ZERO

Policy instruments for large-scale CCS

Front page: Sleipner West. On the right, Sleipner T, the gas treatment platform, where CO_2 is separated from produced natural gas before injection. (Photo: Kjetil Alsvik / Statoil)

Preface

This report is part of ZERO's work to achieve the necessary deployment of large-scale carbon capture and storage (CCS) as an important mitigation solution to solve the climate challenge.

As there are many studies concerning the question of how to ensure the technological scaling up of CCS and instruments for this learning phase, we have gone one step further and considered the following question: What are the policy instruments that will take development beyond the first demonstration projects, to several hundreds of CCS projects?

2020 is nearly here and 2030 is not far away. Long-term predictable frameworks are crucial to boost the speed of investments and development. Short-term challenges are important but must not take the focus away from putting long-term policy instruments in place.

This report has been carried out by the industry division at ZERO. Project leader Marius Gjerset has been co-author of the report with Marie Lindberg. Other ZERO contributors were Gøril L. Andreassen, Kari Elisabeth Kaski, Trond Risberg, Camilla S. Skriung and Marius Holm.

We would especially like to thank everyone who has contributed during the process. Special thanks go to our sparring partner, workshop facilitator and contributor to the report, Anne S. Lycke. And thanks to the members of our reference group and to the participants at our workshop in March 2013. Finally, we would like to highlight the 15 interviewees from all over the world, providing valuable and important input through personal interviews, summarised in Appendix 1. They are not mentioned by name as the interviews were conducted anonymously.

We thank Shell for the economic support that enabled us to carry out the work, and for the study tour to the CCS pioneers in Canada as a part of this process. Thanks also to Indira Mann at Scottish Carbon Capture & Storage (SCCS) and Hans Andreas Starheim for help with proofreading and layout of this report.

ZERO is solely responsible for the content and recommendation in this report.

Oslo, October 2013.

Contents

Executive Summary

This report analyses possible policy instruments for the realisation of large-scale deployment of CCS for all large emissions sources, both in industry and power generation.

Seven instruments are assessed:

- Government funding
- Investment funding via market mechanisms (as NER300)
- Carbon tax
- Emission-trading systems (ETS)
- Feed-in tariffs
- Certificate systems (portfolio standard)
- Emission performance standards (EPS)

In order to ensure large-scale deployment of CCS, ZERO considers a mix of instruments indispensable: at the core, an instrument giving sufficient incentive to make business cases for CCS viable and trigger investments in deployment and innovation. For industry to embark on large-scale investments, a long-term predictable framework is needed. The best policy instruments for scaling up CCS deployment to emerge from this analysis are a CCS certificate system combined with an appropriate EPS. The certificate system finances the cost for CCS deployment through a cost-sharing model, while the EPS sets a very clear regulation, stopping investments in high-emission conventional solutions.

General CCS instruments are preferable to sector-specific instruments, covering emissions beyond power production to give competition for reduced CCS cost across all sectors. And policy instruments for the whole CCS chain are preferable to separate instruments for each part of the chain in the long term perspective.

Serving as a basis for the analysis, a thorough assessment of existing CCS policy worldwide as well as qualitative interviews with stakeholders have been conducted. The assessment of today's CCS policy shows that a combination of instruments has been used for large-scale CCS projects today, with public funding, investment support and tax credits for CO_2 used for Enhanced Oil Recovery (EOR) being the most important. The most successful policy for building CCS has been in the US and Canada, where an EPS has been important part of the policy mix to trigger CCS.

The need for CCS will vary depending on country and region. A sincere CCS policy must take renewable energy developments into account. In power markets, shares of variable renewable energy are increasing fast. CCS must therefore adjust to changing dynamics in the power sector. Even in a scenario where renewables are taking over totally in power generation, there are industry sectors where CCS is the only available mitigation solution today, such as production of cement, steel, ammonia, hydrogen and in natural gas cleaning. CCS may also be necessary on bioenergy production, producing negative emissions.

GOVERNMENT FUNDING

Government funding has been important for the first large-scale CCS project built so far. But in the longer term, public funding will not be sustainable because of limited government budgets.

An important role for government in the shorter term is early stage establishment of storage capacity, both on the regulatory side and incentives. This is important to reduce storage uncertainties and cost, to provide "proven and bankable" storage for early CCS projects.

In the long term perspective government taking the post-storage long-term liability for CO_2 is important to reduce the long term storage cost for all CCS projects.

INVESTMENT FUNDING VIA MARKET MECHANISMS

Investment subsidies via market mechanisms are being used as a support mechanism for CCS in the European Union (i.e. the New Entrants Reserve Scheme, more widely known as NER300), with no success so far. The NER300 competition has shown that few companies have the appetite to cover the cost of project development up to the stage of application without greater certainty of receiving support and being able to fulfil the project. Reduced cost for allowances has reduced the fund substantially. Large projects and uncertain economical support can result in a long and complex stop-start planning process. Application-based support systems are not suitable for large-scale deployment.

CO_2 TAX AND ETS

Qualitative interviews conducted for this report revealed that many stakeholders in the industry advocate the introduction of a comprehensive CO_2 tax as the best solution. Still, the chances for political acceptance are low for a sufficiently high CO_2 tax or strong ETS. Even though a combination of carbon tax and ETS theoretically provides emissions reduction at the lowest cost, it does not promote technology development for step change technologies with higher initial costs. The cost of emissions needs to be high for all emitters before CCS is deployed and will have negative consequences for carbon leakage in industry, without some kind of broader carbon adjustment or free allocation of allowances. While a low or medium price will not provide sufficient incentive to carry out CCS, however, it can be more feasible politically and contribute to covering operational costs, in addition to other instruments to cover investments costs.

FEED-IN TARIFFS

For the deployment of renewables in Europe, national feed-in tariffs have been crucial. An FIT system has its primary strength in stimulating the learning phase of a new technology, in boosting the learning curve and reducing costs. Still, there is a large risk for under or over-compensation, which may be harder to adjust for in CCS than in renewable energy because the projects are fewer and larger. The disadvantage of FIT is that the penetration of abatement technologies will depend on the right price level for the tariff.

CCS CERTIFICATE SYSTEM

A portfolio standard is commonly used for renewable energy, demanding that suppliers have a minimum renewable share in their energy supply. A portfolio standard comprising all companies makes a certificate system. The basis for a CCS certificate is:

- Suppliers of fossil fuels are obligated to do CCS as a share of their production. For flexibility, they can do so themselves or trade CCS certificates from other projects.
- Industry/power with CCS receives certificates per “clean” unit produced (electricity/ cement/steel, etc.)

A way of explaining this system is fossil energy with deposit on CO_2. As for deposit on bottles, the buyers of fossil energy “returns” the CO_2 to safe storage in order to get the deposit refunded. Or in other words, the CCS certificate system obligates the companies who takes carbon up, to bring carbon back in the ground.

The major advantage with the certificate system is that politicians are setting a specific binding target for CCS deployment, while the market is setting the price for the certificates to fulfil the volume. The long-term predictability for the volume and the competition between projects are factors which help in selecting the most cost-efficient projects and bringing costs down. A certificate system can easily work

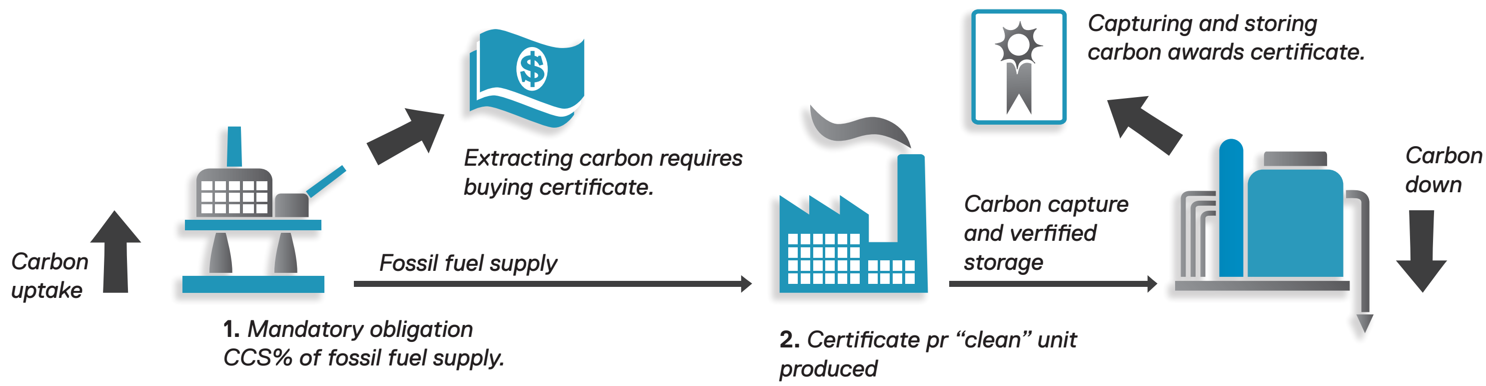


Figure 1: Simple illustration of a CCS certificate system. A more detailed explanation is given in Appendix 3.

together with a quota system, as the volume of CO_2 reduction from the CCS certificates can be withdrawn from the ETS market.

A certificate system is a cost-sharing instrument, distributing the extra cost to all fossil value chains, and creating a minimal effect on carbon leakage issues. Placing the certificate obligation at suppliers of fossil fuels, the abatement cost will be included in the product cost for fossil fuels. This will strongly incentivise these companies to develop the CCS value chain and leverage their large relevant expertise in geology, gas separation etc. This is important for achieving the necessary competence and investments from this industry to ensure large-scale implementation of CCS.

Certificate systems are politically attractive for their efficiency towards reaching political goals. Political acceptance is more likely when costs are covered in the product price for fossil fuels.

Proper design of the certificate system is crucial to reduce the price risk and ensure investments. A concrete proposal for a CCS certificate system is shown in Appendix 3.

EMISSION PERFORMANCE STANDARD (EPS)

EPS is a very clear regulation and market condition representing a stable predictable framework for industry to invest in solutions to meet the standard. The instrument is not technology specific, providing competition between all technologies to meet the standard in the most cost-efficient way.

EPS has proven to be efficient in pollution control, such as for NOx. An EPS with regard to CO_2 was introduced in California in 2006 and Canada in 2012.

Alone, EPS entails a high risk for carbon leakage, but in combination with a certificate system and other policy instruments for renewable energy the risk is reduced. In addition, a carbon border import standard and/or an international sectored agreement for a specific sector can be a part of an EPS policy. This is the case for the Californian EPS, also regulating imported electricity from neighbour states. The same system is implemented in California for fuel through the low carbon fuel standard, which sets an emission performance standard on fuels, and including emissions from foreign production.

EMERGING AND DEVELOPING COUNTRIES

Given the importance of including emerging countries in the global CCS endeavour, instruments that include deployment in developing countries are required. Possible existing and proposed instruments under the UNFCCC are the Clean Development Mechanism (CDM), a green development fund or Nationally Appropriate Mitigation Actions (NAMAs).

Another option, recommended by this report, is to include developing countries in a certificate scheme, to create a market for company-to-company investment to speed up CCS deployment across all economies.

Recommendations summary

- A mandatory certificate system.
    - Obligate suppliers of fossil fuels to do CCS as a share of their supply.
    - Certificates given for production of clean products with CCS.
    - Flexibility for suppliers to do CCS themselves or to cooperate and trade CCS certificates from other projects.
    - Possible ooperation between countries, both developed and emerging countries.
- EPS regulation for new and existing power plants and industry, in combination with the certificate system.
- Government taking the post-storage, long-term liability for CO_2, de-risking storage cost for all CCS projects. In the short term a special government involvement and funding focus is important to establish sufficient early stage storage capacity.

CO_2 injection in Weyburn, USA. (Photo: KEMA)

Introduction

Considerable improvements in framework conditions are required to trigger sufficient development and implementation of CCS. In order to meet this major challenge, ZERO has carried out this analysis to contribute to bringing CCS instruments onto the political agenda and closer to implementation.

PROJECT AIMS

The overall target of this report is to carry out a study of policy instruments for realisation of large-scale deployment of CCS, to identify the instruments best suited and to propose specific recommendations for the way forward towards sufficient large-scale CCS implementation.

CONFINEMENT

The study is confined to looking at measures that ensure sufficient incentives to implement CCS. It does not consider other barriers that also play an important role in the successful deployment of CCS, such as legal barriers or public acceptance of storage.

The study focuses on instruments required to boost large-scale CCS deployment following the demonstration phase, illustrated by the right part of the S-curve of innovation, shown in Figure 2.

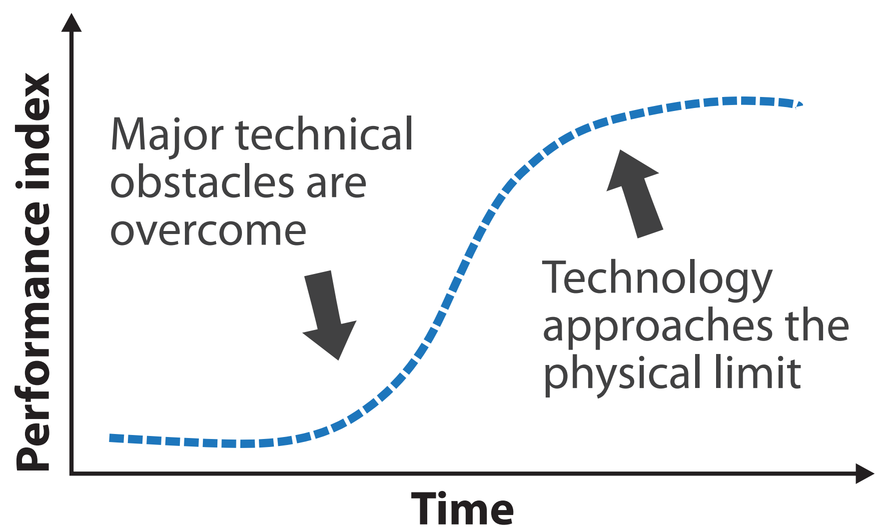


Figure 2: The S-curve of innovation.

METHOD

The study involves empirical as well as theoretical procedures:

- **Literature review and policy instrument analysis**

Relevant publications on the topic have been reviewed in order to learn from and use previously conducted work in the instrument analysis.

- **Player dialogue**

To map views and barriers and get input to form the basis for the analysis, we have engaged in dialogue with key stakeholders. The main players we have engaged with have been companies with large emissions, CCS technology suppliers, politicians, public administration, organisations and research communities. We have carried out 15 in-depth interviews with international players, and arranged two workshops (Oslo and Brussels). These activities have given important input to the study, presented in Appendix 1.

- **Reference group**

A highly experienced group of CCS stakeholders has been part of a reference group and provided input to this report.

- **Comparative analysis**

The analysis points out pros and cons for the most important measures and discuss them against each other.

STRUCTURE OF REPORT

Chapter 1 sets out the background of the challenge and the need for new policy instruments for CCS. The chapter also gives a brief outlook on the situation with increasing shares of renewables in the power markets. This gives an important background and perspective to what role there will be for CCS under these changing conditions.

Cases for types of emissions sources where CCS could be most realistic are described in Chapter 2.

Chapter 3 is the core of the report, with description and evaluation of the most appropriate and efficient policy instruments considered to enhance CCS deployment. The instruments are assessed according to following criteria:

- Proven successful today (for large-scale for CCS or renewables)
- Makes business case viable?
- Brings costs down
- Political acceptance
- Carbon leakage
- Ensures the necessary scale of CCS?

In this chapter, we have also taken a look at instruments for CCS in developing countries.

Recommendations are summed up in Chapter 4.

In Appendix 1 we give a summary of the most valuable findings from the stakeholder interviews and workshops.

Appendix 2 gives an extensive country overview of the current CCS policy, as an important background and starting point for the analysis.

Appendix 3 provides a concrete description of a CCS certificate system.

Background

Capture and storage of CO_2 from major emission sources are important measures for mitigating climate change. Many representatives from science, politics and NGOs have pointed to the fact that achieving the 2°C target will be impossible without the use of CCS within energy production and industry. Several analyses of the global carbon budget claim that negative emissions from CCS on biomass plants is also needed[1]. Despite the urgency, the development of CCS projects worldwide is discouraging.

The International Energy Agency (IEA) has called CCS a fundamentally important technology to reduce global CO_2 emissions and avoid dangerous anthropogenic climate change. According to the 2°C scenario[2] in IEA WEO 2012 a total cumulative mass of approximately 120 $GtCO_2$ would need to be captured and stored between 2015 and 2050. In this scenario, CCS contributes 14% of the total emission reductions through to 2050.

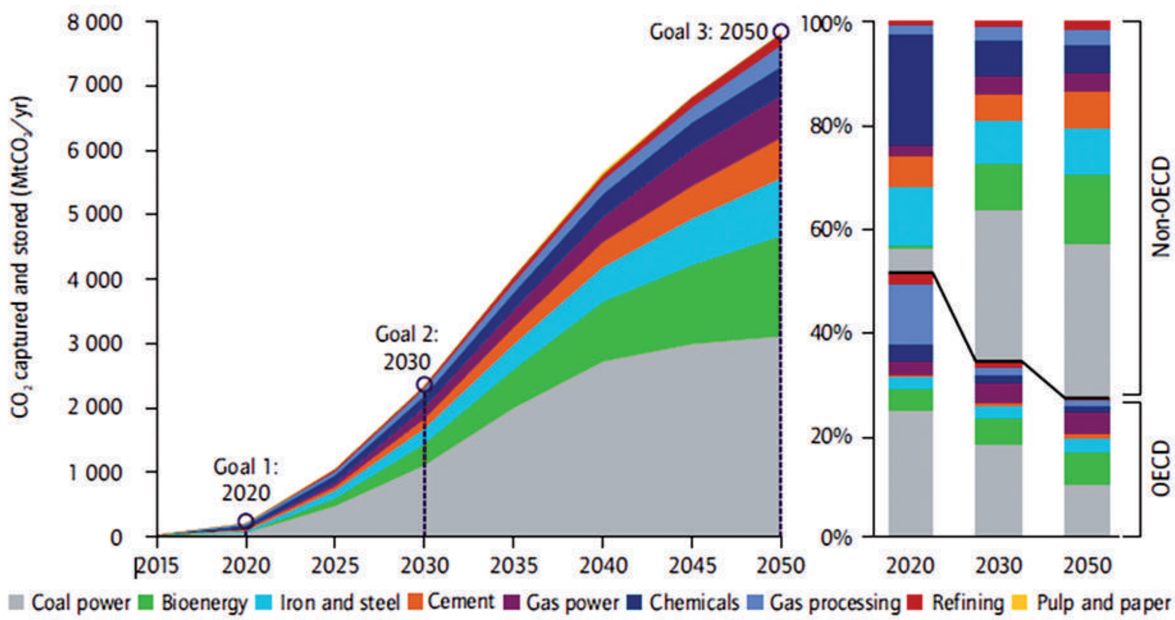


Figure 3: CCS in the power and industrial sectors in the 2C scenario, CCS Roadmap, IEA 2013.

The scenario shows over 70% of all CCS projects taking place in non-OECD countries by 2050. Industrial CCS applications account for 45% of the total volume captured and stored between 2013 and 2050. In some regions, industrial applications of CCS are far more important than applications in power generation. By 2030, CCS needs to be in use in all industries, over a level of more than 2 000 $MtCO_2$/yr.

IEA and GCCSI, in their report to the Clean Energy Ministerial in April 2012, concluded that full-scale CCS demonstration projects are not attracting sufficient investments, and that “CCS deployment will not happen without additional demonstration funding and policy incentives for deployment beyond demonstration, including strong and credible emission reduction policies.”

The IEA have previously underestimated the penetration of renewable energy in their scenarios. The authors of this report hope this will be the case again. But even then, a very large amount of CO_2 emissions will have CCS as the only realistic mitigation option in the next decades. In a special report on renewable

1 For instance: UNEP (2010) The Emission Gap Report, http://www.unep.org/publications/ebooks/emissionsgapreport/

2 450 ppm scenario with 50 % probabilitet for more than 2°C temperature rise.

energy from IPCC[3], even the no-CCS scenarios prescribe the use of CCS to achieve the 400 ppm CO_2eq target, with up to 120 Gt CO_2 stored in one scenario and 720 Gt in another.

Renewable revolution - a power market in change

The deployment of renewable energies worldwide has increased rapidly in recent years, backed by favourable support mechanisms and lowering of costs. The deployment has been especially successful in the electricity sector, where wind and solar accounts for a major share of new production capacity. Total renewable power capacity worldwide exceeded 1,470 GW in 2012, up 8.5% from 2011[4]. This equals more than 26% of total global power generating capacity. The share of total capacity made up by renewables is continuously growing and, in 2012, they made up over half of net additions to electricity generating capacity[5].

The price of renewable technology has decreased remarkably since the early 1980s, as shown in Figure 3, which depicts experience curves for wind and solar energy.

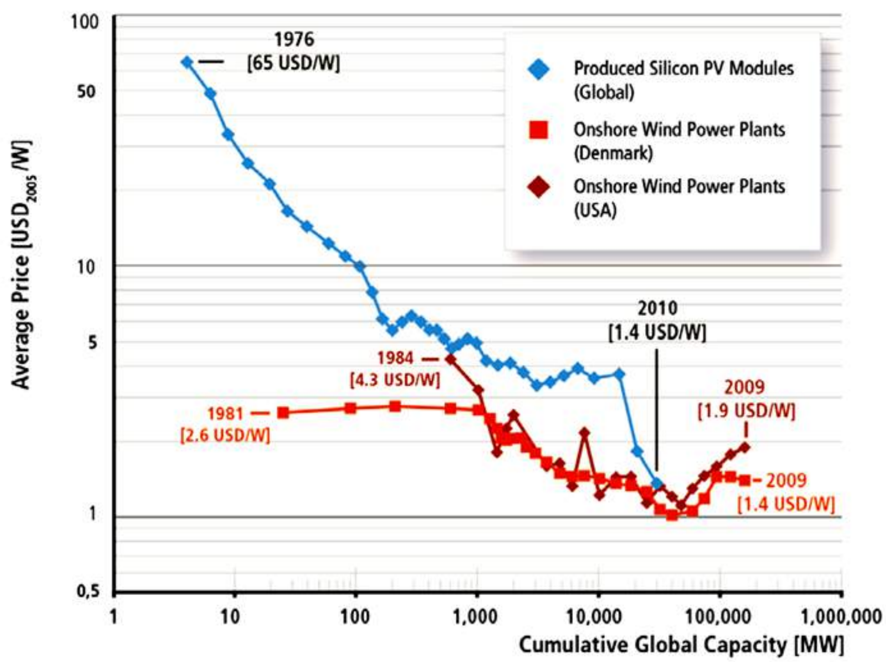


Figure 4: Experience curves in logarithmic scale for the price of silicon PV modules and onshore wind power plants per unit of capacity (IPCC 2011).

Recent cost estimates for renewable energy globally varies between 5 – 38 UScent/kWh in levelised cost of energy (LCOE), depending on location and technology. Comparable cost for CCS is about 25 UScent/kWh (LCOE). The costs are expected to decrease in line with technology up-scaling, down to 14 UScent/kWh in 2030[6].

3 Special report on renewable energy, IPCC, 2011. (Figure 10.6 p. 806) http://srren.ipcc-wg3.de/report/IPCC_SRREN_Full_Report.pdf

4 REN21 (2013): Renewables 2013 Global Status Report, http://www.ren21.org/REN21Activities/GlobalStatusReport.aspx

5 http://www.ren21.org/REN21Activities/GlobalStatusReport.aspx

6 http://www.platts.com/IM.Platts.Content/ProductsServices/ConferenceandEvents/2013/pc365/presentations/10_Allan_Baker.pdf

Variable renewable energy has zero or a very low marginal production price, due to the zero fuel cost. The total system cost with energy storage or backup power is of course higher, but the low marginal production cost changes the whole market dynamics. Once the investment is made, it is the nature, not the market price that decides how much electricity is produced.

The increasing share of renewable energy in the power sector has made electricity prices in some European countries drop to very low and even to negative figures in some hours[7]. This has significant consequences for the power market and for investors in both renewable and conventional energy. As the share of renewables increases further, it creates a system where predictability and likely investment profitability for fossil operators gradually disappears[8]. Large solar deployment has reduced previous high peak prices on daytime significantly. This situation is different in, for instance, North-America, where there is mainly a regional monopoly situation.

This can be illustrated by the development of the *clean spark spread* for gas-fired power plants, defined as the regular (or "dirty") spark spread minus the CO_2 emissions cost. This spread represents the net revenue on power sales after gas costs and emissions allowance costs[9]. In Germany, the spread used to vary enormously within the months April – September, with values from -30 Euro to over 50 Euro/MWh, as shown in figure 5. After the construction of more renewable energy, the spread has diminished considerably.

