furthermore, as discussed at the outset of this research, the question of if "CCS is leading us in the wrong direction" is not addressed.

The following sections present three development paths of CCS: "On a War Footing"; "Better Late Than Never?"; and "Trial and Error".

6.1 Development Path One: On a War Footing

This path describes the rapid implementation of the commercial application of CCS technologies.

This development path, described by the functions above is coined "On a War Footing" as it involves a maintained focus and momentum from government and power companies. Relevant policy milestones could include a strong commitment from COP15, a political shift in the U.S., and strong post 2012 Kyoto agreements from China and India. As per the EU Flagship Program, a minimum of 10 demonstration plants come online no later than 2015. This is followed by a 5-year testing period, wherein plans for the commercial phase are made simultaneously. An aggressive ramp up period of 10-15 years means that by 2030-2035, CCS is applied to all new coal fired generation and other heavy CO_2 industries and is also increasingly entering application in the developing world. This then contributes to the maximum emission avoidances in line with aggressive IEA scenarios.

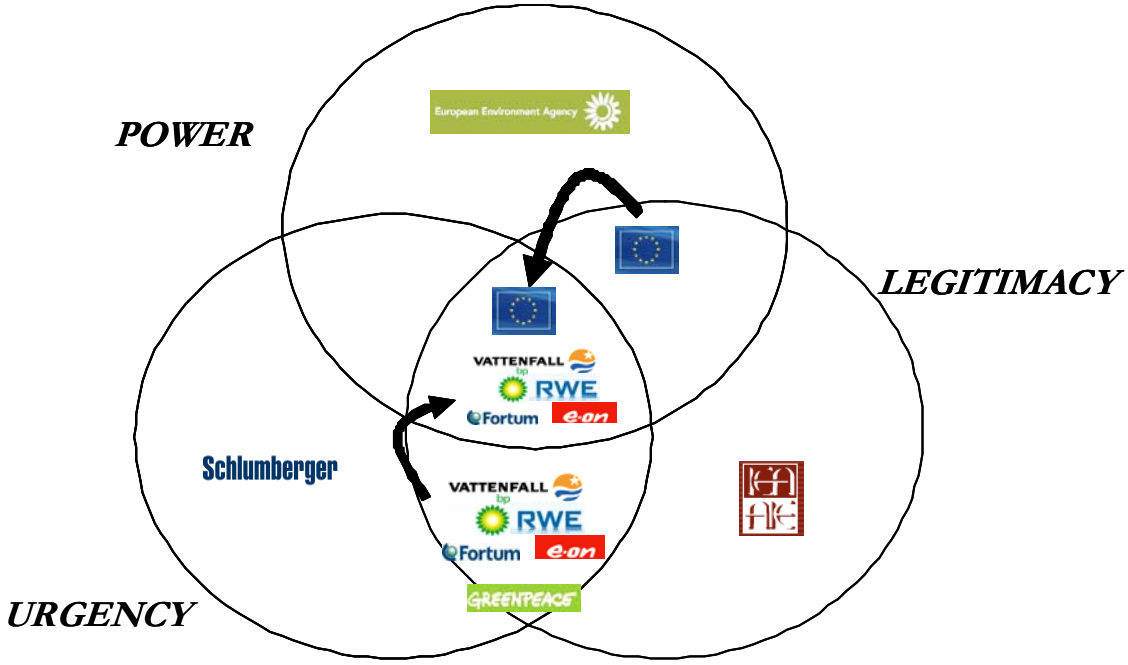

Figure 6-1 – Adapted stakeholder map for "On a War Footing"

The above adjusted stakeholder map is an example of how the CCS Community can look in "On a War Footing". In this scenario, power and oil and gas companies (dependant stakeholders) gain "power", while the EU government (dominant stakeholders) demonstrate urgency in achieving the commercial application of CCS technologies. Both groups move into the "definitive" stakeholder classification, as briefly discussed in Sections 4.2.1 and 4.2.2. In this scenario, NGOs (represented in the above figure by Greenpeace) remain as engaged stakeholders increasing their legitimacy on achieving the commercial application of CCS technologies. The IEA and other discretionary stakeholders (academics, research institutes) continue to research CCS and place importance on CCS in energy scenarios. These types of stakeholders increase in numbers as more funding is allocated to CCS research. Schlumberger and other demanding stakeholders (Alstom, ERM) are increasing and their core business is becoming more entrenched in CCS technologies. The EEA, environmental agencies and national governments are gaining legitimacy as their role in CCS is defined.

