EUROPEAN pathways

NEWSLETTER FROM »PATHWAYS TO SUSTAINABLE EUROPEAN ENERGY SYSTEMS«

#3/2012

Filip's column

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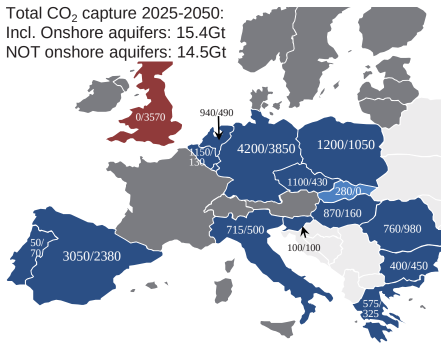
Prof. Filip Johnsson
Project manager of
the Pathways project

Pathways to Sustainable European Energy Systems is a project within THE AGS The Alliance for Global Sustainability

Prospects for CCS in the EU Energy Roadmap to 2050

Reducing greenhouse gas emissions from the European energy system by at least 80% by midcentury, as envisioned by EU, will require action and new solutions in all energy sectors. Obviously this can be achieved in many ways but possible scenarios, presented by the EU Energy Roadmap, suggest that CO_2 emissions from the electricity sector should be cut by 93 to 99 % in order to fulfill this overall objective. At Chalmers, a recent study, which will be presented at GHGT-11 in Kyoto, investigates the prospects of carbon capture and storage (CCS) given these prerequisites.



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Deployment of CCS in industrial applications in the EU

CCS could contribute as a means to drastically reduce carbon dioxide emissions from carbon-intensive industries in the EU up to 2050. This study assesses the possibilities and effects for the industries of petroleum refining, iron and steel production and cement manufacturing in the EU-27 and Norway. The results show how an ambitious deployment of CO_2 capture in these carbon-intensive industries, in combination with extensive implementation of abatement measures currently available, could result in a 80% reduction in CO_2 emissions by 2050.

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Modeling large-scale CCS development

This study analyses the build-up of large-scale pan-European CO_2 transportation networks and the potential lay-out of this CCS distribution system, given that CO_2 emissions from the power supply system is to be reduced by around 95% up to 2050. Two scenarios are studied: with and without onshore aquifer storage. The study gives that transport cost will more than double if aquifer storage is restricted to offshore reservoirs.

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Filip's column

The Pathway project deals with all technologies and measures relevant for the transformation of the stationary energy system over the coming decades. As for large scale introduction of renewable electricity generation there is currently a strong development with exciting opportunities, but the deployment is also associated with challenges, such as those related to the role of thermal power generation. These challenges also holds for CO_2 capture and storage which is associated to thermal power generation and for which the development has slowed down and many – if not all – of the European large scale CCS demonstration projects have been put more or less on hold due to unclear economics as well as problems with public acceptance. Yet, the results of the Pathway project as well as of other studies show that the CCS technology has a crucial role in climate change mitigation. The rationale for developing CCS should be the over-abundance of fossil fuel reserves (and resources) in a climate change context. In our research work we conclude that successful commercialization of CCS will make it easier for fossil fuel-dependent economies with large fossil fuel resources to comply with stringent greenhouse gas (GHG) reduction targets. And there are many such economies! This, and other arguments in favor of, as well as challenges for, CCS are discussed in the contributions from the Pathway project to the upcoming International Conference on Greenhouse Gas Control Technologies, to be held in Kyoto later this month. I am glad that will have several oral as well as poster presentations from the project in the conference, which is the major forum for reporting the latest R&D news in the area of CCS. This issue highlights recent CCS related work in the Pathway project.

Finally, I can only hope that implementation of large scale demonstration of CCS as well as large scale deployment of a wide portfolio of climate change mitigation technologies and measures will regain momentum in the near future. Yet, our Pathway project continues with full steam ahead towards 2013!

