# Geological Storage of $CO_2$ from Power Generation

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## Abstract

Carbon Capture and Storage (CCS) is capable of contributing significant $CO_2$ emission reduction in the near to medium term. When fully deployed, CCS in Europe alone is estimated to be able to deliver reductions of up to 1 GT (giga tonnes) of $CO_2$ annually – equivalent to 1/3 of Europe's current antrophogenic emissions of $CO_2$. CCS could thus be a powerful supplement to European policy on energy efficiency and the longer-term goal of increasing the share of renewable energies. A European Technology Platform within Zero Emission Power (ZEP) has been established. In cooperation with the member states and a wide range of stakeholder, the EC and the ZEP are jointly working to establish the necessary regulatory and economical boundary conditions for the further development and deployment of CCS. The ZEP has recommended the urgent implementation of 10-12 integrated, large-scale CCS demonstration projects Europe-wide. This recommendation has been adopted by the EU.

### Background

Energy is the main factor in climate change, accounting for some 80% of the EU's greenhouse gas emissions. It has been estimated that, without real efforts to reduce emissions, there is an increasing probability that global temperatures will rise by several degrees, dramatically altering the world's landscape, climate and the way we live. There is also mounting evidence that as atmospheric $CO_2$ levels rise, our oceans will acidify in response, damaging many marine life forms.

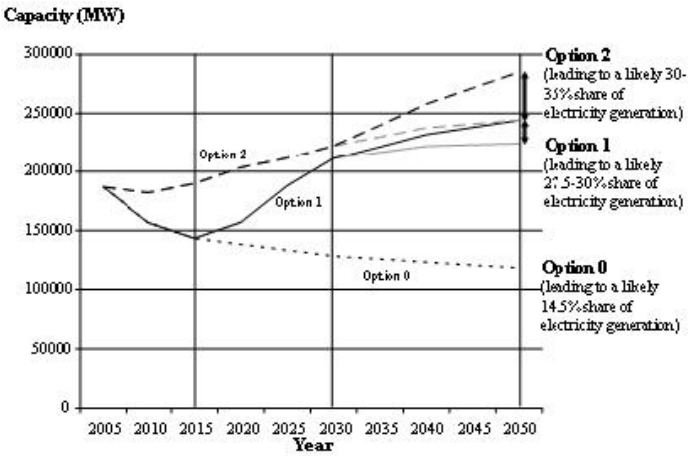
### EU Climate and Energy policy

The EU has agreed to limit global warming to within $2^oC$, which means progressively reducing overall greenhouse gas emissions by up to 80% by 2050 (EC COM 2007/2), but the EU's present energy practice will result in increasing them by 5% by 2030. The EU's current energy and transport policies are not sustainable. In February 2007 Europe's national leaders agreed to adopt a 20% emission reduction target by 2020 for the EU, increasing to 30% if the USA agrees to deploy similar targets and enter a post-Kyoto global agreement. With respect to these aims, Europe has proposed a new Energy policy

(COM 2007/1) which amounts to a new industrial revolution. It recognises that in the EU over the next 25 years, around €900 billion will be needed to invest in new coal- and gas-fired power plants, along with renewable energy infrastructure. There is also a need to increase generating capacity. Electricity demand continues to mount by around 1.5% each year, but existing infrastructure and electricity plants are reaching the end of their useful life. It is also important that the EU can utilise its indigenous energy resources, such as coal - the EU's largest reserve of fossil fuel - as much as is economically feasible, rather than be over-reliant on imports. Low carbon emitting technology for fossil fuels is badly needed, not just for Europe but worldwide, as coal use in electricity generation is set to rise globally.

### EU Power and CCS policy

With respect to power generation the EC recommends that 10-12 large-scale demonstration plants need to be promoted (EC Memo 07/08) and demonstrated by 2015. The EC wishes to have all new fossil-fuelled generation plant built by 2020 onwards fitted with capture, and existing plant then progressively retrofitted (EC COM 2006/843). The Zero Emission Power Technology Platform (ZEP) estimates that at least 1GT of $CO_2$ per annum (= 1000 Sleipners or 250 GW of coal-fired power generation capacity) could be captured and stored via CCS in Europe before 2050. This falls within DG TREN's expectations that coal –fired generating capacity could be at around 250- 280GW by 2050 (about a third of expected EU electricity generation capacity) if near-zero emissions is achieved. If CCS is not deployed and new conventional plant is not allowed to be built so that all that remains is existing plant with extended lifetimes, there will only be 12OGW capacity left, yet it will still emit around 480Mt of $CO_2$ annually.




**Anticipated effects on clean coal technologies on the EU Capacity of Coal-Fired Power Plants 2005-2050**

**Option 0:** No policy Change,

**Option 1:** Removal of Barriers to Sustainable Coal Technologies,

**Option 2:** Pro-active Introduction of Incentives for the Penetration of Sustainable Coal Technologies

*Source: European Commission DG TREN*

Because of early investment in renewable energy technological development the European Union is already the global leader in that sector. Europe has the potential to lead even more in the rapidly growing global market for low carbon energy technologies. Europe's determination to lead the global fight against climate change creates

an opportunity to drive the global research agenda. This applies to $CO_2$ capture and storage, just as in renewables. Even though Europe has led the world through the world first demonstration of $CO_2$ storage in a saline aquifer at Sleipner (since 1996), Europe now risks being overtaken in developing CCS technology, as concern over emissions grow in other developed countries such as the USA and Australia, who are increasingly resourcing and accelerating technological development.