Of note in this development path is the sustained war footing to achieve widespread application of CCS technologies, and the concepts of stakeholder urgency and power. Will this claim hold the attention of stakeholders long enough to see widespread application of CCS technologies? Will stakeholders have the power to make it happen? In this scenario, CCS is prevalent until the economics are no longer favourable, and society "crosses the bridge" to another energy solution.

The dynamics of this development path are discussed in detail in the following sections.

6.1.1 Knowledge Development and Diffusion

Knowledge is developed quickly and broadly within relevant actors in the CCS community, which includes not only members of the power sector, but other heavy CO_2 emitting industrial players like the cement, refineries, iron and steel, petrochemical, and oil and gas processing. This involves long-term thinking (post 2050) by those in the industry, and is spread throughout areas of capture, transport and storage. Competence is built in through recruitment and training of a new workforce, to support the aging expertise, and fill in the necessary gaps in a timely manner as CCS moves from an early to mature stage. The knowledge base for directional decisions comes from a variety of knowledge sources, which takes into account the uncertainties of CCS predictions, and how quickly they can become irrelevant. The public is well informed of CCS, and more opposition groups emerge, adding to the variety of the knowledge base.

6.1.2 Influence on the Direction of Search

The government takes a clear stance and forbids conventional coal-fired generation. This is spawned or accelerated by weather crises in the developed world attributed to climate change. For example, more ice shelves break away in the Arctic, New Orleans floods again, or Europe experiences a crippling heat wave. CCS becomes a "clear license to operate" condition to utilize fossil fuels such as coal.

Political momentum is consistent until at least commercial plants are running, essentially creating another lock-in situation to centralized energy sources while bridging to a cleaner suite of technologies.

A kickstart fund is created, and there is a significant unlocking of public funding dedicated to the demonstration projects. This coincides with a competent authority that provides overall direction and oversees planning. Within this phase, competition and cooperation is promoted through various partnerships involving the power sector, service companies, NGOs, and other market actors (could include oil and gas, mining, big banks).

The money and R&D proves to have been well spent on CCS technologies. Whether or not this pulled away money from other technologies (renewable energy for example), is irrelevant, as CCS becomes a popular and efficient method of provided base loaded energy. A positive feedback loop is created where the increase in the internalization of external costs of CCS levels the playing field for renewables.

6.1.3 Entrepreneurial Experimentation

Power companies and possibly entrepreneurs continue to develop technologies, and within R&D parallel research is made on all CCS fronts. The investment from the EU for the demonstration phase and competent authority entitled to oversee the demonstration phase ensures pluralism in thinking to ensure that adequate experimentation occurs. Extensive and varied testing of capture and storage sites also takes place to attempt to bring down costs during the commercial phase. The demonstration phase delivers clear results, particularly within the storage aspect, and proves to be a valid experiment for moving into widespread commercial applications of CCS technologies.

6.1.4 Market Formation

The Member States[63] prioritize CCS, so the implementation of the Directive allows for an efficient and effective market formation. CCS technology is mature when it reaches the market requiring less investment.

The required investment is sparked by the EU and followed by the operator for the demonstration phase. This is followed by traditional investment as revenue streams are viewed to be more secure. Private investment also plays a significant role in the commercial phase, to fill the gap that may be present even with a CCS-friendly ETS scheme and realized economies of scale.

Developing countries, China in particular, either are inclined towards the inclusion of CCS in the CDM, or quickly ramp up with CCS technologies after it is a proven technology, in this case, after a successful demonstration phase.

The ETS and price of carbon favours (e.g., double allowances for each tonne of CO_2 stored) CCS, and there is an incentive to abate. "Favourable" ETS conditions could also involve the merging of other emission trading schemes and the entry of other sectors (e.g., airplanes).

A universal carbon tax on electricity is initiated, and the money is channeled back into the CCS system somehow.

6.1.5 Legitimacy

Communication efforts are unified and consistent from the pilot phase onwards. This includes transparent communication and involvement of the public. Clear decisions are made on what constitutes both a success and a failure during the demonstration phase. That is to say, problems (e.g., leakage, lower efficiency rate, and longer testing times) are still conveyed in a transparent manner. As such, the public does not perceive "failures" during the demonstration phase as negative events. Furthermore, the concept of CCS as a public good and the "internalization of external environmental costs" are used to gain public acceptance. Liability issues are also made clear, with ultimate liability taken over by the State.

