Hydrogen and CCS – Building blocks for a low-carbon future

By Stephen B. Harrison | 10 February 2021

“Hydrogen is essential for decarbonisation.” That is the strongly held, simply expressed belief of Dan Sadler, UK Low Carbon Strategy Director at Equinor.

”And there is no place better in the world for low carbon hydrogen than the Humber cluster in the UK. We have the perfect combination of natural gas supplies, renewable power generation, hydrogen production, hydrogen demand and the potential for underground hydrogen storage in salt caverns and offshore CCS.”

There are several heavy-industry clusters in the UK. Teesside, in the north east, was where the UK chemicals industry expanded in the 1950s and, until recently, was a large iron and steel-making location. Merseyside, in the north west, is home to the Stanlow refinery and chemicals parks around Runcorn.

“Looking at carbon dioxide (CO_2) emissions, the Humber is the largest emitting cluster. If the UK is to decarbonise, then East Yorkshire must be a central part of the solution.” That is how strongly Sadler emphasised the importance of working towards a carbon neutral Humber cluster.

To the west of the Humber estuary is Drax power station, whilst on the north bank of the river is the Saltend Chemicals Park and on the south bank is Scunthorpe steel works and one third of the UK’s refining capacity. According to the Government’s Energy White Paper, The Humber industrial cluster yields 10 million tonnes of CO_2 emissions per year, compared to Merseyside’s five million and Teesside’s 3.9 million.

The presence of these industries is part of the reason that Sadler says, “Zero Carbon Humber is the vision. This cluster is the leading ‘super-place’ for getting started on large-scale, low-carbon hydrogen production.”

3/3

Gas flows from and to the North Sea

An established pipeline infrastructure brings natural gas from the North Sea to the Humber. This is the main ingredient for making hydrogen at scale on steam methane reformers (SMRs) or auto thermal reformers (ATRs).

To ensure that hydrogen is low carbon, the CO_2 emissions from the SMR or ATR must be mitigated with carbon capture and storage (CCS). The resultant hydrogen is referred to as 'blue hydrogen' or 'Low Carbon Hydrogen' according to the EU CertifHy certification scheme.

Sadler explains his vision for the energy transition, "In the UK, I believe that the production of blue hydrogen will create the business case to build storage and distribution infrastructure that can be used for green hydrogen in the future." Equinor has committed to carbon-neutral operations by the year 2050 and is investing heavily in wind energy to meet that goal.

"Until renewable power generation capacity ramps up sufficiently to make green hydrogen more cost-efficient, we will need to build bridging solutions with low carbon solutions based on fossil fuels combined with CCS. There are only 29 years until 2050. Alongside investment in renewables, blue hydrogen means we can act now to decarbonise quickly and at scale," says Sadler.

"We are planning for at least 95% CO_2 capture and sequestration from the hydrogen production facility," confirms Sadler. "That means that there will be some CO_2 emissions, but they can be offset against bio-energy CCS (BECCS)."

Looking at the bigger picture, the net-zero carbon emissions target can be achieved within the Humber cluster because the Drax power plant runs predominantly on biomass and future implementation of BECCS from its emissions would make it a carbon-negative power generation facility.

In a net-zero future, CO_2 from the industrial cluster will be transferred back out to the North Sea in a pipeline to safely store the gas in suitable underground geological formations. Sadler adds that, "Equinor has more than 20 years of experience operating CCS schemes in the North Sea." The first of these involves the Sleipner-West oil field in the Norwegian sector.

Sadler continues to say that, "The second Equinor CCS scheme started up in 2007, with its first CO_2 injections in 2008. It removes CO_2 from natural gas, which provides energy for the Melkøya LNG plant at Hammerfest, 500km inside the arctic circle."

Equinor is also involved in the Northern Lights project which will transport and store CO_2 from various locations, including a cement plant. In that scheme, liquefied CO_2 is transported from the cement factory by ship to the offshore rig where it is compressed to high pressures prior to being injected deep underground for permanent storage.