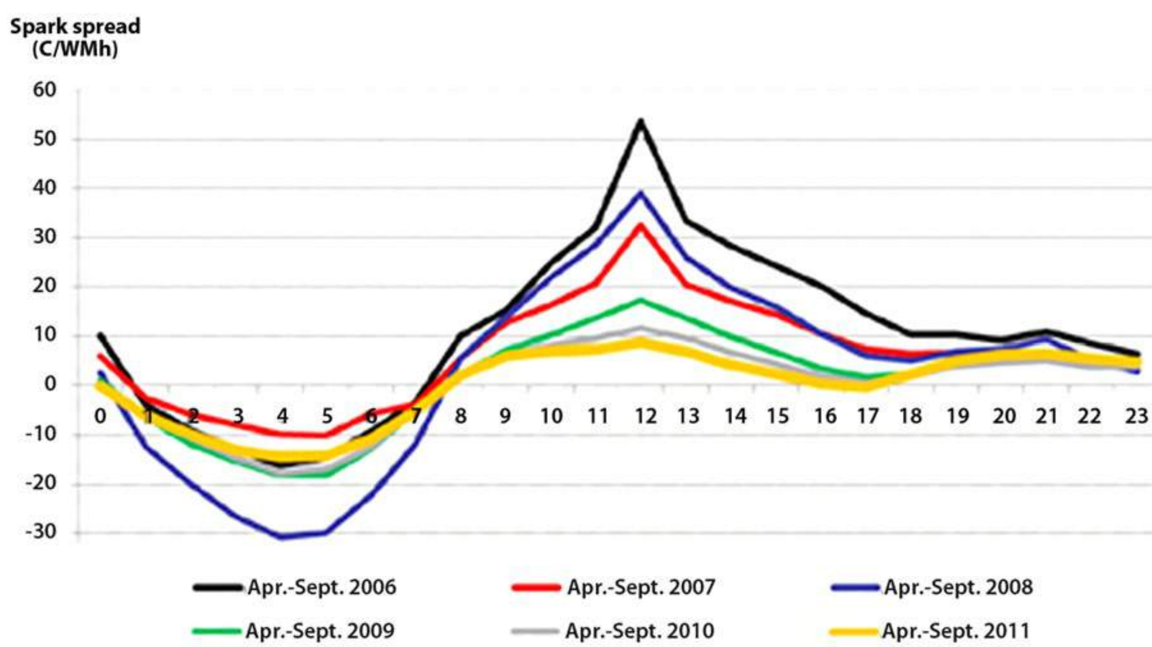


Figure 5: The clean spark spread for Apr-Sep 2006-2011 in Germany, in Euro/MWh[10]

A power system consisting of large shares of variable energy production results in new demands for balancing power and storage capacity and reduced need for fossil base load. There are several options for resolving these new requirements, including hydro storage, power-to-gas technologies (for example, hydrogen), large-scale grid deployment, new battery installations and the use of fossil power stations as back-up and balancing capacity.

7 Operators are thus being paid for taking load out of the grid. http://energiogklima.no/nyhetsblogg/bjartnes/to-bilder-av-europa-fossilt-og-fornybart/

8 http://co2handel.de/article343_20051.html

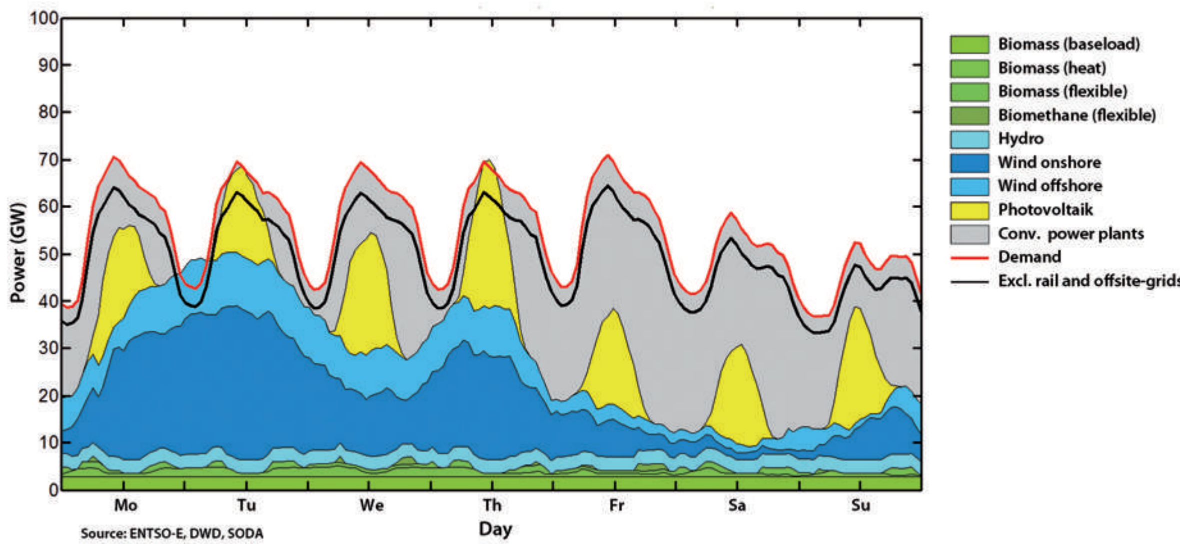
9 An analogous spread for coal-fired generation plants is typically referred to as a clean dark spread or a dark green spread.

10 Presentation, UMB 20.10.2011, Torjus Folsland Bolkesjø.

The global technical potential of renewable sources is not the limiting factor for growth in the use of renewable energy. But renewable energy is facing several barriers that can prevent full use of its potential, such as a lack of grid capacity, opposition to use of areas for renewable energy production, and large investments already made in fossil power plants and infrastructure – which gives a low operation cost for paid-off plants, economical interest and political pressure in continuing this value chain.

A huge amount of fossil energy and emissions in the power sector needs to be replaced with renewables and CCS. The role of CCS needs to take into account this changing situation in the power market in order to provide robust policy instruments for CCS.

RENEWABLE ENERGY GENERATION AND DEMAND DURING SUMMER (MID AUGUST)



RENEWABLE ENERGY GENERATION AND DEMAND IN A WEEK WITHOUT WIND (END NOVEMBER)

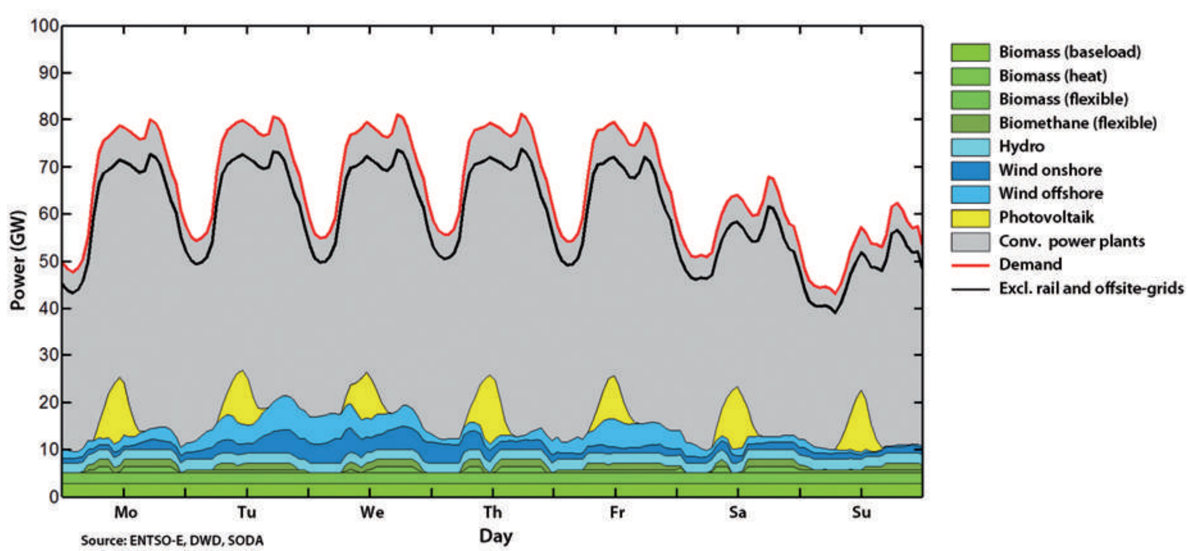


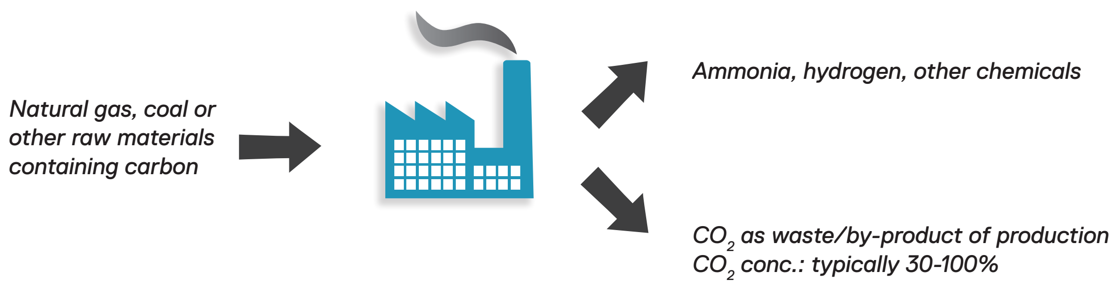
Figure 6: Example of renewable production and demand projections for summer and winter time in Germany in 2022.

Cement factory in Breivik, Norway. (Photo: Norcem)

Robust cases for CCS

Below are some cases where the use of CCS appears more robust. Where the alternatives for other mitigations options to remove the emissions are few there is the potential to have a robust business case for implementing CCS. These cases illustrate different industry segments' need for CCS and the possibility of establishing a robust CCS value chain as effective CO_2 abatement across a wide range of emission types. These cases are used as concrete examples for the evaluation of the different policy instruments later.

Case 1: Industry, Concentrated CO_2



- Fertilisers/ammonia
- Hydrogen production
- Chemical industry

ADVANTAGES

- Lower capture cost
- Stable CO2 source
- Located in industrial clusters/coastal locations => possible lower transport cost
- Industrial experience from commercial use (CO_2 for soft drinks, fire extinguishers, etc.)
- Excess energy can be used CO_2 capture
- Few alternatives for process emissions

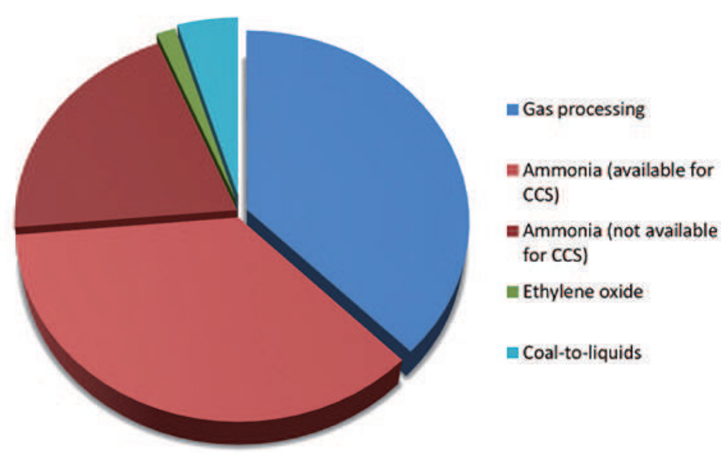
EXAMPLE

Yara ammonia plant, Norway

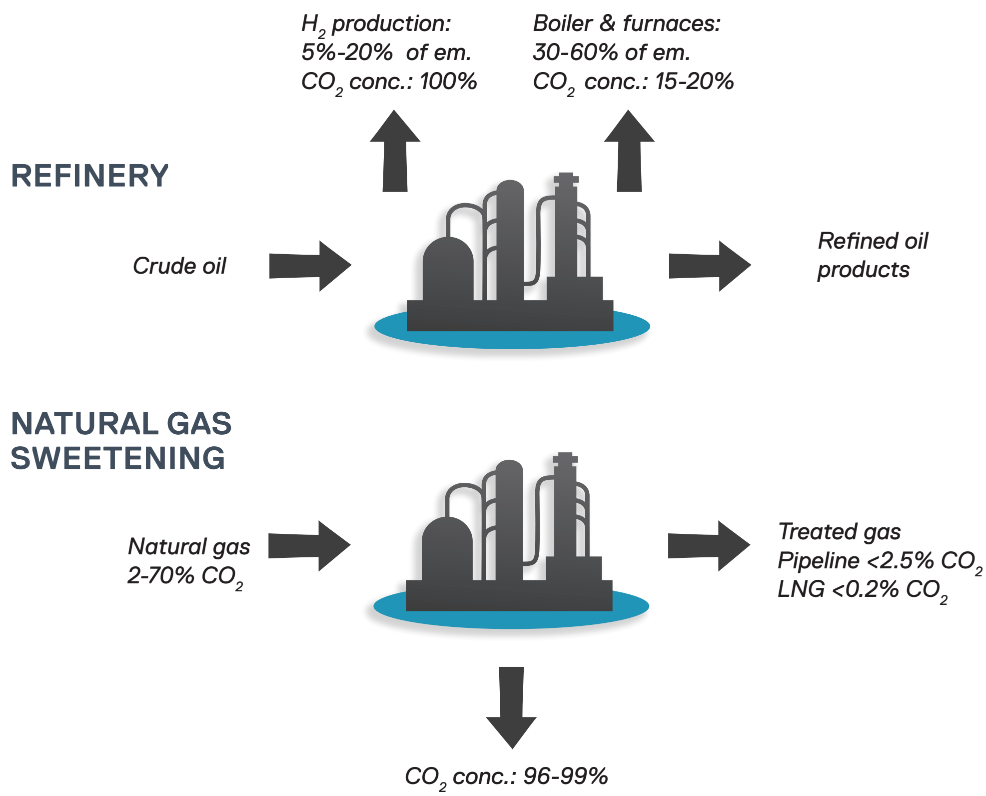
- ~1,2 Mt CO_2/y
- 0,8 Mt captured
- ~0,2-0,3 Mt sold
- Rest is emitted

CCS POTENTIAL

High purity total = 430 Mt CO_2 (Including gas processing, excluding refining)



Case 2: Petroleum industry



ADVANTAGES

- High CO_2 concentration = lower capture cost
- Experience with gas treatment, CO_2 EOR and geology
- Several CCS projects in operation (natural gas sweetening)
- Excess energy can be used for CO_2 capture

CHALLENGES

- Complicated industrial sites/strict HE requirements could lead to higher investment costs

CCS POTENTIAL

- Gas processing: ~160 Mt
- Oil refining: ~1100 Mt

EXAMPLES

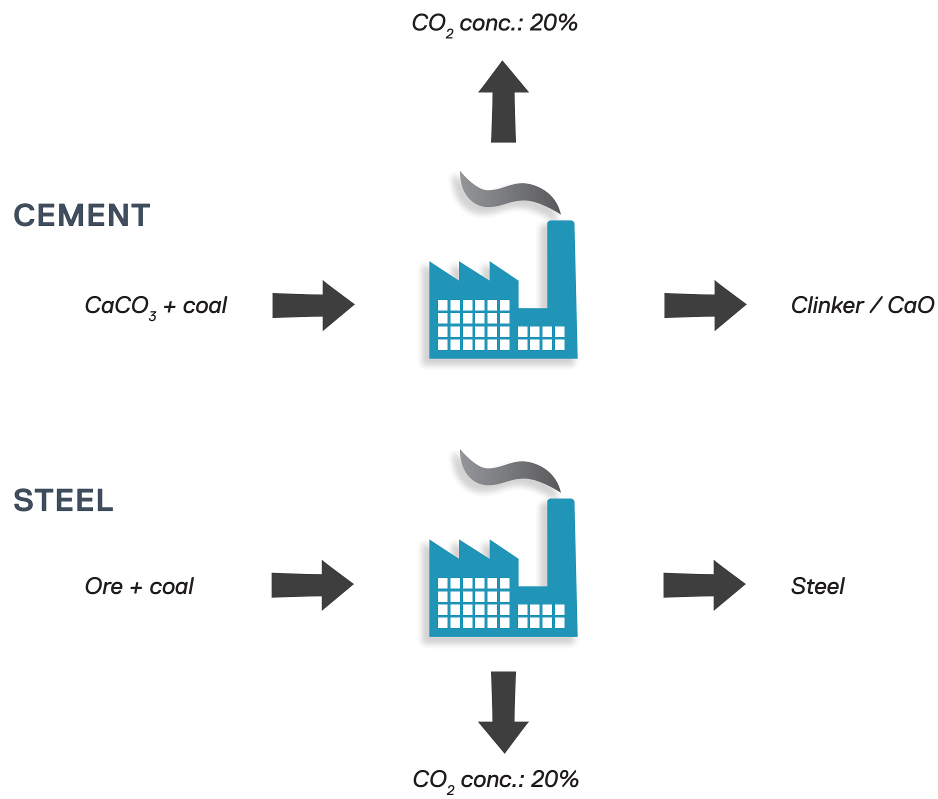
Scotford Upgrader, Quest CCS-project (Shell), Canada.

- Emissions: ~7 Mt/y
- CCS project: ~1 Mt/y from H2 production
- Construction started
- In operation 2015

Shute Creek gas processing plant, Wyoming, USA

- Began storing CO_2 in 2004
- CO_2 for EOR. One of the largest EOR projects in the world.
- Currently ~7 Mt/y
- 400 km CO_2 pipeline.

Case 3: Industry, very large emissions



ADVANTAGES

- High CO_2 concentration = lower capture cost
- Excess heat can be used for CO_2 capture
- CCS only mitigation option for the process emissions
- No replacement products for major use of cement and steel

CHALLENGES

- Steel mills need to be rebuilt/refurbished to yield high CO_2 concentration

CCS POTENTIAL

- Iron and steel: ~2.3 Gt/y (30% of industry emissions)
- Cement: ~2 Gt/y (26% of industry emissions)

EXAMPLES

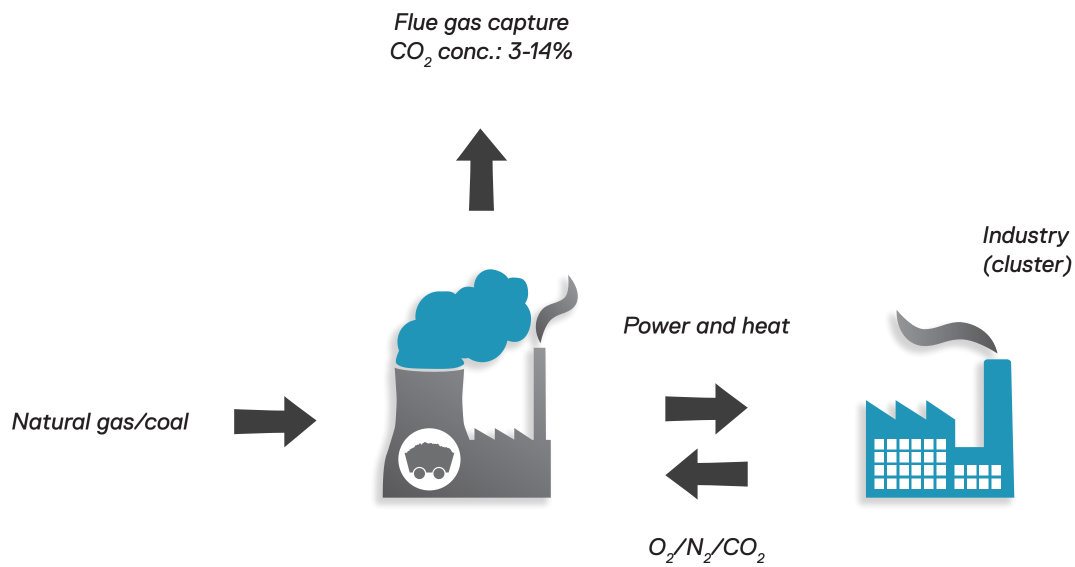
Norcem Heidelberg cement plant, Norway

- CCS potential: ~1 Mt/y
- Pilot phase planning completed

ArcelorMittal/ULCOS CCS demo project

- CCS demo project: 0.5 Mt/y
- Applied for NER300 but withdrawn in late 2012

Case 4: Integrated CCS; Energy supply to energy intensive industry



ADVANTAGES

- High base load power and heat demand. Hard to replace by renewables -> needs base load power production -> good case for CCS
- Excess heat from industry can be exploited for the CO_2 capture process
- Industry cluster: Large emissions in small area gives lower cost for transportation and storage
- Existing industry infrastructure gives lower cost for building, operations and utilities

CHALLENGES

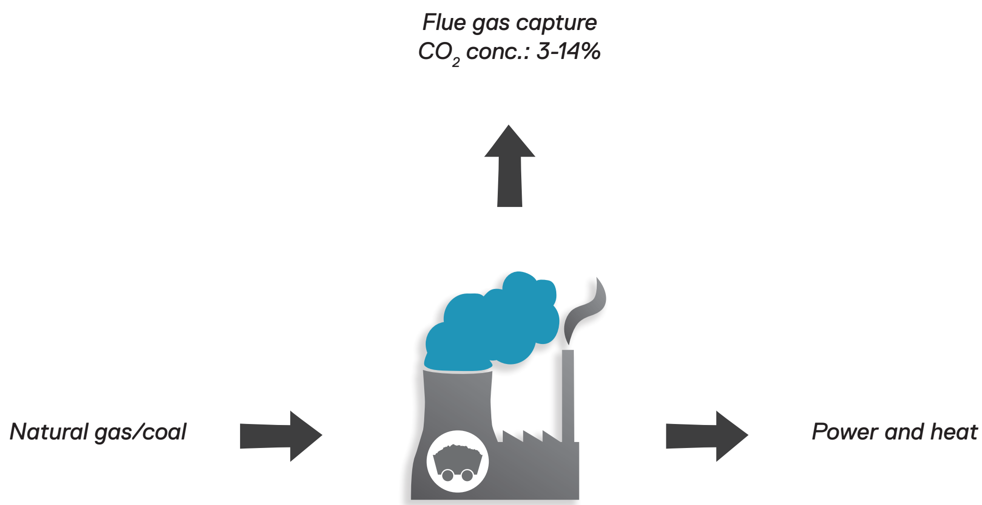
- Energy is major cost & competition factor for these industries. Higher energy cost with CCS

EXAMPLES

Qatalum Aluminium and CCGT Qatar

- One of the world's largest aluminum smelters.
- The complex is served by its own 1350 MW captive combined cycle power plant.

Case 5: Power plants in locations where there are major barriers for full implementation of renewable energy



TECHNICAL LIMITATIONS

- Limited grid capacity for power transfer
- Limited renewable potential compared to energy need
- Volatile renewable production can need fossil base load/backup for security of supply

POLITICAL LIMITATIONS

- Political inertia for changes delaying fossil fuel phase-out.
- Large fossil resources/economic investments/ jobs, delaying renewable implementation

ADVANTAGES

- No alternative or high cost for other mitigations options can give good conditions for CCS.
- Large fossil (coal) reserves with no/low alternative value, can give high willingness to invest in CCS

CHALLENGES

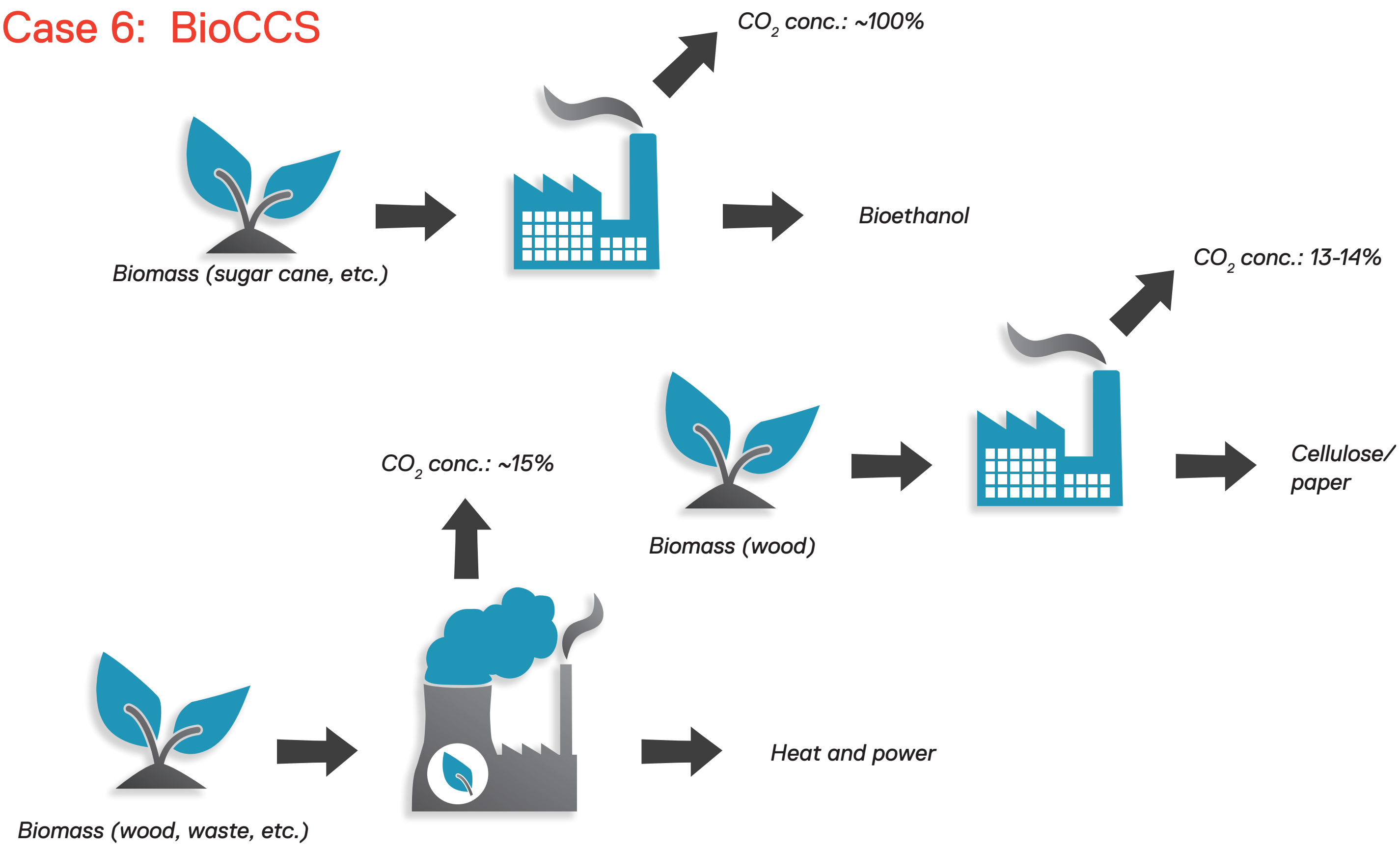
- Political inertia for changes can be challenging for large CCS investments.
- Flexible fossil production as backup/peak power can give increased cost for CCS

EXAMPLES

Boundery dam CCS, Canada

- Coal fired powerplant with CCS, 1 Mt/y
- Construction started 2011, in operation 2014
- Large coal reserves with no/low alternative value
- Weak grid capacity for large reneable production

Case 6: BioCCS



ADVANTAGES

- Bioethanol: Low cost for CO_2 capture.
- BioCCS gives "negative" emissions. Can reduce concentration of CO_2 in atmosphere.
- Co-firing biomass can yield (less than) zero CO_2 from a coal with CCS.
- Biomass is important renewable source for energy and raw materials replacement of fossil.

