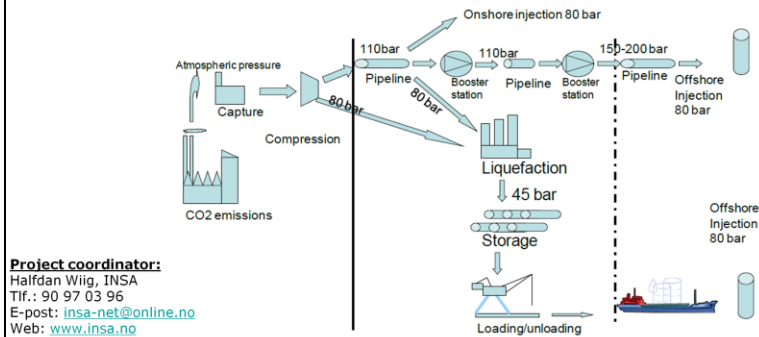


Preliminary study on transportation and storage



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The report was prepared by INSA and its project partners, Lise Siverts from Kvale Advokatfirma DA and Reidar Kierulf from IPAN.

The goal of the project was in short to get a better picture of the risks and challenges facing development of a joint, transboundary and cost effective CO₂ transportation and storage system in the BASREC region.

CO2 transportation and storage in the BASREC region

- The structure of the problem
- The challenges
- Our recommendations



In this presentation we will address the structure of the question, the challenges involved and our recommendations. Tomorrow we will address possible cost effective transportation and storage solutions for the BASREC countries.

A recall of the needs for transportation and storage systems

- Rapid deployment of CCS will be necessary to comply with the 2°C target. The costs of achieving the target *without CCS* could be 70% higher.
- Efficient roll out will be important to preserve a competitive industrial basis in most BASREC nations.
- The Fukushima catastrophe increases the need for CCS as base load solutions in the power markets.
- Efficient development of CO2 transport infrastructure and storage (including pipelines and ships) is the enabler for CCS. Storage has in many ways turned out to be the critical element and will be the key to the success of CCS.



The 2°C target requires that the accumulated emissions up to 2050 stays below certain levels. Currently we are wasting large parts of this budget due to lack of effective regulations and restrictions on emissions internationally. High cost measures and carbon negative technologies must consequently to a larger degree be deployed to comply with the globally agreed target in the future.

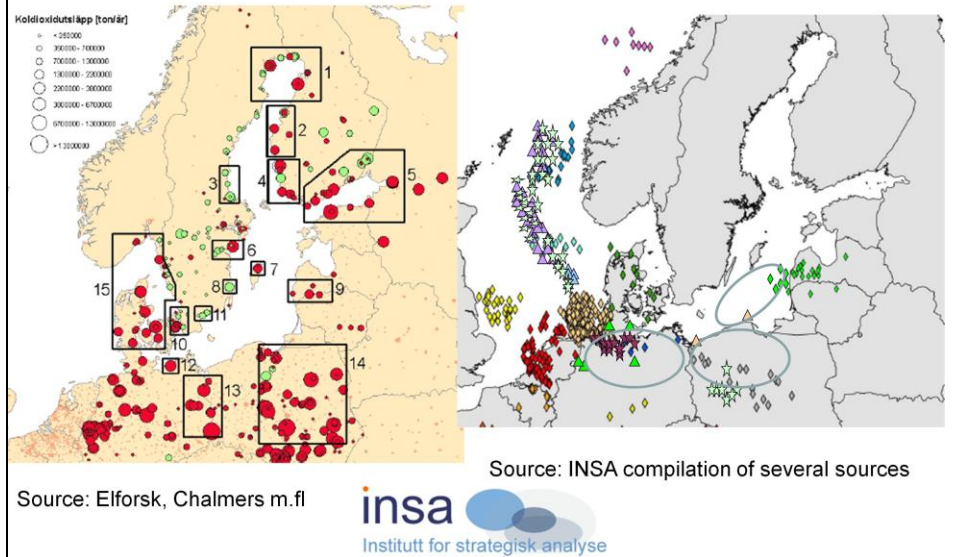
As regards the issue of preservation of industrial competitiveness:

Do we run the risk that basic industries in BASREC countries suddenly faces more efficient CCS equipped industries from China?

