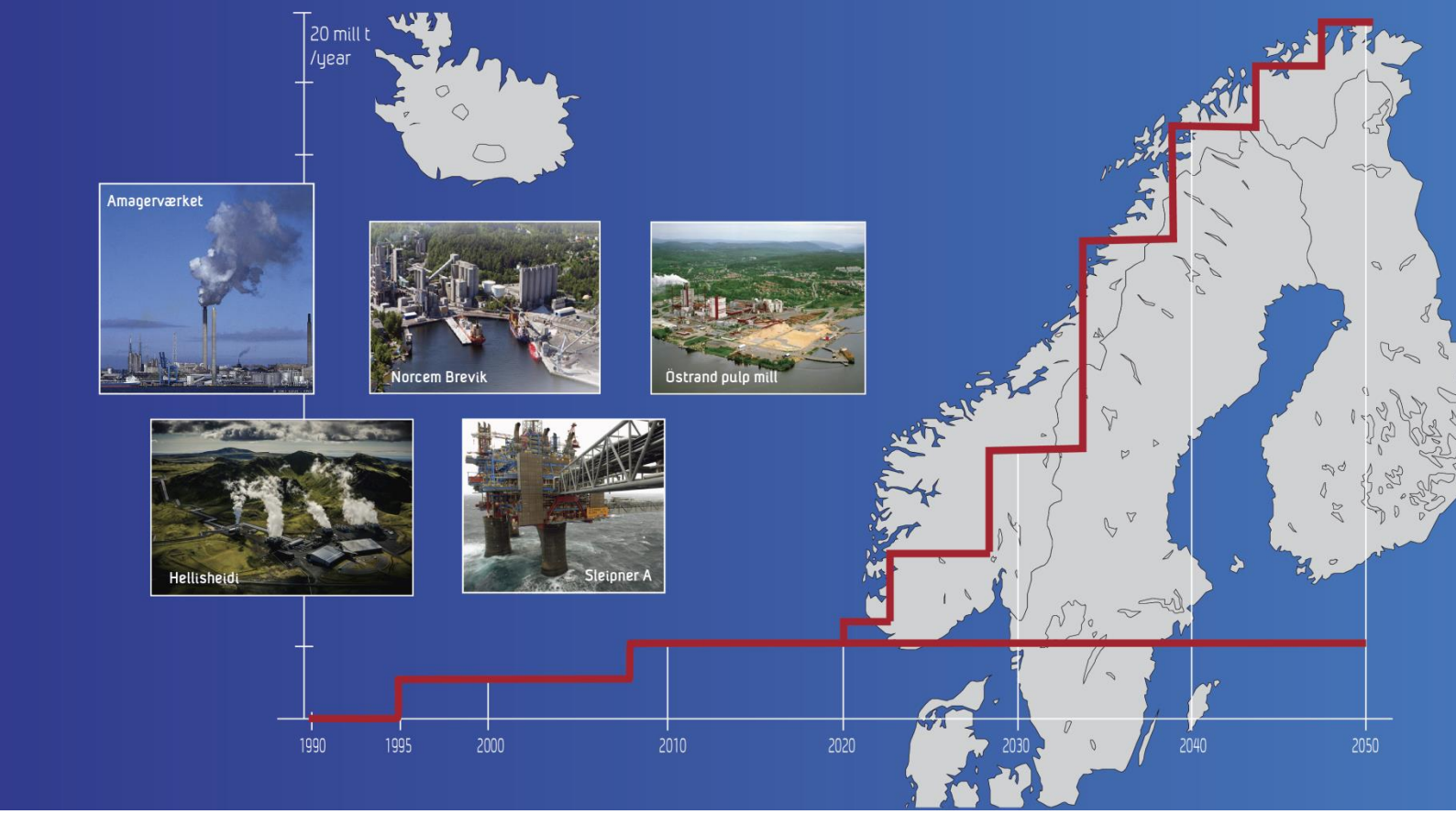

Relevant CCS cases identified

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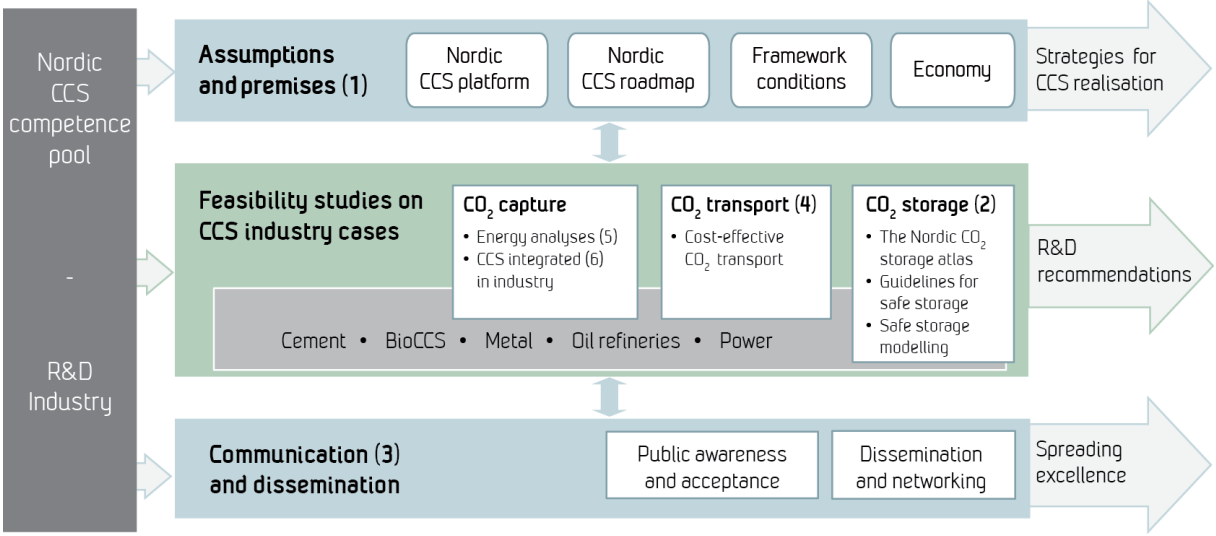
CO2

NORDICCS concept:



Partners:

VTT, CHALMERS UNIVERSITY OF TECHNOLOGY, IVL Swedish Environmental Research Institute, SGU Sveriges geologiska undersökning Geological Survey of Sweden, GEUS, Orkuveita Reykjavíkur, SINTEF, NTNU, UiO : University of Oslo, tel-tek, UNIVERSITY OF ICELAND, Statoil, GASSCO, NORCEM HEIDELBERGCEMENT Group, VATTENFALL, TECHNOLOGY CENTRE MONGSTAD

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Summary

The aim of work package (WP) 3 in NORDICCS is to coordinate integrated CCS cases in the Nordic countries and assess their feasibility. In this report, the selection criteria used for selecting the cases are presented, and 6 full chain CCS cases have been developed, with main source, different transport routes and alternative storage locations. The main sources are from all the different Nordic countries, several different industry sectors and with both large and small amounts of CO_2 emissions. The transport routes include both ship and pipeline and combinations of these. Several different storage locations have been suggested.

The detail level to which the cases are described is expected to increase throughout the course of this project based on the findings from WPs 4, 5 and 6. WP 4 performs the technical assessment of CO2 capture from several types of industry sectors and power plants, in addition, all emission sources in the Nordic countries with emissions above 100 000 tonnes annually are identified. WP 5 assesses possible transport solutions in the region and WP 6 will identify storage locations and develop a storage map for the region.

Keywords CCS chain, CCS cluster, CO2 sources

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About NORDICCS