CHALLENGES

- Bioethanol plants located near field. Uncertainty for storage sites.

CCS POTENTIAL

- Bioethanol: ~69 Mt/y, 190 sources, mainly in Brazil.
- Pulp and paper: ~540 Mt/y global estimate.

EXAMPLES

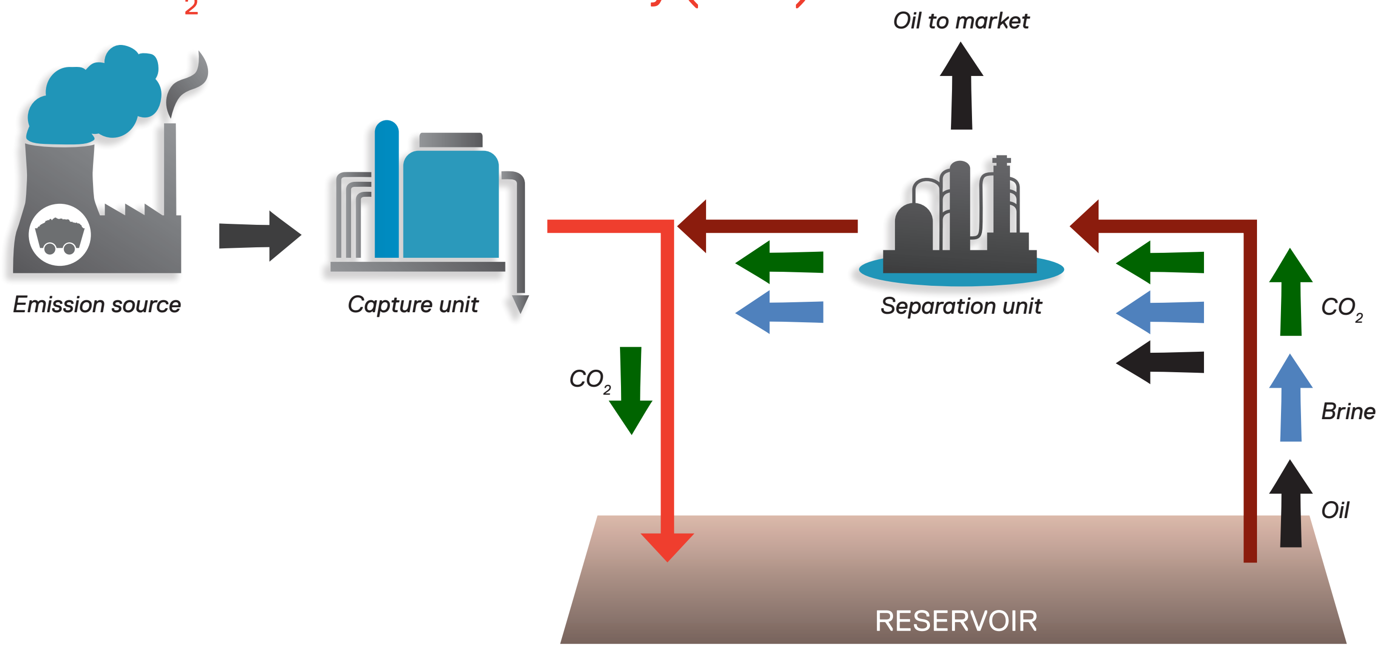
Illinois Bioethanol with CCS

- 1 Mt/y
- Construction began in 2011
- Fully operational summer 2013

Södra Cell Värö

- BioCO_2-emissons: ~1 Mt/y
- Suitable for CCS

Case 7: CO_2 Enhanced Oil Recovery (EOR)



CCS POTENTIAL

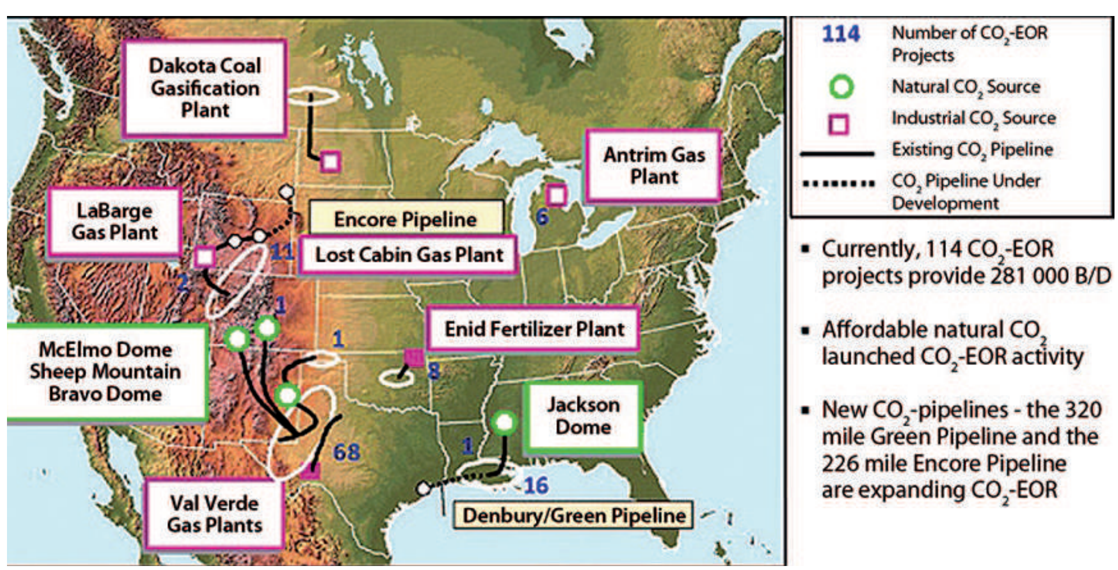
- 50 largest oil basins can store 140 Gt CO_2 with "state-of-the-art" CO_2-EOR technology
- Large potential income covers CCS cost: 470 bn barrels of added oil
- Applied to smaller fields, additional >1 trillion barrels of oil, and 320 Gt CO2 storage.

ADVANTAGES

- CO_2 EOR been in use commercialy in US for more than 40 years
- EOR has been the single largest driver for CCS so far (in US and Canada)
- Value for CO_2 to EOR in the range of 30-40 $/ ton CO_2

CHALLENGES

- Geographical and volume limitations for how much CO_2 potentially to be used for EOR



Source: Advanced Resources International, Inc., based on Oil and Gas Journal, 2010 and other sources.

Policy instrument analysis

This analysis concerns the following instruments:

- Government funding
- Investment subsidies via market mechanisms
- Carbon tax
- Feed-in systems
- Certificate system (portfolio standard)
- Emissions performance standard (EPS)
- Emissions trading system (ETS)

The instruments are analysed according to the following criteria:

- **PROVEN SUCCESSFUL FOR LARGE-SCALE CCS /RENEWABLE ENERGIES?**

Evaluation of previous application of the instrument, either on CCS, or other mitigation technologies, such as renewable energy.

- **MAKES BUSINESS CASE VIABLE?**

Investors need to have sufficient predictability for future income and risk to create a viable business case for large investments to be made. Without this, no CCS deployment will happen.

- **BRINGS COSTS DOWN?**

This involves the innovation aspect of the instrument. This criterion is not about the costs reduction because of increased volume, but whether it provides the right incentives for companies to carry out CCS projects at the lowest possible cost, and invest in technology and cost improvements. This is, in our opinion, the most important factor for cost efficiency in the policy instrument towards the total cost of CCS deployment. In other words, this is *not* the traditional theoretical cost-efficiency of the policy instrument analysis.

- **POLITICAL ACCEPTANCE?**

Considers the chances of political decision and implementation of the instrument. This report keeps the evaluation on a general level, bringing in some barriers to implementation in different contexts, but not conducting a country specific analysis.

- **CARBON LEAKAGE?**

Refers to the shifting of production to countries that do not impose an equivalent climate policy. The major risk for carbon leakage occurs when an industry is exposed to high trade intensity. It is important to keep in mind many other factors than climate policy on deciding the location of an industry's production. All industry moves so far have been due to other causes, since emissions cost and regulations for industry on climate has been non-existent or very low. But with new policy instruments at a total different level than today, this can change.

- **ENSURES THE NECESSARY SCALE OF CCS?**

And finally: does the instrument bring us where we want and need to be by 2050? To what degree will this instrument be efficient in achieving the specific targets?

The reason why we have chosen these criteria is that they together reflect what we consider to be the most important aspects and barriers for CCS deployment worldwide. Other criteria could have been analysed as well, such as cost-efficiency, public acceptance, compatibility with other policy instruments and others. Some of these questions are for more general discussion, which is relevant for all instruments, and been touched upon in the short analysis for policy instruments for components of or the entire CCS chain, and specific instruments for different industries or general CCS instruments.

Policy instruments for components or whole CCS chain?

The CCS chain consists of different technologies and the need for different competences from capture to storage. As both the transportation and permanent storage of CO_2 requires large infrastructure solutions – which are a barrier for many projects – some industry and public authority stakeholders have argued that there should be separate instruments for these parts of the value chain. There are pros and cons for having policy instruments for the whole chain. The most important of these are listed below:

PROS:

- A combined support mechanism for the entire CCS value chain would allow for a simpler system seen from the point of view of regulators and authorities.
- If sufficient instruments for CCS, the operators of different parts of the CCS chain will be able to make commercial arrangements to do the CCS chain with different companies involved.
- Some parts of the CCS chain can be delayed by lack of incentives for the rest of the chain. Specific instruments for the different parts could give incentives that are too large, too small or not optimal investments.

CONS:

- Capture, transport and storage have very different risk profiles. A general picture is that the industries (outside the petroleum sector) traditionally do not have geological knowledge for underground storage of CO_2. Hence, it may be difficult to assess risk. Dependence on third parties for transport and storage could increase risk and cost.
- It can be easier to invest in larger infrastructure for lower transportation cost per ton of CO2. This can give larger flexibility for other projects to be included later rather than accommodating a single project.
- If several capture plants are using the same transportation and storage infrastructure, commercial arrangements – similar to those in gas transport and storage – need to be in place to regulate access and user priorities. Those involved in different parts of the chain will seek to optimise their position. In which case, there might be a need for regulations and/or commercial agreements to cater for an effective economic and risk relationship across the full chain.

Many of the instruments can be introduced either for one part of the CCS chain, or for the whole chain. We have not analysed different variants for each instrument. In general, for long-term instruments for large-scale CCS, we are focusing on instruments for the whole CCS chain and not separate instruments for each part.

In the shorter term there are important issues to be solved to be able to establish sufficient storage capacity. A clear message from the interviews was that the storage part is very important if CCS is to happen at all, and that there is a need for focus and measures to solve this. Special government attention and involvement is important to solve this, and separate instruments can be needed for this part (see more in the government funding chapter).

Specific or general CCS instruments?

The power sector and the industrial sector represent two very distinct entities, with different owners, production conditions, international trade intensity etc. Separate instruments for each could provide advantages, such as:

- Allowing the customisation of policy to best fit the different types of emission sources.
- Ensuring the introduction of CCS in targeted industry, where initial costs are higher in some sectors.

On the other hand, general CCS instruments for all large emissions sources would:

- Lay the ground for good and fair competition between all sectors to achieve the lowest costs of CCS.
- Allow all types of CCS projects, not just the sectors pinpointed in more specific programmes.
- This will increase the amount of projects competing, and reduced the risk for not as robust projects as incentives for just one sector can have.
- Facilitate solutions for CCS clusters involving the capture of CO_2 from different sources in same area.
- Reduce the risk for large opposition against implementing CCS policy from green stakeholders negative to coal power, as a separate CCS in power sector instrument may have.

Many of the instruments can be introduced either as a general or a sector-specific instrument. We have not analysed the two different variants for each instrument, but in general focused on the use of instruments for all large emissions, and not sector specific instruments.

Experiences in gas deposits in populated areas. The 1085 million m³ natural gas deposit underneath the Berlin Olympic Stadium. (Illustration: GASAG)

Government funding

Governments around the world have provided a range of different types of funding support for CCS demonstration projects, making governmental funding the most used policy instrument so far. Government funding is provided in a variety of ways, including support covering certain shares of the project, a 100% state-funded venture, investment or operation support, tax credits and loan guarantees. A government's contribution can also be assistance in reducing risk, such as accepting responsibility for CO_2 storage. Appendix 2 provides a complete overview on the most important existing policies for large-scale CCS in different countries today.

PROVED SUCCESSFUL?

Public funding has been important in triggering the establishment of the first large-scale CCS projects in Canada and USA. In other countries, such as Norway, the UK and the Netherlands, projects have carried out a large amount of planning work based on public funding. Several projects are confident that they will succeed in completing their scheme[11]. However, several projects involving government funding have also been cancelled. Some projects have been halted because of factors such as local opposition or legal barriers, and others because grant conditions have been unfavourable. In other cases, the promise of government funding has not been fulfilled, for varying reasons.

MAKES BUSINESS CASE VIABLE?

Government funding provides certainty and reduces financial risk and costs, after support is given. With investment support upfront economical payments is an advantage. In general, it is easier for the government to help with initial funding of investment costs, than for long-term operational support. So the business case for the operating phase can be more challenging. But operation-linked support can also be viable.

Government funding processes are, in general, limited both in terms of money available for support and the time period in which it is possible to apply for support. For application-based support, a long period for application and evaluation means a project planning process with several "starts and stops". This increases planning time and costs. The result from the process can be zero support and a failed project, reducing the interest and possibility of companies investing in the development of projects up to the stage of application/completion for funding. This does not give a good foundation for viable business cases.

Long-term liability is essentially a barrier to CCS deployment within current legislation. To reduce the cost for long-term risk insurance for companies, and to make a business case for storage possible, governments can have an important role by taking the responsibility for long-term storage liability.

BRINGS COSTS DOWN?

Funding processes have on a number of occasions been shown to be slow and have a high level of uncertainty regarding whether a government will fulfil their promises, dependent on parliamentary budget decisions. This leads to a long and uncertain planning process with increased cost.

When governmental support is available there will be an incentive for companies to try to get as much funding as possible. This can contribute to reduced focus on bringing costs down for the project.

Competition between projects is important to ensure the most cost-efficient schemes, and not support for just one specific project[12]. But with very large projects of different types, it is challenging for the

11 Interviews with industry.

12 Like in Norway, where the government has an agreement with one company to cover the total cost of the project, without limitations for the total expenditure.

government to evaluate large complex projects and set the right support scheme in order to provide good incentive to bring down costs.

In order to ensure cost efficiency, it is crucial that the operator has an economic benefit in fulfilling the projects at the lowest price. This can be achieved by companies paying a share of the cost themselves, and incentives in the support model for the company to reduce cost and time.

It is also important to inspire an overall strategy and interest for the CCS projects among all those involved. Emissions regulations and emission costs can help achieve this. This was mentioned in several of the interviews conducted as part of this study.

POLITICAL ACCEPTANCE

In general, there is political acceptance for public funding for technology development phase. For large-scale deployment, it will be much harder to gain political acceptance for sufficient budget allocations.

Where CCS on coal is concerned, there can be large public opposition in some countries to publicly funding companies which are perceived as “big” and “dirty”. Other policy instruments, which place the cost for CCS firmly at the polluter’s door rather than government, will generally tend to have higher public acceptance.

CARBON LEAKAGE

Public funding is a cost-sharing instrument where society as a whole takes on the extra cost for CCS over the common tax bill. Low extra cost directed at industry gives no risk of carbon leakage. It may well prevent it as the government takes on a large share of the additional costs connected to abatement activities, and reduces the carbon cost risks for the plant. However, increased government spending must be financed. The way the increased taxes, or other ways of financing the government spending, are implemented will decide the total effects of carbon leakage.

ENSURES THE NEEDED SCALE OF CCS?

Government funding is first and foremost an instrument for promoting the establishment of CCS in an early learning phase. It is both political unfeasible and overly expensive to continue with large-scale public funding of a large amount of projects.

SUMMARY

Proven successful	Makes business case viable?	Brings costs down?	Political acceptance	Carbon leakage	Ensures needed scale?
+	÷	÷ ÷	÷ ÷	+ +	÷ ÷

IMPORTANT GOVERNMENT ROLE FOR STORAGE

The best way for governmental long-term support of large-scale CCS can be to take responsibility for long-term storage liability. When considering the prospect of storage for hundreds of years, only governments can have the necessary long-term perspective. By taking on long-term liability, government would also have the responsibility to issue approval of storage sites early on in the planning process.

In the shorter term there are important issues to be solved to establish sufficient storage capacity. Special government attention and involvement are important for this. Both on the regulatory side and also on the incentive side to bring storage forward at a pace needed. Establishing storage is a time-consuming and costly process. Establishing large storage capacity is important for de-risking storing uncertainties and cost, to provide “proven and bankable” storage for early CCS projects to bring the total cost for CCS down.

Investment subsidies via market mechanisms

Investment subsidies through market mechanisms are funding where the money is raised in the market and support is given by a fund. The financing can be either designed as a fee/tax on emissions or product (like electricity, petroleum products), or financed through sales of emission allowances in an ETS, as with the NER300 mechanism in the EU. Funding for CCS projects is provided by a fund administrated by the government or by the industry.

PROVED SUCCESSFUL?

So far, NER300 has not been successful in realising CCS in Europe. The reduced price for allowances has reduced the value of the fund substantially. In the first call for NER300 projects in 2011, there were 22 applicants for CCS projects, but none of these was eligible for funding.

A Norwegian NOx-fund model has been more successful in providing investments and implementation of NOx abatement technologies. Here, the companies are paying a fee for their emission into an industry administrated fund, on the basis of an agreement between industry and government making industry avoid NOx tax in return for agreed emissions cuts and financing of the fund model. However, the scale of investment needed for CCS is much larger than this NOX abatement fund.

MAKES BUSINESS CASE VIABLE?

Investment support provides certainty and reduces financial risk and costs, after support is given. But funding where the business case is totally dependent on the outcome of application for funds, and the result is out of a company’s control, creates uncertainty and reduces the interest in investing in a costly planning process.

The size of the grants may be unknown when the funding is dependent on market prices, as is the case with the NER300. This does not create a good basis for effective business cases.

BRINGS COSTS DOWN

Support to projects based on competition can select the most cost-efficient project among the applicants. But these kinds of competitions have the disadvantage of having a long and complex application and evaluation process due to large projects. Not all companies are in a position to cover the cost for project development up to the stage of application without any certainty of getting support and being able to fulfil the project.

A time-consuming start-and-stop funding and planning process is not good for bringing costs down. It is recommended that long periods between calls for projects are avoided as this may hamper continuous development of projects and cost-effective solutions. An effective and transparent application and selection process is also advised to build trust for a fair competition for applicants.

POLITICAL ACCEPTANCE

Financed by the market and not charged directly to consumers or the government, there is a higher chance of political acceptance. A lack of good results for CCS in the EU is reducing the probability of using this instrument in an up-scaled version.

CARBON LEAKAGE

If the costs are shared equally among emitters, a small carbon leakage risk might occur for industries with hard competition from regions where this cost does not apply. But this cost-sharing model has a much lower cost for each emitter/consumer compared to instruments where the individual emitters are paying the full cost of CCS.

ENSURES THE NEEDED SCALE OF CCS

Financial support for projects based on applications could be a model for the early implementation phase in a market, but is not manageable for large numbers of CCS projects.

Price or volume uncertainty for the funding, in combination with a cost uncertainty for the CCS projects, results in uncertainty for volume CCS with this model. To ensure a targeted volume of CCS the fee must be adjustable and not a fixed volume, such as NER300.

SUMMARY

Proven successful	Makes business case viable?	Brings costs down?	Political acceptance	Carbon leakage	Ensures needed scale?
÷	÷	0	0	+	÷ ÷

Shell Scotford Upgrader in Alberta, Canada. Construction has started for Quest CCS project ~1 Mt/y(Photo: Shell)

Carbon Tax

The carbon tax incentivises mitigation endeavours in general by penalising carbon emissions, and not giving support to any specific technology. In theory, the correct tax level should be set where the marginal benefit of abatement equals the marginal cost of abatement[13]. Taxing CO_2 emissions can be done at either a regional, national or international level. Some countries have already introduced a carbon tax, including Norway, Australia, Canada and the US. The income gathered from a CO_2 tax can be used as a general fiscal income, or earmarked to support carbon mitigation.

The result of CO_2 tax will vary depending on the tax level. Here we analyse consequences for a high tax (>100 USD/tonne) and low tax (<50 USD/tonne).

PROVED SUCCESSFUL?

The CO_2 taxes introduced so far have in general been too low to provide major shifts in emissions and technology implementation such as CCS. There are some exceptions. The CO_2 tax on petroleum production in Norway was the main reason for the two CO_2 storage projects in Norway: Sleipner and Snøhvit. The CO_2 tax was high enough to make it economically viable to inject and store the CO_2 from the natural gas cleaning instead of emitting it and paying the CO_2 tax. The tax level has not been sufficient to trigger CCS from emissions sources other than natural gas cleaning. Another mitigating measure taken because of the CO_2 tax has been a system invented to significantly reduce gas flaring from hydrocarbon producing facilities offshore.

In the Canadian province of Alberta, a low CO_2 tax has been part of the total policy framework, which has led to realising of two CCS projects.

MAKES BUSINESS CASE VIABLE?

A CO_2 tax gives predictability for investors for costs of emissions and reduces uncertainties for business cases for climate mitigation investments. Making a viable business case for CCS depends on the level of the tax and the cost compared to other mitigation options.

The predictability adherent to a stable carbon tax can be reduced if the tax is politically changed. Some countries have regulated the tax by law, which enhances certainty. In other countries, like Norway, the tax level can be changed each budget year.

Without any other incentives or regulations, the carbon tax has to be high to make it economically viable to implement CCS, i.e. making emitting CO_2 more expensive than abating it.

BRINGS COSTS DOWN?

In a CO_2 tax regime, the emitters pay the total abatement costs. This also provides each company with the economic benefit of reducing the cost for abatements and contributes to bringing the cost down.

Carbon tax operates along the economic theory principles that, given perfect competition between all mitigation options, emission reductions will be carried out where they are cheapest. If the market works and the tax is high enough, it brings mitigation costs down. If the tax is too low, there will be no incentives to investments in CCS, and no cost reductions will happen.

13 Metcalf, G. E. & Weisbach, D. (2009): “The design of a Carbon Tax”, http://www.law.uchicago.edu/files/files/447-254.pdf

POLITICAL ACCEPTANCE

The large difference between different sectors in the ability to pay high costs for emissions and the competitiveness in some industry sectors and risk of carbon leakage is a major political factor against implementing a broad national CO_2 tax.

Several interviewees argued that the carbon tax is by far the instrument required to lower emissions. They also stress the need to introduce the tax internationally, which they claim is crucial for making it work without carbon leakage. At the same time, they are very pessimistic about the political chances of this happening. The competitiveness for the industry and carbon leakage issue in general is a major political argument against high CO_2 taxes.

CO_2 taxes provide income to the government for fiscal use or for mitigation funding. If the income from the CO_2 tax is used for funding climate mitigation solutions, the necessary CO_2 tax level to trigger the mitigation investments can be reduced and eventually enhance support for the tax. A compromise with higher possibility for political acceptance is a carbon tax at a low level. This will not incentivise CCS alone, but can be a part of a policy instruments package.

CARBON LEAKAGE

A high tax introduced in one country/region for industry can result in production being relocated. The level of the emission tax triggering this move will vary for different types of industry, locations, and other policy frameworks for industry production. One solution might be to introduce a border carbon tax adjustment (BCA) for CO_2 emissions – i.e. imposing a tax when importing commodities from a country without a carbon tax and providing a rebate for any taxes paid when a commodity is exported[14]. Border tax adjustments are standard in value added tax (VAT) regimes across the world, and would be viable to introduce for a carbon tax regime as well. A challenge would be the values and documentation of CO_2 emissions for a commodity or product. A methodology for benchmark emissions numbers for different industry products are made in the EU for carbon intensive industry for the allocation of free allowances, and can be uses as a basis for a BCA tax.

ENSURES THE NEEDED SCALE OF CCS?

An appropriately sized carbon tax, together with a solution to prevent a relocation of production, such as BCA, can be sufficient to ensure large-scale CCS. Meanwhile, a CO_2 tax at low level will not give sufficient incentive to carry out CCS, but can cover operation cost, and can incentivise CCS as part of a policy instrument package.

SUMMARY

Proven successful	Makes business case viable?	Brings costs down?	Political acceptance	Carbon leakage	Ensures needed scale?
High CO_2 tax ÷ ÷	+	+	÷	÷ ÷	+ +
Low CO_2 tax +	÷	÷	+	÷	÷

14 Metcalf, G. E. & Weisbach, D. (2009): "The Design of a Carbon Tax."

Emission Trading System (ETS)

The emissions trading system is working according to a cap-and-trade principle. A cap is set for the total amount of greenhouse gases that can be emitted by the sectors included by the system. Within the cap, companies buy (or receive for free) emission allowances which they can trade if they have an under or oversupply. The price for the allowances is set in the market and the mitigations are, in theory, done where costs are lower.

The result of an ETS will vary depending on the cap level. Here we analyse consequences for a strong ETS, with a cap in line with the 2°C target (-40% by 2020 for industrialised countries), and a weak ETS.

PROVED SUCCESSFUL?

The EU has been successful in establishing a cap-and-trade system. The emissions trading system in Europe (EU ETS) is the largest operating in the world. The EU ETS started in 2005 and is now in its third phase, 2013-2020. Around 45% of the EU's greenhouse gas emissions are included.

A large amount of surplus allowances has contributed to very low prices (below €5/t CO_2) and few mitigation investments. Estimates have been made that foresees an excess of 2,2 billion allowances by 2020[15]. The large surplus has come from a combination of too large allocation of allowances in previous phases, financial backdrop and a successful renewable energy policy in some member states, and a too high cap. EU ETS has not lead to the deployment of CCS, so far.

MAKES BUSINESS CASE VIABLE?