6.1.6 Resource Mobilization and Free Utilities

During the demonstration phase, parallel steps are made to ensure a fast deployment of technology. This means that suppliers of technology are focused on customers requiring CCS

[63] The current Draft Directive applies the Proportionality Principle, establishing objectives and general requirements, leaving the details of implementation to the Member States.

related goods and services. Technology is deployed at an optimum pace. New entrants come into the CCS arena to strengthen the system dynamics. For example, public-private partnerships emerge into the transportation sector of CCS. This could also include end-users of CO_2.

6.2 Development Path Two: Better Late than Never?

This development path illustrates a slower implementation of the commercial application of CCS technologies.

This development path, is coined "Better Late than Never" as it hinges on a slower market formation and mobilization of resources. The focus and momentum from government and power companies is inconsistent and not urgent. Relevant policy milestones include a moderate commitment from COP15, and weak post 2012 Kyoto agreements from China and India. As per the EU Flagship Program, a minimum of 10 demonstration plants come online around 2017. This is followed by a longer testing period, a result of a poor evaluation of proposals and anti-competitive planning. Problems encountered during this phase are not handled readily due poor knowledge development and diffusion and an inconsistent direction of search. This includes among other things the poor handling of local issues, which emerge when "real" projects are underway. By 2025, plans for the commercial phase are in the making. A ramp up period of 15-20 years occurs, alongside a panic deployment of other low emitting technologies. This means that by 2040-2045, CCS is applied to all new coal fired capacity, and perhaps other heavy CO_2 industries. While low mandatory commitments occur on a global scale, the longer timeframe allows for a higher carbon price, through higher domestic allowances.

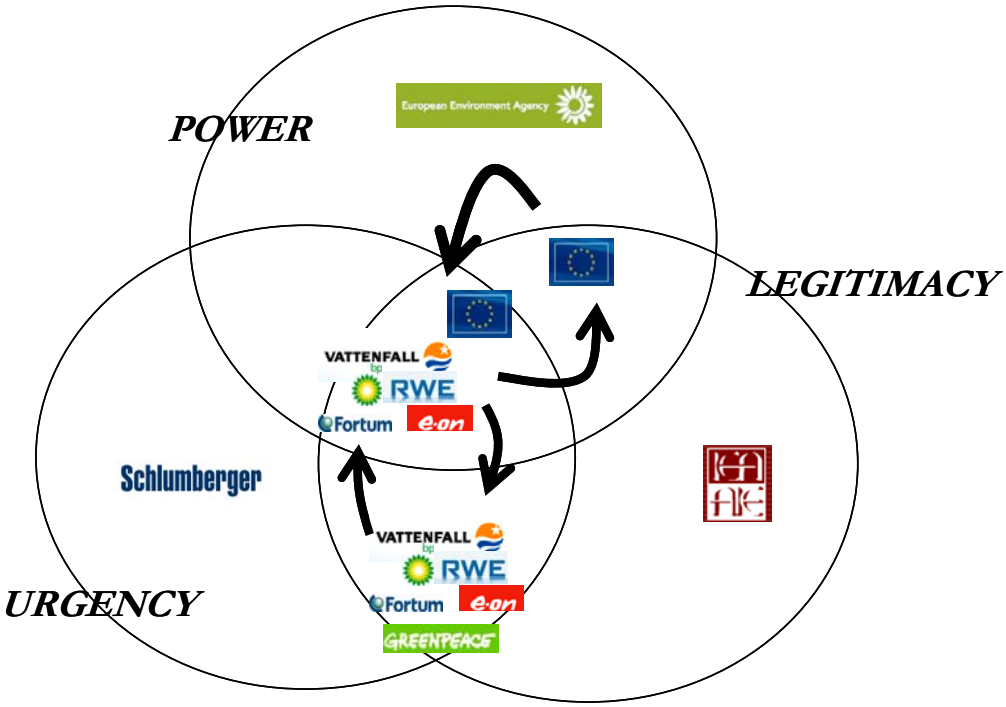

Figure 6-2 – Adapted stakeholder map for "Better Late Than Never?"

The above adjusted stakeholder map is an example of how the CCS Community can look in "Better Late than Never". In this scenario, power and oil and gas companies (dependant

stakeholders) fluctuate in gaining or possessing power towards achieving the commercial application of CCS. The EU government (dominant stakeholders) also fluctuates in gaining or possessing urgency towards achieving the commercial application of CCS. Neither group moves with certainty or longevity into the "definitive" stakeholder classification. This wavering could come if there is for example a weak implementation of the Directive from Germany, lack of authority during the planning phase fuelling uncertainty during the demonstration phase, and slower partnerships between power companies and suppliers and other stakeholders.

