Role of CCS for Finland

Summary for policymakers, Carbon Capture and Storage Program (CCSP)

HIGHLIGHTS

- Global effort to mitigate climate change below 2 °C requires near zero greenhouse gas emissions by 2050. The EU and Finland have set targets to reduce GHG emissions by at least 80% compared to 1990 emission levels.
- One third of the above targeted reduction of greenhouse gas emissions in Finland by 2050 could be achieved cost-effectively with CCS
    - Biomass-related CCS applications represent the main part of this potential (over 80%), while CCS applications in carbon intensive industries stand for the rest.
- Excluding CCS from the technology portfolio in Europe for reducing greenhouse gas emissions more than doubles the estimated price of emission allowances by 2050.
- Most technologies for CCS are ready for application but currently there are no financial motivations to reduce CO_2 emissions. Financial support for early application of CCS in Europe is needed to ramp up the CCS deployment.
- Demonstration of CCS in Finland for combined heat & power plants combusting biomass and peat as well as for pulp and paper plants is recommended
    - Most of the potential for cost-effectively applying CCS in Finland is related to this sector
    - Early application of bio-CCS in Finland provides cost-efficient GHG mitigation option and thus a business opportunity for emission allowance export
    - Bio-CCS is an opportunity for Finnish technology and service export (e.g. fluidized bed boilers, hot solid looping reactors, emission measurement)
    - Demonstration of CO_2 hubs in Europe and intermediate storage in Finland is also of importance
- In order for bio-CCS to be applied, the benefit from the negative net emissions of bio-CCS needs to be acknowledged and accounted for in the EU ETS and other climate policy frameworks.
- Utilisation of CO_2 will not directly have much effect on reducing CO_2 emissions. However, combined with renewable energy systems it could be a route for providing carbon neutral fuels, chemicals and other products in the future.
- Certain concepts for utilisation of CO_2, like converting slags and ashes into more valuable products by CO_2 mineralization, already seem commercially viable.

IMPORTANCE OF CCS

Carbon Capture and Storage (CCS) is one of the technologies needed in Europe to cost-effectively reduce CO_2 emissions in order to meet the target for 2050[1] set by EU's energy strategy and especially the stringent "well below 2 °C" target of the Paris climate agreement. Although Finland is migrating towards fossil-free power production, CCS is still needed. CCS is an essential tool also for Finland for reducing CO_2 emissions in the heavy industry sector, and it has an important role to play in the bioeconomy: combining CCS with biomass (bio-CCS) would form a carbon sink (or "negative" emissions).

According to the analyses done in the Carbon Capture and Storage Program (CCSP), CCS is a cost-effective method also for Finland for reaching the 2050 target[2]: up to 19 Mt CO_2 emission reductions per year could be achieved with CCS by 2050 – roughly one third of the target. On the other hand, excluding CCS from the portfolio of available methods for reducing greenhouse gas emissions in Europe more than doubles the price of emission allowances by 2050. According to the calculations, the annual mitigation costs around year 2050 would in Finland amount to 3000 million euro[3], but emission allowance trade would in return generate 500 million euro per year. The exclusion of CCS would increase the direct annual mitigation costs by 200–800 million euro per year by 2050. In this case Finland would have to purchase emission permits to meet the 2050 target, which would cause an additional burden of up to 2100 million euro per year. In Europe, the total annual mitigation costs around year 2050 would amount to 120 billion euro[3], while excluding CCS would increase the direct annual costs by 45–60 billion euro.

