The future of LNG in a decarbonised world

By Stephen B. Harrison, sbh4 consulting

LNG, a highly transportable fossil fuel, is gaining popularity as an alternative to petroleum products and coal. Per MW of power, electricity generated from natural gas yields less than half the carbon dioxide (CO_2) emissions than coal-fired power generation. Alongside a reduction in other pollutants such as sulfur dioxide (SOx) and soot, these are some of the reasons that many countries are increasing their usage of revaporized LNG for power generation.

Germany and Poland have traditionally used hard coal and lignite as major energy sources. Both countries have built, and are planning more, LNG import terminals. The introduction of LNG as a fuel for buses and shipping is based on the similar logic that, despite LNG not being carbon-neutral, it is less harmful than gasoline or diesel.

On the other hand, natural gas is a very potent greenhouse gas. One tonne of methane released into the atmosphere has the same impact on global warming as 28 tonnes of CO_2. Gas leaks during the extraction, liquefaction, and distribution of LNG must therefore be eliminated.

Amidst net-zero ambitions and the energy transition, the role of LNG as a 'bridge' to renewable energy sources is hotly debated. Despite this, LNG demand is likely to grow through this decade. However, alternative, clean energy vectors are emerging that will challenge LNG.

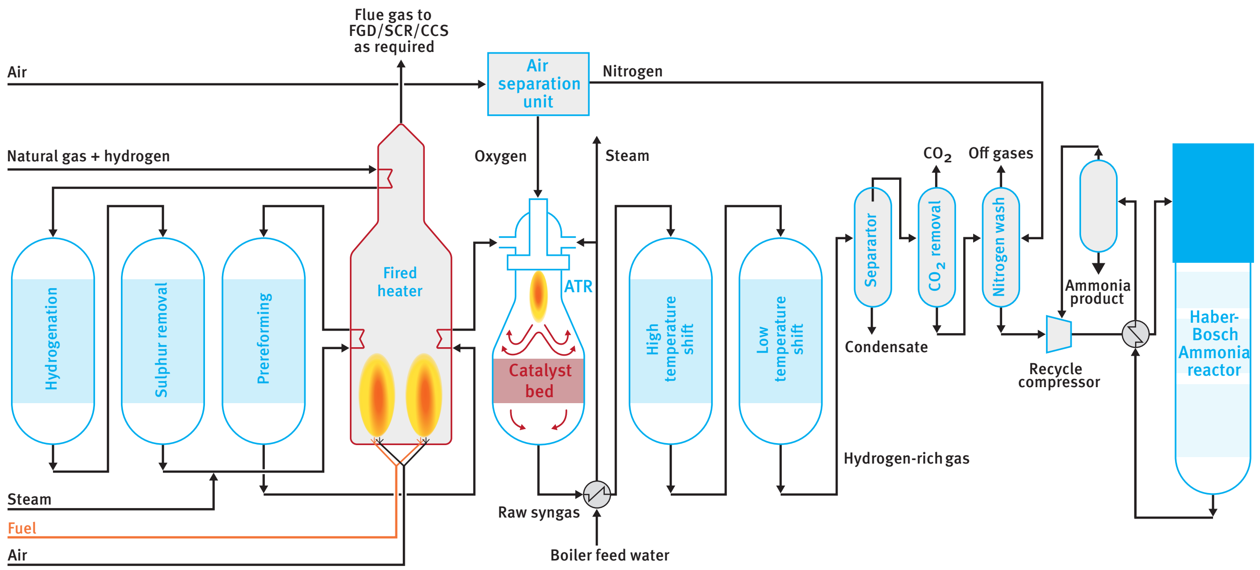
The drive towards green energy is also influencing LNG developers and operators to think differently as project financiers and consumers increasingly demand LNG shipments to be 'green'. In this direction, *S&P Global Platts* launched a Carbon-Neutral LNG price index in June 2021. Carbon offsets and bio-LNG are key enablers of the carbon-neutral LNG concept.

Bio-LNG

Bio-LNG is a renewable fuel that can either be used alone or mixed with LNG. It is also compatible with existing LNG infrastructure and can be used in the same engines, storage systems, and bunker storage.

As a result, it offers one of the simplest decarbonisation alternatives. Bio-LNG ▶

Figure 1. ATR for Ammonia Production



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can be produced from agricultural and forestry waste and is chemically equivalent to fossil LNG.

Low-carbon e-methanol

E-methanol can be produced from green hydrogen by means of an electrolyser and CO_2. With the use of renewable power, low-carbon e-methanol can be achieved.

Alternatively, steam methane reforming of natural gas combined with CCS (carbon capture and storage) to make 'blue' syngas can be the starting point for low-carbon methanol production.

Methanol is an effective gasoline replacement, and it can also operate effectively in diesel engines. Methanol is biodegradable and yields no SOx emissions. It also emits significantly less nitrogen oxides (NOx), and particulate matter than petroleum-derived liquid fuels. On the other hand, like gasoline, methanol is toxic and therefore requires additional safety measures beyond the precautions required for LNG.

Methanol has a Lower Heating Value (LHV) of 15.7 MJ/L, which is about 25% less than LNG at 22.2 MJ/L. Existing transport infrastructure, such as ships, terminals, and pipelines, could be reused with minimal modifications allowing for the low cost and speedy adoption of methanol.

