Attitudes regarding CO_2 Capture and Storage from a Swedish perspective

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Abstract

This study examines the attitudes of Swedish politicians, scientists, NGOs and industry regarding CO_2 capture and storage (CCS), i.e. actors who possess knowledge about CCS today and will influence the public opinion of tomorrow. The study is unique since the phenomenological approach is seldom seen in this specific context. The empirical data is gathered through interviews and is structured and analyzed in respect to expressed basic assumptions, systems view and a theoretical framework stemming from history of technology. From data, different ideal types are constructed - the CCS opponent, the CCS pragmatic and the CCS supporter. Results show a lot of skepticism and even opposition to the technology among NGOs and politicians, while industry and scientists generally are proponents. The large group of pragmatics is especially interesting since it is presumed to take a stand in the foreseeable future.

Over time the energy politics in Sweden has been subject to intense controversies. Between the 1960s and 1980s hydropower and nuclear power were heavily debated. With arguments stemming from environmental protection the public opinion, represented by a wide array of strong organizations, restricted the expansion of those power sources far below the originally planned capacity. Now this new technology, CCS, is about to enter the Swedish debate. It is a controversial technology with similar characteristics compared to its precedents regarding e.g. large-scale, risk, and long-term storage, i.e. characteristics that led to the referendum deciding a nuclear power phase out. Unless a careful approach to implementing the technology, could CCS also be phased out prematurely? Will history repeat itself?

The results should be seen from a Swedish point of view since Sweden has vast bio-fuel and hydropower resources, which together with an extensive amount of nuclear power makes CO_2 emissions per capita and GDP low, and the opposition against fossil fuels high.

1. Introduction

This paper analyses CCS from a broad systems perspective. The focus is on the Swedish energy system and the opinions of different actors, e.g. politicians, representatives from NGO:s, the government, the parliament, the industry and the academy. The analysis aims at distinguishing different ways of reasoning and thinking about CCS. The entire analysis is built upon the idea that CCS is a very complex socio-technical system, which has impacts on the energy system and society that are not possible to capture in unambiguous rational models. This idea is strengthened in the literature review, which shows that several conflicting analyses and conclusions about CCS exist in the scientific discourse.

The empirical findings are deconstructed and reconstructed in three different ideal types. The work is mainly based on an interview study undertaken by the authors between October and December 2004 (Bryngelsson et al, 2005). Besides contributing to the understanding of different perspectives on CCS the aim is to analyze different communication strategies and to demonstrate a fruitful form of communication. The results can to a certain extent be generalized, even though some may apply only in Sweden with its unique conditions.

1.1 The Swedish context

Over time the energy politics in Sweden has been subject to intense controversies. Many times the consequences have reached far outside their traditional domains. Recent history shows three cases of canceled major plans, raised by power companies, in order to heavily expand a specific energy source. The drastic hydropower expansion during the 1930s began with major confidence by the state owned power company Vattenfall[1]. It was not until the 1950s the expansion was questioned. At the beginning the critics of the expansion were marginalized but as time went by and social awareness grew, the pressure towards ending the expansion was inevitable. With arguments based on environmental protection the public opinion, represented by a wide array of organizations, restricted

[1] Vattenfall is 100% state-owned and Sweden's largest power company. It is the 5th largest electricity producer in Europe with electricity sales of 203 TWh (2003) and Net sales of 12,6 Meuro (2004). (Vattenfall Annual Report 2004, 2005)

the hydropower expansion to a maximum of 66 TWh/year, which was far below the originally planned capacity. (Anshelm, 2000)

The process of restricting hydropower expansion was supported by the new rising vision of nuclear power that began in late 40s. The premature ending of the hydropower expansion threatened to contribute to lack of electricity, which supported nuclear power even more. As with the history of hydropower the critics of nuclear power were at the beginning marginalized. The expansion of power generating capacity was intimately coupled with economic growth and welfare. The critics were therefore labeled either as under-informed or opponents to the ongoing building of the “welfare state” and technological development. Sweden deployed a nuclear program consisting of 24 plants over the next decades. (Anshelm, 2000)

During the late 1950s issues regarding ecology and risk emerged on the agenda, even though they were marginalized. The character and focus of the energy debate changed dramatically over the period. At the beginning there were hardly any controversies at all. The first major issue to be heavily debated was how to handle the nuclear waste. This issue was mainly regarded as a strictly technical problem in the energy discourse until the beginning of the 70s when moral dimensions appeared, containing a touch of civilizatory criticism and inter-generational questions. The energy politics were in the center of the election in 1976 and that was probably the cause of the first drawback of the social democratic party since 1932. (Anshelm, 2000, 2005)

The accident in Harrisburg 1979 happened at the same time as Sweden was charging its sixth reactor, which was a technically identical reactor to the one in the accident. The accident immediately gave rise to the parliament and government to hold a national referendum in 1980. The following years the energy related controversies made divides across several intersections in both the political and the public sphere. The referendum made it clear that nuclear power was to be completely phased out by 2010.

Vattenfall and some other major Swedish power companies had major plans of expanding the coal power industry, or rather so called Clean Coal, in Sweden in the 1980s arguing this was the only realistic plan to replace nuclear power. (Lundberg and Lothigius, 1989) These plans were heavily challenged on both an economical and an environmental basis ending up with the introduction of one of the world’s hardest CO_2 emission taxes in 1991. The tax put a stop to the plans of expanding coal power for this time.