Due to the uncertainty created by dominant and dependant stakeholders, NGOs (represented in the above figure by Greenpeace), the IEA and other discretionary stakeholders (academics, research institutes), Schlumberger and other demanding stakeholders (Alstom, ERM) and EEA and other dormant stakeholders (environmental agencies and national governments) also waver on their engagement with the commercial application of CCS technologies.

To note in this development path is the slower momentum and longer timeframe to achieve commercial CCS applications. This also points to the concept of urgency and the time required realizing urgent claims. The question "better late than never?" is spawned as the timeframe for the scenario doesn't coincide with the climate timeline. Peak emissions will be much later than 2025, so CCS loses some of its relevance in mitigating climate change. The questions can also be asked, "How much weight or trust is the CCS sector putting into politicians to implicitly or explicitly generate carbon prices that are high enough?" Will governments or dominant stakeholders acquire urgency to act, or should power companies or dependant stakeholders "go it alone"? If they do this, will it be in time? Do they care if it is in time? If not, perhaps their legitimacy on the claim can be questioned.

The dynamics of this development path are discussed in detail in the following sections.

6.2.1 Knowledge Development and Diffusion

Knowledge gaps are identified during the demonstration phase but are not addressed quickly enough to maintain momentum. This could be due to less variety in the knowledge base or a lack of build up in expertise, leading to an ill-prepared industry for unexpected occurrences. It could also be due to an uneven amount of knowledge in certain areas of CCS over others, for example, a strong understanding of capture technologies, and weaker understanding on the impacts of social perceptions on CCS. Knowledge is likely still developed and diffused well within the CCS community and power companies but is less so amongst the general public and politicians.

6.2.2 Influence on the Direction of Search

The government takes a less definite stance on conventional coal-fired generation, and CCS. Or, a definite stance is taken, but political momentum, likely at a national level is inconsistent throughout the duration of the demonstration phase.

Power companies self-fund demonstration plants, possibly with some government assistance, but incentives are not entirely clear. This causes some ambiguity on the direction of search, and partnerships are slower to evolve. R&D money is still being spent on CCS technologies but for strategic reasons, companies must also ensure other low-carbon emitting technologies like nuclear power or renewable energy and energy efficiency are receiving attention. The overall vision of CCS and belief in its growth is not as strong.

In this scenario, companies that were once front-runners may exit the field, or lower their urgency in the commercial application of CCS technologies.

6.2.3 Entrepreneurial Experimentation

The demonstration phase is not as robust as necessary to "prove" the technology in a timely fashion. Competition within power companies developing technologies and suppliers is not strong, but is still adequate to support demonstration plants. The technology hits the demonstration market slightly less mature, and requires more investment.

The demonstration phase still delivers results, but these results are based on less variance in experimentation. As such, operators are less "ready" to tackle uncertainty.

6.2.4 Market Formation

The market is not particularly inviting for any actor, whether that be power companies as operators or private investors. Among other things, this was due to lack of funding in the demonstration phase. During the commercial phase, this could be due to poor transparency of operators.

The adoption of the Directive by Member States is strong is some countries and weaker in others, to note there is likely not an adoption of a 'super authority' to plan the demonstration phase. As such, each country starts is own planning, in a slightly ad-hoc manner, which then reflects instability on the market.

Globally, inclusion of CCS in the CDM is stalled, and China mobilizes themselves without the help of developed countries, sparking debates over intellectual property rights or the effect of poor governance on CCS in particular storage issues.

The EU-ETS is used, but the carbon price hovers at levels that are insufficient to provide clear economic incentives for investment again, not lending to clear incentives to invest. Less actors are active on the market than would have been hoped by CCS optimists.

6.2.5 Legitimacy

The inherent weaker market and less robust demonstration phase leads to confusion on the legitimacy of CCS. Communication is not unified, does not come from a trustworthy source (as seen from the public eye) and mixed signals are sent to the public. Furthermore, the public is not involved with CCS issues from the beginning in a transparent manner. The opposition for coal is growing.

Liability is still adopted by the State, but is not enough to prove legitimacy, as the public is also concerned on what will happen in the short to medium term (next 100 years).

6.2.6 Resource Mobilization and Free Utilities

The results delivered by the demonstration are not clear, essentially meaning that it takes longer for suppliers and the build up of infrastructure in support of CCS commercial deployment to occur. New entrants are hesitant to enter.

6.3 Development Path 3: Trial and Error

This development path is characterized by an unsuccessful demonstration phase that does not lead to the widespread application of CCS. This happens at any point during the demonstration phase including near the end wherein a "Valley of Death"[64] situation occurs.