To provide global leadership, the EU must provide a clear vision for the introduction of CO2 capture and storage within its borders, establish a favourable regulatory framework for CCS development, invest more effectively in research, as well as taking international action. The EU Emissions Trading System will also need to incorporate capture and storage in the future and this will require significant regulation, including permitting of CCS operations and qualification criteria for such permits.

### Potential for $CO_2$ storage

It is now well accepted that $CO_2$ capture and storage (CCS) is technically feasible, but it still remains to provide viable solutions for large-scale power generation from fossil fuels. If persistent obstacles such as the cost of capture are currently under considerable progress, the recognition of $CO_2$ storage in geological formations as an safe and effective approach in a long-term perspective (over 1000 years) is still largely unachieved. If in fact CCS is to be widely available for deployment by 2020, considerable urgency exists toward further R&D on $CO_2$ storage in deep saline aquifers. This option has by far the largest capacity and the more widespread geographical distribution.

The relative order-of-magnitude potential of the various storage methods may be expressed, very simply, as follows:

| | |
|---|---|
| 1000 | Deep saline aquifer storage (porous rocks) |
| 100 | Oil/gas field use and storage |
| 10 | Deep un-mineable coal bed use and storage |
| 1 | Mineral sequestration |

Deep saline aquifers have the largest storage potential globally (IPCC 2005), but are the least well explored and researched as, up till now, they have not had any economic potential (unlike hydrocarbon fields). We therefore need to build a more comprehensive dataset of their geological characteristics through considerable research and larger-scale injection projects.

Earlier research projects have already begun the task of identifying regional deep saline aquifers that are accessible to large $CO_2$ emissions sources, both on land and close to the shore. Although we

believe these formations hold the most promise, we need to demonstrate storage in a variety of types and settings in order to realise the full potential of this medium. It means exploring as many countries as possible, especially those with few hydrocarbon deposits, where saline aquifers will be the only feasible $CO_2$ storage medium.

Ten years of injection into an aquifer at Sleipner and monitoring of the $CO_2$ have improved the confidence in aquifer storage. For example, the Utsira Sand Formation at Sleipner is a large, regional deep saline aquifer which has been used by Statoil since 1996 to store $CO_2$ removed from gas production at an injection rate of about 1Mt/annum. This world class pioneering project has been researched by a succession of joint EU/industry projects and is the best understood large scale aquifer $CO_2$ injection in the world. The Utsira Sand Formation has an area of over 26,000 km² and according to the ZEP (2006), it potentially is capable of storing up to 600Gt of $CO_2$. To put this into perspective, this is equivalent to all the $CO_2$ emissions from all the power stations in Europe for the next 600 years. Sleipener's injection rate is equivalent to the emissions of a 250MW coal fired plant, or a 500MW gas fired one. Europe's largest coal burning plant at Drax in the UK is 4GW, which if captured and stored would require an equivalent injection rate of 16 Sleipners. There are many power plants in the 1-2GW range across Europe.

Apart from Sleipner the only large scale injection in the world into a saline aquifer is beneath the Algerian Sahara. Operated by BP this has been injecting around a million tonnes of $CO_2$ per annum. The reservoir is much thinner than Sleipner, and contrasts in having low permeability/porosity,and more complex heterogeneity. The other saline aquifer injections around the world so far conducted are relatively small, experimental operations, at the 10-100kt scale. Significant are Frio (Texas USA) and Nagoaka (Japan). At the European $CO_2$Sink flagship project at Ketzin injection will start in June 2007 – injecting up to 60 000 tonnes of $CO_2$ over the next two years.

## The European Zero Emission Power Technology platform (ZEP)

Climate change is one of the most serious single challenges faced by humankind today. Probably one of the greatest impacts in reducing $CO_2$ emissions will be made by the introduction of Zero Emission Fossil Fuel Power Plants including carbon dioxide capture and storage. Therefore, the European Commission, the European energy industry, research community and non governmental organisations have together established a European Technology Platform on Zero Emission Fossil Fuel Power Plants (ETP ZEP) to unite all key stakeholders in this field.

***To enable European fossil fuel power plants***

***to have zero $CO_2$ emissions by 2020.***

***ZEP vision statement, September 2006***

ZEP confirms the EU's continued commitment to its leadership role in reducing $CO_2$ emissions and the immense challenge of keeping the average global temperature increase below 2 degrees Centigrade relative to pre-industrial level. The platform plays a crucial role in enabling the EU to fulfil this commitment: its goal is to develop and deploy new competitive options for Zero Emission Fossil Fuel Power Plants within the next 15 years and hence help European industry to compete effectively on world markets.