Today nuclear power and hydropower contributes by 45 % each of the electricity production in Sweden, coal power only by 2 %. The debate continues on how to transform the energy system in a way that is economically efficient, environmentally friendly and with decreasing risks for the public. It is no longer seen as realistic to phase out nuclear power by 2010, and instead the government is promoting a gradual phase out process. Today (May 2005) two reactors have been closed. Still the issue is controversial, because according to several actors the reactors are still effective from a strictly economical point of view. Other actors are claiming the costs of nuclear power are based on the wrong assumptions and therefore should be considerably higher. Another issue on the agenda, that especially the opponents to the phase out are emphasizing, is that because of the recently deregulated electricity market in Europe the decrease in nuclear power will be replaced by a marginal import of coal power from Denmark and Germany. The attitudes of the public towards coal power is very negative, it is the least wanted energy source both from a risk perspective and an environmental one. (Viklund, 2004)

The recent expansion, with its beginning in the late 90s, by Vattenfall in the German and Polish coal power industry creates a paradox. It has made Vattenfall’s electricity production from coal power larger than both nuclear and hydropower together. Vattenfall is now the third largest emitter of CO_2 in Europe. Because of these activities, the role of Vattenfall has been questioned both from the public and from the parliament. It is still 100% state owned and has an official policy to “place the environment as number one” and act as a role model in the transformation of the energy system. (RiR 2004) Vattenfall on their part claim to take their share of the responsibility by putting a lot of money into clean coal technology research.

This is where CCS comes in. Vattenfall has a large R&D program promoting CCS that could legitimize its recent actions. It is still a risky endeavor though, not only because CCS is in the R&D stage, but also because CCS and its applications have many features similar to those previously mentioned – features that for example gave rise to the beginning of the end for the nuclear power in Sweden. CCS promotes large-scale industry and centralized expert systems, it is risky, it involves long-term storage, and it is technically complex and has a strong focus on supply. CCS is also a technological system that enforces the development along a fossil fuel dependent trajectory – which could be regarded contradictory in the light of the official energy policies, aiming at larger shares of renewables in the energy mix and a long term vision of phasing out the fossil fuels. (Government Bill 2001/2:143). Coal power is suggested to be one of several possible replacements of the nuclear power. (Elforsk, 2004)

The Swedish debate on CCS is still in its fluid phase, if you really can label it as a debate at all. The issue has not yet been raised in the parliament, but some major newspapers and magazines have discussed it lately. Though, one thing is clear – the energy debate is still very turbulent and the history shows it has the capacity to radically change future development of the energy system.

1.2 Methodology

This empirical part of this study was primarily conducted in order to obtain and analyze how different actors in Sweden relate to CCS. Many studies have been done on the subject before, but most of them have focused on the public opinion, people who are not familiar with the technology and therefore not apt to answer questions about CCS. The conclusions have been that the public does not know much about CCS (Curry et al, 2004 and Uno et al, 2004). Some studies have also tried to educate the respondents about CCS in an "objective" manner, but since we are arguing that no such education exists on this topic, we did not try the same methodology (e.g. Itaoka, 2004 and Palmgren et al 2004). In this study, scientists, representatives from industry, politicians and NGOs are interviewed on the subject, i.e. people who should be familiar with the subject and are likely to be involved in the debate on CCS. People from a wide variety of organizations were chosen in order to really see CCS through different perspectives. Churchman's motto (1968) "the systems approach begins when first you see the world through the eyes of another" has been a guiding star throughout the work.

The primary choice of method for collecting data is not obvious when studying how people relate to CCS. Literature review could be used, but that would exclude standpoints of the people who have not written anything on the subject, in this case for example politicians. Questionnaires or structured interviews could also be used, but they require great care when put together in order to provide reliable data. Therefore a highly qualitative form of interview was chosen for this study. The method, more specifically, is influenced by phenomenological methodology, where the interviewer tries not to influence or interfere with the view of the respondents on the subject. The interview is not structured and the interviewers role is laid back. Open questions are preferred as opposed to leading questions, which are avoided. In the beginning general questions about energy was used, like *"What do you consider the most challenging issue regarding our current energy system?"* The result ideally provides the standpoints of the respondents without influence from the interviewers. For a more comprehensive discussion on methodology, read the report that this article is based on (Bryngelsson et al, 2005).

The interviews lasted between 30 and 75 minutes and were transcribed word for word. The content was broken down, sorted and built up again into three ideal types, ideal types A, B and C, which represent generalized standpoints and views of the respondents. Ideal type A has a positive attitude towards CCS, ideal type C a negative one. Ideal type B is ambivalent and has hypothetical or vague standpoints. 12 people representing the following organizations were interviewed:

- Energy spokesmen from three different parties in the Swedish Parliament
    - Folkpartiet, the Liberal Party
    - Vänsterpartiet, the Left Party
    - Centerpartiet, the Center Party
- Ministry of Industry, Employment and Communication of the Swedish Government
- The Swedish Environmental Protection Agency
- Greenpeace Sweden

- Swedish Society for Nature Conservation
- University of Stockholm
- Vattenfall
- Stora Enso (paper, packaging and forest company)
- The Confederation of Swedish Enterprise
- The Swedish Coal Association

A tentative literature review was also done in order to show that the literature on CCS, as well as the ideal types, contains contradictory statements and facts that could lead to future controversies and changed opinions on what is considered as legitimate knowledge. The focus was on respected scientific literature within the fields of energy and environment. The review should not be regarded as representative; it rather shows the large span in which scientific knowledge could be found.

2. Empirical findings and analysis

2.1 Interview study

The material from the interviews is divided into three ideal types A-C, and quotes from the interviews are used to illustrate some typical standpoints.