2/2 SHOW CAPTION

SMRs and ATRs for super-scale hydrogen production

The final investment decision for the Zero Carbon Humber project is expected in 2023, with commissioning in 2026. That leaves some time for detailed engineering proposals and technology selection.

"Equinor is technology agnostic when it comes to hydrogen production," says Sadler. "But there is a drive to develop and use local content where possible. I'm from Leeds, and I hope that is local enough because I really want to be part of this project as we move from planning to execution."

SMRs are used to produce more than half of the world's hydrogen today. ATRs are also used extensively for syngas production. They tend to operate at a slightly higher pressure and the product is richer in carbon monoxide than the gases produced on an SMR. Technology selection is an aspect of the total scheme optimisation which includes a thorough analysis of the gases required by local off-takers in industry, power generation and domestic applications for heating and cooking.

Hydrogen is predominantly used in industry today. "To use it in the home we must demonstrate that it is safer than, or at least as safe as, natural gas," adds Sadler. "One of the main challenges we face in the transition to the hydrogen economy is creating public acceptance. That will come over time as the safety cases are developed and people become more familiar with the gas."

One of the open issues related to hydrogen safety is the question of materials compatibility with the existing natural gas pipeline infrastructure. There are others. For example, unlike to natural gas, hydrogen burns with an invisible flame meaning that an ignition could go undetected by the human eye. Electronic gas and flame detection systems that work well with fossil fuels must also be re-engineered to detection hydrogen leaks or flames.

Furthermore, studies must take place to confirm the most appropriate additive for hydrogen, so that a small leak can be detected by the human nose. Additives such as mercaptans are blended with natural gas at trace concentrations for this purpose today.

Source: Equinor

Equinor Head office, Oslo (Norway)

Hydrogen storage, supply, and demand

One of the applications of hydrogen produced in the emerging Humber cluster will be domestic heating. That is a challenging application to build infrastructure for. Unlike an oil refinery that tends to require stable quantities of feedstocks throughout the year, heating is extremely seasonal.

"I come from this part of the world, so I know what the weather is like," says Sadler. "Cold winters need lots of gas, warm summers mean the demand dries up. This seasonal demand fluctuation can be balanced with good storage. The alternative would be to build a hydrogen facility that can satisfy the winter demand. That plant would be massively over-sized for nine months of the year and the economics would not work."

"We must develop infrastructure without burdening UK industry with excessive energy costs or burdensome CO_2 taxes. Industrial companies will move offshore if the environment here is wrong for their balance sheet."

One of the reasons that the Humber is regarded as the 'best place in the world' for an integrated low-carbon hydrogen production, utilisation and storage cluster is the presence of underground salt strata. It is possible to create very large caverns in the salt that can be used as gas-tight storage chambers for hydrogen. Unlike CCS, where the CO_2 is permanently buried underground, these salt caverns are like hydrogen storage tanks that can be filled and emptied as required.

Underground hydrogen storage is not common, but it is not new. In Texas, the geology has enabled the creation of salt caverns which industrial gases companies use as a strategic reserve of hydrogen to support refineries and petrochemicals customers. Also, three salt caverns at Teesside have been in use for hydrogen storage since 1972. Worldwide, there are many more underground salt caverns in use for strong natural gas and other hydrocarbons.

Salt caverns can be up to 100m wide and 1,000m deep. The dimensions are governed by the shape and geology of the salt layer. Depending on their depth and the type of salt, they can be operated from circa 30 bar to 180 bar. As a seasonal storage buffer, they are charged with hydrogen in the summer months when the hydrogen plant capacity exceeds demand and are depleted during the high-demand winter months.

The combination of this 150 bar pressure differential and their huge size means these caverns can hold thousands of cubic metres of hydrogen gas. Like Type 4 composite hydrogen cylinders that are used in cars, the salt caverns should not be emptied. They require a residual pressure of 'cushion gas' to maintain their shape over the long-term.

About the author

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