Transportation: mid-stream in the CO2 value chain

Connecting CO2 emitters to geological storage sites is the forgotten link in the CCS value chain. The abbreviation CCTS (carbon capture and transportation and storage) brings the midstream link into focus. By Stephen B. Harrison, sbh4 consulting.

Road, rail and maritime logistics will experience phenomenal growth in the coming years as CCTS ramps up to support global net-zero ambitions. CO2 storage terminals must also scale up capacity to meet demand.

As CCTS infrastructure expands, investment in flexible and efficient CO2 transportation assets will be essential. Collaboration across the full value chain will be key. Civil engineering contractors, cryogenic equipment manufacturers, engineering teams and logistics providers are well positioned to participate in this opportunity.

CO2 by rail

In the absence of CO2 pipelines, inland movements of large CO2 volumes will almost certainly be by rail. However, there are very few CO2 rail tankers in service. A significant investment will be required to finance a massive build out of CO2 distribution assets.

A cement plant capturing 1 million tonnes of CO2 per year will need a supply chain capable of transporting 2,700 tonnes per day of CO2. Modern CO2 train waggons are being built to carry around 80 tonnes of CO2.

The cement plant would need one train per day with 30 waggons to transport liquefied CO2 to a port-side CO2 terminal. If the round trip from the capture location to the CO2 terminal is five days, then five trains would be required, meaning 150 rail waggons in total.

An 80-tonne liquid CO2 rail waggon, including the rolling stock and tank may cost in the order of €300,000 to build. A train with 30 waggons would therefore cost close to €10 million. To finance five trains, the rail waggon investment would be in the order of €50 million.

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

Bulk liquid movement by rail - a cement plant capturing 1 MT CO2 per year would need one train per day with 30 waggons to transport liquefied CO2

Multimodal flexibility

Construction of a fixed rail tanker waggon costs less than a flat-bed waggon and a cryogenic ISO tank. Similarly, a dedicated road tanker built to carry liquid CO2 is less expensive than a flat-bed 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 waggon. 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 CO2 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 flat bed waggon to another. Perhaps surprisingly, in Europe, Australia and many other geographies several track gauges exist within a continent.

Committing to dedicated CO_2 waggons will minimise the capital investment. However, the flexibility of ISO tanks may reduce risk and offer an acceptable long term return.

Given the high capital investment and ongoing ownership responsibility, many rail tanker waggons for conventional liquid products, such as aviation kerosene, are owned by leasing companies. Perhaps they will, once again, underpin the railway logistics investment for CCTS.

Northern Pioneer at the Northern Lights CO2 terminal in Norway, With a capacity of between 5,000 and 7,500 tonnes of liquid CO2 such vessels would require two or three train loads. Image © Northern Lights

Canal and river networks

In northwestern Europe, barges transfer millions of tonnes of solid and liquid cargoes from the hinterland to North Sea ports. A similar network exists in the eastern United States. As CCTS ramps up, barges will also be used to move liquid CO2 from emitters to portside CO2 terminals. It is also conceivable that some types of barges may sail directly to inshore CO2 sequestration platforms.

The Rhine, in Germany, is one of the main inland waterways in Europe. Whilst 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.

During the rainy season, the Rhine floods making it impossible for barges to pass under bridges. In the dry season, the water level is too low for fully loaded barges to sail. These un-navigable periods are becoming more frequent and are lasting longer.

For a new cargo such as liquid CO2, with no reserve logistics infrastructure, there would be very little reserve capacity on the road or rail. Therefore, barges might be a risky choice for year-round operations on some waterways.

Ships and shoreside terminals

Nippon Gases Europe operates a fleet of three liquid CO2 tankers (Embla, Frøya and Helle) between a commercial CO2 source in Norway and offtakers in the UK and continental Europe. Each of the three ships has a capacity of around 1,800 tonnes of CO2. In total, they can transport about 300,000 tonnes of CO2 per year from Norway to the destination ports.

While these capacities have been adequately sized to support the European merchant CO2 market over the past 20 years, they are small when compared to the CO2 shipping requirements that will be required to enable CCTS.

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 CO2. The implication is that two or three train loads will fill a ship. The number of ships will depend on the sailing distance and the amount of time it takes to discharge the CO2 to the geological storage site.

The port-side CO2 terminal would generally be sized with the capacity for at least two ships. That means between 10,000 and 15,000 tonnes of liquid CO2. As an example, Phase 1 of the port-side CO2 terminal at Øygarden, near Bergen in Norway serves the Northern Lights project has a storage capacity of around 10,000 tonnes of liquid CO2. This will be increased to about 10,700 in 2028 when Phase 2 is completed.

Phase 1 of the Øygarden CCTS CO2 terminal is about 5 times larger than existing CO2 terminals in the UK and continental Europe which serve the commercial CO2 supply chain. Each of those has a capacity in the order of 2,000 tonnes of CO2.

Investment for hyper scaling

Port areas may become a bottleneck for transportation of CO2 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, CO2 pipeline infrastructure is immature.

As the number of CO2 rail movements increases, some volumes may need to transfer to pipeline or the rail infrastructure must be redeveloped. Either way, hyper scaling is required. The investment to achieve this will be tremendous. And the business opportunities for companies financing and operating the CO2 transportation infrastructure will be transformational.

More information

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