**Abstract**

The Preem CCS project is a new Swedish-Norwegian collaboration that investigates CO₂ capture from the Preem refinery in Lysekil, Sweden, and subsequent transport of captured CO₂ for permanent storage on the Norwegian Continental Shelf.

The project presents a unique opportunity for collaboration between Swedish and Norwegian research and industry partners to demonstrate synergies between CO₂ capture from Swedish large-scale emission sources and the Norwegian full-scale CO₂ capture and storage (CCS) project. The target for Sweden to become climate neutral by 2045 will require CCS to be deployed, especially in the process industry. The proximity to Norway, with its plans to realize a full-scale CCS chain by 2023/24, presents opportunities to implement CCS from Swedish emission sources despite the lack of established large-scale CO₂ storage capacity in Sweden. The transport and storage part of the Norwegian full-scale project comprises ship-based CO₂ transport to a hub on the Norwegian west coast, thereafter pipeline transport to an offshore storage infrastructure in the Johansen formation. This part of the full-scale project is known as the Northern Lights-project.

The vision of Preem AB (Publ) – or Preem – is: To lead the transition towards a sustainable society. Preem is the largest oil refiner in the Nordics and thus one of the largest CO₂ emitters in Sweden (with 1.5 Mt CO₂/year from their refinery in Lysekil and 500 kt CO₂/year from the Gothenburg refinery). At the Lysekil refinery, the hydrogen production unit (HPU) alone emits 480 kt CO₂/year. Preem values CCS as an important building block on the pathway towards a sustainable society. The geographical location of Preem operations on the Swedish west coast makes it suitable as a potential early mover among possible international CO₂ suppliers to the planned Norwegian CO₂ transport and storage infrastructure.

This paper gives an overview of the Preem CCS project which consists of the following parts:
On-site CO₂ capture demonstration

The Preem CCS project is centred around an on-site demonstration of CO₂ capture from the reformer flue gas of Preem’s HPU in Lysekil which is planned to start in spring 2020, with the goal of enabling full-scale CO₂ capture with connections to the Norwegian full-scale project. The main aim of the demonstration campaign is to acquire proof of concept for CO₂ capture from the real HPU flue gas and confirm process performance at realistic operating conditions. Key operating data related to energy requirement, amine degradation and emissions will be established. The planned test will be a significant contribution to reduction of technical and commercial risk for later project development. The testing will be carried out with Aker Solutions’ Mobile Test Unit (MTU), which is based on Aker Solutions’ ACC™ amine-based CO₂ capture technology with a capacity to capture up to 3 ton CO₂/day. The overall test campaign will include MEA baseline testing.

Identification of possibilities for cost reductions in different parts of the CCS chain.

Use of refinery waste heat for solvent regeneration is investigated to reduce capture costs as well as an economic evaluation of the full CCS chain to identify viable business and financing models.

The techno-economic evaluation of capture scenarios are performed consisting of
1) Process modeling of a capture process using a 30 wt.% MEA solvent,
2) Cost evaluation of heat supply technologies using a refinery steam cost model
3) An aggregated cost estimation of the modelled capture plant(s) including information derived from the steam cost model developed in 2).

The candidate technologies for supplying heat to the capture process can be categorized as:
1) Technologies which require additional CAPEX but no OPEX; e.g. excess heat in form of available steam not used today or excess heat from process coolers that could raise steam via investment in a heat collection network
2) Technologies requiring additional OPEX but no CAPEX; e.g. excess capacity in existing boilers/equipment that could supply steam at the expense of additional external energy (fuel, electricity)
3) Technologies requiring both additional CAPEX and OPEX; e.g. new boiler capacity that is installed at site and fueled by additional external energy.

For the CCS chain analysis, several value-chains are evaluated, considering capture from both single and multiple sources at the refinery and different ship-based transport solutions linking up to the Northern Lights CO₂ storage infrastructure. An evaluation of viable business and financing models to realize the full CCS chain from Preem’s perspective will also be carried out.

Legal and regulatory aspects and barriers

Legal and regulatory aspects and barriers for transborder ship transport and storage of CO₂ from Preem’s refinery to the Norwegian continental shelf are addressed. The major legal hurdle to transboundary CO₂ transport was resolved in October 2019 when the International Maritime Organization (IMO) adopted a resolution to allow for a provisional application of the 2009 Amendment to the Article 6 of the London Protocol. This means that it is now, from a legal point of view, possible to undertake transboundary transport of CO₂ from, e.g., Sweden to Norway for the purposes of geological storage, provided that both Norway and Sweden deposit a unilateral declaration on their provisional application to the IMO, and provided that a bilateral agreement or arrangement is established between Sweden and Norway including confirmation and allocation of permitting responsibilities between the two countries, consistent with the provisions of the London Protocol and other applicable international law.

The project also follows the development of the Norwegian request for legal clarifications related to the ETS-directive and the MR-regulation on the potential to subtract captured CO₂ transferred to ship transport for permanent storage from emission allowance duty, that has been submitted from Norway to the European Commission.

A roadmap for CO₂ emission reduction pathways at Preem’s two refineries

The final outcome of the Preem CCS project will be to establish a roadmap for CO₂ emission reduction pathways at Preem’s two refineries in Sweden in the context of national emission reduction commitments, considering strategic
implementation of CO₂ capture in relation to possible future development pathways at the refinery. Preem are pursuing an increase in advanced biofuels production, in both their refineries in Lysekil and Gothenburg. Therefore, there will be an increased possibility for Bio-CCS with negative CO₂ emission as more renewable feedstock is upgraded at the two refinery sites.

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Keywords: Preem, Northern Lights, CCS, amine CO₂ capture testing, legal/regulatory aspects