Nordic CCS Competence Centre, NORDICCS, is a networking platform for increased CCS deployment in the Nordic countries. NORDICCS has 10 research partners and six industry partners, is led by SINTEF Energy Research, and is supported by Nordic Innovation through the Top-level Research Initiative.

For more information regarding NORDICCS and available reports, please visit http://www.sintef.no/NORDICCS.

Introduction

The industrial and power sectors are likely to be subjected to CO_2 emission reductions in the near future. These reductions can be achieved through several measures; increased energy efficiency, change towards less CO_2 intensive fuels and CCS. It is likely that all of these measures will be implemented to some degree. Solutions are therefore needed in order to find sustainable methods to carbon reduction and to minimize the associated costs. By taking a proactive role in these matters, it is possible to reduce the threat of whole industry sectors being transferred to other countries with less stringent regulations regarding greenhouse gas emissions.

The purpose of the NORDICCS project is to identify the possibilities and current obstacles to implementing CCS in the Nordic region. CO_2 capture has mainly been studied for the power generation sector. CCS in the Nordic countries will comprise also of industrial processes (e.g. cement, metal, and pulp & paper) as well as combined heat and power plants, including bio energy with CO_2 capture (BECCS). WP 4, 5 and 6 of the NORDICCS project will identify capture, transport and storage possibilities in the region, respectively, and assess the technological solutions. The aim of WP 3 is to coordinate the work of these WPs into CCS cases. The CCS cases can consist of either one source to one sink or several sources to one sink. The feasibility of these identified CCS cases will be asses technically and economically.