Prof. Filip Johnsson
Project manager of the
Pathway project

The GHGT-11 Conference

18th-22nd November 2012, Kyoto, Japan

International Conference on Greenhouse Gas Technologies (GHGT)

The Greenhouse Gas Control Technologies (GHGT) conference series was formed in 1997 after the merge of two earlier series of conferences: the International Conference on Carbon Dioxide Removal (ICCDR) and the Greenhouse Gas Mitigation Options conference. The GHGT conference has thereafter been held every two years and the series rotates between North America, Europe and Asia. The conference is organised by the IEA Greenhouse Gas R&D Programme (IEA GHG) and the local host of each venue. This year the conference is held in Kyoto, Japan and is hosted by the Research Institute of Innovative Technology for the Earth (RITE).

The conference is a focal point for international research on CO_2 capture and storage, gathering participators from academia, industry and government. Over 1600 delegates are anticipated to attend the conference this year. The different sessions and keynote addresses, spread over the five-day venue, will cover a large range of subjects from specific technical solutions regarding CO_2 capture, storage and transport, to energy system aspects and policy issues.

Researchers from the division of Energy Technology at Chalmers have, over the years, been attending and presenting their work at several of the GHGT conferences. This is also the case for the GHGT-11 conference, where papers related to chemical-looping combustion, CCS infrastructure and future energy systems will be presented. The contributions from the Pathways project, related to this field, are further reported in this newsletter.

Prospects for CCS in the EU Energy Roadmap to 2050

Reducing greenhouse gas emissions from the European energy system by at least 80% by midcentury, as envisioned by EU, will require action and new solutions in all energy sectors. Obviously this can be achieved in many ways but possible scenarios, presented by the EU Energy Roadmap, suggest that CO_2 emissions from the electricity sector should be cut by 93 to 99 % in order to fulfill this overall objective. At Chalmers, a recent study, which will be presented at GHGT-11 in Kyoto, investigates the prospects of carbon capture and storage (CCS) given these prerequisites. The results, based on energy system modeling, indicate a large expansion of renewables but also that CCS has the potential to contribute as much as 25-35% of total electricity generation at around year 2050. The application of CCS on an EU member state (MS) level is influenced by current fuel infrastructures and whether or not onshore storage will be allowed. If on-shore storage is restricted, CCS is more likely to be centralized around the North Sea.

CCS with or without onshore storage

The work takes departure in recent market and policy development which have implications for CCS within the EU. The European Commission´s communication “Energy roadmap 2050”, which presumably will found the basis for targets and goals for the European energy system to 2050, depict different ways (scenarios) to fulfil the EU´s objective of reducing the greenhouse gas emissions from the energy system with least 80% by 2050, relative to the 1990 emission levels. This obviously calls for new power plant technology which must have more or less zero CO_2 emissions, where CCS could be one option. Yet, the CCS development has encountered some draw backs lately partly due to local opposition to CO_2 storage. Therefore, this study aims to estimate the prospects of the CCS under given strict CO_2 emission targets including the effect of whether or not onshore storage will be accepted is investigated.

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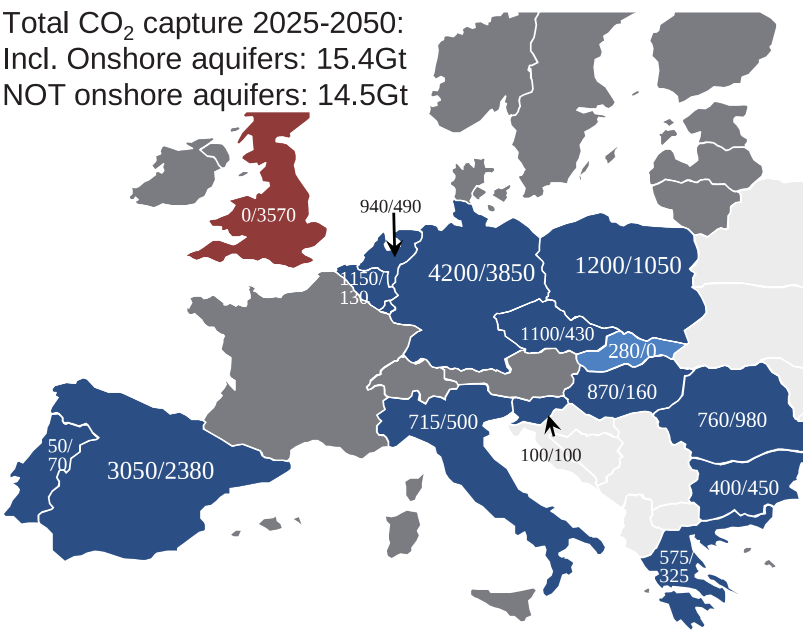

