Strategies for CO₂ shipping and offshore unloading

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Abstract
In a large-scale rollout of CCUS (carbon capture utilisation and storage), reliable and efficient transport of CO₂ from source to sink will be vital. There are essentially two transport modes for large-scale, ship or pipeline. Both are proven technologies. Onshore transport of CO₂ in pipelines has been utilized in the U.S. for decades and offshore natural gas pipelines are common in the North Sea. Small-scale shipping of CO₂ for industrial use takes place today at pressures between 14 – 16 barg, and at -25 - -30˚C, often referred to as medium pressure [1]. This transport is also characterized by relatively small volumes, short distances, and onshore loading/unloading. In [1] it is postulated that large-scale shipping of CO₂ likely will take place at lower pressure near the triple point at ~7 bar and -50 ˚C. The ongoing Norwegian CCS study, where the goal is to have at least one CCS chain in operation by 2022 [2] have for the time being opted for the medium pressure condition as this is proven technology, with the CO₂ transported to an offshore hub for reconditioning before pipeline transport to offshore storage. For CCUS it is likely that the volumes to be transported are larger, and there are other challenges like longer distances, impurities, and offshore unloading.

Both pipeline and ship transport have advantages and disadvantages. The major advantage of pipeline transport is the possibility of a continuous CO₂ stream, which provides predictability on both the source and sink side of the chain. The major disadvantage is the lack of flexibility; rerouting of the CO₂ and changes in volumes. It also seems to be more sensitive towards impurities in the CO₂ stream. For ship transport the major advantage is the flexibility; rerouting and changes in volume are possible. It is potentially also less sensitive towards impurities. However, a major disadvantage is the discontinuous CO₂ stream. This complicates the operation at both the source and sink side of the chain. In the case of EOR (enhanced oil recovery), the flexibility of ship transport might give it an advantage over pipelines, as an EOR operation usually is of limited duration (< 10 years) and with varying CO₂ volume demand. Due to these factors, investing in a pipeline entails too high a risk.

The focus of this article will be on liquefied ship transport, at low and medium pressure conditions, to offshore unloading, either for permanent storage or for use in EOR. Optimum CO₂ transport strategies will be investigated from technical and economic perspectives. The transportation strategy will influence the operation on both the source and sink side of the chain. The consequences for both sides will be identified and included in the assessment. Advantages and disadvantages for transport at low and medium pressure will be addressed. Other important factors that will be studied are the size and number of ships. Finally, the challenges of offshore unloading like weather conditions, the need for safety zones, and conditioning of CO₂ before unloading will be discussed. Here, special focus will be on the temperature of the CO₂ delivered from the ship; is 20°C required or could lower temperatures be tolerable? An unloading temperature above 0°C results in a need of CO₂ heating beyond what a seawater exchange can achieve, and other heating options must be considered. Too
cold CO₂ is likely to pose operational challenges in unloading and injection, therefore careful considerations are needed.

This article is based on work performed in the project ALIGN-CCUS and work package 2 dealing with CO₂ transport. ALIGN-CCUS is a three–year research project with 33 participants from six countries. The project started in 2017, aiming to accelerate the transition of current industry and power sectors into a further of continued economic activity and low-carbon emission, in which carbon capture, utilization and storage (CCUS) plays an essential role.

References