Bulk liquid CO_2 transportation

Is CCUS a cost adder or growth opportunity for industrial gases?

By Stephen B. Harrison

Many stock market fund managers are placing their bets on renewables and the hydrogen economy. Highly influential people in finance, such as Blackrock's Larry Fink, are urging the corporate world to declare and execute their plans towards carbon-neutrality.

The billions of dollars that governments are pouring into the hydrogen economy have great potential. However, they are a drop in the ocean compared to the trillions of dollars of influence that stock market investors and financiers will have in driving the broader climate change and decarbonisation agenda.

The contribution that the industrial gases sector can make will be hugely beneficial for planetary health and there are transformational business growth opportunities that decarbonisation and carbon capture and utilisation (CCUS) will present. The combined imperatives of business continuity and environmental sustainability are positioning the industrial gases sector for pivotal change.

Decarbonisation is a double-edged sword of opportunity and responsibility for industrial gases operators. Within the sector, there is a growing momentum to set a new direction towards decarbonisation of production and distribution operations.

Left image: Marsden point oil refinery, New Zealand, carbon dioxide source

Through imagination, innovation, and ambition, decarbonisation can also be the biggest growth opportunity that has been presented to the industrial sector since its origins 150 years ago. As an example, road, rail, or maritime bulk distribution of liquid carbon dioxide (CO_2) from emissions sources to utilisation or storage locations will be a major logistical requirement where industrial gases companies are ideally positioned to lead.

Making the changes will require bandwidth, focus and capital. The investment, however, will undeniably be worth the cost.

The bulk carbon dioxide business is built on CCUS

Carbon capture is likely to be costly, while simultaneously representing a business opportunity. CCUS involves gas purification, compression, and distribution – areas where industrial gases expertise can be applied. CCUS is a technology that industrial gases companies and their suppliers have been operating for decades.

Much of the CO_2 that enters the industrial gases value chain is captured from ammonia production and other industrial processes, such the Gibson Island ammonia plant on the Brisbane River. However, ammonia linked to fertiliser production can be seasonal and carbon dioxide demand can also be seasonal, with a peak in the summer season when cold beer and carbonated beverages are in high demand.

For much of the year, the timing of the supply and demand peaks are balanced. However, as the UK CO_2 shortage of June 2018 and the repeat episode in summer 2021 demonstrated, a diversified mix of CO_2 sources beyond fertiliser plants is more robust. Bioethanol fermentation is a popular source of biogenic CO_2 for food-grade applications because the gas is derived from a natural biological process. In addition to being sustainable, the CO_2 generated from fermentation is concentrated and the purification process is thereby simplified, reducing cost.

Carbon dioxide is increasingly being recovered from refinery steam methane reformers (SMRs), such as the Marsden Point Oil Refinery in New Zealand and the Repsol Refinery in Tarragona in Spain. The advantage of souring CO_2 from a refinery is that production is highly stable throughout the year because the demand for fuels is not particularly seasonal. A guaranteed all year-round source of carbon dioxide can put the industrial gases supplier in a highly reliable market position, resulting in significant competitive advantage.

Bulk liquid CO_2 from a CCUS scheme can also be converted to dry ice for temperature-controlled supply chains. Dry ice has been a hero product for industrial gases recently, with increasing recognition for its role in the fight against the Coronavirus. Some vaccines must be shipped and stored at around -80°C and dry ice is ideal to maintain this low temperature.

There are several applications for dry ice in the vaccine supply chain, including air freight from manufacturing sites, road transportation and short-term storage at vaccination sites. For larger hubs, onsite dry ice production from bulk liquid CO_2 tanks may also be suitable.

Dry ice pellets and slabs work well with this vaccine storage application. They are longer lasting than CO_2 snow because dry ice is denser and holds its low temperature for longer.

All these technical details are common knowledge to industrial gases applications experts who have been using dry ice for this kind of application for decades. But there is room for many additional high demand applications for CO_2 to utilise the millions of tonnes of gas that is likely to be captured in the coming decades. CO_2 applications expertise will need to be developed in new areas.