Fig. 1 *Captured CO_2 between 2025 to 2050. Numbers gives captured CO_2 in Mt for each MS (first number from calculations including onshore aquifers/second number excluding onshore aquifers). Light blue MS (Slovakia) indicate only application of CCS if onshore aquifers are allowed for as storage, dark blue MSs indicate CCS application whether or not onshore aquifer storage is allowed and red MS (UK) applies CCS only if onshore storage in aquifers is prohibited.*

Techno-economic modeling

The work is based on techno-economic modeling of the European electricity generation sector under different assumptions of the future with respect to electricity demand and fuel prices, and the ELIN-model has been applied for this purpose. The current power plant stock is taken from the Chalmers power plant database and used as input to the modeling to account for vintaging of current capacities. In addition, the work couples techno-economic modeling with an analysis of the transport and storage infrastructure required to meet the CO_2 flows obtained from the modeling. This CCS infrastructure analysis is further described on page 6. Compared to earlier versions of the model, the implementation of wind power and solar PV have been refined by taking into account wind and solar irradiation conditions down to the spatial scope of NUTS-2 level[1]. In this study two scenarios have been analyzed, the “Market” scenario and the “Policy” scenario. The Market scenario only stipulates a target for CO_2 emissions to be met, while the Policy scenario combines this CO_2 target with other policies, for example for use of renewables and energy efficiency.

25-35% CCS electricity

The results from the study indicate that the contribution from CCS on a member state level depends on local conditions, e.g., access to local fuels like lignite, and whether or not onshore storage will be allowed. Excluding on-shore storage in aquifers, the modeling results give that CCS is centralized around the North Sea, see Fig. 1. Natural gas fired power plants is likely to be a serious competitor to coal CCS in the short to medium term providing large emission reduction opportunities by fuel shifting from existing coal power plants to new high efficient gas fired combined cycles. Such development can be a barrier for early deployment of CCS, and hence, result in a delay in commercialization of CCS. The scenarios presented in the Energy Roadmap prescribe power systems almost without net CO_2 emissions by 2050, which implies that CCS technologies by the year 2050 must be of a zero-emission type. This requires advances in CCS technology, or alternatively that biomass is co-combusted in coal-fired CCS with the biomass part adjusted to offsetting the remaining fossil emissions to obtain net zero emissions. The modeling presented here indicates in general a large increase in technologies with low CO_2 emissions, renewables as well as a significant contribution from CCS technologies, where CCS in the investigated scenarios have the potential to contribute as much as 25-35% of total electricity generation at around year 2050. A challenge in the presented scenarios would be the short term balance in electricity generation at around 2050 when most of the energy mix is either intermittent or base load CCS, which should be difficult to handle with respect to load following.

Mikael Odenberger will present this work at the GHGT-11 conference in Kyoto on November 21.

1) The NUTS classification (Nomenclature of territorial units for statistics) is a hierarchical system for dividing up the economic territory of the EU as defined by Eurostat. NUTS2 corresponds to basic regions for the application of regional policies.

For further information:
MIKAEL ODENBERGER, Chalmers University of Technology

Deployment of CCS in industrial applications in the EU

– timing, scope and coordination

CCS could contribute as a means to drastically reduce carbon dioxide emissions from carbon-intensive industries in the EU up to 2050. This study assesses the possibilities and effects for the industries of petroleum refining, iron and steel production and cement manufacturing in the EU-27 and Norway. The results show how an ambitious deployment of CO_2 capture in these carbon-intensive industries, in combination with extensive implementation of abatement measures currently available, could result in a 80% reduction in CO_2 emissions by 2050. However, the results also highlight how a large-scale introduction of CCS would come at a high price in terms of energy use.