Work package structure in NORDICCS

From the NORDICCS application: "*The industry perspective is of uttermost importance in NORDICCS and the centre will be driven by the industries' need to understand opportunities and implications of CCS technologies. NORDICCS will give Nordic industry a basis for selecting and integrating CCS technologies. In particular, the industry perspective will lay the premises for the definition of case studies on CO2 capture, transport and storage, and input from the industry will be attentively taken into account throughout the case and feasibility studies.*"

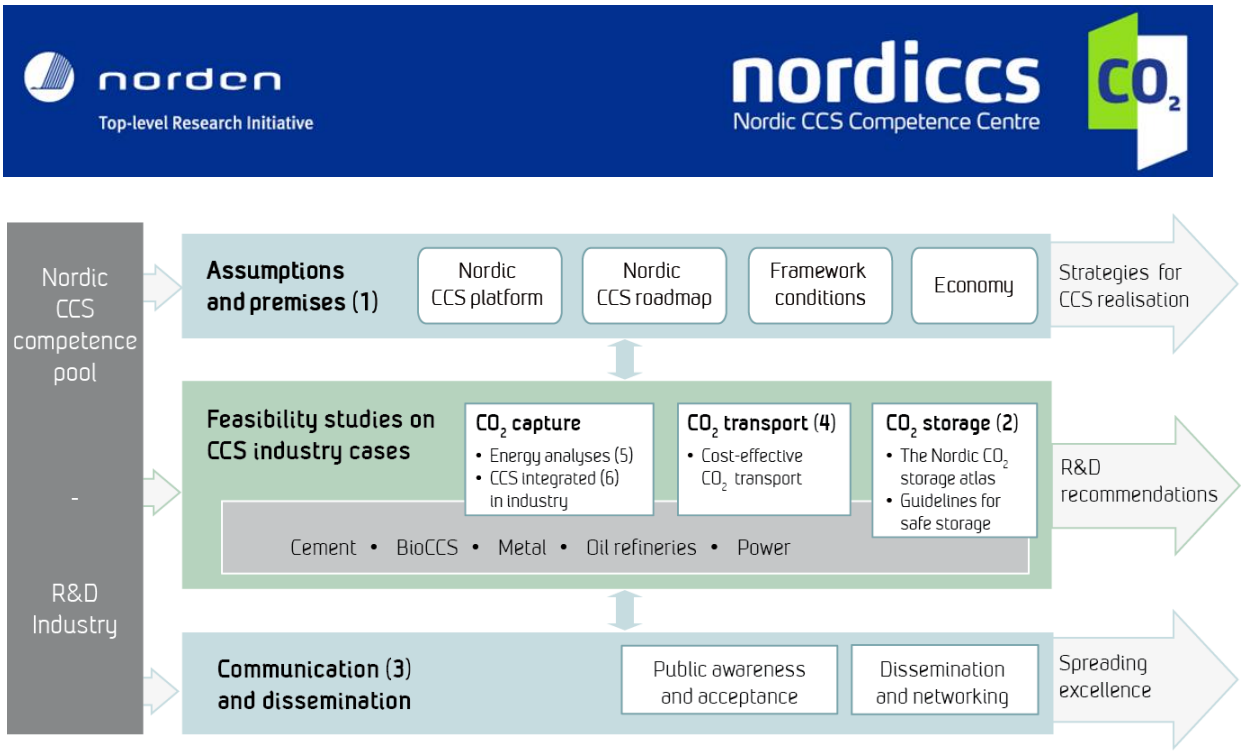

Figure 1 Overview NORDICCS structure

Figure 1 shows the NORDICCS structure, and shows the role of the feasibility studies in this project. Work package 3 coordinate feasibility studies on fully integrated CCS cases for CO_2 emitters in the Nordic region. The feasibility studies will have an economic and a technical approach, and cover several types of industry, capture technologies, transportation methods and sinks. The outcome will benefit the sources that are the focus of the case study, the industry and power sectors as a whole and the governments in each Nordic country. In addition, obstacles to implementation of an integrated CCS infrastructure will be identified and R&D activities that are necessary in order to remove or at least reduce the risk associated with these obstacles will be recommended.

Selection criteria for CCS cases

A CCS case study is a specific set of assets which, together, form a complete CO_2 handling chain, from source, through transportation and finally to storage or utilization. It can include a single source to a single sink or a network consisting of several sources and sinks.