To avoid repetition, the following development path is discussed without the use of dynamic functions.

The unsuccessful demonstration phase creates a niche market for CCS. Power companies were largely unsuccessful in demonstrating the technology in a manner that convinced the public and political actors. An outcome of this is that investment fails to materialize. Market actors include power stations with "lucky locations" and other heavy CO_2 emitters like refineries[65], iron and steel, or gas processing industries that followed the technology and were successful. Timelines are shorter for these industries and the cost and associated risk is lower due to expertise.

The concept of legitimacy is questioned as it seems illogical, or unfair that some polluters capture CO_2 while other emit. The "niche" market is only allocated small amounts of public spending. The EU-ETS fills this gap as power companies are penalized for emissions, and contribute to CCS infrastructure, allowing other industry to maturate the market. The CCS network starts clustered, with close CO_2 storage sites and a more localized grid, one or two key storage sites and a joint transportation network, by truck or ship. This is influenced by end-users of CO_2, including its use in EOR.

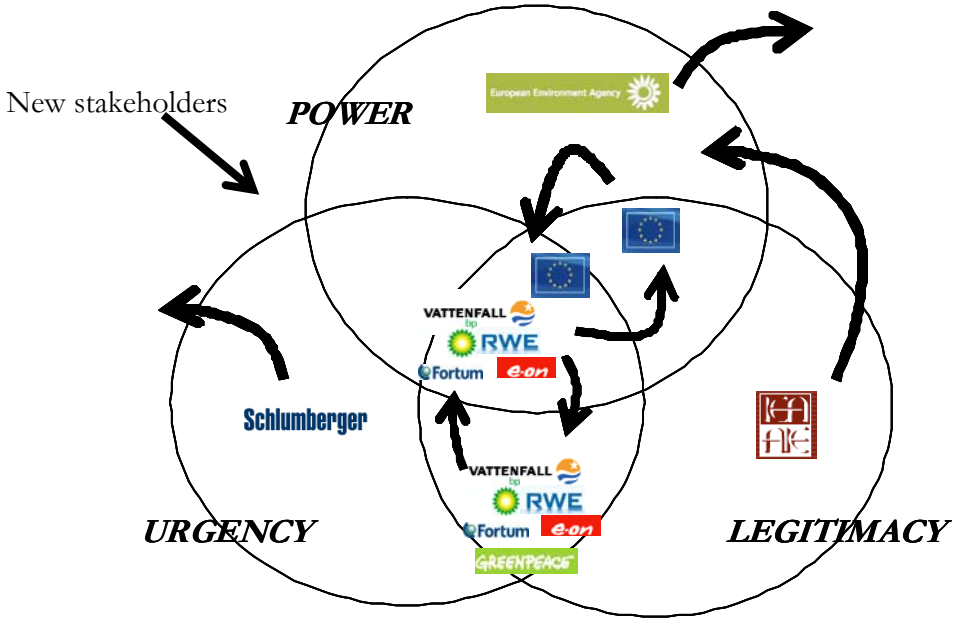

Figure 6-3 – Adapted stakeholder map for "Trial and Error"

[64] The funding gap that arises after federal basic-science support ends and before commitment from investors.

[65] CO_2 streams are more pure, and the willingness to pay may be higher, as compared to other product, the value of heat and electricity is lower.

The above adjusted stakeholder map is an example of how the CCS Community can look in "Trial and Error". In this scenario, power and oil and gas companies (dependant stakeholders) fluctuate in gaining or possessing power towards achieving the commercial application of CCS; or never gain power and stay similar to where they appear to be during the course of this work (as discussed in Section 4). Similarly, the EU government (dominant stakeholders) also fluctuates in gaining or possessing urgency towards achieving the commercial application of CCS; or never gain urgency and stays similar to where they appear to be during the course of this work. Neither group moves with certainty or longevity into the "definitive" stakeholder classification. New stakeholders, perhaps those that could be involved in a niche market like the cement industry enter, while stakeholders once engaged in CCS leave the stakeholder map.

In "Trial and Error", a path of adaptation is inherently chosen through the continued burning of carbon-based sources for electricity.

7 Conclusions

The focus question "What pathways are emerging as the CCS movement proceeds?" aimed to bring forward potential development pathways for CCS through the exploration and analysis of the following two research questions:

- Who are stakeholders in the CCS movement?
- How do they see the field at present and in the future?

In this work, the focus question is answered by describing three CCS development pathways based on power, legitimacy and urgency held by stakeholders in achieving the commercial application of CCS technologies; and the insights and opinions expressed by these stakeholders on the CCS functioning dynamic.