Timing and scope of CCS

Meeting the EU objective of reducing greenhouse gas emissions by 80-95% by 2050 will require commitment across all sectors of society, including carbon-intensive

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intensive industries such as large refineries, iron and steel plants and cement industries. However, measures to drastically reduce the CO_2 emissions associated with the production of refined petroleum products, iron and steel and cement are limited if restricted to proven best available technology as shown in previous studies (see Newsletter 1:2012). Thus, new low carbon processes and technologies, for example CCS, must be developed and deployed.

Johan Rootzén has conducted a study aiming to assess the implications of the timing and scope of a large-scale implementation of CCS in industrial sources in the EU. Based on the age structure of the existing capital stock in the EU refining-, steel- and cement-industries the study assesses: (a) how capital stock turnover influence the penetration rate of CCS in industrial applications, and (b) the effects on industry energy use of different scenarios for the scope of the deployment of CO_2 capture.

Significant emission reductions are possible

The results point at the significant challenge of achieving deep reductions in CO_2 emissions (~85% reduction by 2050, as compared to levels in 1990) for all the studied industry branches. Without CCS, total emission levels in 2050 from the assessed industries will exceed by more than twofold the targeted levels. An ambitious introduction of CO_2 capture in these industries is estimated to be able to reduce emissions to levels in line with the targets for 2050. As an example, emissions from cement production in EU will amount to approximately 110 $MtCO_2$ /year in 2050 in the base case (C0) which assumes extensive implementation of abatement opportunities currently available but no deployment of CCS, see Figure 1. With the implementation of CCS emissions could be drastically reduced as shown for the case C4, where cement kilns fitted for full oxy-combustion are assumed to be the standard for new capacity built after 2030 and where plants commissioned before this year are retrofitted with post-combustion capture. For this case only 20 $MtCO_2$/year are emitted in 2050, see Figure 1.

Increased energy use

However, the results also highlight how an extensive CCS ramp-up would come at a high price in terms of energy use. For the cement industry, electricity and thermal energy use is approximately 80% higher in the case where CCS is assumed to be ambitiously implemented (case C4) than in the base case (C0), see Figure 1. Corresponding results are seen for the other industry branches analyzed. Thus a large-scale deployment of CCS may largely offset the gains of previous efforts to improve energy efficiency. This also suggests that for these industries, unless other alternative low-carbon production processes emerge, there may be a trade-off between CO_2 emission reduction and reduced energy requirements in the longer-term.

