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Carbon Capture and Storage Program



CCSP Deliverable D236

CCSP & NORDICCS Seminar

Carbon Capture and Storage (CCS) R&D in the Nordic countries

Monday 21st October at Hanasaari, Espoo, Finland

A joint seminar between the Cleen Carbon Capture and Storage R&D program (CCSP) and the Nordic CCS platform NORDICCS was held on Monday 21st October at Hanasaari, Espoo, Finland. 60 persons attended the seminar. At the seminar, the work done in CCSP and NORDICCS were presented. In addition, Juho Lipponen from International Energy Agency (IEA) presented the new roadmap for CCS by IEA. The presentations can be found here: <http://www.cleen.fi/en/ccsp/CCSP-NORDICCS-seminar2013>

According to IEA, CCS is a critical component in the portfolio of low-carbon energy technologies. In order to meet the targets for drastically cutting the CO₂ emissions by 2050 the following measures a set of recommendations has been given in the CCS roadmap by IEA that include new financial support mechanisms, new laws and regulations, improved understanding among the public and stakeholders of CCS, policies that encourage CO₂ storage, technology development for reducing CO₂ capture costs, piloting capture systems in industrial applications, and encourage development of a CO₂ transport infrastructure. In his presentation, Juho Lipponen also gave recommendations for how to develop CCS in the Nordic countries, including building on current knowhow, focusing on industry CCS and bio-CCS, Nordic collaboration and a developing a common Nordic vision for CCS.

CCSP is an industry-lead Finnish R&D program (2011-2015), focused on developing CCS-related technologies and concepts relevant for Finland and Finnish technology providers. A further objective is to create a strong scientific basis for the development of CCS components, concepts and frameworks, and to establish strong international networks that enable active international CCS co-operation. The program consortium consists of 9 research organisations and 17 industrial partners, with an annual budget of about 3 million euro per year. The R&D program is coordinated by CLEEN Ltd. with funding from Tekes – the Finnish Funding Agency for Technology and Innovation. The program has now run for two and a half year and therefore a mid-term report highlighting the achievements so far was launched at the seminar and can be downloaded here: <http://www.vtt.fi/inf/pdf/technology/2013/T125.pdf>

For Finland, CCS offers significant opportunities, which are being investigated and developed in CCSP. Being a large consumer of power and heat, Finland has a unique opportunity in integrating CCS with combined heat and power (CHP) plants. Results from a case study made by Fortum for an oxy-combustion-based CHP plant with CCS indicated that the combination could be promising and the economical penalty from CCS relatively small, if all the heat produced is utilized. As Finland is a large consumer of biomass, adding CCS to bioenergy solutions (bio-CCS) would enable removal of CO₂ from the atmosphere. For heavy industry, such as oil refining and steel manufacturing, CCS is the only technology that can significantly reduce CO₂ emissions.

For the Finnish technology developers and providers CCS could provide a significant market share in the future, such as in the area of oxy-fuel combustion and chemical looping technologies, which are being further developed in CCSP. Chemical looping technologies can provide a higher degree of flexibility in future power plants, as thermal and chemical energy can be stored in the solid materials circulating in the process. Flexible



power plants capable of fast load changes and efficient energy production also in partial loads will be in high demand in the near future due to the increasing share of renewable energy in electricity.

Monitoring technologies is another quickly developing area where a growing Finnish expertise can help making CCS a safe and secure emission reduction and improve the social acceptance of CCS. In CCSP, Ramboll has established methods for sampling, analyzing and verifying these emissions, which take CCS processes one step closer to realization. This new, accredited method has already drawn interest from many relevant global actors in the field of CCS.

As the Finnish bedrock does not have any formations suitable for underground permanent storage of CO₂, other options are being investigated. A recent survey of the Baltic Sea area shows a potential for geological storage of CO₂. Several options for using CO₂ as a raw material for production of inorganic carbonates, chemicals and fuel components also show promise. In CCSP, a small-scale pilot plant for conversion of steel slag and CO₂ into pure calcium carbonate is currently being constructed at Aalto University. The Finnish bedrock could, however, be suitable for small-scale intermediate storage of CO₂ in man-made refrigerated caverns, which could play an important role as CO₂ storages in ship terminals as an alternative to steel tankers.