The Fukushima catastrophe puts the future of nuclear power in the region at risk. CCS development may be an important element in securing longer term energy supply at reasonable costs. These are the main arguments in favor of CCS development.

Let us now take a look at the challenges.

Sources and storage structure



The above charts summarises the structure (left) of sources (right) and storage opportunities in the region. Sizes of the spots represents kilotons of CO₂ annually. Green spots represents biogenic sources and red are fossil fuel sources. Squares in the source map represents possible clusters.

The storage map shows identified depleted oil and gas field and saline aquifers as prospective areas. The ovals represents prospective areas for identifying storage sites.

As can be seen from the above maps. The Nordic countries have in general dispersed sources over a large geographical area. Further, they are distributed on several types of industries with large variations in capture costs, maturity of technology and remaining lifetime of plants. All these factors creates a challenge regarding clustering in space and time of sources in order to achieve economics of scale and sufficiently short ramp up times for transportation and storage of CO₂.

At the same time Sweden and Finland are well endowed with forest resources and biogenic industries. This offers the opportunity for a carbon negative development of great value to the solution of the climate issue. But there will a need to amend the ETS directive in order to provide better incentives for the biogenic CCS technologies.

Structural challenges in the Baltic Sea

- Uneven distribution of storage opportunities. Finland Estonia do not have storage opportunities at all. Others like Lithuania have only limited capacity.
- Large structures are poorly mapped, characterised and far from qualified.
- Several structures transboundary in nature and will require extensive transnational solutions.
- Restrictions on onshore storage have created a “catch 22 problem”.
- Makes rational planning of transportation systems difficult.
- Difficult to assess viable CCS projects and the implications for future industrial structures.



At the same time several countries like Finland and Estonia do not have storage opportunities at all. Lithuania have only limited storage capacity in rather small aquifers. Sweden have potential storage capacity in Southern Skåne a long distance from the Northern part of the country. Latvia are better endowed with storage capacity, in particular compared to their own emissions, but will not be able to provide sufficient storage capacity for the region in the future.

Future storage capacity must be found either in South Baltic sea, Denmark, North Sea or Russia. These countries will need long distance transportation either by ships or pipelines. It will be costly, require joint and transboundary solution with great degree of coordination and cooperation between the countries. This is a real challenge.

The challenges are further aggravated by the lack of certainty regarding future implementation of the CCS directive in key countries. The future of CO₂ storage in Denmark will in particular be important for development of transportation and storage solutions in the region.

Future development will further hinge on the situation in the South Baltic Sea, where better mapping, characterisation and qualification of storage opportunities is highly needed.

Clarification on these issues will be key for a transportation and storage system planner in the region.

Continental sources



Source: (Tel-Tek, Haugen 2005)

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Germany, Benelux and to some degree Poland represents areas with high emissions density and consequently better possibilities for clustering of CCS in space and time. This provides a natural basis for exploiting economics of scale in CCS transportation and storage. These countries are in addition well endowed with onshore storage capacity which are less costly to develop.

Germany and Poland have as well large inland sources of coal and seems for the future more dependent upon fossil fuels in their power and energy mix than the Nordic countries which are better endowed with low cost renewable energy.

These countries possibly together with Denmark should have comparative advantages for being in the forefront of CCS development in BASREC region, but then safe and environmentally sound onshore storage must be accepted and developed.

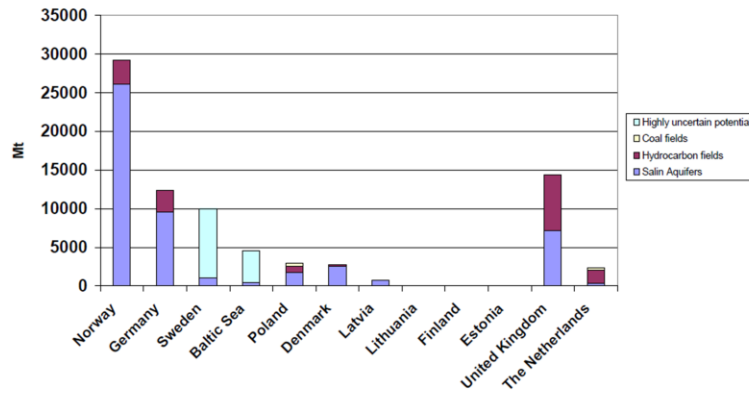
In several countries implementation of the directive have been much more restrictive than originally intended. This has created serious barriers for the planned demonstration projects and development and actual need for roll out of the CCS chains in BASREC nations.