The pathways are to serve as a tangible starting point for further scenario building and speculation on what the future may hold for CCS. As put by Lindgren and Bandhold, scenarios can be "a way to reduce a great and complex amount of information to a manageable format, communicate complex messages to a large and diverse audience, assisting in the shared exploration of the future across a group of stakeholders". It is hoped that this work will serve as a basis for a decision making tool for stakeholders involved in CCS in guiding how to act today based on an understanding of how the future may look.

7.1 Who are stakeholders in the CCS movement?

As it appears in this work, no stakeholders in the CCS movement possess all three attributes of power, legitimacy and urgency to prioritize the "commercial application of CCS" (see Section 4). This work also indicates that it is possible that if the CCS Community stays in this stakeholder snapshot (see Figure 4-2), the claim may continue to not be prioritized.

This analysis shows that one way for the commercial applications of CCS to be prioritized is for power companies and governments to increase power and urgency. This does not mean that it is possible for them to do so. Furthermore, as CCS is in an early development stage, acting urgently now requires a long-term view, and a belief of CCS in the energy future. Even if this belief and long-term view is present, cost explosions must be avoided, so the momentum of urgency may be compromised.

Mapping the stakeholders in the CCS Community provided insights into where different groups of those engaged in CCS "stand" on the prioritization of the commercial application of CCS technologies. It also provided insights into how they can affect, or be affected by the movements of other stakeholders. Understanding the "stance" of various stakeholders was used to provide context when analyzing their views on the current and potential future functioning dynamics of CCS (Section 5); and to provide the storylines for the development paths (Section 6). That is, by having insight into what stakeholders think and know combined with where they stand, one can then understand how they may act, or how they can act. This also applies for new stakeholders. Take for example, a large bank who decides to invest in CCS through the funding of a demonstration plant. This bank then, is giving power companies the attribute of "power" to carry out their will. Another example during the demonstration phase could be if a power company like Vattenfall is involved in a project where there is an explosion in a transportation pipeline, or a leak at a storage site. This could compromise their attribute of legitimacy (the "rightness" of their actions, how well their

actions are understood and "taken for granted"). Losing the attribute of legitimacy could push Vattenfall further away from achieving the objective of the commercial application of CCS technologies. Furthermore, the compromised legitimacy of one power company could impact all power companies.

Strategizing in this dynamic manner can help to understand the possible ways in which stakeholders can affect or be affected by the potential development paths of CCS, one of which is the commercial applications of the technology.

7.2 How do they see the field at present and in the future?

The stakeholders have different viewpoints on the functioning dynamic of CCS based on their apparent power, legitimacy and urgency on achieving the commercial applications of CCS technology. The insights gained from exploring this research question brought forward interesting trends and ideas which are presented below.

Knowledge Development and Diffusion (Section 5.1)

How well stakeholders think knowledge is developed and diffused within the CCS Community and amongst the general public.

- There is an inherent selection of who has the ability to gain or access CCS related knowledge in relation to their financial resources.

- The CCS Community consists of many similar faces and seems to be somewhat insulated. There is a danger that this can lead to a lack of variety or lack of questioning of the knowledge possessed.

- Thus far, knowledge gaps are being filled as a continuous process. It is important to keep up momentum, as there is a risk in waiting to acquire knowledge to ensure success.

- The amount of knowledge amongst the fields of capture, transport and storage is not consistent and transportation is perhaps not receiving the attention it deserves.

- In a sense the information delivered thus far by companies and governments towards the public has missed the proper target as the need for CCS is largely linked to electricity consumption.

- The general public knows very little of CCS. It important to impart this knowledge so they can become engaged in CCS early. It is unclear who should take on this task as the technology is not yet mature or proven to be effective at a large scale.

- Although energy companies may have enough capital to build competence it is still difficult to build wide and deep knowledge in an uncertain field. There is a technical barrier for power companies that are entering a world with different risks, and incompatible knowledge spheres.

- A clear opposition group is not present. NGOs like Greenpeace are placing urgency on engaging and having an informed opinion on CCS. They are communicating with governments, industry and the public.

- The challenge of developing and diffusing knowledge is particularly large, as it involves thinking and concepts far in to the future.

- There is a lack of knowledge in the storage aspect of CCS, and all sites are unique, and leakage is a possibility. Some storage experts are openly communicating this, while others are not so transparent.

Influence on the Direction of Search (Section 5.2)

Incentives for entering into the CCS Community and the visions, expectations and belief in CCSs potential for growth.