A strong ETS can give conditions for a business case for CCS. Long-term predictability for the cap, resulting in long-term high prices for allowances, is a key factor to give right incentives for investments in large-scale mitigation solutions such as CCS. But when the main price signal in the ETS is the marginal cost for mitigation, it is harder to make a business case for long-term step change technologies with higher initial cost. Additional instruments might be needed to cover the extra cost for technology development and first phase of deployment, to get the cost learning curve down to compete with more mature mitigation technologies within the ETS.

A weak ETS with low prices give low incentives for CCS. It can contribute to covering operation costs in combination with other incentives to cover investments cost.

To compensate for the low carbon price in the EU ETS and to reduce price risks, UK has legislated to introduce a carbon floor price, a minimum price on CO2. This strengthens the incentives for investments in low carbon solutions[16].

BRINGING COSTS DOWN?

In theory, an ETS should be one of the most efficient ways to reduce emissions within the cap, enabling competition between all kinds of technologies and projects for lowest cost emission reductions. The emission source is paying the cost for mitigation itself, giving good conditions for cost reductions. But also a strong ETS has the challenge to incentivise investments in long-term step change technologies with higher initial cost.

15 Guardian 24.01.2013, http://www.guardian.co.uk/environment/2013/jan/24/eu-carbon-price-crash-record-low

16 DECC UK Gov (2012), https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/66554/7077-electricity-market-reform-annex-a.pdf

POLITICAL ACCEPTANCE

The principle of setting a cap for the emissions has strong political support at least in international climate policy level. But to achieve a strong ETS is much more politically challenging. Since all of industry has to pay the same cost for emissions and pay for the mitigation cost themselves, there is major political opposition against lowering the cap in EU ETS.

CARBON LEAKAGE

The emitters pay the full cost for mitigation, and the price for allowances will be at the level for the highest abatement cost to reach the cap. This is similar to carbon tax and therefore the same aspects regarding carbon leakage apply as described above.

The ETS has the possibility of granting industry sectors free allowances to reduce the carbon leakage risk. This is done in the EU ETS. The industry's incentives for emission reduction will still be determined by the value of selling allowances. The effect is less income for the government from selling the allowances.

ENSURE THE NEEDED SCALE OF CCS?

A strong ETS with a sufficient long-term cap can result in a price for allowances sufficient to trigger CCS. But it can also have challenges in triggering investments to implement long-term step change technologies with higher cost, such as CCS. For the technology up-scaling of CCS, an ETS will realistically not be the only policy instrument trigger.

A disadvantage with an ETS is that is often used as an argument against any other policy instruments for emission reductions. The assumption is that any efforts in emission reduction will have no effect since the total emission level is set by the cap, and all emission reductions will therefore be offset by an increase somewhere else within the cap. Therefore, an ETS also contributes to blocking other instruments to make CCS and other emission reductions happen.

SUMMARY

Proven successful	Makes business case viable?	Brings costs down?	Political acceptance	Carbon leakage	Ensures needed scale?
Strong ETS ÷	+	+	÷	+	+
Weak ETS ÷	÷	÷ ÷	+	+	÷ ÷

Feed-in tariffs (FIT)

An FIT is a price-driven policy instrument where public authorities decide price compensation per technology, in a long-term contract that pays producers a fixed (additional) price. The feed-in system is used in several countries for supporting renewable electricity, paid by the electricity consumers. However, the system can also be found in other segments, such as agricultural support (e.g. fixed price per litre milk delivered). It may be adjusted to fit other products, such as other processing with CCS, like cement. In the following analysis, we are simplifying this to focus on the power market. An FIT model for electricity from power plants with CCS is illustrated here (Figure 7):

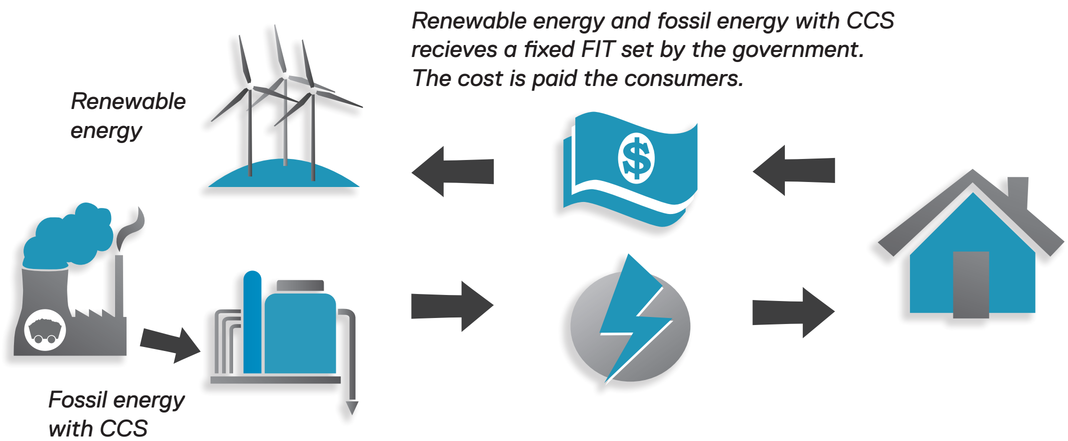


Figure 7: Illustration of feed-in tariff for CCS on electricity. Illustration: ZERO

FIXED PRICE FEED-IN MODEL VS. PREMIUM FOR POWER

Two variants of FIT are used: fixed price and fixed premium. A fixed price gives a guaranteed total price, while the fixed premium gives a guaranteed extra payment in addition to the electricity price, while the electricity price can vary, as illustrated in Figure 8 below:

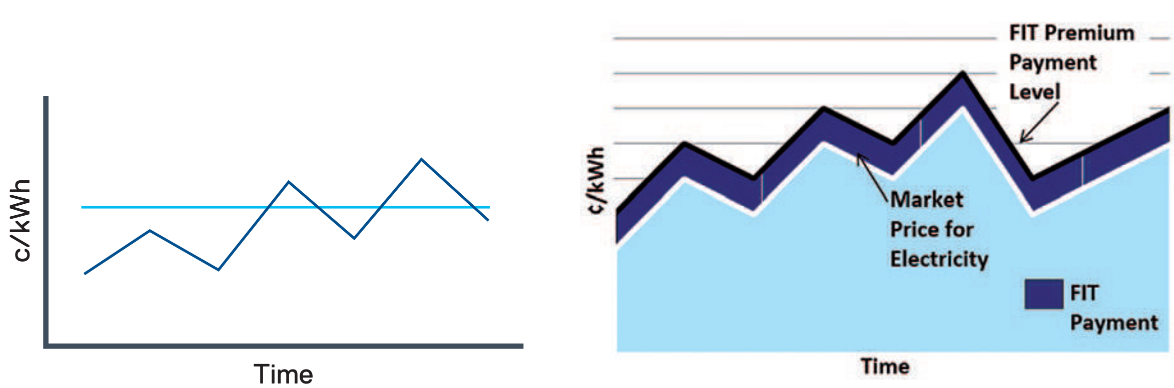


Figure 8: Fixed price feed-in model (left) vs. fixed premium for power[17]

17 http://www.helapco.gr/ims/file/news/2012/FiT_vs_FiP_NREL.pdf

Some analyses have shown that the premium-price FIT system is less cost efficient than the fixed price. The reason for this is that the fixed-price tariffs takes away the whole price risk for investors [18].

With a premium FIT the subsidy covers the extra cost for the CCS, but does not take the whole market price risk away from the power plant. Power plants with CCS have flexibility in operation compared to wind and solar power, and can adjust production according to the price signals in the electricity market. The premium price will therefore be the most preferable variant for CCS FIT.

Within the feed-in premium, there are different models: fixed premium, cap and floor and a Contracts for Difference (CfD)[19], but these details will not be elaborated on here.

PROVED SUCCESSFUL?

FIT systems have proven to be very efficient in deployment of renewable electricity in many countries, including Germany, Spain, Denmark and Italy. FIT for renewables are used in more than 50 countries around the world[20], and several countries have switched to FIT systems from other types of incentives, including France, Ireland and the UK. Figure 9 shows the development of renewable electricity production in Germany from 1990 to 2012.

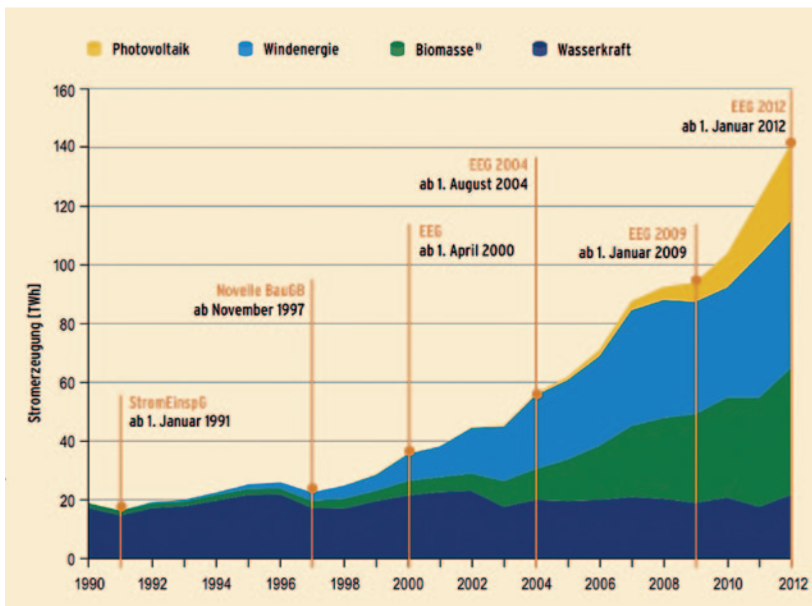


Figure 9: Deployment of renewable electricity in Germany 1990-2012 in GWh. The production has increased remarkably since the introduction of the system of FIT through the EEG (Erneuerbare Energien Gesetz) in 2000[21].

MAKES BUSINESS CASE VIABLE?

The guaranteed price makes the business case economically more predictable and gives easier access to financing and reduces financing cost. This is especially important for smaller companies with less equity and strong financial situation, totally dependent of external financing for projects. The compensation is

18 NREL (2010): A policymaker's Guide to Feed-in Tariff policy design, http://www.nrel.gov/docs/fy10osti/44849.pdf
19 Ragwitz, M. et al (2012): "Recent developments in the feed-in systems in the EU".
20 NREL (2010): A policymaker's Guide to Feed-in Tariff policy design, http://www.nrel.gov/docs/fy10osti/44849.pdf
21 http://www.erneuerbare-energien.de/fileadmin/Daten_EE/Dokumente__PDFs_/ee_in_zahlen_bf.pdf

fixed for all production during the project's lifespan[22] covering also the operation costs.

The government adjusts the tariff level according to changes in cost level for new projects. This gives a political risk for the project development phase, since the future tariff level can be changed before the projects get to the stage of securing the FIT contract for the project. The risk for the government to not find the right price level is higher for CCS than for renewable energy. If the tariff is set too low it will stop all implementation.

It is worth noting that the FIT system for renewables also includes a grid priority for the power, in addition to compensation, contributing to the FIT's success. A possibility for CCS in the power market might be to give a second priority to CCS power, after renewables and before unabated power.

BRINGS COSTS DOWN?

With certainty for investors on price, FITs are efficient in scaling up installation and reducing planning and financing costs.

A FIT system is not based on a principle of competition between projects and does not pick the "best projects" in terms of the lowest costs for each project, but rather sets a limit on how costly projects can be in order to be realised.

FIT is usually technology-specific, providing differentiated support level for different technologies. This has given good possibilities for technologies at different degrees of maturity to develop and bring the cost down for all technologies and not just the cheapest one.

The major factor for bringing the cost down for FIT has been the increased volume lowering the cost for the whole supply and installation chain with mass production. For CCS, with a lot fewer large projects than thousands of solar installations, FIT can be less efficient in bringing the cost down.

If tariffs are adjusted in an ideal way, the tariff's reduction will be in line with and contribute to driving cost down further. But if set too low, no projects will be developed. And set too high, the results will be high costs and over-subsidisation, which does not contribute to bringing cost down.

POLITICAL ACCEPTANCE

Surveys have shown widespread support in the population for FIT on renewable energy in Germany[23]. Several interviewees[24] mentioned that they thought it would be very hard to get political support for a FIT on CCS, especially if consumers are already paying a high FIT for renewable energy.

Financed by the emitters, such as the UK's carbon price floor, or the fossil value chain, and an FIT system also for CCS on industry products and not just power, could enhance political acceptance of this instrument.

CARBON LEAKAGE

The FIT system is mainly paid for by private-end consumers, while industry is largely exempted from the extra fee on the electricity price. With the same payment model a CCS FIT would not increase the risk of carbon leakage. If the FIT is paid by the emitters, the risk of carbon leakage will increase slightly, as the production cost would increase in comparison with unabated production. But since it is a shared cost model, the extra cost will not be large, and no major effect on carbon leakage issues is foreseen.

22 For renewable energy, the period of production for receiving FITs has normally been given for 20 years.

23 Agentur für erneuerbare Energien e.V. (2012): "Akzeptanz Erneuerbarer Energien in der deutschen Bevölkerung"http://www.unendlich-viel-energie.de/uploads/media/56_Renews_Spezial_Akzeptanzumfrage_2011_online.pdf

24 Both from industry and NGOs.

ENSURES THE NEEDED SCALE OF CCS?

Based on the success of FIT for renewables, it is possible to conclude that FIT for CCS can ensure large-scale implementation if designed correctly. Theoretically, the FIT system has its primary strength in stimulating the learning phase of a new technology, in boosting the learning curve and reducing costs to boost market competitiveness.

The penetration of CCS will depend on the right price level for the tariff, since the volume is uncertain.

SUMMARY

Proven successful	Makes business case viable?	Brings costs down?	Political acceptance	Carbon leakage	Ensures needed scale?
+ +	+	+	÷	+	+

Qatalum aluminium smelter plant. (Photo: Hydro)

Certificate system (portfolio standard)

Portfolio standard is commonly used for renewable energy demanding the suppliers to have a minimum renewable share of their energy supply. A portfolio standard comprising all companies in a market creates a certificate system.

The basis for a CCS certificate is:

- Suppliers of fossil fuels are obligated to do CCS as a share of their production. For flexibility they can choose to do CCS themselves or cooperate/trade CCS certificates from other projects.
- CCS certificates received per "clean" unit produced of electricity and industry products such as cement and steel.

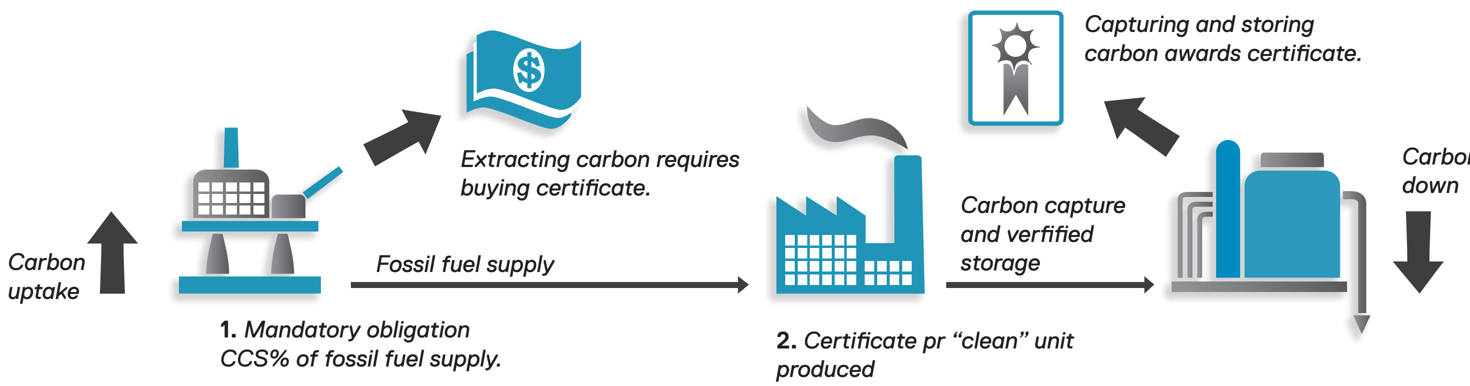


Figure 10: Simple illustration of a CCS certificate system. Illustration: ZERO. More details in Appendix 3.

A way of explaining this system is fossil energy with a deposit on CO_2. As for deposit on bottles, the buyers of fossil energy "returns" the CO_2 to safe storage in order to get the deposit refunded. Or in other words, the CCS certificate system obligates the companies who takes carbon up, to bring carbon back in the ground.

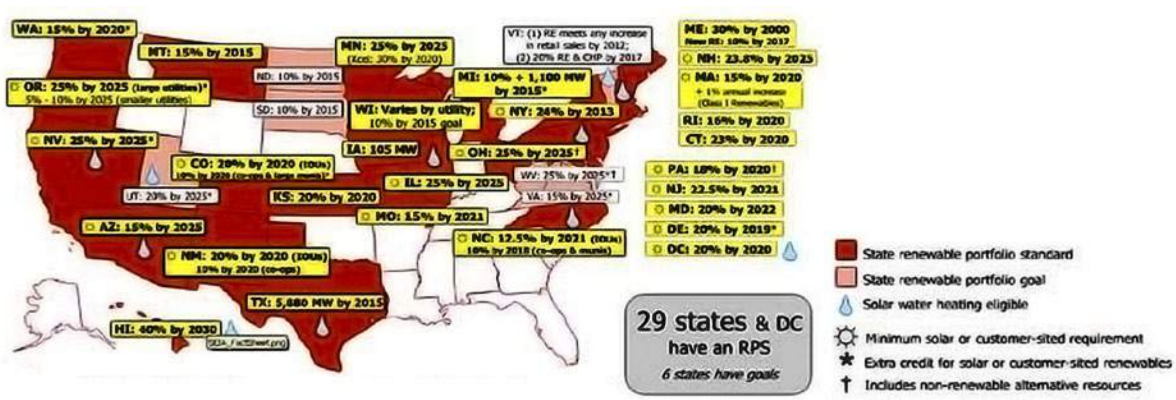


Figure 11: Map of the 29 states in US with Renewable Portfolio Standards (RPS)[25].

25 http://www.solartown.com/community/news/view/renewable-portfolio-standards-and-solar-carve-outs-focus-on-maryland/

PROVED SUCCESSFUL?

Portfolio standards are known from the renewable electricity sector. Twenty nine states in the US have implemented Renewable Portfolio Standards (RSPS). Sweden introduced a renewable certificate system in 2002, and this was expanded to a cross-national system with Norway in 2011, to incentivise development of 26,4 TWh of new renewable electricity production by 2020.

This experience shows that, if certificates are delivered under long-term agreements, effectiveness can be high and the targets can be reached. But there has also been experience of certificate systems where targets are not being met, due to poor policy design and lack of certainty for renewable energy producers[26].

MAKES BUSINESS CASE VIABLE?

The major advantage with a certificate system is that politicians set a specific legally binding target for the deployment (certificates obligation), while the market is setting the price for the certificates to fulfil this obligation. Investors will have long-term predictability for the total volume, but will have a price uncertainty in competition with other projects in the market. Proper design of the certificate system to reduce the price risk is important to create good conditions for investments, such as a price floor in the start-up phase.

A business case would be:

a) Companies with obligation doing CCS themselves.
b) Companies cooperate to solve several companies' obligations.
c) Companies without obligation doing CCS and sells certificates to companies with obligation.

In the case of c) the companies will have market risk for their CCS project to be competitive with others. Due to large-scale projects and investments, we will anticipate more long term agreements and cooperation for projects.

BRINGS COSTS DOWN

The long-term predictability and the commercial market situation is important to pick the most cost-efficient projects and to bring costs down. If there is a high supply of certificates the price goes down, and vice versa. This creates a dynamic system where the learning effects in technology lead to lower prices and contributes to bringing the cost down further.

POLITICAL ACCEPTANCE

Certificate systems are politically attractive for their efficiency in ensuring political goals; and for the market-based system to fulfil the politically agreed goals, without any political price or financing challenges.

Placing the cost for the CCS in the fossil value chain, covered by the industry, included in the price for fossil fuels, is more likely to gain political acceptance.

On the negative side, there is some political opposition to specific (complex) instruments for single mitigation options and scepticism towards instruments influencing ETS.

Due to the fact that CCS represents the only effective abatement for some of the large emissions

26 R. Haas et al (2011): A historical review of promotion strategies for electricity from renewable energy sources in EU countries, http://www.isi.fraunhofer.de/isi-media/docs/isi-publ/2011/ISI-P-5-11.pdf?WSESSIONID=5712ff2ca5ffcf0d9590afc8ef7e1486 & http://www.ecn.nl/fileadmin/ecn/units/bs/Extra/Renewable_energy_obligation_support_mechanisms.pdf

sources, and a certificate system can easily work together with a quota system, withdrawing the same amount of allowances, there is less the political opposition against this instrument.

CARBON LEAKAGE

A certificate system is a cost-sharing instrument, distributing the extra cost to all fossil value chains. Certificate obligation can result in slightly higher fossil fuel prices and/or lower profit for the suppliers. The increased prices represent a small risk of carbon leakage for trade-exposed industry, but compared to the total cost for fossil fuel and taxation level, most consumers are unlikely to experience any major changes.

ENSURE THE NEEDED SCALE OF CCS?

The major advantage with the certificate system is that politicians are setting a specific binding target for CCS deployment (certificates required), while the market is setting the price for the certificates to fulfil the volume. With the right system design, this will efficiently ensure fulfilment of the target. Proper design of the certificate system to reduce the price risk is crucial in order to ensure investment.

The instrument is both possible to use in the first phase of a ramp-up for CCS-projects and for long-term targets, with an incremental increase in the amount of certificates for each year.

Placing the certificate obligation with suppliers of fossil fuel will incentivise actors in the upstream sector to develop safe CO_2 storage to secure continued sale of their products. This will be effective in getting the necessary competence and investments from this industry to ensure large-scale implementation of CCS.

SUMMARY

Proven successful	Makes business case viable?	Brings costs down?	Political acceptance	Carbon leakage	Ensures needed scale?
+	+	++	+	+	++

Emission performance standard (EPS)

An output emissions performance standard (EPS) is a benchmark for production, which sets a restriction of maximum allowed emissions per produced unit. EPS can be used for both power plants and other industry sectors, such as cement, steel, etc. EPS can also be set not on the specific plant but on the total company portfolio or for a market portfolio. This is covered above in the certificate/portfolio chapter, and the use of EPS here covers output for each production.

The effect on realising CCS will differ depending on the EPS level. Here we analyse two levels:

- Weak (~450 g/KWh) and not including existing plants: old plants can continue unabated and new fossil plant (natural gas) can be built without CCS.
- Strong (~150 g/kWh). No conventional fossil fuel plants without CCS are possible. Also including plan for implementing CCS on old plants.

PROVED SUCCESSFUL?

EPS has been introduced in California (2006) and Canada (2012), and has been proposed in several other states and regions, such as in the US and UK. The regulations are valid for new power plants with benchmarks at 400-450g/kWh. In Canada, the EPS obligation is also introduced for old plants that have reached their end-of-useful-life[27]. In effect, the regulation means a prohibition of new coal power plants without CCS[28].

EPS has been effective in stopping new investments in conventional coal power plants in California, but no CCS projects have been realised. In Canada, it was one of the factors that led to the building of the first CCS projects on coal, at Boundary Dam, even before the EPS was formally implemented.

An EPS is also in use for other pollution control. The EU's Large Combustion Plant Directive sets an EPS for SO_2, NOx and particles emissions. This directive has had a deep impact on existing old coal-fired plant, triggering investments in cleaner production and/or shutting down by the end of 2015[29].

MAKES BUSINESS CASE VIABLE?

The EPS is a strong political regulation to avoid new investments in emission intensive sources. Whether it provides good conditions for a business case for CCS will depend on the EPS level, and what alternatives to CCS exist for meeting the standard. With a weak standard, the business case conditions for CCS are low, and other instruments are needed in addition. An exception would be for companies with large stranded coal reserves without alternative value for these resources (due to high transportation costs and/or low quality).

With a strong standard, including existing plant, it makes a clear need for CCS and a viable business case for CCS.

BRINGS COSTS DOWN?

An EPS is a very clear regulation and market condition representing a stable predictable framework for industry to invest in solutions to meet the standard. Companies are paying the full cost for implementing the emission reduction. This leads to a high cost focus for the companies implementing CCS, contributing to making abatement as cost efficient as possible.

27 See Appendix 2 on todays instruments for further details.

28 New coal power plants emit between 676 – 880 g/KWh (Esken et al 2007).

29 Bellona, 2013. "Driving CO_2 capture and storage in the EU"

The instrument is not technology-specific for CCS, giving competition between CCS and other technologies to meet the standard in the most cost efficient way.

POLITICAL ACCEPTANCE

EPS is a simple and clear political regulation, in line with polluter control regulation tradition for emissions other than CO_2. In the US and Canada, EPS is a highly relevant policy instrument already implemented at state and federal level. In Europe, the European Commission has mentioned EPS as one possible instrument in the White Paper on CCS, but questioned whether it would be in line with the ETS.

Many industry stakeholders are against EPS as they fear unfavourable conditions when compared to other regions (i.e. carbon leakage). EPS is a popular instrument among Greens as a clear regulation preventing new conventional coal and making polluters takes up the costs of mitigation.

Achieving a strong EPS seems more difficult to get broad political acceptance for. However, EPS as part of a policy instrument package, together with an instrument for financing, seems more politically acceptable, at least in some countries/regions.

CARBON LEAKAGE

According to our industry respondents, EPS was the instrument associated with the largest fear of carbon leakage. To avoid that challenge connected to a national/regional EPS, a carbon border import standard can be used, setting the same demand for the imported products. This is the case for the Californian EPS, which also regulates imported electricity from neighbour states, and for the Low Carbon Fuel Standard that includes emissions from fuel production as well as imported fuels. It is also proposed in the EU's Fuel Quality Directive. And an international sectored agreement committing participating countries to adopt common emissions standards from specific sector(s) may be a solution, with oil refineries, steel and cement industry being good candidates to begin with.

