Drought on the Rhine

Opportunity and challenge:

Transporting more carbon dioxide for storage

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Today we have a gap in our terminology when it comes to carbon dioxide management. Right now, connecting CO_2 emitters to geological storage sites is the unspoken link in the carbon capture and storage (CCS) value chain. Using the enlarged acronym CCTS (carbon capture and transportation and storage) would bring the midstream part of this crucial value chain into the spotlight. So, at least for this piece, let's start now.

Road, rail and maritime logistics will experience phenomenal growth in the coming years as CCTS ramps up to support global decarbonisation ambitions. CO_2 storage terminals must also scale up rapidly to meet demand.

As CCTS infrastructure expands, investment in flexible and efficient CO_2 transportation assets is fundamental. Collaboration across the full value chain will be key. Industrial gases cryogenic equipment providers, engineering teams and operating companies are each well-positioned to participate in this multi-billion-dollar opportunity.

CO_2 tankers

Right now Nippon Gases Europe operates a fleet of three liquid CO_2 tankers (Embla, Frøya and Helle) that shuttle between a commercial Yara CO_2 source in Norway and industrial gases offtakers in the UK and continental Europe. Purfleet on the river Thames in the UK is one receiving terminal location. Hamburg in Germany is another.

Each of the three ships has a capacity of around 1,800 tonnes of CO_2. In total, they can transport about 300,000 tonnes of CO_2 per year from Norway to the destination port terminals.

While these capacities have been adequately sized to support the European merchant CO_2 market over the past 20 years, they are small when compared to the CO_2 logistics requirements from here.

Hyper-scaling

Let's consider what is coming. A cement plant capturing 1 million tonnes of CO_2 per year will need a supply chain capable of transporting 2,700 tonnes per day of CO_2. Modern CO_2 train wagons are being built to carry around 80 tonnes of CO_2.

The cement plant would need one train per day with 30 wagons to transport liquefied CO_2 to a port-side CO_2 terminal. If the round trip from the capture location to the CO_2 terminal is five days, then five trains would be required, meaning 150 rail wagons in total.

Ships such as the Northern Pioneer, which has been built for the Northern Lights CCTS scheme in Norway and INEOS's Carbon Destroyer 1, have a capacity of between 5,000 and 7,500 tonnes of liquid CO_2. The implication is that two or three train loads will fill a ship. The number of ships needed will depend, then, on the sailing distance and the amount of time it takes to discharge the CO_2 to the geological storage site.

Let's go in further. The port-side CO_2 terminal would generally be sized with the capacity for at least two ships. That means between 10,000 and 15,000 tonnes of liquid CO_2. As an example, Phase 1 of the port-side CO_2 terminal at Øygarden, near Bergen in Norway serves the Northern Lights project has a storage capacity of around 10,000 tonnes of liquid CO_2. This will be increased to about 10,700 in 2028 when Phase 2 is completed.

Phase 1 of the Øygarden CCTS CO_2 terminal is about five times larger than existing CO_2 terminals in the UK and continental Europe which serve the commercial CO_2 supply chain. Each of those has a capacity for about 2,000 tonnes of CO_2.

So hyperscaling is required from here. The investment to achieve this will be tremendous. And the business opportunities for companies financing and operating the CO_2 transportation infrastructure should in turn be transformational.

Inland waterways

In northwestern Europe, barges transfer millions of tonnes of solid and liquid cargoes from various locations to North Sea ports. A similar network exists in the eastern US. As CCTS ramps up, barges will also be used to move liquid CO_2 from emitters to portside CO_2 terminals. It is also conceivable that some types of barges may sail directly to inshore CO_2 sequestration platforms.

The Rhine, in Germany, is one of the main inland waterways in Europe. While it has been a major artery for transportation of coal, minerals, chemicals, and fuels in the past century, there are increasingly questions about its reliability, because water levels are sometimes too high or too low. For a new cargo such as liquid CO_2, there would be very little reserve capacity ▸

on the road or rail. Therefore use of barges for CO_2 transportation may be perceived as too big a risk on some waterways.