- The incentive to enter into CCS hinges on a legal framework that will provide a clear signal that CCS constitutes the only real way to maintain "a license to operate" with coal. At the moment, there is not a clear incentive to become engaged in CCS.

- Unavoidably, a focus on CCS will pull resources away from other technologies, but these resources are not a fixed amount, and climate issues are gaining attention and investment. Within power companies, programs are getting funding; the difference is that normally it would be a slower progression.

- The talk that there is some intrinsic danger that CCS will compete for attention or resources in terms of development of support policy with renewables energy is based on the presumption that they are the best possible technologies

- The term "bridging the gap" is commonly used in relation to the driver and vision of CCS. The length of the bridge and what is on the other side is not clear and differs between and amongst stakeholders. A good definition of a bridging system is one that we can use until we get to another system, but this latter system, we have no idea what it looks like (Johnsson, 2008).

- There is a general feeling amongst most stakeholders that at this point, we need to use everything we have to meet energy demand of the future.

- There is a sense of optimism related to the commercial application of CCS. Some stakeholders see this as a blind faith, while others are convinced that CCS will happen at some point, in some form, due to the continued use of coal coupled with climate change concerns.

- The ultimate direction is dependant on how consistent the EU is in their determination to take the lead on climate change issue and how affordable the EU regards this issue.

- CCS runs a small risk that it will be a self-fulfilling prophecy, and not occur due to reasons that are not necessarily justified technically, but are based on perceptions.

- With respect to predicted energy consumption, the concept of direction of search can be viewed to a self-fulfilling prophecy. Furthermore, the direction of search and the choice that is made now, involves money that can only be spent once.

- There is a strong general position from industry that renewable energies are not currently strong enough to make a big change, and that CCS can. If this is the thinking, then it is up to industry to prove this, without the use of public money.

- There are different views in the research community, where many claim that CCS raises the energy cost of coal, so the marginal cost of renewables are more competitive.

- Primary focus should instead be directed on local environmental effects for they are more certain. So while we have a moral obligation to abstain when we can, at what cost do we do this?

Entrepreneurial Experimentation (Section 5.3)

How uncertainty is handled or is envisioned to be handled within the CCS field, largely focused on the demonstration phase.

- It is important during the demonstration phase that there is competition both within technologies and amongst technologies.

- Some companies have chosen to develop a particular technology, but it is a risk to dismiss other technologies.

- Entrepreneurs find it difficult to get into this area; a role could be to sell proven technology to bigger companies.

- The storage aspect of CCS is particularly tricky, as just because one site works, does not mean another will. In this sense, economies of scale may not be achieved with storage. How will the experiments and testing account for this?

Market Formation (Section 5.4)

What may be needed for a functioning market during the early (pilot phase), bridging (demonstration phase) and mature (commercial) phases.

- The market (early or mature) will not form if those that invest are not transparent enough to share the knowledge.

- This market cannot squash incentives, that is, if "how to invest" takes too long, or if poor criteria are made for this, a functioning CCS market will not be achieved.

- It is unclear if developers will oversize the first projects for the sake of market formation. As such, it makes sense for governments to invest in things not commercially viable, to own the asset, and then sell to the private sector when viable (similar to the formation of railroads, or electricity markets).

- At the moment, carbon funds, traders, and banks are not interested in the demonstration phase, as it is as yet, not permissible in the CDM or ETS, and the scale of investment is too large. It would be unexpected if traditional investors were involved, so a guaranteed framework to help with cost calculations is necessary to secure revenue streams.

- The role of enhanced oil recovery (EOR) on the market is doubtful due to technical mismatch between the requirements for EOR. Promoting the CCS market may involve coming up with a commodity use for CO2.

- The debate surrounding the inclusion of CDM in CCS in developing countries may lead to little or slower market penetration.

Legitimacy (Section 5.5)

The social acceptance and "rightness" of CCS.

- The demonstration phase will be important for the creation of legitimacy. If something goes wrong in the demonstration phase, the public opinion may turn against CCS.

- It is unclear how much power is held in the public sphere. That is to say that the public may or may not be a "show-stopper" for commercial applications of CCS.

- Who is the polluter here? Is it the owner of CO_2, or the user of "value-added" electricity? Will the public be willing to pay for more for these values?

- Extreme caution should be used when comparing CCS to nuclear power or waste. CCS must be more open and transparent than nuclear power, and avoid the bad salesmanship that occurred to "sell" the technology to the public. As of now the public knows very little of CCS, so social perceptions will likely involve comparing to other technologies (e.g., nuclear power or natural gas).

