# Intermittent $CO_2$ injection: injectivity and capacity

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**Abstract.** Carbon capture and storage (CCS), especially offshore, involves a chain of complex and expensive infrastructure connecting emitters to the disposal site. The classic example of an industrial cluster sending $CO_2$ by a large pipeline to a nearby storage site is considered the most favorable solution in term of techno-economics. However, many emitters are located either too far from suitable offshore geology or are dispersed in harder to reach locations, making pipeline transport uneconomical. In these instances, ship transport is a viable option for shuttling $CO_2$ from source to sink. The Northern Lights project in Norway will implement this approach, using shuttle tankers to deliver $CO_2$ to an onshore receiving terminal. One should note that onshore terminals add significant cost to CCS, and their permanence can hinder flexibility and delay future expansion to new regions. High costs can also hinder small emitters to embark on CCS journey until the larger infrastructure is in place and the price for joining the value chain drops. Direct injection from ships can be a good supplement to the offshore transport portfolio, allowing ships to offload $CO_2$ directly to the injection well on a periodic basis. While direct ship injection introduces a planned intermittency into the CCS chain, intermittency can also be caused by planned maintenance and technical issues along the value chain; energy supply and demand (where either less emissions are available due to, for example, higher renewables production or less energy is available for injection, in, for example, offshore renewable energy driven case); seasonal variations (part of $CO_2$ used in agriculture or seasonal variation of injection temperature). The effect of intermittency, in general, is not fully understood.

**Part 1: aspects of intermittency on the storage reservoir**

Little is known about the impact of injectivity $CO_2$ injection on storage performance, i.e. injectivity and capacity. Recent studies indicate that cycling injection can delay bottom-hole pressure build-up, thus increasing capacity of the reservoir. On the other hand, evidence from field tests show that pressure relief can cause dissolved $CO_2$ to exsolve into bubbles that block pores and reduce injectivity. Salt precipitation is another aspect that can be either positively or negatively impacted by flow cycling. In this case, repeated drainage-imbibition cycles may dissolve salt crystals formed in a previous cycle, improving injectivity, or it may continue to feed the system with new saltwater, thus impairing injectivity. The topic of salt precipitation is an active area of research.

**Part 2: how to deal with it**

We present results of the recent study down for NEMO Maritime AS in a research council of Norway sponsored NEMO project. The talk will briefly highlight simulation outcomes on the near wellbore and field scale.

**Part 3: where do we go from here**

Finally, we shortly introduce a recently funded CTS project which will focus on several aspects of direct injection from ships, including full-chain LCA/TEA based on Strategy CCUS H2020 project approach and scenarios. The project focuses on four different regions of Europe, including Baltics.

**Keywords:** intermittent injection, direct injection from ship, pressure impacts, salt precipitation, injectivity, capacity.

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