ENSURES THE NEEDED SCALE OF CCS?

If a strong EPS is implemented, it can be an efficient policy instrument to ensure the necessary large-scale deployment of CCS. A weak EPS, however, will not ensure this but it can be an important instrument in combination with a financing mechanism for CCS.

SUMMARY

Proven successful	Makes business case viable?	Brings costs down?	Political acceptance	Carbon leakage	Ensures needed scale?
Strong EPS +	++	+ +	÷	÷ ÷	+
Weak EPS +	÷	÷	+	0	÷

Summary analysis

Policy instrument	Proven successful	Makes business case viable?	Brings costs down	Political acceptance	Carbon leakage	Ensures needed scale
Government funding	+	÷	÷ ÷	÷ ÷	+ +	÷ ÷
	• Triggered some large scale CCS projects, investment support and CO_2 EOR tax credits US • Projects granted support also been canceled (÷)	• Limited money available • "Starts and stops" planning process. few companies able to take planning costs when result can be zero • Certainty for funding after support is granted (+) • If Government take long-term storage liability it helps business case for storage (+)	• Challenging to set correct support incentives high enough but not too much, and to evaluate large complex projects • Focus can be to get as much funding as possible	• Low support for large public funding with government budget deficit & austerity measures • Opposition (in some countries) against funding for "big" and "dirty" companies	• Cost sharing by whole society. • Shape of taxes to finance extra gov. spending decides the total effect.	• Politically unfeasible and overly expensive for large scale deployment • Government funding suitable for early learning phase, and long-term storage liability.
Investment subsidies via market mechanisms	÷	÷	0	0	+	÷ ÷
	• No success for CCS in Europe(NER30) • Success for NOx fund model in Norway (+)	• Success or failure depends on the outcome of competition • Can be short of funding if low prices • Certainty for funding after support is given (+)	• Competition for most cost-efficient projects (+) • start&stop planning increases costs (÷) • Few companies can cover all planing cost withou any certanty for fulfilling the project.(÷)	• Financed by market, not charged consumers or state directly (+) • No good track record for CCS in EU (÷)	• Cost sharing model • Small risk dependent on financing	• Not possible to manage investment support for large amount of CCS projects
Feed-in system	++	+	+	÷	+	+
	• Very successful for renewable electricity in many countries (Germany)	• Guaranteed income reducing risk for investors • Covering also operation costs	• If tariffs set right it can bring cost down. • Risk for tariffs too low (no projects)or too high (over-subsidisation)	• Not same support for FIT on CCS, as for renewables (÷) • Financed by the emitters/fossil chain can have higher acceptance (+)	• Cost sharing model • Industry can be largely exempted, as FIT Germany.	• Primary strength boosting learning phase of new technology • Can ensure large-scale implementation if designed correctly. • Volume uncertain, depends on the price level for the tariff (÷)
Certificate system/ portfolio standard	+	+	+ +	+	+	+ +
	• Renewable portfolio standard in many states in the US + certificate system Sweden-Norway with good effect. • Some countries with lack of success due to poor policy design (÷)	• Long term predictability for volume. • Commercial price risk. Agreements/ cooperation for large projects reduces price risk. • Price volatility in the upstart phase without price regulation (-)	• Market predictability & competition ensures realisation of cost-efficient projects first. • Dynamic certificate price reflects (reduced) cost level.w	• Long term predictability and efficient for politicians in terms of volume. • No political decision for price/ funding • Cost sharing model • Higher when fossil chain pay • Compatible with ETS • Complicated policy design for a single mitigation solution (÷)	• Cost sharing model • Cost included in the fossil fuel chain.	• Law binding obligation for volume - efficient ensure fulfilling of the target. • Possible also for first phase of a ramp-up. • System design essential for stability to trigger investments.

Policy instrument	Proven successful	Makes business case viable	Brings costs down	Political acceptance	Carbon leakage	Ensures needed scale
EPS Strong (~150 g/KWh)	+	++	+ +	÷	÷ ÷	+
	• Regulation contributed to trigger CCS investments in Canada • Works very well for pollution control (i.e. NOx, Sulphur)	• Clear policy regulation gives clear marked conditions for investments to meet the standard	• Clear market conditions • Competition between technologies (also non CCS) to meet the standard • Emission source paying the full cost: high focus on reduced cost	• Clear and simple political regulation (+) • In line with polluter control regulation tradition (÷) • Widespread reluctance among industry • Popular instrument among environmentalists (+) • more realistic together with instrument for financing and not alone	• Full cost for CCS on emission source • Possibilities to avoid carbon leakage by emission standard also on imports, or international sector agreement	• Can ensure large scale CCS, if combined with financial instrument and carbon leakage issues are solved
EPS Weak (~450 g/KWh)	+	÷	÷	+	0	÷
		• Trigger CCS just for stranded coal reserves, when conventional NG without CCS is an alterative.	• Leads to fuel switch, and not investments in CCS cost reduction? (÷)	• In use in several countries already • In line • US/Canada higher political acceptance than Europe.	• No/less number of plants that need to take the cost of CCS.	• Will not make CCS happen in large scale. • Can have positive effect combined with other instrument. (+)
Carbon Tax High (>100$/t)	÷ ÷	+	+	÷	÷ ÷	+ +
	• No excample of CO_2 tax at this level.	• Predictability for costs of emitting, reduce uncertainties for business case • Small policy risk for reduced the tax if open to political amendments (÷)	• Clear market condition • Competition between all technologies to meet the standard • Emitter paying the full cost but equal conditions for all - high focus on reduced cost	• Favored by many as the correct climate instrument. Support for global CO2 tax, but reluctance towards national tax • Full cost for emissions source and large difference between sectors ability to pay • CO_2 tax provides income to the government/mitigation funding (+).	• Full cost for CCS on emission sources • To avoid carbon leakage, same tax on import (Boarder Carbon Adjustment) is needed.	• Can ensure large scale CCS, if carbon leakage issues are solved
Carbon Tax Low (<50 $/t)	+	÷	÷	+	÷	÷
	• Main economical trigger for two CO_2 storage projects from natural gas cleaning • Invented system to reduce gas flaring from petroleum facilities offshore. • Not sufficient to trigger CCS (÷)	• Incentive just for "low hanging fruits", as from natural gas cleaning.	• Little incentive for CCS, will give less investments in development of CCS	• Already implemented a low CO_2 tax in some countries, but mostly on other sectors than industry.	• Low CO_2 tax gives lower carbon leakage. Risk will vary between different industries.	• Little incentive for CCS • Can cover of operation cost together with other instruments

Policy Instrument	Proven successful	Makes business case viable	Brings costs down	Political acceptance	Carbon leakage	Ensures needed scale
ETS Strong (Low Cap)	÷	+	+	÷	+	+
	• No ETS in line with 2C target	• If long term cap in place and high price for allowances. • Harder to make business case for long term step change technologies, with higher initial prices (÷)	• Competition between mitigation technologies within the cap • Emission source paying the full cost/selling quotas - high focus on reduced cost • Risk for price changes in large ETS system can trigger less investments. (÷) • Less incentives for long term technology development with higher initial costs. (÷)	• Low political support to strong ETS with low cap and high prices	• If free allowances for industry => no carbon leakage risk (as done in EU). • If not – high cost for emissions and full cost for mitigation for industry will give high CL challanges (÷ ÷) Risk can be reduced by border carbon adjustment, and international linked systems.	• Strong ETS gives high prices and can trigger CCS, if carbon leakage issues are solved • Challenging for investments in long term technology development with higher initial costs
ETS Weak (High Cap)	÷	÷	÷ ÷	+	+	÷ ÷
	• EU ETS has not been a driver for implementation of CCS	• No incentive for CCS. • Possible cover of operation cost, if other incentives covers investments.	• No incentive for CCS	• Strong support for ETS in general. Established as a main policy instrument in Europe.	• If free allowances for industry => no carbon leakage risk	• No incentive for CCS • ETS "blocking" other policy instruments: "specific emission reductions have no effect - total emission set by the cap"

Policy instrument analysis CCS cases

CCS Cases	Government funding	Investment subsidies, market mechanisms	EPS (strong)	Feed-in	Certificate system	CO2 tax (high)	ETS (Strong)
Industry, high CO2 % Ammonia ++	÷ Can work for some projects, but not needed scale.	÷ Some projects, but not needed scale	÷÷ Carbon leakage if industry to pay full CCS cost self, if not Border Carbon Adjustment (BCA)	÷ Good for business case and cost share model. Less probable with feed-in model for all industry CCS	++ Good possibilities for large scale CCS for low cost industry projects	÷÷ Carbon leakage if industry to pay full CCS cost self. (if not Border Carbon Adjustment	÷ Full CCS cost for industry can give Carbon leakage, if no free allowances or BCA
Industry,large emissions Cement, Steel	÷ Some projects, but not needed scale	÷ Some projects, but not needed scale	÷÷ Carbon leakage	0 Less probable with model for industry CCS, but cement&steal could be if feed in for industries	++ Incentives for large scale CCS for industry CCS projects	÷÷ Carbon leakage	÷ Carbon leakage, if not free allowances or BCA
Petroleum industry Refinery & Natural gas cleaning	÷÷ Less probability for gov. fund. to petroleum	÷÷ Less probability for gov. fund. to petroleum	++ Geographical resource location. CCS cost to be included in product price	÷ Less probable with feed-in model for petroleum products with CCS	+ Carbon leakage, if not free allowances or BCA	++ Geographical resource location. High emission cost can trigger CCS.	++ Geographical resource location. High emission cost can trigger CCS.
Energy supply to energy intensive industry	÷ Some projects, but not needed scale	÷ Some projects, but not needed scale	÷÷ Higher energy price if energy supply to pay full cost of CCS. Carbon leakage	+ Possible, but less probable for integrated energy supply to industry to pay for feed in	++ Incentives for large scale CCS for energy production	÷÷ Carbon leakage	÷ Carbon leakage, if not free allowances to industry energy supply and/or BCA
Power plant, where major barriers to renewables	÷ Some projects, but not needed scale	÷ Some projects, but not needed scale	++ Geographical location. If no alternatives, cost for CCS can more easily be included	++ Can give large scale CCS. Feed in most probable on energy production to regular consumption	++ Incentives for large scale CCS for power production	++ Geographical location. If no alternatives, cost for CCS can more easily be included	++ Geographical location. If no alternatives, full cost for CCS can be included without carbon leakage issues
BioCCS Bioethanol, Pulp&Paper, Bioenergy	÷ Some projects, but not needed scale	÷ Some projects, but not needed scale	÷÷ No BioCCS incentives	÷ Less probable with feed-in model for biomass products with CCS	+ Incentives for BioCCS, if included and cost compatible to fossil CCS	÷÷ Emission cost for fossil CO_2 gives no BioCCS incentives	÷÷ Emission cost for fossil CO_2 gives no BioCCS incentives
CO_2 EOR	++ Tax credits have worked to incentivise many CO_2 EOR projects	÷÷ Less probability for economical direct support to CO_2 EOR projects	++ EPS for use of CO_2 in suitable petroleum production will give CCS	÷÷ Little probability for feed in for CO_2 EOR in petroleum production	+ Less probable incl. petroleum production. But will be if allowed with CO_2 EOR storage for CCS within the certificate system	+ Emission cost gives no direct incentives for CO_2 EOR projects, but can be result of other CCS projects	+ Emission cost gives no direct incentives for CO_2 EOR projects, but can be result of other CCS projects

CCS in emerging and developing countries

The IEA foresees a large share of CCS to be installed in emerging and developing countries, as suggested by the change in power generation shown in the graph below. Non-OECD Countries account for nearly half of the CCS requirements by 2020, and nearly 70% by 2050. According to the IEA's World Energy Outlook, the largest share of increase in energy demand and fossil energy use will be in emerging economies.

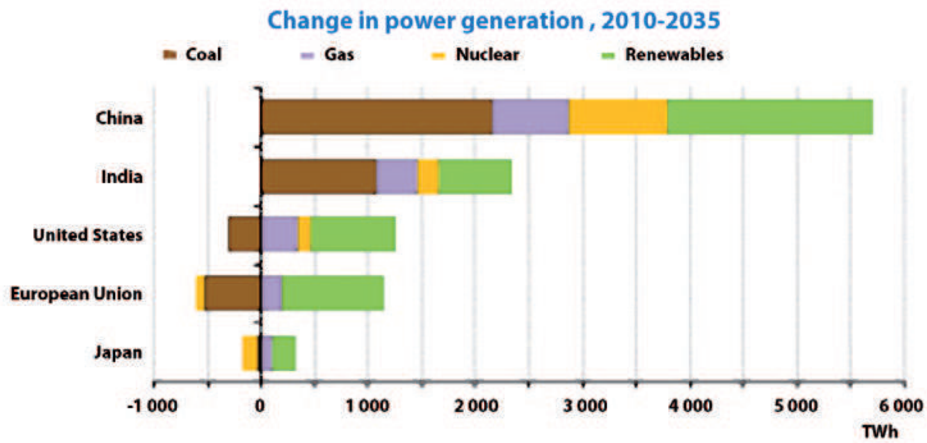


Figure 12: The need for electricity in emerging economies drives a 70% increase in worldwide demand, with renewables accounting for half of new global capacity, (IEA WEO 2012.)

China became the largest emitter of energy-related emissions in 2007, overtaking the US, and further increased from 6,5 Gt/y in 2008 to 7,5 Gt/y in 2010[30]. Per-capita emissions in China were 7,2 t/capita in 2011[31] and is likely to exceed to those of the EU within four years, but is still approximately half those of the United States.

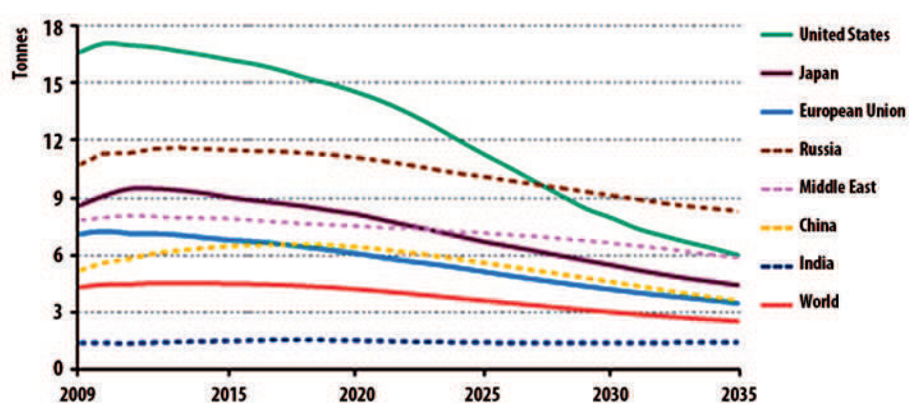


Figure 13: Energy-related CO_2-emissions per capita in different regions in the IEA 450 ppm Scenario. (IEA WEO 2012.)

30 IEA World Energy Outlook 2011.

31 http://en.wikipedia.org/wiki/List_of_countries_by_carbon_dioxide_emissions_per_capita

The emissions must be reduced substantially from the 2009 level in most countries and regions as shown in Figure 14:

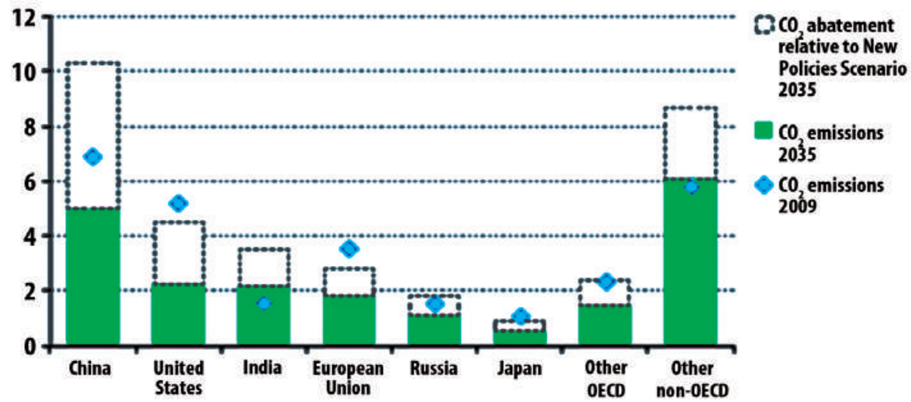


Figure 14: Energy related CO_2 emissions in the IEA 450 ppm scenario and "New policy Scenario". This graph shows that emissions must be reduced substantially in China from the 2009 level for the 450 ppm scenario, while India can increase emissions some. The rest of none-OECD countries can have emissions in 2035 approximately on same level as in 2009, far below expected levels without mitigation.

Policy instruments for CCS in developing countries

Policy instruments for abatements will be different for the least developed countries and for emerging countries. For the least developed, transfer of money for abatements is essential. For implementation of CCS, it is the emerging countries with the highest increase in emissions that are the most relevant.

At some stage of their economic development, emerging countries will be in an economic position to fully implement greenhouse gas mitigation at their own cost. However, due to the urgent need for emissions reduction, this must be implemented at an earlier stage than their historical emissions responsibility would imply, prompting the international community to contribute financing.

GLOBAL CARBON TAX OR CAP-AND-TRADE SYSTEM

It has repeatedly been stated that equal regulatory conditions regarding carbon constraints is needed to prevent migration of industry locations to countries with lower or no restrictions. Most often proposed is an international global emission trading system or CO_2 tax. Because of immense differences in GDP, and large differences in economic and political interests and power, such measures are either unlikely to happen, or they would not have the necessary level, thus being insufficient to trigger step change abatement technologies, such as CCS.

TRANSFER OF MONEY FOR ABATEMENT PROJECTS

Instruments for money transfer for abatement purposes in developing countries are mostly discussed within the Clean Development Mechanism (CDM), a climate fund, soft loans and Nationally Appropriate Mitigation Actions (NAMAs).

CCS IN CDM

CCS has been included in CDM since 2011, which allows CCS projects in developing countries to receive

CDM credits. However, since credit prices are at a historically low level – almost zero – the likelihood of the realisation of CCS via this mechanism without major changes in the credit value is very low. The EU has been a large buyer of CDM credits and has limited these post-2012 to the least developed countries[32], making it even more unlikely to have any CCS projects realised based on the CDM.

CLIMATE FUND/CCS FUND

Both the IEA and the World Resources Institute have conducted assessments of possible instruments for funding CCS in developing countries. They both recommend organising support from developed countries through a fund. This could be a separate CCS fund, or part of a larger one for a broad scenario of mitigation policies, as proposed in UNFCCC negotiations. Characteristics of this CCS fund might be as follows:

- Be large enough to facilitate large-scale implementation.
- USD 5-8 bn in 10 years[33] or USD 9-24 bn/y.
- Multilateral development banks should have a role in disbursing these resources.
- The money should only be eligible to finance incremental costs and not cover the full cost of the entire investment for a new power/industry plant.

SOFT LOANS

A common model in international financing institutions is to combine non-concessional loans with concessional (soft) funds. The non-concessional loans help to finance the baseline cost of a project, while soft concessional loans or grants are used to finance low-carbon aspects. One such example is the World Bank Clean Technology Fund (CTF) approved in 2008 to finance "projects and programs that contribute to demonstration, deployment and transfer of low carbon technologies with a significant potential for long-term greenhouse gas emissions savings". The fund has to date received pledges of around USD 4,4 billion from developed countries and grant element of funds range from 45 % to 75%[34]. The CTF is currently blocked from supporting CCS projects, but could be changed. Or a similar model could be used for concessional loans/grants to CCS projects.

NATIONALLY APPROPRIATE MITIGATION ACTIONS (NAMAS)

NAMAs are actions by developing countries, where costs, emissions reduction and timeframe are outlined. These will be matched by support from developed countries made available through a NAMA registry. NAMA was first used in the Bali Action Plan agreed at the United Nations Climate Change Conference in Bali in December 2007. At COP 16 in Cancun in 2010, governments decided to set up a registry to record and facilitate the matching of finance for NAMAs[35].

CCS might be financed through this mechanism, but there are no indications so far that this will be prioritised by developing countries (one country so far has mentioned CCS in the registry[36]), or that the funding will be large enough to ensure large-scale implementation.

CCS CERTIFICATE SYSTEM

A CCS certificate system can be implemented in a way that includes CCS deployment in developing countries. This can be done in different ways.

The CCS certificate obligation can be fulfilled by certificates from CCS projects in developing countries.

32 http://www.emissions-euets.com/cers-erus-market-as-from-2013

33 Almendra, F. et al (2012): "CCS Demonstration in Developing Countries: Priorities for a Financing Mechanism for Carbon Dioxide Capture and Storage". WRI working paper. World Resources Institute, Washington DC.

34 IEA (2012): A policy strategy for carbon capture and storage. Information paper.

35 http://unfccc.int/essential_background/glossary/items/3666.php#N

36 http://namapipeline.org/

It can be open for all CCS projects in developing countries, based on the existing CDM system. Or it can be limited to specific countries/projects. It can also be limited to companies with a CCS obligation, to have the flexibility to realise a CCS project in a developing country in order to fulfil parts of that obligation.

Alternatively, there could be a common certificate system, with CCS obligations also on companies in the developing country. Fossil production in these countries, as in developed ones, could have the same profit and ability to include a cost for CCS in the fossil value chain. And in several countries many of the same companies are involved. This can be done either on equal conditions for CCS obligation, or it can be designed with a "discount" for the CCS obligation for companies in the developing countries. With a likely lower cost level in developing countries, it may result in a relatively higher share of CCS projects, making this a mechanism for transfer of money as well.

This is an interesting possibility creating a market for a company-to-company investment scheme for CCS in developing countries. But having the collapse of the CO_2 prices in both CDM and the EU ETS in mind, it must be designed properly to avoid being too complex and to make it robust against price collapse and fraud.

The SaskPower Boundary Dam lignite power plant. (Photo: ZERO)

Recommendations

In order to ensure deployment of CCS in the necessary large-scale, we consider a mix of instruments indispensable. At the core, an instrument giving industry sufficient incentive to make business cases for CCS viable is needed, to trigger investments in deployment and innovation. For industry to embark on large-scale investments, policy instruments need to be clear and predictable in the long term.

General CCS instruments are preferable to sector-specific instruments, covering emissions beyond power production and giving competition for reduced CCS cost across all sectors. In the long-term, large-scale CCS policy instruments for the whole CCS chain are preferable to separate instruments for each part of the CCS chain.

The best policy instruments for the up-scaling of CCS deployment from this analysis are a CCS certificate system combined with an appropriate EPS. The certificate system finances the cost for CCS deployment through a cost-sharing model, while the EPS sets a very clear regulation of allowing no investment in high emission conventional solutions of any kind.

CCS CERTIFICATE SYSTEM

The major advantage with a certificate system is that politicians decide the volume for CCS, and it is mandatory for companies to fulfil this obligation. Placing the certificate obligation at suppliers of fossil fuels, the abatement cost will be included in the product price for fossil fuels. This will strongly incentivise these companies to develop the CCS value chain, leveraging their large relevant expertise. Flexibility is inherent in the system by leaving it to the companies to find the most cost efficient way to fulfil the obligation, to build CCS themselves, cooperate for large CCS projects or buy/sell certificates.

EMISSION PERFORMANCE STANDARD (EPS)

In addition to a certificate system it is important to have a clear regulation on emissions. This will help focus investments and innovations towards the future abatement solutions. A clear regulation and level playing field will create a predictable framework for industry. An EPS should be implemented across power and industry both for new and existing plants, in line with the climate goals, to cover all base load[37] fossil fuel use.

GOVERNMENT FUNDING

Government funding will be important for the deployment of CCS. But for large-scale projects, the investments grants seen up until now are not suitable. Governments' most important role will be to take the post-storage, long-term liability for CO_2, thereby de-risking storage for industry and reducing the cost of CCS. In the shorter term government funding and involvement is important to establish sufficient early stage storage capacity. Early stage establishing of large storage capacity is important for de-risking storing uncertainties and cost.

EMERGING AND DEVELOPING COUNTRIES

Using a CCS certificate system can be a good option for international cooperation both between developed countries and for CCS deployment in developing countries. Creating a market for company-to-company investment schemes for CCS could speed up implementation across all economies.

37 Peakload/backup natural gas plant to be exempted.

SUMMARY OF ZERO'S RECOMMENDATIONS:

- A mandatory CCS certificate system.
  - › Obligate suppliers of fossil fuels to do CCS as a share of their supply.
  - › Certificates given for production of clean products with CCS.
  - › Flexibility for suppliers to do CCS themselves or to cooperate and trade CCS certificates from other projects.
  - › Cooperation between countries, both developed and emerging countries.
- EPS regulation for new and existing power plants and industry, in combination with the certificate system.
- Government taking the post-storage, long-term liability for CO_2, de-risking storage cost for all CCS projects. In the short term a special government involvement and funding focus is important to establish sufficient early stage storage capacity.

Appendix I: Qualitative Interviews and Workshop

As part of this project, we have carried out 15 personal interviews and conducted a workshop with 20 stakeholders in Oslo. The interviewees and workshop participants were stakeholders from a number of countries, including Norway, Sweden, Netherlands, UK, US, Canada, South Africa and France. We have representatives from industry, government and science/NGOs in our sample. The industry group includes power producers, steel, cement, ethanol, financing and insurance. The quotations are marked according to which group the interviewee belongs to: Industry (I), Government (G) and Science/NGO (S/N).

In the workshop, people worked in groups and it was not always known which statements came from whom. Statements made in the workshop are therefore marked (W). The majority of interviewees were industry representatives (9 out of 15). Further, four were from government and two from the science/NGO group. This was to some extent a result of difficulties with finding people from the other categories to take part. Therefore, the perspectives highlighted here are mainly, but not exclusively, those of different industry sector stakeholders. Moreover, all of the interviewees have been working with CCS in one way or another. They largely agree that CCS is an important technology for mitigating climate change. Most of them cite the IEA's predictions as the scale at which they believe CCS will be needed. A few commented that they have started doubting if CCS will get to this share of total emissions reductions, due to slow development in recent years. As such, the sample mostly consists of people favourable to CCS.