Ideal type A – The CCS supporter

Ideal type A does, with some skepticism, consider the greenhouse effect as a scientifically proven fact.[2] Proved or not, it is a political reality and therefore forced upon industry and society. Since the greenhouse effect definitely at least is a political fact, measures might have to be taken, but the measures must not be larger than what is absolutely necessary and they should always be governed by an economical rationality. Coal, as a basis for the energy supply of the world is not problematic.

> *I don't think there are problems with the use of coal; it is both cheap and secure. There is no political tension with coal as with oil and gas.*

The ones that have a negative attitude towards CCS do not consider the whole energy system. They do not realize the small potential and huge costs for renewable alternatives and have not realized that energy efficiency together with rebound effects lead to increasing energy use. An increasing supply of energy is important and desirable and all sources are needed, mostly fossil fuels but also renewable ones. An increasing supply of energy contributes to the well-needed growth and higher welfare.

> *In Sweden people believe that renewable energy sources are endless. Yet, people don't want to expand hydro power, even if it in Europe is seen as an important contribution to renewable alternatives. Here at home they talk about bio-fuel as if it could cover our whole energy supply. I say, in the long run we cannot cover our energy needs without nuclear power, coal power or anything similar. On top of that wind power and solar power can work on the margin.*

> *We have politically decided to have a system that finds the cheapest solutions to mitigate climate change. If we want a system to support only renewable alternatives, it has to be something else, something that is motivated by just a wish to have renewables, not motivated by getting rid of CO_2 emissions. If we want to get rid of CO_2 emissions, the choice is CCS.*

The use of fossil fuels is important and rational since these fuels are highly available, cheap and can be used with existing technology and infrastructure. Together with CCS fossil fuels can fulfill political, environmental and economical requirements. To develop CCS the rules and regulations concerning technological development, energy use and emissions must be adjusted to the needs of industry in cooperation with politicians and universities.

> *I think that in a couple of years a pilot plant based on coal gasification with CCS will be built in the USA. Before you let politicians see a pilot plant you cannot say this is a working technology. It has to be done like in the USA, in cooperation between industry, universities and DOE. We need the same kind of cooperation in Europe.*

[2] To consider the green house effect not as a scientifically proven fact also exists in this ideal type, even though it is the extreme point.

An early opportunity for implementing CCS is in combination with enhanced oil recovery (EOR), which has an economical advantage compared to other options. Ideal type A wants EOR as soon as possible, especially in the North Sea where oil production is about to decline. The possibility of an increasing oil production while mitigating climate changes is like killing two birds with one stone.

> *There is no place in the world more suitable for CCS than the North Sea. Together with EOR it is estimated that 500 million tons of additional oil can be extracted, compared to using only conventional techniques. It is practical… it is economical. In such large quantities of oil there are also issues regarding security of supply and political stability.*

Power production based on fossil fuels is going to increase in the future, also for Sweden. Technical and social barriers for CCS will be overcome with time and by technological development. Whatever resistance after that, for example social resistance, has no legitimacy. Nuclear power is also desirable and a technology clearly within what is socially acceptable in terms of risk. Centralized power plants are superior when it comes to efficiency and control, and they are preferred to renewable and decentralized alternatives. The progress for renewable alternatives is actually supported by CCS since CCS incurs additional costs to fossil fuels, which make renewables more competitive. Progress is however slow and renewables may only replace fossil fuels in a distant future.

> *Everybody is talking about hydrogen, but the hydrogen has to be made out of something. I think the final solution will be based on energy from the sun, but wind energy is foolish. I think it's frightening when people build those silly "wind things".*

CCS is as well necessary to mitigate the effects of the inevitable Chinese coal power expansion. Therefore the western countries have to develop this technology and diffuse it to China.

Ideal type A thinks ideal type C is irrational, often arguing from an emotional point of view on issues that are primarily technological and economical.

> *For a lot of people energy related issues have become religion rather than technology. For us it is still a technological issue – how do we fix this? – I think its is a common way of thinking in my organization.*

Ideal type B – The CCS pragmatic

The greenhouse effect is scientifically proven and has to be handled. One way is to combine efficiency measures with a decrease in fossil fuel use. The one and only long-term solution is a transition to exclusively renewable forms of energy. An increasing supply of energy is not necessary for continued economical growth because of an extensive potential for efficiency measures. CCS might be a complement to renewable energy and increasing efficiency but ideal type B has a rather diffuse attitude towards CCS.

> *There are systems where renewable energy is cheap and competitive. There are also places where conditions for renewable energy are poor and where CCS is preferable.*

Energy cannot be too expensive from an economical point of view. It is important that the most profitable solutions are chosen, even if all other solutions are kept alive as future alternatives. Depending on different time scales, different methods should be considered. In the short run efficiency measures yield the highest result in cutting energy use and emissions. In the long run however, Sweden has a problem with shutting down all nuclear power plants. They have to be closed eventually, but the process must be spread out over a long period of time. It is preferable to spread out the cost and at the same time create the possibility of replacing the nuclear power with renewable power.

> *First of all I would like to see the fossil fuels being phased out of the Swedish power system. Then perhaps you could start to phase out nuclear power, but we are not there yet. You can definitely not start to phase out nuclear power today.*

With the exception of nuclear power, the future energy system is created on the market in competition with all alternatives, together with rules and regulations decided upon by politicians. There is no reason for doubting the scientific results concerning CCS; CCS is thus not a moral issue. If CCS is a competitive technology on the market it should be applied. Ideal type B has a feeling that CCS might leave other technologies and research areas out in the cold, which is not good since many methods should compete on the market. Even if it does, it is not a big issue, CCS might be a good acute solution in the short term, during the transition period to a renewable future.