Infrastructure investment

Port areas may also become a bottleneck for transportation of CO_2 by rail to shoreside terminals. For example, there is often congestion on the rail routes into Rotterdam. Traditional refined products such as gasoline enter and leave major ports by pipeline and thereby avoid rail terminals at the ports. However, CO_2 pipeline infrastructure is immature.

As the number of CO_2 rail movements increases, some volumes may need to transfer to pipeline or the rail infrastructure must be re-developed. Either way, infrastructure investment will be required.

Furthermore, in the absence of CO_2 pipelines, inland movements of large CO_2 volumes will almost certainly be by rail. However, there are very few CO_2 rail tankers in service today. A significant investment will be required to finance a massive build-out of CO_2 distribution assets.

An 80-tonne liquid CO_2 rail wagon, including the rolling stock and tank, may cost in the order of €300,000 to build. A train with 30 wagons would therefore cost close to €10m. Considering the cement plant case above, where five trains may be required, the rail wagon investment would be in the order of €50m.

Annual operating costs are also incurred. The wagons must be maintained and inspected to ensure their railworthiness. Not only the cryogenic vessel and its associated piping must be certified, but also the wheels and brakes must be validated.

Given the high capital investment and ongoing ownership responsibility, many rail tanker wagons for other services, such as refined products movement, are owned by leasing companies. Perhaps they will, once again, underpin the next wave of railway logistics infrastructure investment.

Multimodal optionality

Construction of a fixed rail tanker wagon costs less than a flatbed wagon and a cryogenic ISO tank. Similarly, a dedicated road tanker built to carry liquid CO_2 is less expensive than a flatbed truck transporting a cryogenic ISO tank.

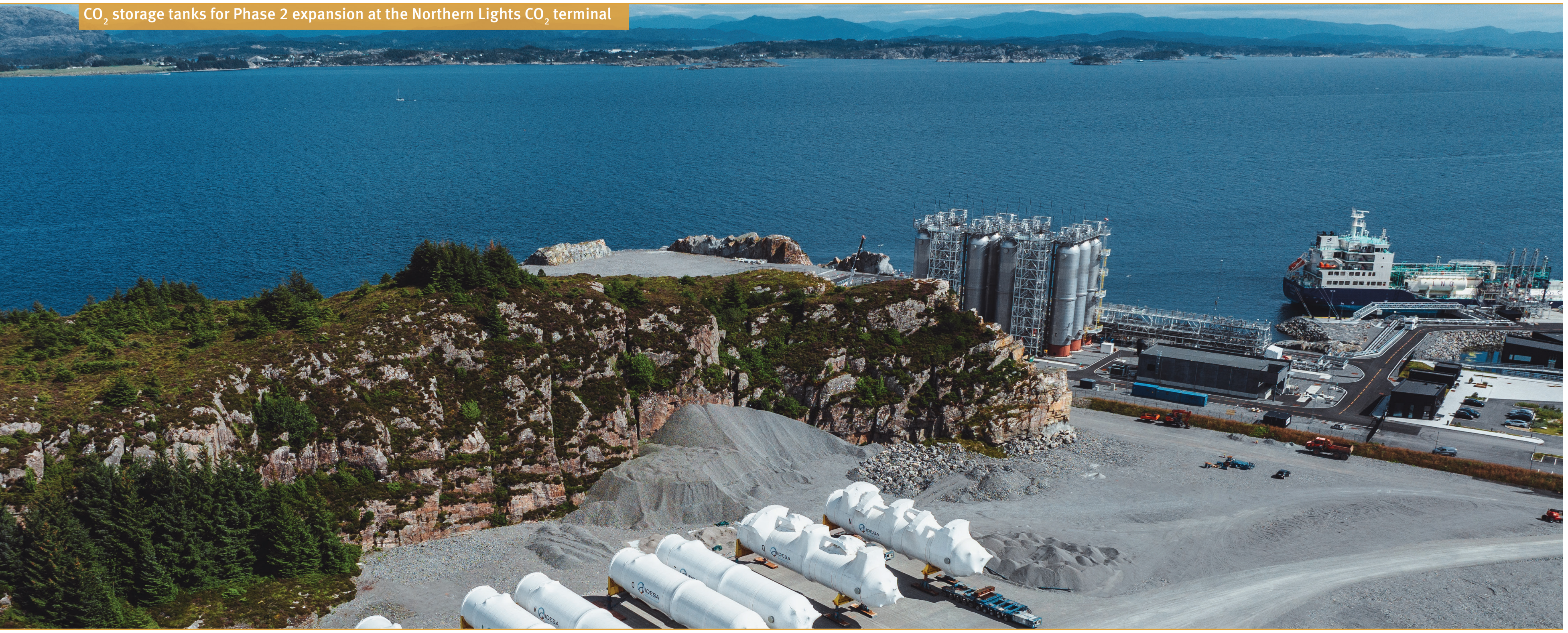
At first sight, the conclusion might be that fixed tankers are a better choice than ISO containers. However, this is not always the case. An ISO container can be used as static storage, can be loaded onto a truck to move to the rail terminal, then loaded onto a flatbed rail wagon. At a port it can serve once more as storage and then be loaded onto a ship.