Nils Røkke, centre director for NORDICCS, gave an overview of the Nordic CCS Competence Centre NORDICCS. NORDICCS is a virtual CCS networking platform aiming for increased CCS deployment in the five Nordic countries. The vision for NORDICCS is to become a Center of Expertise on CCS by developing joint Nordic strategies to promote widespread implementation of CCS, and effectively communicate the strategies to the decision makers and the general public. Operating under the Top-level Research Initiative (TRI), NORDICCS involves the major CCS stakeholders in the five Nordic countries. NORDICCS is financed by Nordic Innovation and the partners themselves, and has a planned operation of five years.

It seems likely that the Nordic countries as a group cannot reach their CO₂ emission reduction goal without CCS. The NORDICCS has therefore recently published a Nordic CCS roadmap that outlines key strategies for reducing costs, achieving economies of scale – and accelerating wide deployment of CCS. This is based on economic analyses of 10 case studies deemed likely to be the most cost-efficient solutions for CCS deployment. The analyses found natural gas sweetening (i.e. removing CO₂ from natural gas before it is exported) to be the most economically viable case for CCS. Also cement, steel and petrochemical industries were among the most economically viable cases. Many of these are in the Skagerak industry cluster, a collection of Swedish, Danish and Norwegian large CO₂ point sources. There are great advantages to be gained from a Nordic collaboration on CCS. Large CO₂ point sources in Sweden and Finland, complemented by large storage capacity off the coasts of Norway and Denmark, could give a benefit of scale to keep the costs down. Combination of enhanced oil recovery using CO₂ with permanent CO₂ storage in oil reservoirs is seen as a critical, near-term solution for creating economically viable CCS projects, facilitating early CCS infrastructure – and kick-starting deployment. It is important to ramp up the deployment of CCS now while there is still development of oil and gas projects in the North Sea that could make use of the captured CO₂ for enhanced oil recovery (EOR). The Nordic CCS roadmap is available here:

http://www.sintef.no/project/NORDICCS/NORDICCS-bok%20-%20small_2013-11-1.pdf



Another ongoing work in NORDICCS is a CO₂ Storage Atlas. The main objective is to create a Nordic CO₂ storage atlas comprising potential storage sites in all the Nordic countries. This atlas will be public available as a web-based geographical information system (GIS), allowing visual overview of CO₂ storage options and access to data connected to the storage site e.g. storage capacity. Public acceptance of CCS is another topic being studied in NORDICCS.

A closing discussion was held, where the main question that was discussed was “what steps are needed to enable CCS in the Nordic countries”. The following issues were raised:

- The use of fossil fuel is increasing → CCS is a crucial method for curbing climate change in a world where the use of fossil fuel increases
- An increased political discussion on CCS is needed, especially in Finland and Sweden, where CCS is hardly visible on the political agenda. This could be motivated by arranging meetings with Nordic ministers.
- Currently, there is no common Nordic vision for CCS, although this is an important issue. For instance, construction of the necessary transportation and storage infrastructure for CCS involves many countries for which a common vision is important.
- EU needs a more solid plan for after 2020
- Climate policies should provide a solid ground for future decisions and should not be able to be interrupted by leadership changes.
- The Nordic industry could come together and form their own long-term vision and find means for their long-term survival
- Favouring smaller scale demonstration projects could boost CCS technology development. Smaller scale demonstration projects would cost less but provide a valuable learning.
- Although enhanced oil/gas recovery is a cost-effective way to CCS, the net CO₂ reduction is questionable as it leads to the production of more oil/gas which in turn also produce CO₂ emissions.
- The possibility for CO₂ storage in the Baltic Sea provides a motivation for CCS in Sweden and Finland, as it would reduce the transportation costs.
- The development of CCS in EU could be sped up if the interest for CCS Germany could be restored. UK has made an electricity reform and incentives, which motivate the deployment of CCS.
- The opportunities to produce a CCS technology export from the Nordic countries were discussed. CCS technology export needs demonstration of the technology in the Nordic countries, or partnership with an international partner.
- A better communication of R&D results to the public is needed.