> *The research on CCS should compete on equal terms with other alternatives. It is then up to the research community to decide on which technology is the best bet. I personally would not put my money on CCS. There are easier ways to reduce CO_2 emissions.*

Ideal type C – The CCS opponent

Like ideal type B, ideal type C thinks the greenhouse effect is scientifically proven and has to be handled. The burning of fossil fuels is the main contributor to the climate change and using fossil fuels, with or without CCS, is not compatible with the environment. To develop large-scale CCS is neither economically nor technologically rational.

Efficiency improvement has a large potential to cut emissions of carbon dioxide in the short term, and it has to be the first step in getting the energy system in line with climate change. In the longer-term renewable energy sources have to increase. Since climate change is an urgent issue these measures have to be taken as soon as possible. CCS could contribute to lower carbon dioxide emissions in the short-term, but would probably make the situation worse in the long run.

> *I think it is yet another end of pipe technology that stands in the way of the real solutions. It doesn't solve the problem of fossil fuels use and all the other things that are connected with the use of fossil fuels. And it siphons a lot of money away from energy efficiency and renewables - what we think are the real solutions. You get away a long way from energy efficiency and renewables, because you are putting a lot of money into the red herrings. How much money have they put on nuclear fusion? - and now this is the new wet dream of the fossil interest group.*

Security of supply is a necessity to secure growth and welfare. Increasing energy use on the other hand does not contribute to growth since the energy supply, especially fossil fuels, is not compatible with socioeconomical efficiency on account of external costs.

> *If you have CCS from coal you still have all the problems related to the carbon cycle. If you look at China and their coal mining, that's not exactly something we are proud of. Acid rain emissions when burning coal, I'm pretty sure that is not taken into the concept of clean coal – I would be surprised if it was. I mean there are of course cleaning methods when burning coal, but even if you have reduced sulphur emissions from coal relatively well you would still have the problem.*

Today's energy market does not result in efficient energy solutions since rules and regulations are not optimal. CCS could not be realized with existing market imperfections such as subventions and an incompletely deregulated market. The technology is an example of a non-optimal energy solution that would get an excessive amount of subventions, result in large external costs, and have a negative effect on the development of renewable energy sources. The scientific community that studies CCS does not see CCS in a systems perspective, usually for example life cycle analyses are missing. CCS has not only technological flaws; it is also a technology with moral issues, a technology that leaves waste in the form of carbon dioxide to future generations. The question of permanence is also an important issue for ideal type C, especially if a large amount of CO_2 is stored and the rate of leakage is too high. Ideal type C thinks that it might lead to large emissions, making all other measures useless.

> *…and then of course you have questions concerning permanency – Can you guarantee us that this stuff stays underground for hundreds or thousand years? - because otherwise it will not have any effect. /…/ And if it doesn't work you have no window of reaction because you have foreclosed all other options; you have all gone on this way. Maybe it is one generation from this one that will find out it doesn't work. Maybe it works? But I won't take the risk!*

Ideal type C thinks that assumptions made about CCS by ideal type A, which are presented above, are wrong, consequently resulting in incorrect conclusions on what is best for society.

2.2 Literature review

The literature review in this study was done in order to find scientific sources that could strengthen the opinions expressed by each of the ideal types. The result could have been that only one of the ideal types had literature to back up its statements, but that was not the case. The issue is more complex than that, and therefore it is not obvious which one of the ideal types that represents a more valid or "correct" view on CCS than another. The uncertainty is especially obvious when considering assumptions about future development. It is important to think of the fact that it is not our intention to make a judgment whether a specific statement or scientific article better represents the reality or truth than another. The following will cover the main findings and will focus on the polarized views of ideal types A and C.

The question of permanence seems to be one of the most controversial issues in the literature, which will decide whether CCS is an efficient mitigation option or not. Ideal type C's opinions are in line with for example Hawkins (2004) who state that not even a retention rate of 99.9 % might be enough to stabilize CO_2 at 450 ppm. Ideal type C also thinks that CO_2 storage is polluting and insecure. The polluting effect of CO_2 is discussed regarding for example groundwater contamination (Bruant et. al., 2002) and ocean storage, where CO_2 is acidic, which may have adverse effects on the marine environment (Johnston and Santillo, 1999). Security issues seem to be most crucial when it comes to on-shore CO_2 storage, and also during transport where CO_2 leakage can lead to asphyxiation (Holloway, 1997). CO_2 might also induce seismic activity, which indeed is also a security issue (Sminchak and Gupta, 2002). Ideal type A on the other hand thinks that many storage options are secure, especially oil reservoirs, which are seen as proven traps as they have held oil entrapped for millions of years (IEA, 2001). Leaky reservoirs can simply be avoided. The ocean is also seen as a good storage option, since all CO_2 will end up there eventually (Caldeira et. al., 2001). Storing CO_2 for 100 years or more is often considered a permanent storage (Herzog, 2003).

The degree of systems perspective also differs between the ideal types. While ideal type A focuses mainly on the combustion process, ideal type C argues that they see things in a bigger perspective. For example when efficiency loss is discussed regarding carbon capture processes, ideal type A typically refers to increasing costs of electricity while ideal type C also talks about effects of the need for increasing fossil fuel use, e.g. increasing pollution of other types than CO_2 and mining accidents (Hawkins, 2001).