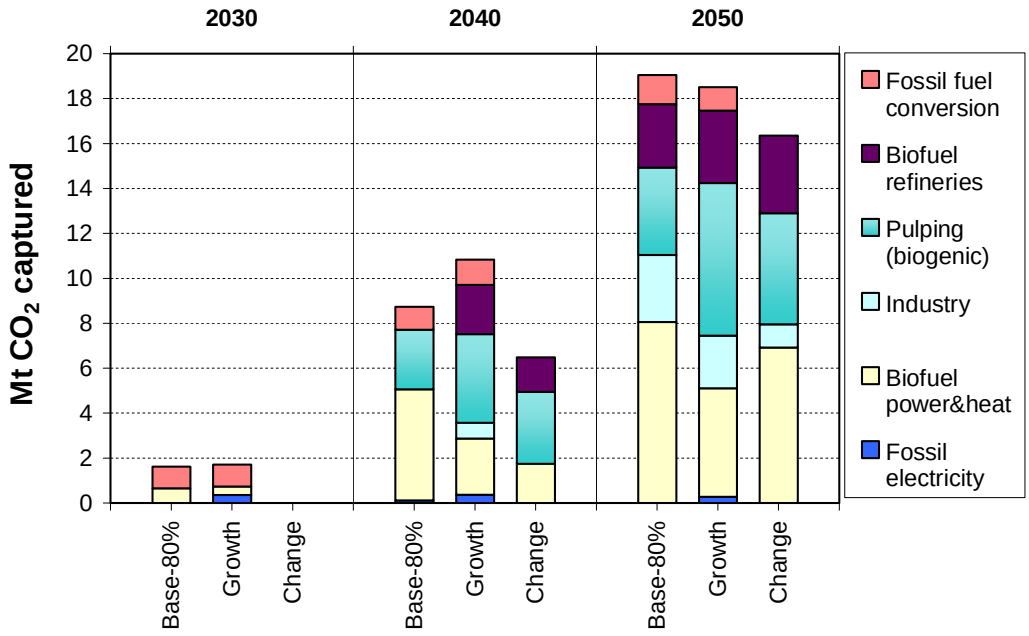
The results from CCSP show that CCS is expected to have a significant role in emission reduction in Europe already around year 2030. In Finland, implementation of CCS is not required until after 2030, because the share of fossil energy in the energy mix decreases by 2030 due to the planned investments in nuclear power capacity and renewable energy.

Bio-CCS is a too important climate mitigation technology for Finland to overlook. According to the analyses done in CCSP, most of the cost-effective CCS applications in Finland would be in the biomass power & heat sector and in the pulp and paper industry. With bio-CCS alone, Finland could by 2050 reach up to 15 Mt CO_2 emission reductions per year – roughly one fourth of the 2050 target.

According to our analyses, the need for bio-CCS in Europe could become as large as 400 Mt CO_2/a by 2050 (7-8 % of the total target for reduction of greenhouse gas emissions for EU by 2050). The

[1] The EU has set itself a long-term goal of reducing greenhouse gas emissions by 80-95% when compared to 1990 levels by 2050.
[2] In our calculations the target for Finland and Europe by 2050 was set to a reduction of greenhouse gas emissions by 80 % when compared to 1990 levels.
[3] These costs were calculated only for the "Base-80%" scenario.

implementation of bio-CCS in Finland could even enable Finland to become a net seller of emission allowances. Bio-CCS is also an opportunity for Finnish technology providers, as they have the know-how to develop the technology and are already developing it.



The role of CCS in scenarios targeting a reduction of greenhouse gas emissions of 80 % by 2050: in the "Base-80%" scenario a slower technology learning and penetration of renewables increases the demand for CCS. In the "Change" scenario fossil-CCS in energy production is excluded as a mitigation option to show the impacts of "fossil-free" energy production.

Utilisation of CO_2 (or Carbon Capture and Utilisation; CCU) will not directly have much effect on reducing CO_2 emissions, but can have an important role in renewable energy systems, in which CO_2 would be captured for converting renewable (wind, solar, hydro) electricity into hydrocarbons to be utilized in various processes (transportation, chemicals, P2G). By this approach, the entire energy system would be carbon neutral if biogenic sources of CO_2 were used. In addition, certain concepts developed in the CCSP program, like converting slags and ashes into more valuable products by CO_2 mineralization, already seem commercially viable due to the high market value of the products.

BARRIERS FOR DEPLOYMENT OF CCS

With 15 demonstration plants already in operation globally and 7 more being constructed, the technology for CCS is ready for application. There are no technical barriers either for storage of CO_2 in underground geological formations – tens of millions of tonnes of CO_2 has been injected and stored safely and securely in deep saline reservoirs for more than 15 years, and in oil and gas

reservoirs for decades. However, in Europe there is currently no commercial driver for the industry to start implementing CCS. As an extensive deployment of CCS in Europe would decrease the costs for achieving the targets set out by the climate agreements, financial support for early application of CCS in Europe is needed to ramp up the CCS deployment.