During this multi-modal journey there are no losses of CO_2 as it is transferred from one container to the next. Boil-off may occur, but it can be minimised with the use of full cryogenic vacuum insulation.

An additional advantage of ISO containers is that they can be used on almost all rail gauges because they can be transferred from one flatbed wagon to another. Perhaps surprisingly, in Europe, Australia and many other geographies several track gauges exist within a continent.

Asset flexibility

Capital utilisation is key in modern business. Cryogenic tank flexibility can improve utilisation because tanks can potentially be diverted from CO_2 service to LNG, LOX, LIN or LAR service. However, specifying a cryo-tank for multiple service increases the capital cost versus building a dedicated CO_2 storage vessel.



CO_2 storage tanks for Phase 2 expansion at the Northern Lights CO_2 terminal

> "Port areas may also become a bottleneck for transportation of CO_2 by rail to shoreside terminals"

Committing to dedicated CO_2 distribution assets will minimise the capital investment. However, asset flexibility may maximise the long-term return. Leasing companies and larger industrial gases operators can leverage their scale economies by purchasing dedicated assets for the core of their business and using flexible assets for a portion. However, smaller entities may benefit from a deeper degree of asset flexibility.

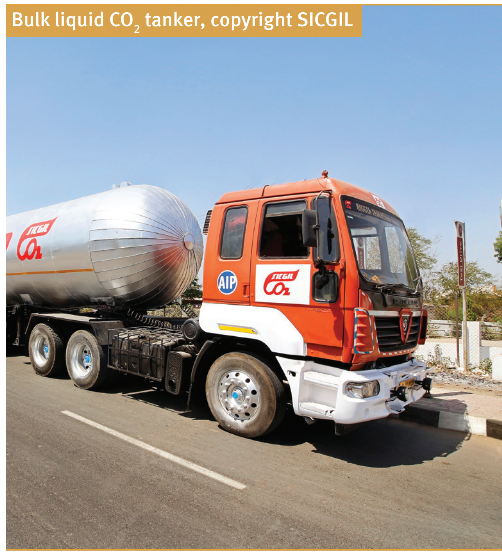
Insulation

There is also the question of insulation. It is possible to use either foam insulation or cryogenic vacuum insulation for a liquid CO_2 container on a truck or rail wagon. Foam is less expensive and lighter. For road vehicles capped at a maximum weight due to traffic regulations, a lighter tanker means more payload.

On the other hand, full cryogenic vacuum insulation minimises boil-off losses. For journeys of longer duration this boil-off reduction can be a meaningful advantage. When considering CO_2 capture and storage, CO_2 losses in the full value chain must be considered. If the target is to achieve 90% total capture rate, the impact of every percentage of CO_2 loss must be considered, including the potential to use a refrigeration unit to re-condense CO_2 boil-off.

As you can see, there are many factors to consider when it comes to moving CO_2, but the work needs to ramp up fast. gw

Bulk liquid barges



Bulk liquid CO_2 tanker, copyright SICGIL

Tank wagons on the railway