Path dependency and "lock-in" are issues that are discussed a lot, and IPCC (2001) among others has commented on this particular subject:

> *Yet, despite their ability to select adequate technologies, markets sometimes "lock-in" to technologies and practices that are suboptimal because of increasing returns to scale, which block out any alternatives.*

Ideal type C agrees and thinks that the world is locked into using fossil fuels. CCS is a suboptimal response to climate change, and the technology is only a response in line with a path dependency. Ideal type A may agree that the world is locked into an infrastructure and into the use of fossil fuels, but it is a good thing. Fossil fuels have given mankind a manifold increase in the standard of living and CCS might be a way for the world to develop even more still using the fossil fuels based energy system, without affecting the climate. CCS also makes it possible to get an increasing return out of the trillions of dollars invested in fossil fuel infrastructure (Herzog, 2003b).

Legal issues have also been discussed in the literature, where some conclude that CO_2 storage is illegal according to the London Convention, especially in the oceans (Johnston et. al., 1999), while other just point out that the laws were not written with CCS in mind. Ideal type C would agree with the former and ideal type A with the latter by stating that the laws have to be amended to fit CCS (Heinrich, 2002). The precautionary principle is often applicable but, since it is used in laws and conventions to protect both the climate and e.g. the marine environment, it is hard to interpret. Which is more important to be precautious about, the climate or the marine environment?

When it comes to economy there are some truly conflicting opinions in the literature. All sources agree that CCS might become expensive, but sources that support ideal type C even more so. Ideal type C emphasizes the possibilities that CCS would not be as cheap as prognoses show (Tarlo, 2003). In combination with being convinced that CO_2 may leak from storage sites, every penny invested in the technology is a waste of money because you have more cost efficient measures to make. Therefore CCS should not even be considered as an option. Riahi et. al. (2004) show on the other hand that costs will decrease rapidly due to technological learning, which will lead to a break through for CCS around 2050. Both the literature supporting Ideal type A and C state that all options for mitigating climate change should compete on the market, which brings us to the final issue brought up here: Do investments on CCS lead to decreasing investments on renewable alternatives? This question does not seem very relevant if Ideal type A is right – CCS is undoubtedly the most powerful way of mitigating climate change. But the question is very relevant if you cannot exclude that ideal type C is right.

Some sources are in line with the attitudes expressed by ideal type A, that investments on CCS do not lead to decreasing investments on renewable alternatives. They may even discuss CCS as a way of increasing renewable alternatives, partly because hydrogen can be produced using fossil fuels together with CCS, hydrogen that in turn could boost the use of fuel cells and a more rapid development towards a hydrogen society. In the same context CCS is said to be an advantage to the development of renewables since CCS adds costs to fossil fuels, which makes renewables more competitive.

Ideal type A claims the potential of renewables is small because of huge costs. Jacobsson & Lauber (2004) claim however, based on findings from the German context, that if external costs[3] and subsidies were taken seriously most renewables would be in a competitive range right now. According to their calculations the average cost of wind power generation is 7.5 eurocent/kWh and the cost of hard coal power is 9.9-12.5 eurocent/kWh.[4]

The argument that CCS has to be implemented in China is often seen as a factor legitimizing continued development and implementation of CCS. The expansion of Chinese coal power is according to some unstoppable. The implementation of CCS in China is however questioned. Gantner et al (2004) claim that several of the CCS studies in the Chinese context are underestimating some crucial aspects. For example one of the most industrialized and energy intensive and coal power dominated regions, Shandong with its 90 million inhabitants, has serious scarcity of fresh water supply. Clean coal technologies demand a very high consumption of fresh water and pollute the water, especially in countries with inferior control of water emissions.

Different perspectives regarding time are also a potential controversy. Some say that CCS is a bridge to an energy future based on renewables (Simbeck, 2004), while others say it is an excuse for continuing using fossil fuels as long as possible (Muttitt and Diss, 2001). The question is, once this bridge is built, when is the time to tear it down?

An intriguing concept connected to CCS is EOR with the use of CO_2, which is advocated by ideal type A. By injecting 1 tonne of CO_2, 0.6 tonnes of additional oil can be extracted (Hustad, 2004), but what does that do for the CO_2 emissions? The combustion of 0.6 tonnes of extra oil releases well over 1 tonne of CO_2 into the atmosphere, which takes us back to where we started. While some think it is a great early opportunity for CCS (van Bergen et. al., 2004), others think it adds to the problem by making more carbon available to burn (Muttitt and Diss, 2001). But to understand the effects of EOR one would not only have to look at the amount of incremental oil EOR is adding to the market. Some of the oil could off course meet an unmet need, but it could also replace another fuel. If it would replace synthetic fuels from coal EOR could perhaps decrease CO_2 emissions, but not if the fuels are made of biomass.

3.Systems perspectives

As we have shown, deeply polarized attitudes were found about CCS, even if several respondents have not formed an opinion yet. There is a general view that science will show if CCS is an appropriate energy technology or not, but science does not give a clear-cut answer. This study shows there is science to support both the ideal type A and C. The ongoing process has similarities with the initial controversies regarding both the hydropower and nuclear power expansion. What was regarded as true and relevant knowledge shifted over time, and not only as a result of scientific development. In the case of nuclear power the scientifically and morally complex issue was finally decided upon in a national referendum. The outcome of the referendum was that the scientifical truth was finally legitimized by the people and not by the scientists or by the technicians. (Anshelm, 2000, 2005). Knowledge shifting over time is especially problematic when dealing with issues associated

[3] The social costs and external costs are based on the European Commission's figures.