As Finland has no suitable underground geological formations, CO_2 would need to be transported abroad for final storage. Therefore, application of CCS in Finland is 10–20% more costly than in Europe on average. For CCS applications in Finland ship transportation would be favourable over transportation of CO_2 by pipeline. Ship transportation benefits largely from "CO_2 hubs", where CO_2 can be collected from several sources and distributed to final storage sites, but this requires intermediate (i.e. temporary) storage of CO_2 close to the terminals. The work in CCSP has indicated that building intermediate storage facilities in the Finnish bedrock could be a cheaper alternative than the use of steel tankers. Although the closest operational storage sites are currently located in the North Sea and Barents Sea, work in the CCSP has identified potential storage formations in the bedrock of the Baltic Sea. Although ship transport of CO_2 for storage is not currently covered by the European Emission Trading Scheme (ETS), it is possible for Member States to decide to include it under the scheme.

A low public acceptance is one crucial barrier in deploying CCS technologies and has contributed to halting of a couple of projects in the past. CCS has been seen as an excuse for continuing the use of fossil fuel. However, the work done in CCSP shows that the main potential for CCS in Finland is with biomass-related applications, not for fossil fuel-related CCS applications, except in carbon intensive industries. People have also been concerned with geological storage of CO_2, although the industry has good experience from safe and secure storage of CO_2. From a Finnish perspective, international collaboration is needed in relation to geological storage, as CCS applications in Finland would require transportation of CO_2 abroad. Research carried out in CCSP shows that there is hardly any public discussion about CCS in Finland and the majority of the media coverage of CCS has had a positive tone. In the future, special attention should be paid to stakeholder and public engagement and communication in fostering social acceptability of CCS policy.

Currently, there is hardly any incentive for investing in CCS in Europe, mainly due to the low price for CO_2 emission allowances in the European Emission Trading Scheme. In addition, there is no incentive for bio-CCS, as CO_2 emissions from biomass are not part of the ETS. In order for bio-CCS to be applied, the benefit from the negative emissions of bio-CCS needs to be acknowledged and accounted for.

WHY CCS SHOULD PLAY AN IMPORTANT ROLE IN FINNISH RD&D

- ➔ The Paris Climate Agreement and EU Energy Strategy set the long-term targets for the EU member states, including Finland, at a radical reduction of greenhouse gas emissions by 2050. Business opportunities for Finnish CCS technology export are expected to arise from the global demand for CCS. Rapid deployment of CCS in Europe is expected by 2030. However, action is needed now because of the significant lead times in CCS deployment and

in order to retain economically important CO_2-emitting industries and associated employment in Europe[4]. Large-scale demonstration plants are needed for gaining vital experience from large-scale operation and further development of the technology. Considering the biomass resources and technological expertise in the field, Finland could be the ideal place for demonstration of smaller-scale CCS applications for bio-CHP plants and larger-scale CCS applications for pulp and paper mills. This would both strengthen opportunities for Finnish technology export and contribute to emission reductions in Finland.

➔ Although application of CCS is slightly more expensive in Finland, the significant potential for negative CO_2 emissions through bio-CCS could more than compensate for this, making early application of bio-CCS in Finland a business opportunity for export of emission allowances. However, this requires that "negative" emissions from bio-CCS are included in the ETS.

➔ In order to enable export of CCS technologies and emission allowances, technology development and application of CCS in Finland need financial support. The EU's NER400 Innovation Fund could provide needed support for bio-CCS implementation.

➔ Similarly to CCS, the vast majority of processes for utilisation of CO_2 require also capture and purification of CO_2. Therefore, the knowledge and expertise gained from R&D into CCS applications can also be used for CCU applications.

PROPOSED ACTIONS

For speeding up the deployment of CCS applications in Finland, and for realizing the business opportunity for CCS technology providers, the following is needed:

1. Planning of stakeholder and public engagement as well as communication activities
2. Incentives for application of bio-CCS and decarbonizing the industry
3. Demonstration of CCS for combined heat & power plants combusting biomass and peat
4. Demonstration of CCS for pulp and paper plants
5. Demonstration of CO_2 hubs in Europe and intermediate storage in Finland
6. Continued development and piloting of future technologies related to CCS and CCU
    - Hot solids looping technologies for biomass (for instance, chemical looping combustion and calcium looping capture)
    - Combined valorisation of mineral resources and CO_2 mineralisation, processing residues from mining activities while extracting valuable metals and fixing CO_2 into carbonates with market value.
    - Concepts utilizing captured CO_2 as a process medium to produce materials, transportation fuels, power-to-gas, or other chemistry products.

[4] European Technology Platform for Zero Emission Fossil Fuel Power Plants (ZEP): Response to issues paper No. 9 – CCS and CCU, April 2016.