- There is reluctance for some politicians to enter into the CCS arena for fear of backlash. For example, will CCS be seen as similar to supporting nuclear power, biofuels, or genetically modified organisms (GMOs)?

- The term capture-ready, as proposed by the Directive, should not be used to increase legitimacy of actions.

- Early involvement of the public in all stages of CCS and involvement of opponents is critical to aid in the creation of legitimacy.

- The only way to limit coal is not to put faith into CCS, as it will lead to the increased speed of carbon use. Rhetorical words like "natural" and "sequestration" should not be used to describe any aspect of CCS in attempts to gain legitimacy

- It is possible that power companies who have begun to engage in CCS may be locked into doing so, due to legitimacy concerns of the use of coal without CCS.

Resource Mobilization (Section 5.6)

For CCS to evolve (to commercial applications), technical, scientific, and financial resources must be mobilized.

- The total cost of a commercial sized plant that operates reliably is not known (the cost of steel, the unsure technology, maintenance costs), so a quick expansion of production capacity will be difficult.

- There is competition for supplier attention with the Asian market, where conventional power plant components are in demand.

- On a system level, how quickly can the deployment of technology occur if all goes well in demonstration phase? There will likely be a lag for resources.

- The asset of experienced workers is their years, but they are soon retiring and this type of work is not attracting the youth.

Free Utilities (Section 5.7)

As the CCS market matures, the entry of new firms ("free utilities") essentially strengthens the functioning dynamic.

- There is no decision on who will operate transportation pipelines. This could be a private company, the State, the same people that operate storage, the oil and gas industry, divided amongst the utilities, vertically integrated like the natural gas industry, or consortiums of companies.

- It is improbable that the required CO_2 pipeline infrastructure can be financed from EU sources.

- While there is much speculation, it is not certain that the oil and gas industry will be active in transport and storage.

7.3 Use of This Work and Areas of Future Research

This work can be used to provide insight into which stakeholders are involved in the CCS movement, how they view the CCS field, and what pathways are emerging as the CCS movement proceeds. Stakeholders absolutely need to be extremely focused on the details, for example, proving storage and capture technologies. While optimism and short term focus is imperative to the development of CCS, a "long view" is also important to keep in mind.

The three development paths presented represent a fast, slower, and failed realization of the commercial application of CCS technologies. These paths "emerged" based on the knowledge and opinions of stakeholders interviewed throughout this work. These paths are an attempt to take an extremely complex situation and bring it down to a level that can help those who can affect or will be affected by this realization to plan for the future. By examining the views of 37 stakeholders, these paths hopes to represent what those engaged in the CCS movement are thinking. They do not represent any absolute truths. Rather can be used as input into more complex scenario building or strategic planning, all with the intention of knowing how to act today with a thought of how the future may look. Qualitative scenarios can identify key

leverage points and signals. When coupled with an analysis of who has the power, urgency, and legitimacy to act, one can start to identify who can drive the paths in certain directions.

If this work were to be repeated, it would yield different results, as the potential stakeholders that can be interviewed is limitless. To this end, the results of this work (stakeholder map and their insights on the CCS field) are a reflection of the CCS field at current. Similar work done at a different time, with different stakeholders would yield different insights. However, the process in which the data is gathered and analyzed, that is, the concept of stakeholder mapping, understanding the functioning dynamic of the CCS field, and finally, the presentation of the work into three tangible scenarios can be repeated to achieve a similar result, the basis for a decision making support tool.

This exploratory work touched on a number of interesting points for further research:

- This research did not explore how dependant stakeholders like power companies may gain "power". Of particular interest may be to research market actors like big banks or asset management firms to understand details surrounding favourable conditions for investment in CCS.

- This research did not explore how dominant stakeholders like governments may gain urgency. Might urgency be gained from accelerated weather crises, or a strong commitment to CCS by the United States? Do stakeholders believe they are acting urgently? How might urgency be influenced so that the commercial application of CCS may be realized? While it appears that during the time of this work, claims towards the commercial application of CCS technologies are not urgent "enough", further research may be applicable surrounding the concept of urgency as it relates to CCS. What criteria can be developed to regard actions as "urgent" when keeping in mind issues of time and feasibility?

- Functions could be researched in more detail, for example functions of market formation (what is needed for private investment to occur); legitimacy (CCS as compared to biofuels, GMOs or nuclear waste); or influence on the direction of search (examination on what is meant by "bridging the gap") could be explored across the stakeholder map, within certain stakeholders, or amongst stakeholders not represented in this work (e.g., media, public, or market actors).

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