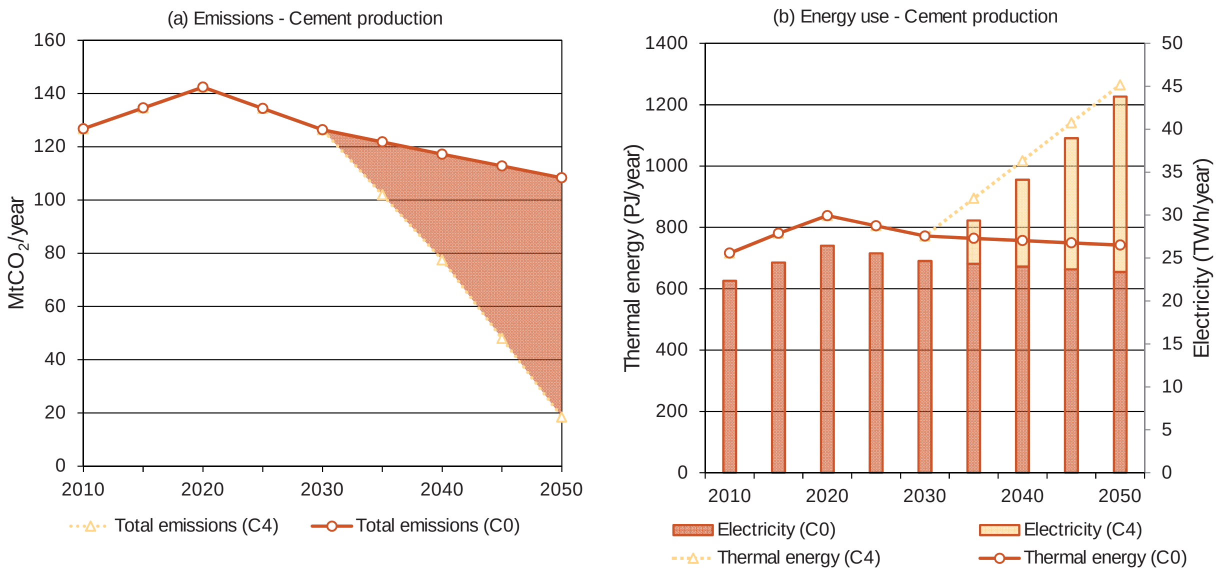

Figure 1. *Estimated CO_2 emissions and energy use from the EU cement industry, 2010–2050. (a) The estimated annual CO_2 emissions from EU cement manufacturing, 2010 – 2050, with (dashed line) or without (solid line) introduction of CCS. In both cases total emissions include both fuel-related and process-related emissions. (b) Gives the estimated development of thermal (solid/dashed lines) and electrical (bars) energy use with (light orange) or without (orange) introduction of CCS.*

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Modelling large-scale CCS development

This study analyses the build-up of large-scale pan-European CO_2 transportation networks and the potential lay-out of this CCS distribution system, given that CO_2 emissions from the power supply system is to be reduced by around 95% up to 2050. Two scenarios are studied: with and without onshore aquifer storage. The study gives that transport cost will more than double if aquifer storage is restricted to offshore reservoirs. Thus, it is found that the total investments for the pan-European pipeline system is € 31 billion when storage in onshore aquifers is allowed and € 72 billion if aquifer storage is restricted to offshore reservoirs with corresponding specific cost of € 5.1 to € 12.2 per ton CO_2 transported.

Considering spatial distribution

The EU Commission has recognised the continued importance of fossil fuels in order to have a diversified energy mix and thereby achieving a high degree of supply security and that continued use of fossil fuels will have to be combined with CCS if long-term GHG emission reduction objectives are to be reached. Researchers at Chalmers and the EU Joint Research Centre (JRC) have conducted a study of a possible large-scale CCS development in Europe, which will be presented at the GHGT-11 conference in Kyoto by Jan Kjärstad. The potential lay-out of the CCS infrastructure in Europe is a result of combining techno-economic modelling (see page 3) with the analysis of a CO_2 transport infrastructure. The modelling (using the ELIN model) gives the lowest system cost for the electricity generation system under a given CO_2 emission reduction target providing at the same time the annual additions of CCS based generation capacity and CO_2-volumes being captured by country and fuel. These flows are then used as input to JRC's InfraCCS, a cost optimization tool for bulk CO_2 pipelines at European scale. Finally, the results from InfraCCS are applied – along with Chalmers databases on power plants and CO_2 storage sites – to design the development over time of a detailed CO_2 transport network across Europe considering the spatial distribution of power plants and storage locations. When designing the transport network, CCS plants are assumed to replace existing plants based on age while at the same time CCS based capacity additions in each year and for each country correspond to the annual capacity addition provided by the modelling. Two scenarios are studied. The first case assumes that all storage sites in the EU GeoCapacity project are available. The second assumes that onshore saline aquifers are not available. Thus, this will provide a first estimate of the economic implications of rejecting onshore storage on a country-by country level.