Sufficient offshore storage capacity exists but onshore CO₂ storage is significantly cheaper and will be key to the long-term business case for CCS .

Gaining public confidence through the demonstration of onshore storage will consequently be vital.

Relative storage capacity

Storage capacity BASREC + North Sea



Source: INSA compilation of several sources

As can be seen from the figure above, clarification of the costs and potentials for CO2 storage in the south Baltic Sea, Germany and Denmark will have long term implications for the development of the transportation system. This will be further highlighted in the presentations tomorrow.

North Sea and enhanced oil recovery

- High potentials in the North Sea
- Short window of opportunities
- Need for secure CO₂ supplies and coordination between CCS projects and storage operators.
- High willingness to pay for CO₂ in EOR projects in US, but



Depleted oil and gas fields can be developed into CO₂ storage sites within a shorter time span. This will, however, require intensive coordination of planning, development and operation between the capture and the storage operators. The need for coordination is as well imminent in EOR projects (the use of CO₂ for enhanced oil recovery) since such projects require precise timing and a high level of security of CO₂ supplies. The potentials are high in the North Sea. Do we witness a major mismatch between actual development in capture projects and windows of opportunities offshore DOGFs and EOR projects?

High willingness to pay for CO₂ in EOR projects have been seen in US. 30-40 USD have been reported and benefits may increase with increasing oil prices. But as indicated, offshore operations of EOR projects are far more demanding than onshore projects, which may considerably reduce the willingness to pay for CO₂ at site.

Long lead-times and the need for cooperation

- It will be time consuming, challenging and require high levels of investments to develop a cost efficient transportation and storage system for the future.
- Lead times for exploration and development of offshore storage sites may be 8-10 years.
- There will be need for a transnational pipeline network as well as storages that extend across several borders. Negotiation of such agreements may add considerably to the lead times.



Figure 31: Project schedule plan for pipeline

Source: INSA



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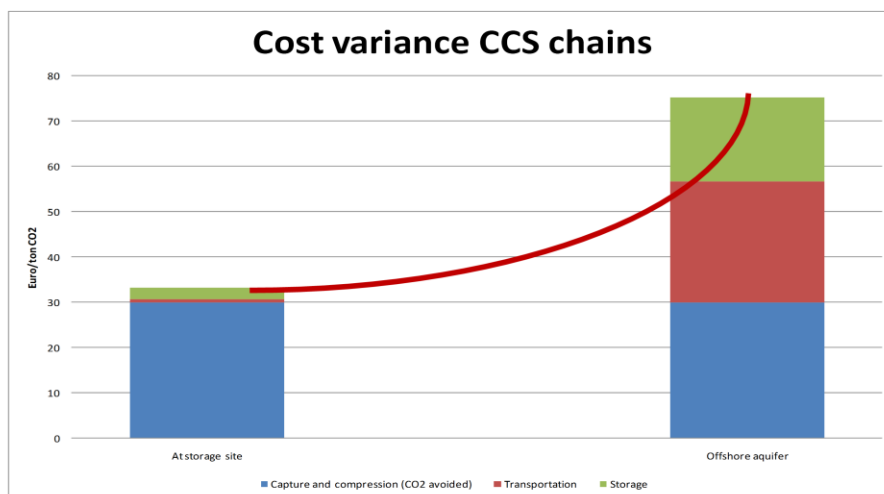
Even in order to be able to achieve major roll out starting from 2025, the timeframe for development of CCS technologies, transportation and storage solutions is very short.