CCSP (Carbon Capture and Storage) program home page: <http://www.cleen.fi/en/ccsp>

Nordic CCS platform NORDICCS home page: <http://www.sintef.no/nordiccs>



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Monday 21st October at Hanasaari, Espoo, Finland

PROGRAM

11:00 Lunch

12:00 Welcome – Åse Slagtern, Nordic Innovation/Research Council of Norway

12:15 Presentation of CCSP

- Overview of CCSP – Sebastian Teir, VTT
- Selected highlights from CCSP
 - Oxy combustion-based CCS for CHP, case study - Kalevi Kankkunen, Fortum
 - Development of emission monitoring technologies for CO₂ capture - Eerik Järvinen, Ramboll
 - Bio-CCS - Antti Arasto, VTT
 - Development of looping technologies - Tero Tynjälä, Lappeenranta University of Technology

14:15 Coffee

14:45 Presentation of NORDICCS

- Overview of NORDICCS - Nils Røkke, Sintef
- Selected highlights from NORDICCS
 - NORDICCS CCS Roadmap - Marit Mazzetti, Sintef
 - NORDICCS Storage Atlas - Karen Lyng Anthonsen, GEUS
 - Public Acceptance - Peter Stigson, IVL

16:45 IEA 2013 CCS Roadmap: What needs to happen next? – Juho Lipponen, IEA CCS

17:15 Closing discussion, wrap-up

Seminar home page: <http://www.cleen.fi/en/ccsp/CCSP-NORDICCS-seminar2013>

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NORDICCS is a virtual CCS networking platform aiming for increased CCS deployment in the five Nordic countries. Operating under the Top-level Research Initiative (TRI), NORDICCS is the Nordic CCS platform involving the major CCS stakeholders in the five Nordic countries. NORDICCS is financed by Nordic Innovation and the partners themselves, and has a planned operation of five years. <http://www.sintef.no/nordiccs>



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Monday 21st October at Hanasaari, Espoo, Finland

Participants

Aarlien	Rune	SINTEF
Ahonen	Lasse	GTK
Anthonsen	Karen Lyng	GEUS- Geological Survey of Denmark and Grenland
Arasto	Antti	VTT Technical Research Centre of Finland
Arponen	Timo	Helsingin Energia
Berstad	David	SINTEF Energy Research
Eldrup	Nils Henrik	Tel-Tek
Eloneva	Sanni	Aalto
Genoud	Guillaume	MIKES
Haapalainen	Risto	Oulun Energia
Hankalin	Ville	ÅF-Consult Oy
Hujanen	Sari	Fortum Power and Heat Oy
Hyppänen	Timo	LUT
Jussila-Suokas	Jatta	CLEEN Oy
Järvinen	Eerik	Ramboll Finland Oy
Kaikkonen	Hannu	Neste Oil
Kainiemi	Laura	Aalto yliopisto
Kankkunen	Kalevi	Fortum / Power Solutions
Karimi	Farid	University of Helsinki
Keipi	Tiina	TTY
Kjärstad	Jan	Chalmers University of Technology
Kojo	Matti	University of Tampere
Kuivalainen	Reijo	Foster Wheeler Energia Oy
Kujanpää	Lauri	VTT Technical Research Centre of Finland
Kärki	Janne	VTT Technical Research Centre of Finland
Laitinen	Teija	CLEEN Ltd
Laitio	Jussi	Neste Jacobs Oy
Laukkanen	Timo	Aalto yliopisto/Energiatekniikan laitos
Lipponen	Juho	IEA CCS
Mathisen	Anette	Tel-Tek
Mazzetti	Marit	Sintef Energy Research
Meriste	Tõnis	Eesti Energia AS/Enefit
Möl Mortensen	Gry	Geological Survey of Sweden
Nieminen	Matti	VTT Technical Research Centre of Finland
Nilsson	Per Arne	panaware ab
Nordbäck	Nicklas	GTK
Nyberg	Katri	Fortum Power and Heat Oy
Obraztsov	Yaroslav	Trade Representation of Russia
Peippo	Karoliina	CLEEN Oy
Peltola	Heljä	Outotec (Finland) Oy
Pihkola	Hanna	VTT Technical Research Centre of Finland