[4] For hard coal 3.4-3.8 eurocents/kWh is direct generation costs, 2-4.2 cents are from coal subsidies, and 4.5 cents are external costs.

with long-term storage and huge infrastructural systems because of its inflexibility. This relativity, difficulties of stabilizing knowledge, could be of major concern and raises the epistemological question – how do we evaluate knowledge? One way of handling this decision and evaluation process, which was dominant in the empirical findings of this report, was letting the market decide.

The function of the energy market is however questionable. First of all there are contradictory goals, especially for the European Union[5] who has sustainability, security of supply, and economical efficiency as the three top priorities. In fulfilling the first goal, to achieve a sustainable energy system, the use of fossil fuels would have to decrease, which most certainly would make it hard to reach the two other goals. The efficiency of the market is not the best either. A few large actors dominate the market, which limits competition. Even though a European market for electricity has existed since 2004, fewer than 50 % of the commercial customers have switched supplier. Something similar could be expected when the market is deregulated for small consumers too in 2007. As well, several countries have problems with market structure and lack of intercountry integration (DG Energy and Transport, 2004) Is it on this insufficient or imperfect market the actors in the empirical study are relying on for choosing the energy system of our future? Instead of as a first measure relying on an embryonic market, which cannot be a better decision maker than its inherent components - physical capabilities, rules and institutions and consumers' activities, we are arguing for an open dialogue.

Important to have in mind in these dialogues is, as mentioned before, that different actors are entering the debate with different perspectives. On a theoretical level the economist Giovanni Dosi (1984) points out that the development of a technical system is always being shaped by past practice and routines. The direction in which you are searching for the solution of course affects where the solution will be found. Dosi's term selective device illustrates how the problems are defined and the solutions are found according to the specific momentum and system culture the specific actors are a part of. The economic historian Thomas P Hughes (1983) claims that the system culture is closely related to momentum, and to the fact that the system builders gradually develop a common outlook on what is rational and desirable for the future development of the system. This is important to have in mind for energy policy makers. The evaluation of knowledge is always done from a standpoint and a certain system perspective. To continue with Hughes terminology, it is from a specific perspective that the salients of the system and the reverse salients[6] are defined[7].

When moving towards stabilization the shaping and the reshaping of the system is dependent upon the relative power of relevant social groups during a certain crucial moment. System building is a dynamic process and the successful system-builders are those who have the ability to distinguish and understand the interrelationships of not only the system as it is today but even more important – to be able to define the critical problems, not only from their own perspective but from the eye of "the others" as well. As seen from the interviews the definition and development of CCS is still in its fluid phase. The system builders of the fossil fuel power industry are only one of several forces in the shaping process, even if they are the most articulated ones.

From a social scientist's perspective the outcome of shaping the energy system is not mainly the outcome of a rational evaluation of the technological core. It is more likely that the shaping of the energy system is the result of the actors' perceptions of the technical core and the boundaries that they define for the system. For example there is an ongoing struggle whether to define CCS as a sustainable energy technology or not, which is very important for public and political acceptance or rejection. As we have shown, specific actors define the technology in different ways depending on their view of the system boundary – regarding e.g. time, life cycle and connection with other systems.

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[5] In July 2004 the process began of integrating the previously 15 national electricity markets to one single European. Sweden is of course involved in this process.

[6] A reverse salient could be compared to "bottle neck" or a problem that stands in the way of system development and growth.

[7] In Hughes analysis the perspective is mainly the so called system builders'.

The figure below, with inspiration from Hughes (1983), illustrates how the critical problems could be defined from two different perspectives and the role of CCS for fossil fuels.[8]

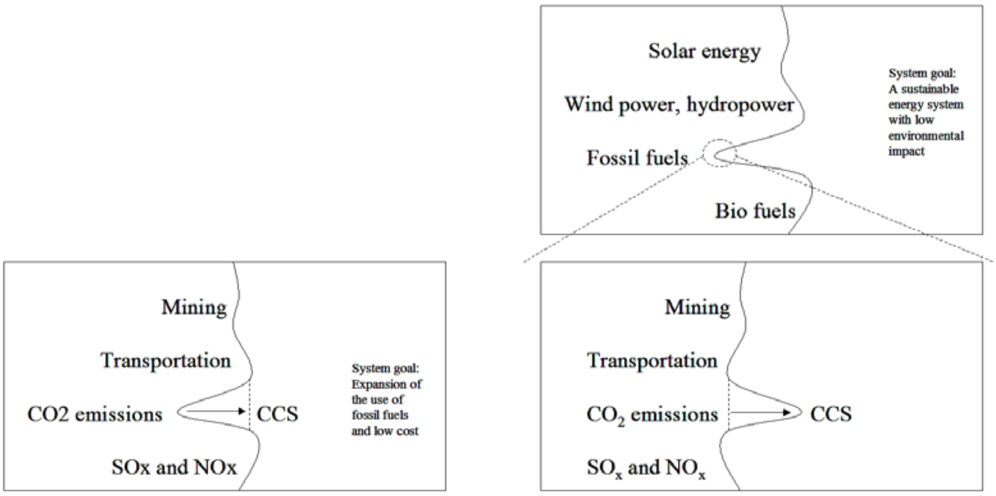

Figure 1 Salients and reverse salients

The figure to the left illustrates ideal type A's perspective. Fossil fuels make up more than 80 % of the global supply of energy, and that share is increasing in the foreseeable future. Fossil fuels are therefore the most interesting, if not the only interesting part of the energy system. There is however a reverse salient, i.e. the carbon dioxide emissions. It has to be handled in order to make it possible to expand the use of fossil fuels, and CCS is the only possible solution. The most important issue is whether the problem is solved in a cost effective manner or not, and CCS is likely to fulfill that criteria. The figure to the right illustrates ideal type C's perspective, which prefers to see CCS in a broader systems perspective. The use of fossil fuels is a reverse salient in achieving a sustainable energy system (the upper right figure). If we zoom in on that reverse salient (the lower right figure) we see that the development of CCS might solve the problem with carbon dioxide emissions for fossil fuels, but the risks are high. CCS will however, if it works, only create a salient for fossil fuels that is far ahead of the other components in the fossil fuel system, letting the development of other crucial aspects, e.g. sulphur emissions, mining and transportation problems fall behind.