There are several aspects to take into account when these cases are selected. Essential parameters are listed below.

- All of the Nordic countries should be represented.

  This is a Nordic project with attendees and partners from all of the five Nordic countries. It is therefore important that there are CCS cases from all the Nordic countries, to show how CCS networks can be developed for sources in different climate, under different laws and regulations and cross border related challenges.

- Clusters

  It is essential to see the CO_2 sources in relation to other sources nearby, as a cluster can benefit from cooperating with capture, transport and storage.

- Type of sources:

  Several different industry and power sectors will be investigated. The main emission source in each CCS case from which the rest of the CCS chain is developed will represent a sector. Some important parameters are

  - Include different sectors that are representative for the region, like metal, power, cement, bio, oil
  - Relevance (different type/size of industry, size of emissions, etc.)
  - Location (distance to transport/storage facility, surrounding industry, etc.)
  - Select sources amongst existing partners and potential new partners. Other sources may be included due to being a relevant industry or as a member of a cluster

- Legal aspects with cross border transport and storage

  The Nordic countries have some international laws that must be followed. National laws and agreements also need to be discussed for each CCS case.

- Estimation of amount of CO_2 for transport and storage

  CO_2 emission reported in 2009 is used as a basis for the emissions from the sites and it is described in deliverable D4.1.1201 “Nordic emission database”. Work package 4 will focus on finding the available energy at some sites and if the emission is discharged from one or several stacks and an evaluation of the most appropriate capture rate will be performed. The results from Work package 4 will be used in the CCS cases.

- Future aspects (potential, growing/declining industry, etc.)

  Some industry sectors are with the current production technology used less likely to implement CCS unless new production technologies are developed (especially aluminium production, which has only 1 % CO_2 in the flue gas). If information from industry on likely changes in production is made available for the project, it will be taken in to account. If we do not get any information, emission data from 2010will be used.

- Different capture technologies

  Work package 4 will perform detailed technological assessment of several capture technologies for one industrial source. These technologies will be evaluated in the

feasibility studies and some will be cost evaluated. For the other sources in the cluster, a generic MEA capture plant will be assumed.

- Transportation options

  Most of the emission sources in the Nordic countries are located close to the coast and can therefore utilize offshore transport. Nevertheless, onshore transportation will be evaluated for some cases when appropriate. Transportation methods that will be considered are;

  - Ship
  - Onshore pipeline
  - Offshore pipeline
  - Combinations of ship and pipeline, including hubs and intermediate storage

- Sinks

  There are several storage possibilities in the Nordic region, most of them offshore. In addition, on Iceland an ongoing project looks into storage in onshore basaltic rocks.

The sources in the Nordic countries are well describes in the VTT report "Potential for carbon capture and storage (CCS) in the Nordic region" form 2010. The NORDICCS project has updated the data and mapped all the CO_2 sources in the Nordic region that emit more than 0.1 mill ton annually. This information will be used in the development of the CCS cases

Potential storage sites are to be identified during the NORDICCS project in work package 6 and their suitability assessed. As these results are not expected closer to the end of the project some preliminary sinks has been identified for use in the feasibility study, in cooperation with WP 6. These are the North Sea, The Skagerrak/Kattegat basin, the southern part of the Baltic Sea, and the Barents Sea North of Norway.

Feasibility study cases

Cooperation between WP3, 4, 5 and 6 is essential for identification of relevant CCS cases. The work packages have worked, and will continue to work close together to make CCS cases based on information gained through this project.

Figure 2 shows the elements of the CCS cases. 6 main sources have been chosen based on the criteria given in this document. Detailed assessment of these sources will be provided. Work package 4 will analyse these main sources further, in regard to suitable capture technologies and benchmarking energy penalty for the chosen technology. The main sources

will together with surrounding sources constitute a cluster of CO_2 emissions. Full CCS chain cases, including different transport scenarios and storage locations, will be built up around these clusters.