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Pikkarainen	Toni	VTT Technical Research Centre of Finland
Pirhonen	Leena	ÅF Consult Oy
Rajamäki	Jaana	Tampere University of Technology
Rathnam	Renu Kumar	VTT Technical Research Centre of Finland
Rodriguez	Milena	VTT Technical Research Centre of Finland
Rydberg	Nils	Bastor II
Rökke	Nils	SINTEF
Said	Arshe	Aalto University
Skagestad	Ragnhild	Tel-Tek
Slagtern	Åse	The Research Council of Norway
Stigson	Peter	IVL Swedish Environmental Research Institute
Suojanen	Juha	Vaasa University
Suomalainen	Marjut	VTT Technical Research Centre of Finland
Teir	Sebastian	VTT Technical Research Centre of Finland
Toikka	Arho	Helsingin yliopisto
Tsupari	Eemeli	VTT Technical Research Centre of Finland
Tynjälä	Tero	Lappeenranta University of Technology
Tähtinen	Matti	VTT Technical Research Centre of Finland
Virtasalo	Joonas	Geological Survey of Finland
Vähäkuopus	Tuija	Geologian tutkimuskeskus
Väänänen	Hannu	ABB

Summary:

CCSP & NORDICCS Seminar and Workshops, October 21-22, 2013, Espoo, Finland
(by Rune Aarlién, SINTEF; Sebastian Teir, VTT)

With the aim of exchanging information and potential identification of joint activities, the NORDICCS project and the Finnish CCSP program met in Hanasaari, Espoo, Finland on October 21-22, 2013, for a joint seminar and three workshops. The seminar was very useful in terms of information exchange on ongoing work and progress so far. The workshops showed that there is significant potential for coordination and joint activities between the two programs in the future.

CCSP & NORDICCS Seminar

Both the NORDICCS project and the CCSP program are now half-way through their five years of operation, and preliminary results are materializing. On this background the two initiatives decided to meet for information exchange and identification of joint networking activities, and potentially also joint project activities.

The half-day seminar on October 21, which was also open to the public, was intended for dissemination of mid-term results and information exchange between the two programs. 60 persons attended the seminar. The seminar was opened by *Åse Slagtern*, who represented the Research Council of Norway and the Top-level Research Initiative (TRI) under Nordic Innovation. Ms. Slagtern gave credit to both initiatives for seeking to join forces, and underlined that increased networking and sharing of information can only be positive in realization CCS in the Nordic countries.



Left: Ms. Åse Slagtern opening the joint NORDICCS – CCSP seminar.



Right: Seminar participants at the Hanasaari-Hanaholmen conference centre

Sebastian Teir of VTT gave an overview of the industry-driven CCSP program, which seeks to develop CCS-related technologies and concepts leading to piloting and demonstration. Also, the CCSP seeks to create a strong scientific base for technology, concepts and frameworks, and is actively pursuing international cooperation. In particular, the program focuses on CCS concepts, long-term breakthrough technologies, monitoring technologies and framework conditions for CCS. As examples of CCSP projects *Kalevi Kankkunen* (Fortum) presented a case study on oxy combustion-based CCS for CHP, *Eerik Järvinen* (Ramboll) talked about development of emission monitoring technologies for CO₂ capture, *Antti Arasto* (VTT) talked about Bio-CCS, and *Tero Tynjälä* (Lappeenranta University of Technology) presented development of looping technologies.

In the next session, *Nils Røkke* (SINTEF) gave an overview of the NORDICCS project. The aim of NORDICCS is to be a Center of expertise on CCS by developing joint Nordic strategies to promote widespread implementation of CCS, and effectively communicate the strategies to the decision makers and the general public. Mr. Røkke stressed that NORDICCS is more a networking project than a project for deep research, and said that the joining of forces between CCSP and NORDICCS fits very well with the strategy. As examples on ongoing activities in the project, *Marit Mazzetti* (SINTEF) discussed the NORDICCS CCS Roadmap, *Karen Lyng Anthonsen* (GEUS) presented the Storage Atlas, and *Peter Stigson* (IVL) gave a talk on communication and public acceptance.