4. Communicating CCS

Before heading into a discussion on dialogue and openness, there is a need to comment on the fact that several communicators have been doing well because of other features far from dialogue and openness. They have been successful e.g. by simplifying things without a deeper analysis, appealing to people's emotions and by not inviting people to a dialogue. Zimbardo and Leippe (1991) have done extensive research in the area and have found five common features that have made for instance presidents, dictators and marketers successful.

- To simplify complicated issues
- To talk only about things that are advantageous to you and ignore the disadvantageous
- To tell people work has already begun, and make your conclusions and proposals sound irrevocable, then people tend to seek only supporting information.
- To stress rationality when it comes to new and unfamiliar questions and subjects.
- To be an optimist, convinced that all future problems can be solved.

A discussion about communicating CCS could end here with a recommendation to use these strategies to make CCS successful, but we would rather oppose them. It is a standpoint based on previous discussions claiming CCS is a too complex and too important issue to simplify and make hasty decisions on. Connected to this is the earlier discussion on path-dependence, which seems to be a very

[8] Please note that the figure only gives a very simplified view of the energy system

important phenomenon within the development of energy systems. Once the building of a CCS system is underway it is hard to change. Also as mentioned earlier, plans for building large scale energy systems have been revised before when they have been subject to social pressure and changed criteria for legitimate knowledge. In addition to the metaphors used, e.g. hydropower and nuclear power expansion, there are also examples from CCS that has shown great controversy. The question still remains though how this process is to be performed? In Hawaii, where the testing of CO_2 storage in the ocean was to take place, work with the involvement of the local population was initiated too late. A strong opposition was established among the public with the support from local papers, and opinion regarding CCS and its risks was formed rapidly. The system builders were surprised of this rapid development and that opinion was hard to influence once formed, even though the public understanding of CCS according to them was poor. Information and education proved to be of no use at this late stage, while an earlier attempt would probably have yielded better results.

When a problem is being solved or communicated, the first step should be to analyze what type of problem it is. This identification is important since different kinds of problems need different courses of action to be communicated or even solved. Societal and technical problems can roughly be categorized into three different types depending on two variables, the definition of the problem and the solution to it (Adler & Kranowitz, 2005). The three types of problems are of different complexity and the solutions are characterized by a varying degree of dissonance. They also need totally different strategies to be handled.

Table 1 Problem Typing (Adler & Kranowitz, 2005)

	Type 1 (“Technical/ Convergent”)	**Type 2 (“Value/Divergent”)**	**Type 3 (“Wicked/Intractable”)**
Agreement on problem definition	Yes	Yes	No
Agreement on possible solutions	Yes	No	No

Type 1 problems, called technical convergent, are characterized by total agreement when it comes to definition and solution. The problem does not have to be simple but there are only a few possible solutions since it is one-dimensional and do not require moral considerations. The more that people of reasonable intelligence will study the problem, the more likely it is that ideas about possible solutions will congregate into a narrow range of choices. Often the problem is of the type “how”-problem, e.g. how do we get from point A to B in the shortest amount of time? Or how do we construct a CO_2-storage system that does not leak? The handling of a type 1 problem is done by a linear flow and one-way communication.

Type 2 problems are called value/divergent. The problem definition is agreed upon but the solutions differ. A type 2 problem is more complicated than type 1 problem. All consequences of the solutions are not certain and the system border is not obvious. Different groups are formed that argue in favor of their specific solution, and the discussions and the confrontations between the groups are usually non-constructive. The groups tend to diverge. For type 2 problems attention has to be paid to different values, not only to those of the experts but also to the values of other interest groups such as the public who may have to live with the consequences of certain choices. Information is not enough for creating consensus, since emotions, attitudes and ideologies all matter. The more that people of reasonable intelligence will study the problem, the more likely it is that ideas about possible solutions swerve away from each other. Type 2 problems are usually a “why”-type of problem like why are we going from place A to B? Why are we building an energy system based on fossil fuels when there are other alternatives?

Type 3 problems are so called wicked/intractable. They are very complex and include many different interest groups, areas of responsibility, moral issues and old tensions from earlier controversies. These aspects are clearer if the problem requires a lot of resources and there is competition between different ways of using the same resources. The interest groups can neither agree on the problem definition nor on how to proceed. The communication between the groups is also very poor or nonexistent. The communication that does exist is usually non-direct and often performed through e.g. the press. Creating ways of communicating is hard since there is no trust. Without trust the groups try to defeat or rather destroy each other. Offerings are seen as bribes and demands as blackmail. Why are we heading towards place B when B is just a dead-end and @ is the goal? Why put money into increasing the production of electricity when we do not really need more electricity?

4.1 What type of problem is CCS?

Both ideal type A and C argue in several aspects as if CCS is a type 1 problem. A common characteristic on the rhetorical level for both types is *"if only my opponents were as rational as I am, then they would come to the mine conclusions too"*. They both talk about the lack of rationality on the other part and that they have the wrong system boundaries. They have the belief that CCS is a type 1 problem with an inner logic containing the only right solution. Our empirically founded hypothesis is that the actors rhetorically handle CCS as a type 1 problem. If the major part of the experts see the problem in the same way, it could be a good start for communication since the different opinions are evaluated in the same way, e.g. efficiencies, risk of leakage, cost of CO_2 capture.