Experts agree that CO2 capture and storage technology (CCS), together with improved energy conversion efficiency, is a near-term solution to reducing carbon dioxide emissions from fossil fuel power generation on a massive scale. Its immediate deployment is therefore vital if we are to avoid the catastrophic consequences of climate change we are facing today. Yet despite most of the technology elements being available, CCS is still not deployed for two key reasons:

1. The costs and risks still outweigh the commercial benefits
2. The regulatory framework for $CO_2$ storage is not sufficiently defined.

Following the priority given to “zero emission power generation” in the Sixth Framework Programme (FP6), industrial stakeholders and the research community therefore united to form the European Technology Platform for Zero Emission Fossil Fuel Power Plants (ZEP). The aim of the ZEP is to identify and remove the barriers to creating highly efficient power plants with zero emissions, which would drastically reduce the environmental impact of fossil fuel use, particularly coal. In the autumn of 2005, the Advisory Council and Coordination Group – along with the Working Groups and Mirror Group – were established. The Technology Platform was officially launched in December and a Vision Paper was published the following May. In August 2006, the Technology Platform then published two key documents – the Strategic Deployment Document (SDD) and the Strategic Research Agenda (SRA). While the SDD outlines how we can accelerate the market for deployment, the SRA describes a collaborative programme of technology development for reducing the costs and risks. This Strategic Overview is a summary of both documents, providing key highlights and recommendations on concrete actions required to realise the ZEP Vision.

**ZEP Deployment Strategy**

1. **Kick-starting the $CO_2$ value chain with urgent short- and long-term commercial incentives:** inclusion in EU Emissions Trading Scheme (EU ETS), guidelines for State Aid, create early mover funding mechanisms to support the development of 10-12 large-scale CCS demonstration projects,. mechanisms to supplement EU ETS.

2. **Establishing a regulatory framework for the geological storage of $CO_2$:** amend existing EU legislation concerning waste and water, implement new EU guidelines for Member States permitting geological storage projects.

3. **Gaining public support via a comprehensive public information campaign:** Generic EU-wide multi-media and local, focused outreach in support of early mover CCS projects.

**ZEP Research Agenda**

- **Urgently implementing 10-12 integrated, large-scale CCS demonstration projects Europe-wide:**
- **Developing new concepts already identified, but not validated, for demonstration by 2010-2015 and implementation beyond 2020, e.g.**
- **Supporting long-term exploratory R&D into advanced, innovative concepts for implementation of next-generation technology, e.g.**
- **Maximising cooperation at national, European and international level:**

With a view to addressing the legal and regulatory issues associated with CCS, the European Commission (DG Environment) is currently developing an enabling legal framework for CCS in Europe. This development takes place in dialogue and consultation with national member states as well as the stakeholders in the field of CCS. The following preliminary timetable is envisaged by DG Environment:

- Draft impact assessment and legislative proposal by end July
- Internal procedures July-November 2007
- Adoption by Commission by November 2007

## Danish CCS potential

The possibilities for underground storage of $CO_2$ in Denmark has previously been evaluated in two regional studies, Joule II and GESTCO including storage potential in depleted hydrocarbon fields and deep saline aquifers. In the Joule II report the total storage capacity for $CO_2$ in Denmark in unconfined onshore aquifers of Triassic and Jurassic age was estimated to 47 Gt based on a general assumption that 2% of the entire pore volume of the mapped formations was filled. Restricting the storage capacity to confined traps reduced the estimated total storage capacity to 5.6 Gt. Using experiences from natural gas storage facilities in Denmark, Germany and France the GESTCO study assumes that 40% of the total pore volume within a defined trap may be filled with $CO_2$. In the GESTCO project eleven well-defined closures all located in the central part of the Danish Basin were mapped from seismic surveys and their storage potential was evaluated using data from existing deep wells. Initial calculations suggest that these structures alone may provide storage for at least 16 Gt $CO_2$. The different storage capacity estimates between the Joule II and GESTCO projects illustrates the principle of "less storage capacity with better confidence" and it is anticipated that the site characterization process developed in the CO2STORE project will increase the amount of knowledge, but also reduce the estimate of total storage capacity within the countries. In the site selection phase four stratigraphic Jurassic and Triassic intervals were considered for potential storage in deep saline aquifers. The sandstones of the Jurassic Gassum Formation are known from a number wells (porosity 18-27%, maximum 36% and permeability up to 2,000 mD) and acts as reservoir for storage of natural gas at Stenlille and as geothermal reservoir at Thisted. The aquifer storage of $CO_2$ is dependent not only on the properties of the reservoir but also on the integrity of the sealing formation. The primary sealing unit for the Gassum Formation is marine mudstones of the Lower Jurassic Fjerritslev Formation characterised by a relatively uniform succession of marine slightly calcareous claystones. The formation is present over most of the Danish Basin with a varying thickness of up to 1,000 m. It is the sealing formation at the Stenlille natural gas storage site and has proven tight to natural gas stored in the Gassum reservoir below. A possible secondary seal is formed by carbonate rocks of Late Cretaceous-Danian age and chemical reactions between dissolved $CO_2$ and the carbonate rock.

## References

European Technology Platform ZEP: www.zero-emissionplatform.eu

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