In addition to being a potential energy vector that can be transported across the oceans, methanol itself is being lined up as a marine fuel. The container giant Maersk plans to launch the world's first carbon-neutral container ship powered by renewable methanol in 2023.

Liquid ammonia

Liquid ammonia, stored at -33.3°C and ambient pressure, has a LHV of 12.7 MJ/L, which is about half that of LNG. A massive ammonia infrastructure already exists around the world which has been built up around the use of ammonia to produce urea fertilizer.

Roughly 180 million tonnes of ammonia are produced per year worldwide, and 120 ports have ammonia terminals. So, the use of ammonia as an energy vector would leverage existing infrastructure and enable a low-cost energy transition. On the other hand, ammonia is toxic.

Ammonia has the potential to be produced with minimal CO_2 emissions. Renewable power can feed electrolysers for hydrogen generation and air separation units (ASUs) for nitrogen production. Alternatively, blue hydrogen can be produced from LNG by an auto thermal reformer (ATR) with CCS to mitigate CO_2 emissions. This process has the benefit that the oxygen from the ASU can feed the reformer and the nitrogen can be used to make ammonia.

Many shipping operators and marine engine developers are considering ammonia as a bunker fuel. Unlike methanol, ammonia combustion would yield zero CO_2 emissions from the ship.

Compressed hydrogen gas

Due to the low volumetric energy density of hydrogen under standard temperature and pressure conditions, compression is widely used for efficient storage and distribution of hydrogen.

Hydrogen is stored in fuel cell electric vehicles (FCEVs) at 700 bar. This results in an energy density of 6.8 MJ/L. Buses and trucks tend to use 350 bar for on-board hydrogen storage.

Taking this concept to the oceans, Global Energy Ventures in Australia has confirmed the development of compressed hydrogen shipping, building on their expertise in compressed natural gas shipping. Their hydrogen tankers are proposed to operate at 150 bar. Fully green propulsion concepts have been proposed for these tankers. The hydrogen cargo could feed either a large Ballard Power Systems fuel cell or a Wärtsilä hydrogen-fired propulsion system.

Liquid hydrogen

Liquid hydrogen has a LHV of 8.5 MJ/L, which is about one third the value of LNG, and it must be stored at cryogenic conditions of -253°C.

That is significantly colder than LNG, which can be stored at -162°C. Liquid hydrogen occupies roughly 1/800th of its original gas volume under standard conditions. The reduced volume is attractive for transportation, however, liquefaction equipment and cryogenic storage tanks add to the capital cost of a liquid hydrogen supply chain. The energy required for liquefaction is also significantly more than for hydrogen gas compression to 900 bar, which is the pressure required to decant hydrogen into FCEV storage tanks at 700 bar.

There are significant investments in liquid hydrogen shipping underway. In 2021, the Suiso Frontier completed sea trials in preparation for the first liquid hydrogen shipment from Australia to Japan. In 2022, Kawasaki Heavy Industries plans to follow up with the first purpose-built liquid hydrogen tanker, the Asahi Shimbun which will be 116m long and carry 75 tonnes of liquid hydrogen.

(LOHC)

Liquid organic hydrogen carriers (LOHCs) are cyclic hydrocarbons that can be repeatedly hydrated with hydrogen and then dehydrated to release that hydrogen.

They have a volumetric storage density of hydrogen of around 48 g/L, about 30% less than liquid hydrogen, which is 71 g/L. With 6.2% hydrogen by weight in the LOHC, the energy density of the loaded LOHC is 5.76 MJ/L, which is very low compared to LNG.

The key benefit of LOHCs over liquid hydrogen is that they are liquids at ambient conditions. The technology therefore allows hydrogen to be stored and transferred in a similar way as crude oil or refined products. This implies that current fossil fuel infrastructure, such as oil pipelines, crude oil tankers, gasoline trucks, and storage facilities, may be carefully cleaned and adapted to transport large amounts of hydrogen by rail, sea, and land.

Leveraging existing crude and refined products infrastructure for LOHC can help to accelerate the energy transition and minimise the costs of change. On the other hand, there is the disadvantage that dehydrogenation to release hydrogen from the LOHC at the point of use requires heat. In a future development of the LOHC technology, the Japanese companies Eneos and Chiyoda have proposed a process that electrolyses water and toluene to create methylcyclohexane (MCH), which is loaded with hydrogen. This simplification could significantly reduce the cost of hydrogen generation and transportation compared to state-of-the-art electrolysis and LOHC technologies.

What is the future for LNG?

Despite the array of clean energy challengers, LNG is likely to be used for many decades. With Japan recently pledging $10bn in financial support for LNG and renewables in support of Asia's energy transition, the construction of additional gas-fired power stations, LNG terminals and regasification facilities remains a likely scenario.

Another reason to believe that LNG may be around for decades to come, is that the decarbonisation of LNG can take place either at the source or at the destination. Low-carbon hydrogen can either be produced at the 'well head' and exported, or LNG can be shipped to the destination and low-carbon hydrogen can be made there.

If CCS is possible at the destination, blue hydrogen may be the technology of choice. If CCS is not possible, turquoise hydrogen with solid carbon formation might be preferred. By continuing to use the existing LNG production, storage, and shipping infrastructure, the costs of the energy transition can be deferred to make the long-term change more affordable. gw

ABOUT THE AUTHOR

Stephen B. Harrison is Managing Director of sbh4 consulting. Harrison has over 30 years' experience of the industrial and specialty gases business.