Lead times for CO₂ storage exploration, permitting and licensing can be as high as 8 years while lead time for CO₂ transportation planning, permitting, engineering and construction can be 8-10 years. The preliminary evaluation of transportation and storage opportunities reveals the need for a transnational pipeline network as well as storages that extend across several borders. Based on experience from natural gas transport, development of treaties for transboundary transport and storage of CO₂ may add considerably to the leadtime.

Hence it is necessary to speed up development of regulatory frameworks, storage site clarification and transportation planning and development.

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Significance of cost efficiency



Source: INSA

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The above chart shows the large variance in transportation and storage costs, and illustrates the benefit of a cost effective development. The two bars illustrates possible low end and high end projects in the cost curve.

Plants close to low cost storage such as depleted onshore oil and gas reservoirs may face very low costs as illustrated by the left bar (cost for capture, transportation respectively by different colours). Suitable EOR projects may even offer considerable negative storage cost. Transportation from an inland source in a single purpose pipeline to the coast for further transportation by ship to an offshore saline aquifer may represent a high cost example (right bar).

The large cost variances makes it important to implement projects on the basis of their merit order in a marginal cost curve, both on and offshore in order to reduce total costs of CCS projects.

Market based systems will tend to sort out the most cost effective projects for implementation. But the frameworks must be developed in order to foster efficient solutions.

Recommendations

BASREC nations should foster development of safe and cost effective transportation and storage systems by

- Development and implementation of a coherent and predictable policy and legal framework.
- Carrying out public engagement programs
- Stimulating better mapping and pre commercial exploration of storage sites and potentials.
- Stimulate information sharing about storage opportunities, capacities and costs of transportation and storage.
- Establish coherent stimulation of the whole CCS chain.



A more coherent and predictable policy for implementation of the CCS directive as well for low cost onshore storage should be considered. Recent experience from the legislative processes has demonstrated that authorities due to public opposition have been forced to amend the draft regulations aimed at implementing the CCS directive to be much more restrictive than originally intended.

Hence it seems necessary to carry out a public engagement program to identify the real concerns, risks and possible mitigation opportunities involved as a basis for reaching public acceptance and a more rapid regulatory clarification.

Further work is necessary to map, explore, characterize and develop storage opportunities in the region. It is in particular important to improve understanding of cost, capacities, barriers and timeline for development of storage in South Baltic Sea basin.

The development of shared CO₂ transport networks will generate efficiency benefits on a system level, but the costs and benefits of such networks will go well beyond the interests and budgets of individual CCS projects. Consequently infrastructure companies able to execute long term system planning, like in the natural gas and electricity business, should be developed.

Governments may need to play a role in fostering such companies by taking ownership and subsidize in an early phase. In the longer term governments may substitute ownership with transmission company regulations.

Recommendations

- Contribute to business participation and efficient organization of CO₂ transportation and storage.
- Establish independent storage and transportation companies capable of long term system planning.
- Incentivizing CCS chain development by creating licenses/property rights and possible improved support and market systems.
- Intensify negotiations of transboundary agreements, regulating joint and transnational transportation and storage issues.
- In this way BASREC countries will help pave the way for an efficient roll out of CCS in due time for reaching the climate targets.
- The recommendation is based on the view that availability of storage sites is potentially a major constraint to the rapid and widespread deployment of CCS.



Organizing transportation and establishing licenses/property rights for transportation and storage are two key issues. Establishment of storage concessions incentivizes development and supply of storage services. In the CCS Directive, a concession system for storage is envisaged. Such system will create a formal framework for privileges and duties of the concessionaire. In addition, it may create the incentives for development of different storage opportunities. It may be necessary to reinforce a concession system by a support system. This will mobilize resources for storage site development, establish better knowledge of costs and capacity of storage in the region and provide a more efficient supply of storage services. In theory, expected higher and firm prices on emissions may provide sufficient incentives for the required storage development. But such relations are weakened by the high level of uncertainty and considerable lead time in development of storage and transportation.

The development of shared CO₂ transport networks will generate efficiency benefits on a system level, but the costs and benefits of such networks will go well beyond the interests and budgets of individual CCS projects. Consequently infrastructure companies able to execute long term system planning, like in the natural gas and electricity business, should be developed. Governments may need to play a role in fostering such companies.