Left: Nils Røkke, project leader of NORDICCS
Right: Sebastian Teir, program leader of CCSP



The final presentation at the seminar was given by *Juho Lipponen* (IEA) who discussed the IEA 2013 CCS Roadmap and the challenges ahead from a broader perspective. Mr. Lipponen emphasized that CCS is a critical component in a portfolio of low-carbon energy technologies aimed at combating the climate change, and that given the dominant role that fossil fuels continue to hold in primary energy consumption, the urgency for CCS deployment is only increasing. In his presentation, Juho Lipponen also gave recommendations for how to develop CCS in the Nordic countries, including building on current knowhow, focusing on industry CCS and bio-CCS, Nordic collaboration and a developing a common Nordic vision for CCS.



Juho Lipponen, IEA

The seminar was rounded off with a short session for questions and discussion. The main question that was discussed was “what steps are needed to enable CCS in the Nordic countries”. The following issues were raised:

- The use of fossil fuel is increasing → CCS is a crucial method for curbing climate change in a world where the use of fossil fuel increases
- An increased political discussion on CCS is needed, especially in Finland and Sweden, where CCS is hardly visible on the political agenda. This could be motivated by arranging meetings with Nordic ministers.
- Currently, there is no common Nordic vision for CCS, although this is an important issue. For instance, construction of the necessary transportation and storage infrastructure for CCS involves many countries for which a common vision is important.
- EU needs a more solid plan for after 2020
- Climate policies should provide a solid ground for future decisions and should not be able to be interrupted by leadership changes.
- The Nordic industry could come together and form their own long-term vision and find means for their long-term survival
- Favouring smaller scale demonstration projects could boost CCS technology development. Smaller scale demonstration projects would cost less but provide a valuable learning.
- Although enhanced oil/gas recovery is a cost-effective way to CCS, the net CO₂ reduction is questionable as it leads to the production of more oil/gas which in turn also produce CO₂ emissions.
- The possibility for CO₂ storage in the Baltic Sea provides a motivation for CCS in Sweden and Finland, as it would reduce the transportation costs.
- The development of CCS in EU could be sped up if the interest for CCS Germany could be restored. UK has made an electricity reform and incentives, which motivate the deployment of CCS.
- The opportunities to produce a CCS technology export from the Nordic countries were discussed. CCS technology export needs demonstration of the technology in the Nordic countries, or partnership with an international partner.
- A better communication of R&D results to the public is needed.

Presentations from the seminar can be found here (<http://www.cleen.fi/en/ccsp/CCSP-NORDICCS-seminar2013>).

CCSP & NORDICCS Researcher workshops

The second day of the joint event was used for workshops between the researchers of the two projects. All together more than 30 participants attended. The following three workshops were held:

- Transportation and infrastructure, storage of CO₂ in the Baltic region
- CCS in industry and bio-CCS
- The Nordic CCS Roadmap

Below are given short summaries from the different workshops by the workshop chairs.

Transportation and infrastructure, storage of CO₂ in the Baltic region

(by Karen L. Anthonsen, GEUS)



Karen Lyng Anthonsen, GEUS

Per Arne Nilsson from the *Bastor Project* presented preliminary results from the work with assessment of storage capacity in the Baltic Sea and agreed with *Gry Møl Mortensen* (SGU) to stay in contact regarding storage capacity estimations for the Falluden Structure.

The presentation of mineral carbonatisation by *Sebastian Teir* (VTT) concluded that there is no obvious possibility for cooperation between the Finnish mineralisation projects and the Icelandic CarbFix project because of the very different carbonatisation processes needed due to the different geology in Finland and Iceland.

The work in CCSP on CO₂ transport and infrastructure was presented by *Lauri Kujanpää* (VTT). Afterwards *Jan Kjørstad* (Chalmers University) spoke about the NORDICCS infrastructure studies. The two studies have approached the transport and infrastructure system studies differently, but it was agreed to investigate if there is a common way forward by cooperation between the two studies.