The overall aim of the qualitative work is to complement our analysis with important insights and to get perspectives from affected stakeholders regarding the different instruments discussed and various other aspects of CCS. Because of a small and uneven sample, we do not intend to give an account of all perspectives revealed in the interviews. Nor do we aim to provide a detailed picture of what different groups think about different instruments. Instead, we have chosen to highlight important aspects mentioned in the interviews and in the workshop, in order to present different views on what the best suitable instruments for CCS are, and possible ways forward for CCS. These views are organised under the following headlines:

- Why do CCS?
- What should be the responsibility of government/public authorities?
- Separate mechanisms for different steps in the chain?
- Perspectives on different instruments for CCS.
- Who should pay the bill?
- How to facilitate CCS in developing countries.
- Implementation of policy instruments.

Motives for the industry to engage in CCS

Interviewees mention economic reasons when asked why they want to do CCS: "We are choosing the cheapest measure in order to reduce emissions" (I). Another argument is licence to operate: "If we want to be in this business, we must do CCS - to survive" (I). Some of them also add that this depends on CCS being available at a competitive price, and that they also consider alternatives to CCS: "We will look at all other options for reducing emissions before doing CCS" (I). Further drivers for doing CCS are the wish to influence government/politics, and to bring their perspectives to the politics.

What should be the responsibility of government/public authorities?

A major criticism raised against politicians is that they do not take action to make CCS happen. “There is no strategy of the authorities” (I). “They (the politicians) have to do something. Have to be clear what they want to do. Industry needs stable or predictable incentives. Industry is waiting for these things to happen. Industry would like to be there when decisions are being made. Politicians don’t know everything about our business” (I). This leaves the stakeholders wondering if the politicians really want CCS to happen or not.

The acceptance issue is also frequently mentioned: “If governments or society want to have storage possibilities, they have to create acceptance for this” (I).

“For CCS activities, there is a need for clarifying what should be the responsibility of the industry and what is the duty of the state. In all other sectors, this distribution of responsibility is very clearly defined, for instance for the power grid” (W).

What this distribution should look like must be negotiated. A major share of the sample argue that the government must take more responsibility when it comes to transport and storage: either by covering all costs for transport and storage, or to have the responsibility for a larger storage project and create synergy effects. “Funding the infrastructure could help industry to develop CCS, because they have less financial means available for doing CCS” (I). But the opposite view also exists: “It is not the responsibility of the government to pay for infrastructure and storage. But in order to reach a critical mass for large enough scale of these units, there could be a partnership of industry and government. The critical mass could be too large for a single company” (I).

In the context of solving the liability issue, there is an urgent demand for clarification. “If you look at the document 4 [Guidance Document 4 to the CCS Directive from the European Commission] that sought to clarify these [liability] issues, it was very unclear. It is written by people who didn’t know how to set the long-term liability. It should not be necessary to set aside all the money that could pay for a large leakage. This has been stopping all the projects. No one would set aside such a large amount of money. If you read the documents of DG Energy and DG Climate: you get the competing perceptions of whether you want it [CCS] to happen […]”

Another issue is: the whole licensing and permitting of a storage site. What is the financial security in the CCS Directive? It should not be a lot of money, if you calculate it according to how the insurance industry works. The authorities argue that you have to set aside a large amount of money, but this is not true – it doesn’t correspond to how you normally put a price on the risk and the liability. We have to define and limit the risks – unless you will not have any one [project] with support from the government. And you will not have any one going to carry out the projects. And compared to the risks of CO_2 actually leaking out: It’s far better that we get this industry up and going from the perspective of climate change” (I).

One final and important requirement addresses the possibility to have an official, binding target for CCS in a certain country or region. This is also the task of the authorities: “You’re going to have some volume call” (G). Here, it is the responsibility of policy makers to say “we need this much CCS” (G). This would be a regulative, which is “an alternative to large capital grants – and I believe that there will not be any, because the recession is too difficult” (G).

Separate mechanisms for different steps in the chain?

There are differing views regarding separating the responsibility for different parts in the CCS chain: “It is a very different risk portfolio. Transportation – quite simple, low risk compared to capture. Storage – different part. But in our project […] we ended up by integrating the whole chain. We worked out different options for splitting the chain, but I think in the end the conclusion was that integration of the chain had certain advantages before splitting them up" (I).

"If you split them up, you can have a system where the capture plant receives the incentives, which is then responsible for the means being allocated along the other parts of the chain. For the earliest projects: It is easier to keep it integrated" (I).

There are also challenges for the transport step when separating the steps: "If you have five suppliers delivering into one pipeline you will have issues like: Who will be cut off if you have over-supply into the chain? When there is only one operator – it is a simpler and straighter approach for the first projects. Later, in a long-term perspective: One can think about having separate units" (I).

Arguments for splitting the chain were provided by one government stakeholder: "There will have to be a separation of the chains" (G). The reason for this is that "different companies are dealing with different steps of the CCS chain. The power station operators are not active in oil and gas" (G).

It is argued that the storage part is so essential for CCS that this part should be solved first: "In order to make CCS projects happen: you have got to start with the storage. Lots of projects have been stopped because of lack of storage sites or opposition to onshore storage" (G).

Several alternatives for distributing the responsibility of finding suitable storage sites have been mentioned:

- The government pays for it.
- Tax breaks for gas and oil producers to appraise the storage sites. Could also be in connection with EOR.
- Centralised funding model. You get five or six companies that take a shared responsibility – analogy in Australia: coal industry got together and set up a fund to put money in it to get a volume to look at storage sites.

It is important that financial means are set aside for the search of storage sites: "Without some pool of money coming from somewhere – nothing will happen" (G).

Perspectives on different instruments

The interviewees were asked about their preferred instruments and also to share their views on selected instruments. From the NGOs, it was argued that "We absolutely need more than one instrument. First, we need long-term liability. There are environmental issues that should be taken care of. Second: financial incentives where there is several alternatives. It could be a cap-and-trade. In the longer term, it could also be a carbon price. For CCS, you need a stronger standard: an EPS or a moratorium on fossil fuel" (S/N).

In order to make CCS happen, there is a call for an instrument-mix that takes care of the following: "What is needed is that the cost of operating the CCS plants is not too high and the alternative cost, i.e. that of emitting, is sufficiently high" (I).

PUBLIC FUNDING

In the workshop, it was mentioned that public funding and investment subsidies were instruments for demonstration projects. It was also stated that it is important not to give too much funding to one project. "Too much funding can be given to one project" (W). It was argued that because CCS is in a learning phase, the most important in the coming 10 years is to get the costs down. For this purpose, "we don't need only one single project; we need several types of project. It is better to use money on several demonstration projects than on one full-scale project" (W). But too little money granted to one project can also be problematic: "50% public funding is apparently not enough [to make CCS happen]" (S/N).

One NGO is clear that it should be a public-private partnership, where the private should contribute, but that the cost sharing so far has not worked so new models must be considered: "I think that – one of the interesting things happening now is that if you look at the financial incentives, they have been very insufficient. Even if you have more than 50% funding from the government, CCS is not happening because industry is backing out because of the financial crisis. [...] The subsidies – even in the near-term: the subsidies and grants should be matched with contribution from the industry. [...] In the longer term: the price on carbon should prove sufficient. Particularly if combined with a moratorium on fossil fuel or a strong EPS" (S/N).

To have a competition where the government picks the best project is also not without problems, according to one government representative: "The competition model used in Alberta: it was a hard task for the government to run a competition. [...] There are some advantages with this model: you can move relatively quickly and start the projects. On the other hand, there are disadvantages too: government picks winners and losers. It worked in Alberta because there was a very limited amount of projects. You have to define the risks very clearly. Our criterion was that it had to be a fully integrated capture, transport, storage chain" (G).

FEED-IN TARIFFS

There was a lot of contention regarding the feed-in tariffs among the interviewees. In the workshop, it was argued that a FIT can only be a support scheme in a commercialisation phase, not in the up-scaling of technology because the CCS projects are so different from renewable energy production: "It doesn't boost technology development like for renewables. For CCS, the investments required are too large" (W).

Many interviewees from all groups were quite positive about introducing FIT for CCS. They did not share the opinions presented at the workshop, and believed the FIT could work for CCS as well: "There is one thing that can work: Feed-in tariffs; designed as the premium tariffs in the UK. This is a sound solution. It would only cover the cost that actually occurs" (G). "In the UK, it is still an issue how much money will be available for the tariffs. If it works for the first project, you have a template, which will be much easier to follow. The first project sets a benchmark. If the prices decrease, the Levy for Contracts for Difference (CfD) adjusts. It is a very elegant system if introduced properly. I can't see any other similar mechanism that would give the same clarity to the industry" (I).

"The FIT has been incredibly successful for the renewables. I believe it would benefit CCS as well" (S/N). "It is a possible way forwards. The idea is not that bad. I have not thought about it before" (I).

One challenge regarding the FIT is political acceptance, such as in the US: "The chances for a FIT for CCS are not very great – no chance of getting this in the US" (S/N). But also in the EU: "It could help get the first projects up and going. It would make things move. But it is realistic to get consumers pay for this in the EU? Difficult to get support for this" (I). Especially because there is already lack of support for FIT for renewables: "The issue with the renewable FIT is that [...] people think the FIT are expensive. People are stepping back from this now, and may be less willing to accept a FIT on CCS as well" (G).

More critical voices argued that: "I think it will lead to all people buying the products from China – it is a way to stop all the CO_2 emissions by killing the industry" (I).

And the FIT for electricity production does not solve the storage issue: "– it's fine if you are a power station. But somebody needs to assure access to storage site, proven sites must be found. A lot of money connected to that. Why would people do that – take this risk?" (G).

EMISSION PERFORMANCE STANDARD (EPS)

The EPS is assessed rather negatively by many industry actors. Government, science and NGOs are far more positive about an EPS. The most commonly used argument from industry is that an EPS does not give you CCS. Despite scepticism within the industry, many advantages with an EPS were mentioned:

- To set a cap on emissions is an old and well-used instrument (G).
- There is good experience with this kind of regulation on other areas. To regulate emissions (pollution) is an important instrument from pollution policy (W).
- It works independent of the economic situation and financial backdrops (W).
- Is possible to use in a predictable way and tighten the emission standards incrementally (W).
- Defining benchmarks, best available technology – is good. Everybody should try to reach the best standard, and produce as efficient as possible. But it is important that these benchmarks are realistic and make them improve their production and not forbid it (I).
- In the longer term: it could work. The problem is that the standards are too weak to reduce the emissions from gas. Not convinced it is the way. We have to make the standards stricter so that they lead to a real decarbonisation. Perhaps by tightening the EPS over time (S/N).
- It's a bit prescriptive. You might not get the most efficient projects. But it would send the signal that the government is very committed to CCS. The first movers would show that it is possible. This would also drive the efficiency (G).
- It could work in a regulated market, for sure (G).
- If applied all over it would be okay. For the power industry – it would be sufficient to have it on the European scale (I).

The following counter-arguments were raised. The argument that EPS leads to a closing down of the production is the most frequently mentioned:

- EPS is a detail regulation where the state tells us what is good for us – has proven to be inefficient. And it would only work for the power sector, what about industry? (W).
- It does not help technology development (W).
- EPS – locks you into technology. EPS is set with currently available technology. You constrain the carbon path into the technology that is available for the moment (I).
- For the major part of our production, we would rather shut down the production. It could work if the technology is relatively mature. Now: the technology is immature. We don't know how long it takes to build the whole value chain and how to set up a business model for CCS (I).
- The standards proposed for industry are not realistic. It's better to have standards that just force producers to improve their current technologies than to shut it down (I).
- There can be small separate measures where it could work (where conditions are suitable), but for the major share of our production we would rather turn of the production. It could work if you have a technology that is somewhat mature. Now: the whole technology chain is not mature. We don't know how long it takes to build the whole chain for CCS, how to set up a business model for CCS (I).
- An EPS does not promote CCS. It's both ineffective and inefficient; in the end CCS is not provided. The operators don't do anything because of an EPS. The alternatives: close the plant, which is a good thing. Switch to gas: halves the emissions. So I do not support the EPS if you want to have CCS. You could also have a tradeable EPS, but this would then be quite similar to a portfolio standard, but this could work (G).
- EPS – you have other alternatives: you can close plants and you can build gas plants instead. EPS is more crucial in changing the markets from coal to other types of power, for instance

you can put bio in your coal plants. EPS is not pushing towards CCS, but towards bio (I).

- The EPS which is proposed now in the US only get you to a combined natural gas cycle. In a long-term, we need to be thinking of CCS with gas (S/N).

As an alternative to the EPS for the industry, a sector-specific approach is proposed: "The measure should rather be a sector specific approach: The cement sector should reduce emissions by x % – and that should be valid for everyone. EPS – that is not the key solution for the sector. The production specific features: The clinker substitution, use of fuel is a key one – you can't compare the fuel situation in Romania with Norway and China. That's why EPS will have to take this into account" (I).

CERTIFICATES

A certificates system is the instrument that is assessed positively by most interviewees. In order to make a certificate system work, it was mentioned as important to make certificate tradable and to have a price floor and cap – or even a fixed price – on the certificates. There were also some interviewees who said they knew little about the certificate system and were asking for more information about how such a system could function – both from industry and government.

Again, it is a question of whether it is introduced in the power sector or for industry – or both combined. For the industry sector, it is argued that it "Would not work if is not on the global level. No one in the construction sector is interested in carbon reduction" (I).

There were also disadvantages associated with a certificate system, including:

- It could be a solution that hits very differently for different power stations. If we, for instance, had a lot of power stations in Germany – where it's impossible to do CCS now – and a large production and are forced to buy a lot of certificates, we would rather close down the production (I).
- Even if you have the portfolio standards, you still have to get approval for the different projects. In Illinois, they do not meet their target. You need a champion for the volume, but it is a problem if it's not met (S/N).
- The certificates don't give the same security for investors as the FIT and not the same long-term predictability (S/N).

Statements in favor of the certificates were addressing the possibility to decide the volume of CCS, and to prove a long-term commitment to the technology:

- They are fine as long as they are transparent and work in a market sense. Risk that something politically driven could influence how the certificates are used. It works. Also, the carbon floor scheme in the UK. Almost as good as the FIT. You can raise more debts with the FIT (I).
- The key point with the certificates: they are volume based. So you (producers/industry) must do a volume, it's a regulation. It's going to be more certain that it works (G).
- The certificates are relatively efficient and very effective. In creating a volume liability for the industry. It's this that actually makes the industry build it. If you want to make it easier for people to do CCS, you can give them a FIT to help them. And you can make a carbon floor, but the price in the floor will (in my opinion) not be high enough to make CCS happen. First when you have a fixed volume, the producers are obliged to do the CCS. It's a regulation (G).

ETS

The statements about the ETS are very much addressing how the situation in the carbon market is for the moment – and not evaluating the theoretical potential in a cap-and-trade system. It is clear that for industry today, the price on allowances is too low and too uncertain to make any investments decision on this basis:

- The most efficient way: to have an ETS. The current scheme is completely ineffective. But have no impact on technology now (G).
- With current price, does not deliver sufficient incentives. So it is not the optimal instrument, as we see it (I).
- So far, we never financed projects on the basis of ETS because to uncertain. Carbon price is very political. We would need 20-30€/ton in a 15-20 year perspective. Not possible to get this today, especially not for this timeline. You must make sure that you get this investment back.
- The problem with the ETS today is that you don't have supply side control. You only control the demand side. This is very ineffective. For a proper carbon market, these things should be included (G).

A carbon floor could help in this situation:

- You need a price floor. This makes it more certain for investors and for those developing new technology and investing in full-scale CCS (W).
- "A carbon floor price, as proposed in the UK also helps. This has been done because the price is too low in Europe. [...] And the UK has done this even though there will be carbon leakage, for several reasons: to help renewable energy, nuclear energy, CCS etc" (G).

CARBON TAX

The carbon tax is mentioned by many as the most important way to get emissions down: "A price on CO_2 is the main pillar of climate policy" (W). "Globally, the best instrument would be a price on carbon"(I). This view is shared by representatives in all groups. "I actually think that a price on carbon in the long-term is maybe enough. But in the near-term it is never going to be high enough to cover the cost of CCS today"(S/N).

The challenge is to get political acceptance for a CO_2-price or tax, which is high enough to get the technology development required for CCS. "It is true that a kind of carbon tax would be the most efficient to get down emissions in an ideal world – but this doesn't exist. That's why we need alternative measures" (G).

An option mentioned is to introduce a low carbon price, which is increased slowly. This could help in combination with other instruments. "A low tax could be enough to finance the first 10-15 projects. Then make the tax higher when the technology is available [...] It could start at £20-30 by 2030. In the end: closer to £60" (G).

One interviewee specified to be a tax on the resource holders, i.e. fossil fuel producers. The tax should be set on the carbon content in the products imported to Europe, so it will be a border tax adjustment. In Europe most of the hydrocarbons consumed are imported. So it could be taxed at landing and collected by the treasuries [...] There could be a payment back to people that are vulnerable to higher prices (G). There could also be a rebate for industry because of carbon leakage, but this would mean that you have to have a higher tax.

WHO SHOULD PAY THE BILL?

When industry representatives were asked about who should pay for CCS, they were all arguing that consumers would have to pay for CCS in the end.

- "In the end, in a mature system, it is clear that consumers have to pay. But in the process of building up the system, it can be necessary to look other ways, where industry and society is helping and sharing the costs" (I).
- "The customers will have to pay for abated electricity. If the consumers don't pay directly, they have to pay it through taxes to the Government" (I).

- “In the long-term, the consumers will have to pay. But when you go to the big mass of consumers – they are not willing to this. Temporarily, there is the need for government funding – 100%. The companies will walk out of the countries where there are constrains on the industry – we have discussed this in our company” (I).

Both NGO and government representatives had opposite perspectives on this:

- Who pays? is the essential political question. If the industry has to pay, they would have to squeeze it out of their profits – in an open market. And it’s the question how much you can be doing this before they start move their investments into other business – or move out. You can make economical calculations on it, but you will not be able to get a straight answer (G).
- “I have a big objection to the argument that the costs have to be handed over to the consumers, especially if the project includes EOR. Industry is making money on these things. I know that EOR is helping gaining experience with CCS, but we should be very careful about EOR, because there are so many problems occurring with this” (NGO).
- Perhaps for a pure storage project, it could be possible to make consumers pay. But as of today: the industry is benefitting from involvement in research and the government is supporting establishment of this industry (NGO).
- Producers (industry) always argue against measures that work in the long-term i.e. for our grandchildren. If you say to industry that they will have a levy, they will almost always be against it. Therefore, you have to make it compulsory. The shareholders should be forced to take this risk. We have to persuade shareholders that depend on short term incomes. The politicians have to have the courage and introduce the necessary measures (G).

FACILITATE FOR CCS IN DEVELOPING COUNTRIES

Not all of the interviewees had a clear opinion on this issue, it was rather those in the sample working in developing countries or in sectors with international trading that came up with the perceptions rendered here.

From the trade-exposed industry, skepticism was brought up regarding the capacity of the industrialised countries to pay for CCS in the developing countries. Especially if industry is moving out of industrial countries because of carbon taxes and emissions standards, there will be no means left to finance CCS – neither in developed nor in developing countries. “If the industry is sourced out away from the developed countries, there will be no money there to pay for CCS in the developing countries. The system has to work” (I).

Interviewees from both government and NGO disagreed on this point. They were clear about that the rich countries have to pay the major share of mitigation costs, as stated in the CBDR principle (common but differentiated responsibility):

“I think that for the projects in emerging economies, there should be a set of criteria defining what should be funded. Governments in industrialised countries should then help support the projects fulfilling the criteria. [...] One option for how to provide this support is for instance through joint research and twinning on demonstration. Like the US and China is working on now. Another option would be to establish a dedicated fund, or a window of a dedicated fund. Before this is done, it would be useful to do an analysis and look at how other funds have been designed, draw from other experiences”(NGO).

It was also proposed to fund CCS in developing countries by using the certificate system: “The developed countries will have to pay for it (CCS in developing countries). NAMAs could be articulated against performance norms. We would buy certificates from those who do better than the norms. One option is to do this through the certificate (portfolio) system. Developing countries could produce certificates that could be bought by European actors and surrendered in the European certificate system.[...] If you include oversee reductions– you have to increase the amount of certificates, to be sure that you actually get the needed emissions reduction" (G).

Industry and government representatives in South Africa differed in their opinions about the role of NAMAs and the CDM: "A mechanism for developing countries would be to have access to a climate fund brought about by the carbon price. The NAMAs is a model that would work" (I). "The CDM has been a very successful programme. The issues people have with the CDM, don't see that it would become better by replacing it through NAMAs. A NAMA which is founded by developed countries – I believe that we would spend a few years trying to organise thing new, ending up the same place we started"(G).

"A better alternative would be to speed up the application process for the CDM. In Durban we had CCS being approved as CDM, which was essential for CCS. At the same time, the EU will not pursue CDM credits from other than from least developed countries.[...] It would be necessary to include the EIT in the CDMs" (G).

The funding option is considered not necessarily to be the most favourable, especially because of the experiences with the fund for funding green technologies in developing countries. "The actual funding is significantly lower than originally signalised" (G). To earmark funding for CCS in a technology fund is equally turned down: "This has been the renewable focus globally. I don't think it would be a good idea to promote specific technologies in particular in such a fund – better to keep the funding support on a general basis for emission reductions" (G).

IMPLEMENTATION OF POLICY INSTRUMENTS

- The perspectives on conditions for implementation of CCS instruments varied from addressing the general situation for funding CCS to the chances of implementing specific instruments:
- Nobody is very fond of CO_2 storage at this moment. One main reason: the lack political courage in Europe (I).
- It's not a level playing field for CCS. Renewables get subsidies, but they are not available right now for CCS because of the financial situation. In an ideal world, you should also have subsidies for CCS that would make it happen (G).
- At the moment, it would be politically unacceptable to get subsidies for CCS. There is a lot of unhappiness about any subsidies (G).
- An alternative way forward, in order to get the required emission reductions: you maybe set up targets for what you want in your energy mix – coal, nuclear, gas. You will still need some kind of encouragement for reaching that target (G).
- The chances for a FIT are not very great – no chance of getting this in the US. The certificate system is much more plausible (NGO).
- We need global standards – carbon constraints that are valid for all countries. [...] The perspectives for this are not very optimistic. We are very disappointed by the UN negotiations – are not able to find compromises and measures. [...] Developed countries are not able to pay for emissions reduction in developing countries; they are not going to do this. It is impossible" (I).

Transport of CO_2 by ship. (Photo: Yara)

Appendix II: Current CCS policy, country review

Governments around the world have provided a range of different types of funding support to CCS demonstration projects. Cumulative spending for 2007-2012 on CCS projects in large scale[38] reached almost USD 10.2 billion[39]. USD 7.7 billion came from private financing, and this figure reflects, in most cases, the costs related to the full industrial project and not just CCS components for controlling the facility's emissions[40]. Government grants contributed USD 2,4 billion, with the US and Canada (federal and state or provincial) being the largest contributors.

USA

GOVERNMENT SUPPORT AND LOANS

The government has initiated a series of co-funded demonstrations through public-private partnership programs the last decade, like the Clean Coal Power Initiative, Industrial CCS projects, FutureGen, and Regional Carbon Sequestration Partnership Program. Nearly USD 400 million/year was appropriated in 2009-2011[41], in addition to USD 3,4 billion under the American Recovery and Reinvestment Act (ARRA) of 2009[42].

LOAN GUARANTEES FOR CCS

The Energy Policy Act of 2005 (EPACT) contains a series of incentives and initiatives too, expressly including CCS projects. Guarantees can cover up to 80% of the project cost. This was increased to 100% in the 2009 regulation and the loan funded by the Treasury Department's Federal Financing Bank[43]. USD 8 billion of loan guarantees for CCS and other emissions-reducing carbon technologies were announced in 2008[44]. And up to USD 8 billion was issued in President Obama's Climate Action Plan[45] in 2013 to advanced fossil energy and efficiency projects to support investments in innovative technologies. The Rural Utilities Service (RUS) also has direct loans and loan guarantees to power plants, including at least one CCS project[46].

TAX CREDIT FOR CCS

The Internal Revenue Code contains a number of incentives to support CCS technology development and deployment: A 20% tax credit for qualified research expenses, Investment tax credit for IGCC or other advanced coal-based electricity generation technologies[47], tax credit for CO_2 EOR and storage,

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38 Power greater than 100 MW, and at all scales for industrial application construction or operating between 2007 and the end of 2012.

39 IEA CCS roadmap, 2013.

40 The private finance share includes significant spending on capture projects that supply CO2 for EOR, some of which may not carry out monitoring sufficient to prove that injected CO2 will be permanently retained. Global CCS Institute (2013).

41 http://www.globalccsinstitute.com/networks/cclp/legal-resources/financing/usa/fossil-energy-rnd

42 USD1.5 billion for industrial carbon capture ('ICCS programme'), USD1billion R&D mainly intended to be awarded to FutureGen, and USD800 million Clean Coal Power Initiative (CCPI) Round 3 solicitation, http://www.epa.gov/climatechange/Downloads/ccs/CCS-Task-Force-Report-2010.pdf, p.87.

43 http://www.globalccsinstitute.com/networks/cclp/legal-resources/financing/usa/ccs-investment-incentives http://www.lgprogram.energy.gov/

44 USD2 billion for advanced coal gasification projects, which convert coal cleanly into electricity, hydrogen, and other valuable energy products, https://lpo.energy.gov/?p=845

45 http://www.whitehouse.gov/the-press-office/2013/06/25/fact-sheet-president-obama-s-climate-action-plan

46 http://www.epa.gov/climatechange/Downloads/ccs/CCS-Task-Force-Report-2010.pdf, p.94.

47 http://www.epa.gov/climatechange/Downloads/ccs/CCS-Task-Force-Report-2010.pdf, p.95.

USD 20/tonne for geological storage and USD 10/tonne for EOR operations[48] for up to max 75 million tonnes of CO_2 per year[49].