In the case of CCS it can be treacherous to convince oneself that the problem can be handled as a type 1 problem since it only reflects the rhetorical surface. As we have mentioned there is a forcing environmental discourse that makes individuals in a certain position, in order to gain legitimacy, forced to discuss in a technically and economically rational way. Neither a NGO representative nor a CEO for a utility company could say that *"we should not have wind power since it is ugly"* or that *"we should have CSS since it is a technology I have put my whole career into"*, without loosing credibility. They could not say *"nuclear power is not good since it is large scale, and large scale decreases democratic influence"*. These opinions are probably more common than what is reflected in media, and in the debate between experts. That does not mean though that the opinions do not exist. They are covered in a more accepted form of communicating. With these speculative arguments we mean that the signs of CCS as a part of type 1 problem is probably illusory.

In line with our argumentation above and the previously mentioned complexity surrounding CCS it is easy to claim CCS is not a type 1 problem. There is no logic that automatically generates the answer that CCS is the best solution to our energy problems. A lot of things are still uncertain when it comes to time, storage, cost, risk, intergenerational questions, system boundaries and overlapping areas of responsibility. The complexity increases even more when considering that it is a future system that only exists on the drawing board and in the mind of the actors. Furthermore several possible solutions to the problems with the energy system of today exist, which the different ideal types show. Of course this description is more or less applicable to all energy techniques.

CCS shows a closer resemblance to a type 2 problem. The definition of the problem is fairly homogenous. All ideal types want a sustainable energy system in the long run, while the path to get there differs. There are channels for communication, e.g. conferences and meetings, and there are few verbal attacks or emotional concerns expressed in media. The complexity of CCS is also in favor of classifying it as a type 2 problem. The solution to the problem is entirely dependent on who is answering. Some may say the solution is renewable energy, others nuclear power, and yet another CCS. Both the questions *"how can we decrease CO_2 emissions"* and *"where shall we store the CO_2 emissions"* fit here. Type 2 problems sometimes stir emotions and in the communication between the CCS supporter and the CCS opponent, many emotional arguments are to be found. In the interview study for example, the CCS supporter referred to wind-power as "*silly wind-things*" and to the CCS opponent as the "*less informed environmental friends*".

The three problem types are not totally isolated from each other and CCS can in some instances be referred to as a type 3 problem, i.e. if definitions of the problem are too different. If one person says that no more power production is needed since there are huge possibilities for energy conservation. Then fossil fuels are not needed, and then CCS is a part of the problem rather than a solution. The conclusion is that we see CCS as a type 2 problem and it should be handled with a strategy that fits a type 2 problem. A reservation is also made that CCS is closer to being a type 3 problem rather than a type 1 problem.

5. Concluding remarks

The tendency that the actors treat CCS as a type 1 problem can be explained by Hedrén's (1994) hypotheses, that technical problems have been objectified lately, primarily on account of their increasing complex nature. There has also been a change in the environmental discourse as a forcing structure that make arguments that are not technically or economically rational lose their legitimacy. Is it then the right strategy to communicate CCS in a reductionistic manner? Curry et al (2004) emphasizes the importance of basic public education programs on climate change and CCS. The most important element in these programs, they claim, is education on the relative costs of various technological options. We are claiming this is not the right way of dealing with the problem. The complexity of measuring the relative costs corresponds to the complexity of technologies in focus. The relative prices, including the external costs and subsidies, are as shown highly subjective and dependent on what is considered as the legitimate knowledge and system perspective at a particular time. Also climate change is poorly understood, especially the effects of expected threshold effects, that are not usually accounted for in existing economical models (Keller et. al., 2005). The education programs should therefore rather focus on basic understanding of the energy system. This could then be the cornerstone for further public debates and discussions on acceptable relative prices as well values beyond the rational models.

As shown in this study, the discourse surrounding CCS is about techno-scientific facts and about the appreciations of the economical outcomes thereof. But in several cases the actors are not sharing the same systems perspective and neither some of the basic assumptions regarding e.g. permanency, the renewables potential and lock-in effects. This makes the reduction of the issue into a techno-economical one controversial. Still in the light of the more marked greenhouse effect, actions have to be taken and the decisions made would probably be more constructive if they were analyzed by different actors and from many perspectives. The different actors may not share the same perspectives – but at least they should have some basic understanding that the outcome in the process of knowledge production is most likely neither stable over time nor applicable in all contexts. What is considered as legitimate knowledge does not only change because of new discovered scientific facts. In line with this, the word acceptance, commonly used in the discourse, should be subject to more reflections - whose and what knowledge should this acceptance be based on? And finally, would not the aim of creating acceptance be trustworthier if it held open the option of rejecting CCS, in other words not treating it as a type 1 problem?

Already in 1959 Ragnhild Sandström, a female member of the Swedish parliament, was discussing related issues regarding nuclear power, and those issues are certainly applicable also for CCS today (Anselm, 2000). In a newspaper she wrote:

> *The men that work within the nuclear industry have done so in a lofty isolation only possible because the subject is new and exclusive. Ordinary people view it with the same reverence as primitive tribes regard the work of the medicine man. However, nuclear issues are not so complicated so that ordinary people cannot try to understand them. Maybe it is even necessary, because after all, it is the tax-payers who are paying for it.*

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