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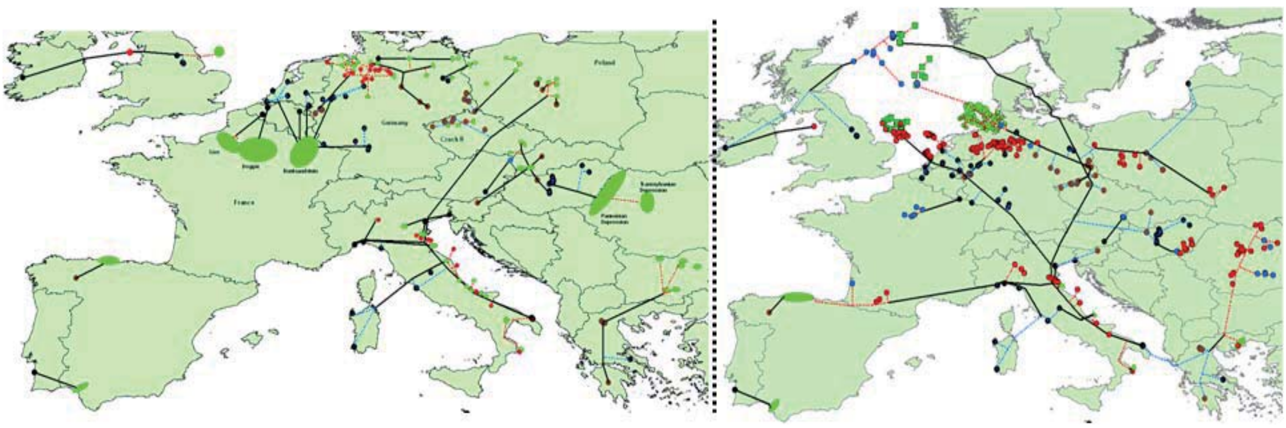

Figure 1. *The left pane shows the final CCS transport system in 2050 in the case where onshore aquifer storage is allowed. The right pane shows the final transport system in 2050 in the case where onshore aquifer storage is not allowed.*
The coloured lines in the map indicate different types of pipelines: collection (blue); bulk (black); and distribution (red) pipelines. Gas, oil fields and aquifers are shown in red, blue and green respectively. Black circles denote coal plants while brown circles denote lignite plants

Storage capacity and injectivity are key factors

The work shows that the spatial distribution of capture plants over time along with individual reservoir storage capacity and injectivity are key factors determining routing and timing of the pipeline network. Our results imply that uncertainties in timing for installation of capture equipment in combination with uncertainties related to accurate data on storage capacity and injectivity on reservoir level risk to seriously limit the build-up of large-scale pan-European CO_2 transportation networks.

A doubling of transport cost

The two cases – allowing for and not allowing for onshore aquifer storage - suggest two very different layouts of the European CO_2 distribution system, see Figure 1.
In the case when storage in onshore aquifers is allowed, the total European system comprises 19,100 km of pipelines including 1,000 km offshore segments. Total investments reach € 31.4 billion with corresponding system specific cost amounting to € 5.1 per ton transported CO_2. Specific cost on national levels ranges from € 0.7 to 12.4 per ton.

In the case where storage in aquifers is restricted to offshore reservoirs, total pipeline length increases to 28,100 km including 6,200 km offshore pipelines, mostly in the North Sea. Total investments more than doubles to € 72.3 billion while corresponding specific cost reach € 12.2 per ton. Specific cost on national levels ranges from € 3.1 to 30.3 per ton. It should also be noted that while this study analyses cost for transport only, cost for storage is also likely to increase markedly if large volumes have to be stored offshore. In both scenarios, the collection and distribution networks account for 55% of the total system cost.

For further information:
JAN KJÄRSTAD, Chalmers University of Technology

The Energiewende – is there a Nordic way?

The Pathway project, through Filip Johnsson, participated in the conference "*The Energiewende – is there a Nordic way?*", which was held October 15-16, 2012, in Berlin. The conference gathered representatives from Germany and the five Nordic countries in the area of policy, industry, civil society, and science. The participants presented and discussed future energy scenarios as well as Nordic solutions for a more sustainable energy future, including the common Nordic electricity market. In the conference, Filip Johnsson held an introductory talk to a workshop on Green-Green conflicts and concluded that there must be a focus on opportunities rather than conflicts in order to meet the climate challenge. Filip Johnsson also concludes:

- *I think it was evident from the conference that because the energy systems of the Nordic countries differ substantially, it is not obvious how to cooperate around common strategies for the Nordic region and it will be a challenge how to develop the Nordic region to facilitate efficient production and exporting of green energy, which is what many hope for.*

According to European-energy-review (October 22, 2012) an outcome of the conference was that the German government seems to now realise that it may have been mistaken in pursuing its Energiewende and nuclear phase-out without involving its neighbor's. At the conference, German Environment Minister Peter Altmaier said he regretted the unilateral course his country had taken and he proposed setting up an international club of countries going renewable and called for more cooperation between Germany and its neighbor's to ensure the success of the Energiewende.