EOR

CO_2 from CCS projects has been used for EOR projects in the US since the 1970s. 40-50 mill tonnes CO_2/y are used in more than 100 EOR projects, accounting for the production of about 280,000 barrels/day of extra oil. The majority of the CO_2 is from geological formations containing CO_2, while approximately 15% of the CO_2 is from CCS projects. Of the 10 CCS demonstration projects selected by the US Department of Energy for development by 2016 (2010- task force), around 75% of the captured CO_2 is expected to be used in EOR operations[50]. Studies have indicated a large potential for EOR in the US (2-3 million barrels per day) if additional sources of CO_2 were available[51].

STATES

EPS:

- **California**: set into law (2006) an EPS for new base load power plants[52].
- **Montana**: standards that require CCS for all new coal plants, and special taxation rates for CCS equipment[53].
- **New York and Washington**: EPS for new base load power plants of the emission level of combined cycle gas plants.
- **Maine and Idaho**: A temporary moratorium on coal until CCS is developed.

PORTFOLIO STANDARD:

- **Illinois**: Clean Coal Portfolio Standard Law Approved in 2009, establishes emission performance standards for new coal-fired plants of 50% capture from 2009, 70% from 2016 and 90% post 2017[54]. The Clean Coal Portfolio Standard makes it mandatory for each utility to enter into agreements with the initial clean coal facility, covering electricity generated by the initial clean coal facility representing at least 5% of each utility's total supply in 2015. The goal is to have 25% of the electricity from clean coal facilities by 2025[55].
- **Pennsylvania**: 2009: Act amending for CCS to the Alternative Energy Portfolio Standards 2004. The alternative Energy Portfolio standard sets demand for 10% in 2021, up to 20% in 2026[56].

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48 In 2008, the Emergency Economic Stabilization Act (EESA) adds a new section to the Internal Revenue Act introducing a 'Tax Credit for Carbon Sequestration, which was amended by ARRA in 2009 Section 45Q in its current form.

49 A 'qualified facility' is an industrial facility operating in the US, which is owned by the taxpayer claiming the credit and equipped with CCS technologies that capture at least 500,000 metric tonnes of CO2 a year, http://www.globalccsinstitute.com/networks/cclp/legal-resources/financing/usa/ccs-investment-incentives

50 http://www.globalccsinstitute.com/networks/cclp/legal-resources/financing/usa

51 see Interagency Task Force on CCS, Report 2010 and Advanced Resources International, White Paper 2010

52 Global Warming Solutions Act in 2006 to reduce GHG emissions through a combination of regulatory and market mechanisms.

53 2007: This Act provides that the Montana Public Service Commission cannot approve new coal plants unless 50% of CO2 is captured. http://www.globalccsinstitute.com/networks/cclp/legal-resources/dedicated-ccs-legislation/us/states-in-force

54 http://ilga.gov/legislation/publicacts/95/PDF/095-1027.pdf (p.20)

55 Taylorville Energy Center, http://www.cleancoalillinois.com/tec.html "The bill also provides that an initial clean coal project that has a final air permit on the effective date of the legislation is entitled to enter into 30-year contracts with utilities and other retail suppliers. Christian County Generation believes that the Taylorville Energy Center will be Illinois' initial clean coal project." http://www.cleancoalillinois.com/qa.html

56 http://www.legis.state.pa.us/CFDOCS/Legis/PN/Public/btCheck.cfm?txtType=PDF&sessYr=2009&sessInd=0&billBody=S&billTyp=B&billNbr=0092&pn=0683

TAX CREDITS++

- **Colorado**: Project demonstrating CCS on coal will get full cost recovery methodologies for one project[57] (2006).
- **Kansas**: The Kansas Carbon Dioxide Reduction Act (2007) includes property and income tax reductions for CCS[58].
- **Mississippi**: Reduced rate of income tax on the sale of CO_2 for EOR or CCS (2009).
- **Texas**: Tax incentives for CCS.
- **Utah**: Incentives for producing Hydrogen Power with CCS.

PROPOSED CCS POLICY

EPS

January 2011, the Environmental Protection Agency (EPA) required large stationary sources obliged to obtain permits under the Clean Air Act to also tackle GHG emissions. In March 2012[59], EPA issued a rule proposing that new fossil fuel-fired power plants had to meet an output-based performance standard of 1000 pounds CO_2/MWh[60]. The average natural gas plant meets that standard, while conventional coal plants emit almost double the limit. In President Obama's new Climate Action Plan (June 2013), EPA is directed to establish carbon pollution standards for new and existing power plants[61].

Canada

General climate policy – relevant for CCS

CO_2 TAX

- Alberta has introduced a carbon tax of CAD 15/tonne for large emitters. The emitters can either buy credits from other emitters with lower emissions than the standard, or pay the tax to a technology fund. The fund gives support to mitigation projects managed by Alberta's Climate Change and emissions Management Cooperation (CCEMC)[62].
- British Columbia has a CO_2 tax of $30/tonne.

EMISSION STANDARDS (EPS)

In 2011 the Federal Government proposed an EPS for coal fired electricity production. Environment Canada announced that final regulations in September 2012[63] would come into force in July 2015. These regulations also include old units that have reached the end of their lifecycle, defined to be 50 years from the unit's commissioning date. Units commissioned before 1975 can be run until at the latest the end of 2019, and commissioned before 1986 by the end of 2029. Units that incorporate CCS may apply for an exemption from the performance standard until 2025.

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57 http://www.state.co.us/gov_dir/leg_dir/olls/sl2006a/sl_300.pdf

58 http://www.globalccsinstitute.com/networks/cclp/legal-resources/dedicated-ccs-legislation/us/states-in-force

59 http://www.washingtonpost.com/national/health-science/epa-to-impose-first-greenhouse-gas-limits-on-power-plants/2012/03/27/gIQAKdaJeS_story.html

60 (453g/KWh). New power plants with CCS would have the option to use a 30-year average of CO2 emissions to meet the proposed standard rather than meeting the annual standard each year. The proposal does not apply to existing units and transitional sources that commence construction within 12 months of the proposal. http://yosemite.epa.gov/opa/admpress.nsf/bd4379a92ceceeac8525735900400c27/9b4e8033d7e641d9852579ce005ae957!OpenDocument

61 http://www.whitehouse.gov/the-press-office/2013/06/25/fact-sheet-president-obama-s-climate-action-plan

62 Large emitters with more than 100 kt/y, for emissions higher than the standard set for the specific sector (Specified gas emitters regulation). http://ccemc.ca/

63 Reduction of Carbon Dioxide Emissions from Coal-fired Generation of Electricity Regulations, at 420t/GWh equivalent to a combined cycle natural gas plant. http://www.ec.gc.ca/default.asp?lang=En&n=714D9AAE-1&news=4D34AE9B-1768-415D-A546-8CCF09010A23. http://www.gazette.gc.ca/rp-pr/p2/2012/2012-09-12/html/sor-dors167-eng.html

REGULATED ELECTRICITY PRICES

The provinces have jurisdiction over electricity production[64] (like in the US). Each state has a utility board, and many of the power companies are owned by the government and have a cost recovery based business model. The utility board in each state must then approve the projects. If this is approved, the cost for the project is included in the electricity price, on a cost recovery basis. The price for electricity to customers is based on the cost for the portfolio for the power company. This gives a lower investment risk than in a marked based system with price competition.

This can be seen as a kind of a feed-in system where the price is set to the cost level for the project and financed by the electricity consumers - if approved by the utility board. For the Boundary Dam CCS project in Saskatchewan, it is important to mention that Saskpower promised that the new capture unit would not add to the rate base. The goal is to sell CO_2 to EOR on a break-even basis.

SPECIFIC CCS POLICY

DIRECT GOVERNMENT SUPPORT

Canada's federal and provincial governments have committed a total of approximately CA$3 billion in funding for CCS, provided through a number of federal and provincial programs. The federal government funding has been up to CA$1 billion as well as CA$240 million to Boundary Dam, but not all has been spent because the Pioneer project was cancelled.

STATES

The government of Alberta has allocated $2 billion towards CCS projects, to reduce CO_2 emissions by up to 5 million tonnes per year by 2015 through the development of three to five commercial-scale CCS projects[65]. Projects are eligible to receive up to a maximum of 75% of the total cost of capturing, transporting and storing CO_2[66]. Two projects are going ahead, but two of the projects selected for support are cancelled, and the funding is not reallocated to new CCS projects due to the budget situation[67], so the total funding can be substantially lower if the rest of this money isn't reallocated later. Saskatchewan has royalty relief on CCS for CO_2 EOR.

Norway

GENERAL CLIMATE POLICY – RELEVANT FOR CCS

A carbon tax on CO_2 emissions from offshore petroleum production was introduced in 1991 (342 NOK-45€/tonne, 509 NOK–68 €/tonne inflation corrected to 2012 value). The tax has been important for the two commercial CCS projects in operation in Norway, injecting CO_2 from natural gas cleaning at Sleipner (1996)[68], and the Snøhvit LNG plant (2008)[69]. The tax in 2013 is 410 NOK/tonne (~€50/tonne), in addition to ETS. Part of the funding from the CO_2 tax is used in a new technology fund for support to emission cuts in the industry.

EXISTING CCS POLICY

The pollution authorities mandated CCS for the permission to a new gas-fired power plant in 1997

64 http://www.electricity.ca/about-cea/provincial-regulation.php

65 Carbon Capture and Storage Funding Act, Legislated in 2009. http://www.canlii.org/en/ab/laws/stat/sa-2009-c-c-2.5/latest/sa-2009-c-c-2.5.html

66 http://www.zeroco2.no/projects/support-mechanisme/alberta-ccs-fund
http://www.solutionsstarthere.ca/24.asp

67 Canceled funding: Project Pioneer CA$436 million, and Swan Hills Synfuels CA$285 million.

68 http://www.zeroco2.no/projects/sleipner-west

69 http://www.zeroco2.no/projects/snoehvit

(Kårstø). In 2000 it came to a conflict in the Parliament considering the discharge permits, which lead to the resignation of the government, and removal of the CCS obligation.

In 2005 the new government declaration set goal to build full scale CCS at the Kårstø gas power plant as soon as possible (within 2009). A state owned company, Gassnova SF, was established in 2007 to manage the governmental commitments to the CCS projects. The CCS project was ready to start tender for EPS-contract in early 2009, but was kept on hold due to uncertainties concerning the operation of the power plant

In 2006 Statoil was permitted to build a combined heat and power plant at Mongstad refinery. The government and Statoil agreed to deploy CCS technology at Mongstad in two stages; a 100 kt/y test center (TCM) in operation by 2010, and full scale CCS plant completed by 2014. The agreement commits the government to pay for the planning and cost for the CCS plant, while Statoil should pay the possible emission cost and for cost overruns after investment decisions. The planning process has been slow and the date for the investment decision has been postponed several times. In september 2013 the project was cancelled.

DIRECT GOVERNMENT FUNDING

In total the Government has spent ~ €1,5 billion (2006-2013) for planning and building CCS projects, mainly for building TCM and planning full scale CCS at Mongstad and storage.

EPS

In 2005 the government declaration promised no new gas-fired power plants to be built in Norway without CCS. In 2009 the government gave permission for a new gas-fired power plant at Eldnesvågen mandating CCS from day one. The project has so far not been built.

Australia

DIRECT GOVERNMENT FUNDING

Australia CCS's Flagships Program of AUD 1,68 billion has the goal of completing 2-4 commercial-scale projects.

The state of New South Wales has a Clean Coal Fund of $100 million (2008).

PRIVATE FUNDING

The COAL21 fund, which is fed by a voluntary levy on coal production, is expected to collect AUD1 billion over 10 years (from 2006) to fund a CCS demonstration program. More than a quarter of the Fund has been committed to demonstration projects as well as a national research programme managed by Australian National Low Emissions Coal Research (ANLEC)[70].

European Union

GENERAL CLIMATE POLICY – RELEVANT FOR CCS

EMISSIONS TRADING SYSTEM (ETS)

The Emissions Trading System is in its third phase (2013–2020). The target is set to decrease linearly ance is now around €5[71], far too low to trigger technology step changes such as CCS.

70 http://www.australiancoal.com.au/coal21.html

71 http://www.nasdaqomx.com/commodities €4,4/tonne, 21.aug 2013.

PROPOSED POLICY

ENERGY ROADMAP 2050

In December 2011, the European Commission adopted the Communication "Energy Roadmap 2050", committing to reduce greenhouse gas emissions to 80-95% below 1990 levels by 2050 - in the context of necessary reductions by developed countries[72]. The Energy Roadmap 2050 is the basis for developing a long-term European framework to achieve a secure, competitive and decarbonised energy system by 2050[73]. The assessments made in the context of the Roadmap see CCS as an important technology contributing to low carbon transition with 7% to 32% of power generation using CCS by 2050, depending on the scenario considered, in addition to CO_2 reduction from industrial processes.

GREEN PAPER 2030

The Commission published a Green Paper[74] (March 2013) launching a public consultation on what the 2030 framework should contain, with intention to table the framework by the end of 2013.

CCS POLICY

As a part of the Energy and Climate Package (2009)[75], the EU set the goal to enable commercial deployment of CCS by 2020 through the development of a demonstration programme of 10-12 CCS plants by 2015. The main financing mechanism for this demonstration programme was adopted in 2010 through the NER 300[76].

Additionally, the directive on the geological storage of CO2[77] was adopted in 2009. The directive covers all CO_2 storage in geological formations in the EU and lays down requirements which apply to the entire lifetime of storage sites.

NER 300 (MARKED BASED DIRECT PROJECT FUNDING)

Under the NER300[78] funding mechanism, 300 million carbon allowances from the ETS New Entry Reserve are set aside to co-finance demonstration projects, both CCS and innovative renewable energy technologies. The EU funding is set at maximum 50% of the additional cost. Member States can contribute with up to 50% in addition to the NER 300 funding. The European Investment Bank is in charge of selling the ETS allowances on the carbon market to provide financial assistance, to be awarded through two bidding rounds.

Reduced price for allowances has reduced the expected value substantially, so only €1.2 bn was available from the sale of 200 mill allowances in the first round. 13 CCS projects submitted applications in the first round[79], but no CCS project was awarded funding. The EC has stressed its commitment to funding CCS[80]. Only one country has applied for funding to a CCS project (White Rose, UK)[81] in the second round, expected to be decided by the end of 2014[82].

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72 http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:52011DC0885:EN:NOT
73 http://ec.europa.eu/energy/energy2020/roadmap/index_en.htm
http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2011:0885:FIN:EN:HTML
74 http://ec.europa.eu/clima/policies/2030/index_en.htm
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77 http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32009L0031:EN:NOT
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81 http://ec.europa.eu/clima/funding/ner300/docs/project_proposals_en.pdf
82 http://ec.europa.eu/clima/funding/ner300/index_en.htm

DIRECT GOVERNMENT FUNDING

The European Energy Programme for Recovery (2009), granted €1bn to six CCS projects[83] for planning costs. Due to terminated projects not all is spent.

EEA GRANTS CCS PROGRAM

The Norway EEA Grants[84] are providing funding for CCS projects in the Czech Republic (€7 mill), Poland (€137million Belchatów[85]) and Romania (€40 million)[86].

PROPOSED CCS POLICY

CONSULTATIVE COMMUNICATION ON CCS

The European Commission published a new consultative communication on the future of CCS in Europe (March 2013)[87]. This Communication discusses options for encouraging CCS deployment. Two possible measures are described specifically; EPS and a CCS certificate system.

United Kingdom

GENERAL CLIMATE POLICY – RELEVANT FOR CCS

In 2008, the Climate Change Act was introduced with a binding emission reduction target of at least 80% by 2050 relative to 1990 levels[88]. The government strongly recognises the need to decarbonise the power sector and that CCS has great potential.

CARBON PRICE FLOOR

A Carbon Price Floor was introduced from April 2013, to secure a minimum price for emissions from fossil electricity production. A "carbon price support" is charged on top of the ETS carbon price, decided two years ahead by the Treasury. The rates are £4.94 in 2013, £9.55 in 2014, and £18.08 in 2015. Indicative rates for 2016-17 and 2017-18 are £21.20 and £24.62 per tCO_2[89]. The goal is £30 per tonne by the end of the decade, and £70 per tonne in 2030[90].

EXISTING CCS POLICY

DIRECT GOVERNMENT FUNDING

The first CCS competition in UK was launched in 2007, but failed to reach a financing deal with the one remaining finalist – Longannet – for the £1 billion grant on offer, after four years of effort.

A tax on electricity was proposed (The Energy Act 2010) to support these CCS projects. In the 2011 budget it was announced that one would not pursue the levy as a method of funding the demonstration programme, and would instead provide funding from general taxation[91]. The Government announced a new

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83 (Jaenschwalde (Germany), Porto-Tolle (Italy), ROAD (The Netherlands), Belchatow (Polen), Compostilla (Spain), Hatfield (UK)). http://www.zeroco2.no/projects/support-mechanisme/15-energy-projects-for-european-economic-recovery
84 http://eeagrants.org/What-we-do/Programme-areas/Carbon-capture-and-storage/Carbon-capture-and-storage
85 http://eeagrants.org.ez.07.no/programme/view/PL11/PA20
http://eeagrants.org/News/2011/Norway-and-Poland-sign-agreements
86 http://eeagrants.org.ez.07.no/programme/view/RO16/PA20
87 http://ec.europa.eu/energy/coal/doc/com_2013_0180_ccs_en.pdf
88 http://www.legislation.gov.uk/ukpga/2008/27/contents
89 http://www.hmrc.gov.uk/budget2013/tiin-1006.pdf & http://www.sandbag.org.uk/site_media/pdfs/reports/Sandbag_Carbon_Floor_Price_2013_final.pdf
90 http://www.businessgreen.com/bg/news/2258336/carbon-floor-price-launches-at-gbp16-per-tonne
91 http://www.globalccsinstitute.com/networks/cclp/legal-resources/dedicated-ccs-legislation/uk

£1 billion CCS Commercialisation Programme in April 2012[92]. The bids closed in July 2012 and in March 2013 Peterhead (gas) and White Rose (coal) was taken forward, while the two others remain as "reserve bidders"[93]. DECC expects the projects to proceed on to final investment decisions by early 2015.

EPS

In 2009, the government established a framework for the Development of Clean Coal. Any new coal-fired power station and existing power stations upgrading to supercritical technology[94] will be required to demonstrate CCS for at least 300 MW[95].

PROPOSED POLICY

CONTRACTS FOR DIFFERENCE

The Electricity Market Reform Bill[96] (2012) features a Contracts for Difference (CfD) - a form of Feed in Tariff mechanism for low-carbon electricity projects (renewables, new nuclear power and CCS). Draft Contracts for Difference were published in Aug 2013. The final contract drafting will be published in December alongside the final strike prices, and implemented through regulations laid before Parliament in 2014[97]. The Government's intention is that future CfD allocation for CCS projects takes place through competitive project selection processes[98].

EPS

An emissions performance standard is proposed with a limit for fossil-fuel power plants of 450g CO_2KWh, to prevent coal-fired power stations being built unless they are equipped with CCS[99]. The climate change envoy for the Labour Party introduced an amendment to the standard to 200g/kWh, also including gas power plants[100].

The Netherlands

EXISTING CCS POLICY

The Netherlands' CCS Roadmap sees support for large-scale demonstration projects from 2015 to 2020 (phase 3), and commercial use of CCS in phase 4. The cabinet was aiming at two large-scale demo projects (out of the 12 proposed by the EU) in 2015 or earlier if possible.

DIRECT GOVERNMENT FUNDING

The government has provided €150 million in support for the Road CCS project (Spring 2010)[101].

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92 https://www.gov.uk/government/news/ccs-competition-launched-as-government-sets-out-long-term-plans
93 https://www.gov.uk/government/news/preferred-bidders-announced-in-uk-s-1bn-ccs-competition
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99 Until the year 2045. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/48375/5350-emr-annex-d--update-on-the-emissions-performance-s.pdf & https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/48367/5315-aide-memoire-on-emissions-performance-standard.pdf
100 http://ghgnews.com/index.cfm/uk-lawmaker-proposes-tighter-emissions-performance-standard/
101 http://www.road2020.nl/en/2011/04/staatssteun/

France

DIRECT GOVERNMENT FUNDING

The French government confirmed co-funding the NER300 process for the ArcelorMittal steel mill CCS project (ULCOS[102]) at Florange. The project was withdrawn from ArcelorMittal due to closing down the steel production at this site.

South Korea

GENERAL CLIMATE POLICY

South Korea is listed as one of the top 10 largest emitters globally, driven by its energy-intensive economic activity (manufacturing). The two major objectives of their Five Year National Plan for Green Growth are to reduce emissions by 4 % below 2005 levels by 2020, and to allocate 2 % of annual GDP to Green Growth investments and development projects. In May 2012 South Korea approved the establishment of a cap-and-trade scheme for 2015.

DIRECT GOVERNMENT FUNDING

According to GCCSI, 2012, South Korea has given significant monetary support from public funding programs for CCS, nearly USD800 million for two CCS projects. The government has indicated that it will spend USD150 million over the next decade specifically on CCS[103].

Major Emerging Economies

At least 19 developing countries are engaging in CCS activities. Most of these countries are at an early stage of scoping out the opportunities and potential for CCS, and have not established large funding and financial incentives. The countries with most CCS activities are Algeria, Brazil, Mexico, South Africa, the UAE, and China[104].

CHINA

China's 12th Five Year Plan (2011-2015) has significant targets for low-carbon energy, including a potential role for CCS. A series of CCS demonstrations are planned and under way, including GreenGen (IGCC with CCS), test injection at a coal liquefaction plant in Inner Mongolia, and an operational post-combustion CO_2 capture on a supercritical coal plant near Shanghai. The State power giant "Huaneng Group" has two fully integrated post combustion capture pilots – in Beijing and Shanghai and the Greengen IGCC project.[105]

China is also involved in CCS projects abroad, they have been involved in the Futuregen in US for several years, and the Texas Clean Energy Project with a loan and construction deal in 2012.

In March 2011, the National Development and Reform Commission (NDRC) issued China's Notification on Orderly Development of Coal-Chemistry, which requires all new coal-chemical demonstration projects to be capable of substantially reducing CO_2 emissions. This means that newly built coal-chemical demonstration projects will need to consider installing technologies such as large-scale CCUS facilities in order to control their CO_2 emissions.

102 http://www.ulcos.org/en/index.php
103 GCCSI,2012.
104 GCCSI, 2012.
105 http://gasification-igcc.blogspot.co.uk/

SOUTH AFRICA

South Africa's Vision, Strategic Direction and Framework for Climate Policy (2008)[106] supports CCS for coal-fired power stations and all CTL plants, with an assumption that power plants that are not CCS ready should not be approved.

Sasol is a large Petrochemical company with high emissions in SA. In 2010 they got involved in the CCS test activities at the Technology Centre Mongstad (TCM), by purchasing a 2.44 % stake[107]. Sasol has indicated that it is committed to developing the human and technical capacity to implement CCS as a possible greenhouse gas mitigation solution for the company's existing operations.

The South African Centre for Carbon Capture and Storage (SACCCS) was set up in 2009, and an Atlas on Geological Storage of CO_2 in South Africa was published in 2010.

United Arab Emirates

The Masdar Initiative launched in 2008 to build Masdar City as the world's first zero-carbon sustainable city. They have been working with Hydrogen Power Abu Dhabi (HPAD) CCS project for several years. Funding of USD15 bn comes from the Abu Dhabi government.

CCS in the international arena

CCS IN CDM

In 2011 it was decided that CCS was to be within the list of activities eligible under the Clean Development Mechanism (CDM)[108]. CCS in CDM has been a long process with a high grade of opposition from some countries and NGOs. The price for CDM is currently very low, and it is unlikely to result in a large CCS implementation.

CCUS ACTION GROUP

The governments of Australia and UK established the Carbon Capture Use and the Storage (CCUS) Action Group in 2010. It brings together governments, institutions, and industry to facilitate political leadership and provide recommendations to the Clean Energy Ministerial (CEM) on concrete, near-term actions to accelerate the global deployment of carbon capture and storage (CCS)[109]. The CCUS Action Group recommended that USD 200 mill is allocated internationally to accelerate the deployment of CCS in the near term. In 2012, UK allocated up to £60 million to support this development of CCS in emerging markets.[110]

WORLD BANK CCS FUND

The Carbon Capture and Storage Capacity Building Trust Fund was set up in 2009 by the Global CCS Institute and the Norwegian Government's joint contribution of USD 8 million. The Trust Fund supports capacity building activities in several developing countries[111].

ASIAN DEVELOPMENT BANK, CCS TRUST FUND

In July 2009, the Asian Development Bank (ADB) announced the establishment of the CCS Trust Fund, capitalized at AUD21.5 million from a contribution of the Global CCS Institute. The Trust Fund will pro-

106 Vision, Strategic Direction and Framework for Climate Policy (2008)

107 http://www.engineeringnews.co.za/article/sasol-buys-stake-in-ccs-technology-centre-in-norway-2010-05-03

108 http://www.globalccsinstitute.com/networks/cclp/legal-resources/cdm

109 http://www.cleanenergyministerial.org/Portals/2/pdfs/factsheets/FS_CCUS_April2012.pdf & http://www.cleanenergyministerial.org/our_work/carbon_capture/index.html

110 http://www.decc.gov.uk/en/content/cms/news/pn12_053/pn12_053.aspx

111 http://www.zeroco2.no/projects/world-bank-ccs-trust-fund

vide grant financing for CCS components in investment projects, along with technical assistance, policy support, and other capacity building activities, and assist in preparing demonstration projects that will lead to commercial-scale deployment of CCS[112]. The Clean Energy Program has become one of ADB's highest priorities, with over one fourth of the total approved loans in 2008 supporting projects with clean energy components[113].