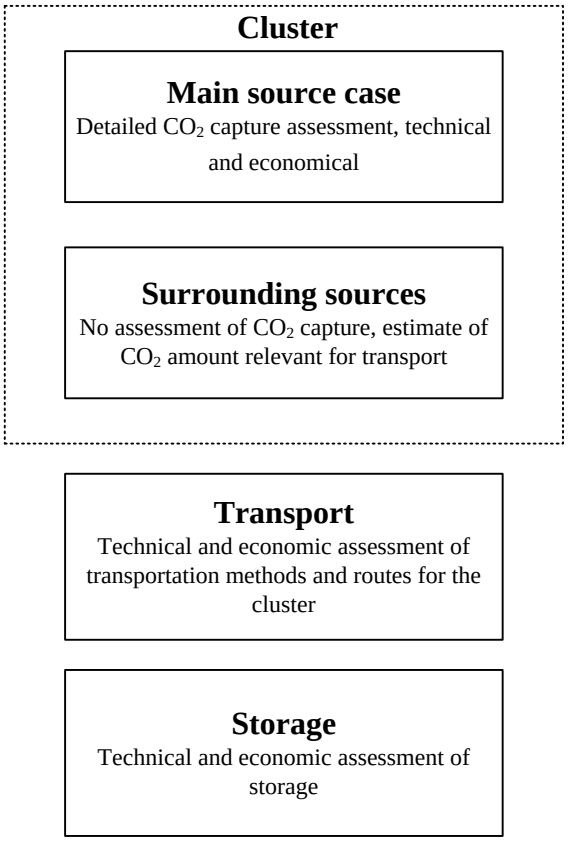

Figure 2 Elements of the CCS cases

First, 6 different main sources have been selected based on the selection criteria. Table 1 gives an overview over the main sources in this project and their CO_2 emissions in 2010. The chosen sources vary in amount of CO_2 emitted, and this makes it possible to investigate both large and smaller sources. Additionally, several different industries are investigated and that gives valuable insight into how CCS can be adapted for different types of industries.

Table 1 Main sources

Source	Type industry	CO2 /year (2010) [1]
Rautaruukki Oyj	Steel	3 414 113
Amagerværket	Power	1 776 386
Norcem	Cement plant	927 000
Reykjavik Energy	Power	40 000
Preem Lysekilen	Refinery	1 670 000
SCA Östrand	Pulp and Paper	1 400 000

In Table 2, six integrated CCS cases have been identified based on the criteria for case selection. Available information about the cases varies; some are already well defined while some need to be further specified (small changes) as the NORDICCS project continues.

[1] The emission data, except Reykjavik power is collected in WP 4. Reykjavik Energy emission is collected from "Carbfix Annual Status Report 2010"

Table 2 CCS cases

	Country	Main source	Cluster	Transportation and storage
1	Iceland	Reykjavik Energy Plant	Aluminium and ferrosilicon plants in Iceland	• Onshore pipeline to storage in basaltic rocks in Iceland • Ship transportation to storage in Utsira Fm
2	Skagerrak	Norcem in Brevik	9 large sources around Skagerrak	• Ship/pipeline transportation to Gullfaks, EOR project • Ship and pipeline combined to storage in Gassum Fm • Ship and pipeline combined to storage in Utsira Fm
3	Finland	Ruukki steel plant	Sources in the Gulf of Bothnia	• Onshore pipeline to storage in Norwegian sea • Offshore pipeline/ship transportation to storage in Baltic sea (Faludden) • Ship transportation to storage in Utsira Fm
4	Sweden	SCA Östrand (Pulp and Paper)	Sources in east coast Sweden and west coast of Finland	• Onshore pipeline to storage in North sea • Offshore pipeline/ship transportation to storage in Baltic sea (Faludden) • Ship transportation to storage in Utsira Fm
5	Denmark	Amagerværket (Power plant)	Large emitters in Fyn and Sealand	• pipeline transportation to storage south in Denmark • Ship and pipeline combined to storage in Gassum Fm • Ship and pipeline combined to storage in Utsira Fm
6	Sweden	Preem refinery in Lysekilen	Large emitters around the main source	• Ship and pipeline combined to storage in Gassum Fm • Ship and pipeline combined to storage in Utsira Fm

Figure 3 gives an overview over the locations of the main sources (black circles) and the possible storage area (orange areas).

Figure 3 Overview over emission clusters and storage places selected as start-up cases.

Conclusion

Six CCS cases have been identified based on the selection criteria proposed in this report. All the Nordic countries are represented, and different kinds of industry will be investigated. The main sources will be a base for the cluster in that area and several transport and storage scenarios will be developed for each main capture source. It is expected that some of the transport routes, and storage sites will need to be re-assessed later in the NORDICCS project, as progress is been made in WP 5 (CO_2 transport) and 6 (CO_2 storage). The chosen CCS cases have several disparities, according to emission of CO_2, industry, country and transport solutions.

Relevant capture technologies for representative industry sectors in the region will be investigated in WP 4. WP 5 has already identified several transportation options, while WP 6 currently working with possible storage locations in the region and are assess their potential.