Barriers to large-scale implementation of CCS in Europe

A large-scale deployment of CCS could be a key technology in the transitions towards a truly decarbonised energy system. There are, however, several barriers to large-scale deployment of CCS that need to be addressed. The institutional barriers are mainly linked to the establishment of an integrated CO_2 transportation and storage infrastructure. Another important barrier is the lack of a clear and coordinated "CCS discourse" with respect to how CCS is motivated in a policy context.

During the last decade there has been a significant increase in research and development of CO_2 capture and storage technologies with CCS now considered an important option for climate change mitigation both for Europe and globally. The large scale deployment of CCS should be seen as a transitional instrument towards a truly decarbonised energy system, a system which is presently relying on the abundance of fossil fuel reserves (and resources). This, until other low carbon technologies are deployed on a sufficient scale to meet energy demand. Yet, at present there is a slow pace in taking CCS from pilot scale to large scale demonstration. A recently published peer reviewed paper from the Pathway project (Thermal Science, 2012, Vol. 16, No. 3, pp. 655-668) discusses policy and institutional barriers to large scale implementation of CCS in Europe and the implications for the further development of CCS. In addition, these issues are further developed in co-operation between Chalmers and DG-JRC.

Barriers must be overcome

Currently, the most obvious and important barrier is the cost of CCS versus the projected cost to emit CO_2 within the EU-ETS over the next decade. At present (October 2012), the price of an emission allowance is less than 10€/tonne CO_2 which is far too low to impose a significant driving force for the development of CCS. In addition, the price will remain low up until the year 2020 and, after 2020 there is little known on what the system will look like.

Another key issue in achieving the large scale deployment of CCS is the establishment of an integrated transportation and storage infrastructure in a timely manner (see also page 6). Obviously, planning must be commenced within a few years if large-scale deployment of CCS is to be expected to start soon after 2020. Also there is a need to identify and establish market regimes for an such an infrastructure (e.g., public-private partnerships). This is especially important since economy of scale in pipeline construction usually makes it more cost-efficient to build larger pipelines that are underutilized for a period instead of building several smaller pipelines as the volumes increase. This is challenging since an efficient coordinated transport infrastructure involves CO_2 sources from several countries and several separate sources. Moreover, we need to gain additional experience of CO_2-reservoir behavior across a wide range of reservoirs as most of the available storage capacity values rely on rather rough estimates. Ways and policies to stimulate actual CO_2-injection and site-specific investigations of storage capacities must be found.

There are also other well-known barriers such as related to public acceptance and establishment of a legal framework as discussed in other publications from the Pathways project.

The way ahead –a call for a clear "CCS discourse"

Another important barrier is the lack of a clear and coordinated "CCS discourse" with respect to how CCS is motivated in a policy context. It is concluded that the strongest argument for developing CCS should be that CCS will make it easier for fossil fuel-dependent economies with large fossil fuel resources to comply with stringent greenhouse gas (GHG) reduction targets (i.e. to attach a price to CO_2 emissions). Surprisingly, this argument has not been used in the public and political debate. This, in spite of the fact that failure to implement CCS will require that the global community, including Europe, agrees to almost immediately start phasing out the use of fossil fuels. An agreement which seems rather unlikely, especially considering the abundant coal reserves in developing economies such as China and India and not at least seen from the extensive activities with respect to development in the fossil fuel industry, including recent development of shale gas. From a geopolitical point, it can be argued that the most important outcome from the successful commercialization of CCS will be that fossil fuel-dependent economies with large fossil fuel resources will find it easier to comply with stringent greenhouse gas (GHG) reduction targets (i.e. to attach a price to CO2 emissions). This should be of great importance since, from a geopolitical view, the curbing on GHG emissions cannot be isolated from security of supply and economic competition between regions. Thus, successful application of CCS may moderate geopolitical risks related to regional differences in the possibilities and thereby willingness to comply with large emission cuts.

Related to this, industries and governmental institutions must find and develop a common ground for explaining and motivating the need for CCS.

For further information:
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