112 http://cdn.globalccsinstitute.com/sites/default/files/publications/20671/carbon-capture-and-storage-developing-countries-perspective-barriers-deployment.pdf (p.68)
113 http://www.adb.org/sectors/energy/programs/clean-energy-program

Summary todays policy instruments for CCS, country review

Country	Government funding	Investment subsidies, market mechanisms	EPS	Portofolio standard/ Certificates	Regulated el. prices / Feed-in	CO2 tax/ETS
USA	• Public-private partnership programs last decade, DoE support USD 3,8bn. Loan guarantees in addition 80 %/100 % of project cost. • Tax credit for investments in IGCC, and for storage: US$20/ton CO2 or US$10/ton used for EOR operations. • Montana: Special taxation rates for CCS equipment • Kansas: Property and income tax exemptions/ reductions for CCS (2007) • Mississippi: Reduced rate income tax on the sale of CO2 for EOR or CCS (2009) • Texas: Tax incentives for CCS • Utah:Incentives for producing Hydrogen Power with CCS		• California: EPS for new base load power plants (2006) • Montana: Requiring 90% CCS for all new coal plants • New York and Washington: EPS for new base load power plants • Illinois New coal plants: 50 % capture before 2015,70 % 2017 & 90 % post 2017 • Maine and Idaho: Moratoriums on coal until CCS is developed	•Illinois: Mandatory min.5 % of each utility's supply clean coal by 2015. Goal 25 % by 2025 • Pennsylvania: CCS included to the Alternative Energy Portfolio Standards (2009); 10 % in 2021, 20% in 2026 (total alternative energy)	•Colorado Full cost recovery for IGCC and CCS for one project (2006)	
Canada	• Committed CA$1bn for CCS. Not all spent due to canceled project. •Alberta: CA$2bn CCS fund (2009). Not all is spent due to 2 canceled projects • Saskatchewan: Royalty relief CCS EOR		• Max. 420 g/KWh for new & end-of-lifetime coal power plants, from 2015. (decided Sept 2012)		• The provinces have jurisdiction over power production. Many power companies owned by regions, with cost recovery model. As in Saskatchewan	• British Columbia CO2 tax: CA$30/tonne • Alberta: CA$15/tonne to a technology fund (>100't/y for higher emissions than standard). Tradable credits
Norway	• ~€1,5bn spent for CCS projects(2006-2013), for building test center (100') & planning full scale CCS Mongstad and storage.		• First mandatory CCS for gas-fired power plant in 1997, changed by new gov. in 2000. • Government declaration 2005: no new gas-fired power plants without CCS.			• CO2 tax petroleum production, 1991. Tax ~€50/ tonne CO2 in addition to ETS.
Australia	• AUD1,68bn CCS Flagships Program, ~1bn allocated by 2012. • New South Wales: AUD100 mill. Clean Coal Fund	• Voluntary levy coal prod. (Coal21fund). Exp. AUD1bn (2006-2016)				• Carbon-pricing mechanism commenced 2012. Linked to EU ETS from no later than 2018. • New government 2013 promised to end carbon taxes.

Proposed policy, not yet implemented

Country	Government funding	Investment subsidies, market mechanisms	EPS	Portofolio standard/ Certificates	Regulated el. prices / Feed-in	CO2 tax/ETS
EU	• €1bn to planning of six CCS projects (Economy Recovery Plan 2009). • Norwegian EEA Grants to CCS projects. Poland €137mill at Belchatów, Romania €40 mill and Czech Republic €7 mill	• NER300. 300 mill allowances from ETS for investment support to CCS and innovative renewable projects. No CCS projects supported first round.	• The European Commission: Consultative communication on CCS (March 2013): Two measures described specifically; EPS and CCS certificate system.	• The European Commission: Consultative communication on CCS (March 2013): Two measures described specifically; EPS and CCS certificate system.		• EU ETS third phase 2013-2020. Linearly decrease by 1.74 %/y. Allowance price wis now below €5/tonne.
UK	• £1bn CCS competition. 2 projects chosen for detailed planning. Expected final investment decisions 2015		• New fossil power stations: CCS for at least 300MW (2009).		• Contracts for Difference for low-carbon power. Implementation in Parliament, 2014	• Carbon Price Floor: carbon price support charged for power production. 2013: £4.94, 2014: £9.55, 2015: £18,08 per tCO2. Goal £30 in 2020.
The Netherlands	• €150mill to the Road CCS project					
France	• Confirmed co-funding to NER300 for steel mill CCS project, but project was canceled.					
Korea	• Nearly USD800 mill is allocated for two CCS projects (According to GCCSI).					
United Arab Emirates	• Masdar initiativ to build a zero-carbon sustainable city, with total USD15 bn fund from Abu Dhabi gov. A CCS project are planned as a part of this.					
China	• China's 12th Five Year Plan (2011-2015) has significant targets for low-carbon energy, incl. a potential role for CCS. A series of CCS demonstrations are planned and under way in China.		• The National Development and Reform Commission (NDRC) required (2011) all new coal-chemical projects to be capable of substantially reducing CO2 emissions.			
South Africa			• South Africa's Framework for Climate Policy (2008) assumption that power plants that are not CCS ready should not be approved.			
International arena (UNFCCC++)	• CCUS Action Group, UK allocated up to £60 million to support development of CCS in emerging markets. • World Bank: Carbon Capture and Storage Capacity Building Trust Fund • Asian Development Bank (ADB) announced the establishment of the CCS Trust Fund	• 2011 CCS was eligible under the Clean Development Mechanism (CDM) in 2011				

Proposed policy, not yet implemented

Policy instruments used for the existing CCS projects

	Under construction / In operation	CO2 income EOR	Goverment direct funding	Tax credit	Carbon tax/ETS	Regulated el. prices/ Feed-in	EPS
USA	40-50 mill tonnes CO2/y is used in more than 100 EOR projects. ~15% is from CCS projects (rest is natural CO2 reservouars) . Large industry CCS projects are Century plant 8,4Mt and Shut Creek 7 MT/y, both natural gas cleaning.	Yes		USD10/tonne CO2 to EOR			
	Air Products Port Arthur (Oil refinery). Capture from hydrogen plant, with pure/high % CO2. 1Mt/y. Construction started Aug 2011. In operation May 2013	Yes	DOE: 66% of the USD384 mill project cost	USD10/tonne CO2 to EOR			
	Illinois ICCS bioethanol plant. Pure CO2 from bioetanol fermation. ~0,3 Mt/y since nov. 2011. 1Mt/y begin opweration in 2013.		DOE: USD141 mill. Total project cost ~USD208 million	USD20/tonne CO2 for geological storage (not EOR)			
	Lost Cabin Gas Plant. (Wyoming). Natural gas cleaning. 1 Mt. Construction began in 2011. Operation started in 2013	Yes		USD10/tonne CO2 to EOR			
	Kemper County IGCC (lignite). 3,5Mt.CO2- 65% of facility's CO2 emissions. Construction began 2011, scheduled operational May 2014.	Yes	DOE: USD270 mill 2.round Clean Coal Power Initiative. Total project cost: USD 3,4bn.	$412 mill. investment tax credits		Yes	EPA proposed EPS for coal power plants in march 2012
Canada	Weyburn. CO2 EOR. CO2 from Great Plains Synfuels Plant - Coal to gas plant. In US ~3MT/y injecting CO2 since 2000. Stored >17 Mt CO2.	Yes	Loan from DOE (US) for construction of Coal to gas plant (not just CCS part)				
	Boundary Dam, 1 Mt Coal. Finished 1.Q.2014. Construction started april 2011.	Yes	CA$240 mill Fed.gov.			Yes. CCS project accepted by state/utility board, but will not invrease the rate basis.	Proposed EPS 2011. In law from July 1, 2015
	Quest. Scotford Upgrader, Alberta. 1,2 Mt from 2015. Construction startet sept. 2012.	Possible. Aquifere storage is prepared	CA$745 milli, Alberta gov. & CA$120 mill. Fed.gov. Total cost of project: CA$1,35 bn.		CA$15/tonne for emissions higher than standard. Project got double credits for CO2 reduction.		
	Alberta Carbon Trunk Line (ACTL), a 240 kilometre large CO2 pipeline for many CO2 sources. CO2 sources start: Agrium Fertilizer Plant and North West Upgrader. Landpreparation started. Pipeline construction starts 2014.	Yes	CA$495 milli, Alberta gov.		CA$15/tonne for emissions higher than standard.		
Norway	Sleipner. Natural gas cleaning. ~1 Mt/y (1996)				CO2 tax emissions petroleum production since 1991. Today ~€55/tonn) + ETS		
	Snøhvit LNG. Natural gas cleaning. ~0,7 Mt/y, (2008)				CO2 tax emissions petroleum production since 1991. Today ~€55/tonn) + ETS		
Australia	Gorgon LNG. Natural gas cleaning. 3,4-4Mt. Construction started 2010. epected to be in operation in 2015.		A$60mill from Low Emissions Technology Demonstration Fund to CCS part of project. Total project ~A$2 bn				

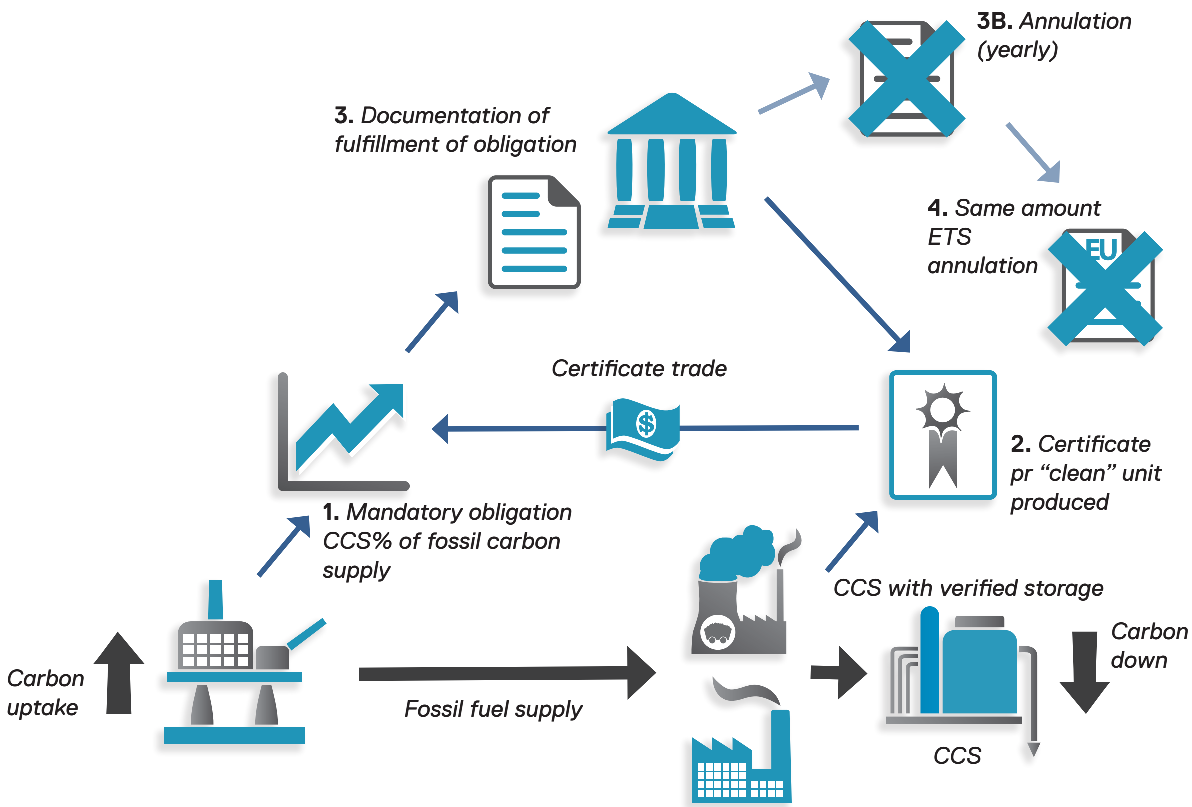
More information about the projects, see: www.zeroco2.no

Appendix III: Design of a CCS certificate system

THE MAIN ISSUES IN DESIGNING A CERTIFICATE SYSTEM ARE:

- Who will get the certificate obligation (who will pay for them?)
- Who will receive the certificates (who will get paid to do ccs - which industries to cover)
- Quota obligation, escalation plan
- Certificate mechanism/design to ensure a well-functioning system
- Geographical scope

A DETAILED ILLUSTRATION:



1. Mandatory obligation to do CCS as a share of the fossil carbon uptake. Gradual (yearly) increase in obligation in line with climate tragets.
2. Certified production of clean products receives certificates pr unit produced
3. Certificates can be used for own obligation, be "banked" or traded. Submitted for annulation (yearly). High penalty for failure to deliver.
4. Companies that receive the CCS certificates delivers ETS allowances in return, to be permanently withdrawn from ETS.

WHO WILL GET THE CERTIFICATE OBLIGATION (WHO WILL PAY?)

Suppliers of fossil fuels[114] are obligated to have certificates equivalent to a certain percentage of their embedded emissions, calculated on the basis of the carbon content of their fuels sold. Import of fossil fuels gets the same obligation as production inside the certificate area, and exports can be substracted. The cost for CCS will then be included in the fossil fuels value chain.

Companies can fulfil their certificate obligation by doing CCS themselves, by cooperating with other companies, or buying certificates from other CCS projects.

WHO WILL RECEIVE THE CERTIFICATES (WHO WILL GET PAID?)

The CCS certificate is given to production of "clean" products from certified facilities with verified storage. The certificate amount is calculated on the basis of the product benchmark for emissions from each production type. This is already made in the EU for the free allocation to the industry in the EU ETS (details see below).

QUOTA OBLIGATION AND ESCALATION PLAN

The quota obligation should be set in line with the 2°C target, with a yearly[115] increase. With an implementation in 2015, the first year of operation could be 2020. This allows companies sufficient time to plan and build the first projects within the first year of certificate obligation[116].

Based on the numbers from the IEA WEO 450 ppm scenario and the IEA CCS Roadmap we have calculated a scenario for a CCS certificate system in Europe. The quota obligation, CCS amount and total emissions are showed in the graph. On a global level the percentage of obligations and cost per tonne CO_2 supplied will be a bit less than for the European case.

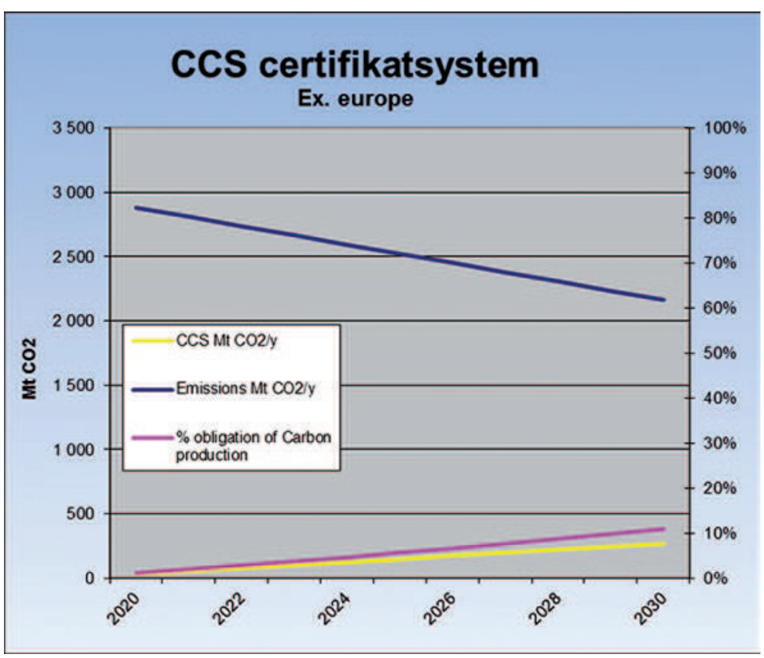


Figure 15:

2020: ~2,9 Gt CO_2 emissions, 30 Mt CCS, 1,1 % obligation of Carbon supply

2030: ~2,2 Gt CO_2 emissions, 270 Mt CCS, 11% obligation of Carbon supply (2,4 Gt)

114 Carbon uptake from mining for industry use such as cement may be considered to be included. Shared obligation between carbon uptake and the emissions source can also be possible.

115 The period between each certificate delivering could be longer than 1 year to increase the flexibility for the companies. A longer period before certificate delivery and penalty cost may give less incentive for early investments.

116 Some projects can be completed faster than within 5 years, so the first year with obligation could also be earlier.

COST/INVESTMENTS

A simple calculation for the cost/investments for a CCS certificate system based on the same numbers is shown in this graph. The calculation is done with 60 €/t CO_2 in average for all CCS projects for the whole period[117].

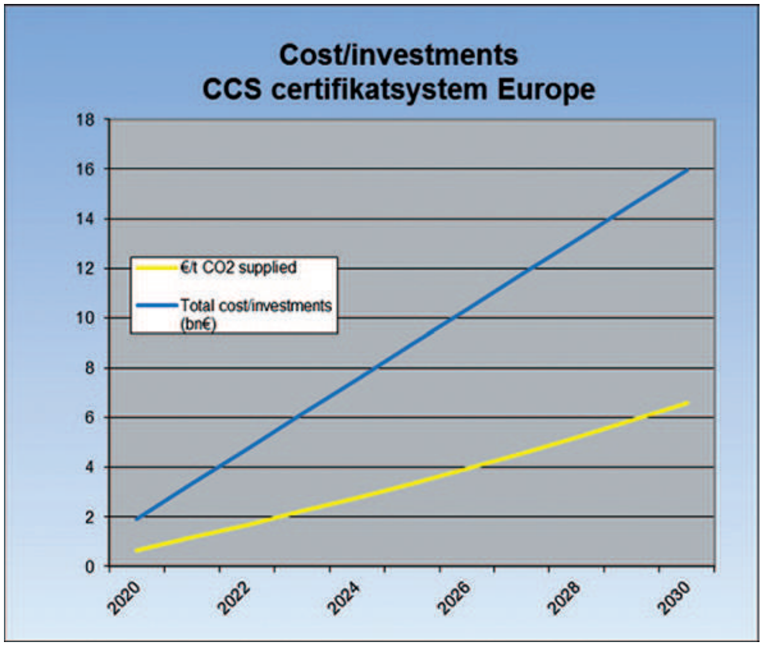


Figure 16:

2020: €0,7/tonne CO_2 supplied, €1,9bn in total for 30 Mt CCS and 1,1% obligation of Carbon supply.

2030: €6,6/tonne CO_2 supplied, €16bn in total for 270 Mt CCS and 11% obligation of Carbon supply.

CERTIFICATE DESIGN TO ENSURE A WELL-FUNCTIONING SYSTEM

DURATION

Long-term predictability is necessary to ensure investments in large-scale CCS projects. Start-up can be realistic in 2015 and the first CCS projects in operation financed by the certificates in 2020. Duration to 2030[118] will then give a 10-year up-scaling period from 2020-2030. The need for a certificate system after 2030 should be evaluated at a later stage and decided no later than 2025.

PENALTY IN CASE OF INSUFFICIENT AMOUNT OF CERTIFICATES

Each year the companies have to deliver the obligated amount of certificates. A penalty for not delivering is needed to ensure sufficient investment.

117 Cost for CCS from different emissions sources and over time will vary. Economy of scale and technology development will bring cost down over time, while the cost for the first projects will be higher. €60/tonne is in the higher range of cost estimate from IEA CCS Roadmap 2013, from USD40-80/tonne.

118 After the final year, a period of 15 years is needed to complete the certificate period for all projects. This is how it is done in the Swedish-Norwegian renewable certificate system, where the projects receive certificates for the first 15 years of production. This is for a shorter period than the lifetime of the projects, but enough to make projects economical for investment decisions. Income after 15 years has little influence on NPV, and it limits the total cost for the system. CCS projects will have extra operation cost and it may be a risk for the project to stop capturing the CO2 if the certificates ends. This can be solved by including an obligation to continue CCS or by giving the projects certificates for all years of operation.

One possible design of a penalty is to increase the amount of certificates to be delivered next year in addition to a fee[119] to a CCS fund[120].

EARLY STARTER RISK AND FLOOR PRICE

There is a risk of under-/oversupply of certificates, resulting in price uncertainty. This can be a major challenge in the beginning with a small volume of certificates. One design to provide security for investments is to have a floor price for a start period/volume[121].

OBLIGATORY CCS FUND/POOL TO ENSURE INVESTMENTS

To reduce the risk of investments in CCS projects not going ahead, a mandatory obligation for the companies to either build CCS themselves or to participate in a common CCS pool could be a solution. The pool will invest in CCS projects delivering the needed amount of certificates to the companies in the pool. This can be organised fully by the companies participating, or there could be government involvement[122].

RELATION TO AN ETS SYSTEM

A swift integration with an ETS system is achievable simply by reducing the amounts of ETS allowances as the volume of CCS certificates increase. A practical solution will be if the companies who receive the CCS certificates have to deliver ETS allowances for the same volume in return, and these would be permanently withdrawn from the ETS.

GEOGRAPHICAL SCOPE

A CCS certificate system is well suited for international cooperation. The certificates issued in one country can be used to fulfil the obligation in another country with free trade of certificates across borders. This will increase the flexibility and cost effectiveness, but can be more politically challenging to establish.

A certificate system can also be used to fund CCS deployment in developing countries. A limited part of the obligation can be fulfilled with certificates from CCS projects in specific developing countries[123].

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119 E.g. 120% obligation at next delivery date and fee of €50/certificate. Another design of the penalty is 150 % of the average price for all certificates trading the last year, as in the Swedish-Norwegian renewable certificate system.

120 A CCS fund can be used for investments in CCS infrastructure to get more projects up and running.

121 In the first two years of the Swedish renewable electricity certificate system, a top- and floor price was used to reduce the price risks. This can be used also for a CCS certificate system, at least the floor price to reduce the price risks for investments. Top price to reduce price risks for buyers of certificates can have the adverse result in setting the price level for certificates. Since the certificate buyers are companies in position to do CCS themselves, this is not needed.

122 This can be done for the start-up phase, but can also be permanent to ensure sufficient investments and reduce risks and challenges for smaller companies with certificate obligation. This pool can possible be the buyer of the floor price.

123 This can be limited to projects done by the obliged companies themselves in developing countries. It can also be possible to have a common system with a “discount” for the CCS obligation in the developing countries.

PRODUCT BENCHMARK CCS CERTIFICATE TABLE

The amount of certificates per product is based on the numbers for carbon emissions per industry product from product benchmark made in EU for the free allocation in EU ETS[124]. The benchmark principle is "one product = one benchmark", from the top 10% installations of conventional plants. This means the benchmark methodology does not differentiate according to the technology, fuel used, size of an installation or geographical location[125]. The benchmarks level is then multiplied with the capture rate (in percentage) to get the CCS certificate numbers for each installation[126].

Example of values for product benchmark:

Product benchmark	Definition of products covered	Certificates /tonne product
Coke	Coke-oven coke (obtained from the carbonisation of coking coal, at high temperature) or gas-works coke (by-product of gas-works plants) expressed as tons of dry coke. Lignite coke is not covered by this benchmark	0,286
Sintered ore	Agglomerated iron-bearing product containing iron ore fines, fluxes and iron-containing recycling materials with the chemical and physical properties such as the level of basicity, mechanical strength and permeability required to deliver iron and necessary flux materials into iron ore reduction processes	0,171
Hot metal	Liquid iron saturated with carbon for further processing	1,328
Pre-bake anode	Anodes for aluminium electrolysis use consisting of petrol coke, pitch and normally recycled anodes, which are formed to shape specifically intended for a particular smelter and baked in anode baking ovens to a temperature of around 1150 ℃	0,324
Aluminium	unwrought non-alloy liquid aluminium from electrolysis	1,514
Grey cement clinker	Grey cement clinker as total clinker produced	0,766
White cement clinker	White cement clinker for use as main binding component in the formulation of materials such as joint filers, ceramic tile adhesives, insulation, and anchorage mortars, industrial floor mortars, ready mixed plaster, repair mortars, and water-tight coatings with maximum average contents of 0,4 mass-% Fe_2O_3, 0,003 mass-% Cr_2O_3 and 0,03 mass-% Mn_2O_3	0,987
Lime	Quicklime: calcium oxide (CaO) produced by the decarbonation of limestone ($CaCO_3$) as "standard pure" lime with a free CaO content of 94,5 %. Lime produced and consumed in the same installation for purification processes is not covered by this product benchmark	0,954
Dolime	Dolime or calcined dolomite as mixture of calcium and magnesium oxides produced by the decarbonation of dolomite ($CaCO_3.MgCO_3$) with a residual CO_2 exceeding 0,25 %, a free MgO content between 25 % and 40 % and a bulk density of the commercial product below 3,05 g/cm3. Dolime shall be expressed as "standard pure dolime" quality with a free CaO content of 57,4 % and a free MgO content of 38,0 %	1,072
Sintered dolime	Mixture of calcium and magnesium oxides used solely for the production of refractory bricks and other refractory products with a minimum bulk density of 3,05 g/cm3	1,449
Float glass	Float/ground/polish glass (as tons of glass exiting the lehr)	0,453

Specific product benchmark for different refinery products are in published, but not shown here.

OTHER EMISSIONS SOURCES FOR CCS TO ADD TO THE BENCHMARK TABLE

Some emissions sources suitable for CCS are not included for ETS free allowances and are therefore not in the industry product benchmark table now. These emission sources need to be added:

- Power plants[127]
- CO_2 from natural gas production/sweetening (cleaning)
- BioCCS. Bioenergy[128], biomass industry (pulp & paper), biofuel production.

124 http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2011:130:0001:0045:EN:PDF
If no other reference is given, all product benchmarks refer to 1 ton of product produced expressed as saleable (net) production and to 100 % purity of the substance concerned. All definitions of processes and emissions covered (system boundaries) include flares where they occur.

125 http://ec.europa.eu/clima/policies/ets/cap/allocation/index_en.htm

126 Min.50% capture rate during last year's production can be set to receive certificates. For the "low hanging fruits" for CCS from sources with pure CO2 sources, criteria for CCS cost could also be considered for adjustments for these products.

127 ~0,350 t/MWh is benchmark for best conventional fossil power production (CCGT).

128 Possible the same benchmark numbers as fossil power plants 0,35 t/MWh.

ZERO

Zero Emission Resource Organization is an environmental organization dedicated to reducing climate change by demonstrating and gaining acceptance for zero emission energy solutions. We believe a zero emission solution exists for all energy use. Our mission is to work consistently for these solutions.

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