CCS in industry and bio-CCS (by Antti Arasto, VTT)



Antti Arasto (right), VTT

The target for the workshop was to find new collaboration topics for CCSP and NORDICCS, and strengthening the existing ones.

For the background of the work, the following presentations were held: *Antti Arasto* (VTT) gave an introduction to the workshop and presented CCS in industry & Bio-CCS. *Ragnhild Skagestad* (Tel-tek) presented CCS in the Nordic countries – Industry cases, *Eemeli Tsupari* (VTT) talked about feasibility of CCS for an integrated steel mill, *Anette Mathisen* (Tel-tek) presented industrial CCS, and *Janne Kärki* (VTT) talked about feasibility of bio-CCS in CHP production - case study of biomass co-firing plant in Finland.

The identified reasons for industry were increased market share world-wide in long-term and a vision of carbon neutral products like Norcem vision for 2030. Future research areas in industrial CCS and bio-CCS identified in the workshop were:

Potential topics for industrial collaboration:

1. Iron and steel: Capture technologies, pressure swing
2. Cement- PSA/other capture technologies, partial oxyfuel
3. H₂ from natural gas with CCS

Potential topics for bio-CCS

1. Bio SNG plant – Gasification plants that are biomass based
2. Bio ethanol may not be feasible, in US subsidized
3. CCS on FT diesel
4. Better assessment of viability of bio CCS: Does it make sense to do bio-CCS? Potential is huge, is there enough biomass available? What would the other uses be? - How large can the market be?

Workshop on Nordic CCS Roadmap - Framework Conditions
 (by Marit Mazzetti, SINTEF)



Marit Mazzetti, SINTEF

The Nordic Countries all have set ambitious goals to become carbon neutral by 2050. Several of the Nordic countries are showing commitment to reduce climate gases by laws like emission performance standards in Denmark and carbon tax in Norway. However, this is not sufficient to start CCS projects. The Emissions Trading System (ETS) is not proving to be an effective tool as the carbon price is too low. It does not help make CCS projects economically viable.

The aim of the workshop was to come up with suggestions for the most effective framework conditions for CCS to put in place in order to implement CCS projects in the Nordic countries. The following was listed as the most important framework conditions for implementing CCS:

- Feed-in tariffs
 - Renewables in Sweden and Finland benefit from feed-in-tariffs, the same must be established for CCS
- CCS certificates: Delivered by producers of fossil fuels, oil and gas companies
 - Cost is taken by sector with better margins
- ETS must be made into a competitive tool by structural change
- Emission Performance Standards (EPS): If anything else fails
- Pilot-demo projects: 3-5 plants in Europe by 2020
- Biomass to liquid technology most relevant for Bio CCS
- Implement EU Directive - onshore storage is currently forbidden in Sweden and Finland
 - The EU directive would enable onshore storage
- Establish a carbon tax on imported products
 - This will turn the ETS into a global system
 - The tax can be used to fund CCS infrastructure
- Establish a first storage hub in Europe
 - Open for CO₂ import
 - Could be funded with Nordic resources
- A long-term CO₂ support mechanism is required that outlasts political election
 - There is a need to establish Measurement Reporting Guidelines for ship transport of CO₂ enabling ship transport across country borders

VTT proposed collaboration on a MRG project since similar projects on establishing a MRG for shipping is ongoing both at VTT as well as NORDICCS. Both NORDICCS and CCSP steering committees will make a decision if joint collaboration is desirable on MRG.

In conclusion

The joint two-day event between NORDICCS and CCSP was regarded very positively between the attendees. A considerable amount of information was exchanged, creating a foundation to build future collaboration upon. The two projects have a slightly different approach; while the CCSP is more focused on scientific results and new technology, the NORDICCS project is more a networking effort. This means that we can build on each other's strengths, and that limited resources can be optimized to the benefit of both parties. The workshops identified both areas where collaboration and further information exchange could happen, and areas where it is not likely. Both parties expressed a strong interest in holding another similar event in the near future.