Deep decarbonisation will put the U into CCUS

The future of CO_2 utilisation will evolve in the coming decades as decarbonisation deepens. Synthetic liquid fuels, known as e-fuels, is one area of high potential. They are called e-fuels because electrical power is where the energy to create them comes from. Electrolyser technologies such as alkaline water electrolysis (AWE) or proton exchange membrane (PEM) electrolysers are ideal for producing green hydrogen for this application.

The solid oxide electrolyser (SOE) can also achieve this and can go one step further. When fed with a mixture of steam and CO_2, it can make syngas. Liquid fuels such as petrol, diesel and aviation kerosene can be made from syngas, using Fischer Tropsch conversion.

> "Decarbonisation is a double-edged sword of opportunity and responsibility for industrial gases operators"

Fischer Tropsch conversion was developed at scale by SASOL in South Africa several decades ago. Today, major gas to liquid (GTL) projects such as Bintulu, Onyx, Escravos, Lu'an and Pearl use this technology to convert syngas – which is produced on partial oxidation (POx) reactors, coal gasifiers

Bulk liquid CO_2 distribution, Linde

or autothermal reactors (ATRs) with the help of super-scale air separation units (ASUs) – into liquid fuels. The production of hydrogen on an ATR relies on oxygen and these GTL plants have pulled for some of the world's largest ASUs and industrial gases supply schemes.

To decarbonise synthetic liquid fuels production, the coal or natural gas feedstocks need to be replaced with steam and CO_2 and the gasification unit or ATR must be switched out with a solid oxide electrolyser unit. It sounds simple, but the reality is that the change will take time and scale up is not yet proven.

Another pathway to syngas from CO_2 is dry reforming. Dry reforming uses CO_2 to react with the methane, instead of steam. As with solid oxide electrolysis, the result is syngas which can be converted to liquid fuels. Using CO_2 to make fuel that then burns to release CO_2 is an example of carbon recycling.

Dry methane reforming is related to steam methane reforming, but it is more challenging. The process has been known about for decades. The barrier to commercialisation has been the difficulty in finding a catalyst that is able to break apart the CO_2 molecule to produce syngas without getting deactivated by sooty carbon deposits. Innovation in this area is ongoing, with companies such as Linde and BASF active in the field.

The opportunity to serve and the responsibility to decarbonise

The list of areas where industrial gases products and technologies can make positive difference to climate change is extensive. For example, high precision specialty gas mixtures are needed to enable emissions monitoring of CO_2, nitrous oxide and methane. Modern refrigerant gases such as R1234yf, propane and ammonia that have low or zero global warming potential (GWP) are distributed by industrial gas companies. Additionally, industrial gases expertise is required for membrane separation technologies that enable biogas upgrades to biomethane.

Bulk liquid CO_2 distribution in the US

On the other hand, the industrial gases sector must also decarbonise its own operations. ASUs consume many megawatts of electricity and power purchase agreements (PPAs) must be transitioned to use renewable electricity to produce air gases. Green bulk liquid medical oxygen is an emerging product and Linde has achieved notable success with its commercialisation in Poland.

Steam methane reformers consume natural gas to make grey hydrogen and emit CO_2. In the long-term that can be mitigated with a transition to 'green' hydrogen production using electrolysers, which can be fed with renewable electrical power or steam methane reformers fed with renewable biogas.

In the short-term, retrofitting carbon capture to SMRs, ATRs and POx reactors to make so-called 'blue hydrogen' will make a big difference. In early 2021, the European Parliament voted that blue hydrogen produced from natural gas with carbon capture and storage (CCS) will be an acceptable bridge on the journey to full decarbonisation with green hydrogen.

The EU Sustainable Investment Taxonomy also gives a green light to 'blue' hydrogen, although the colour terminology is replaced by explicit scientific references to CCS and quantitative specification of CO_2 emissions from hydrogen production. These are some of the most important hydrogen policy decisions that have been taken recently and they mean that that the risk of stranded assets and poor investments have been reduced.

> "There are several applications for dry ice in the vaccine supply chain, including air freight from manufacturing sites..."

Blue hydrogen and blue ammonia will also be developed as low-carbon energy vectors through two major projects announced by Air Products in 2021: The Western Canada Hydrogen Hub in Alberta, Canada and the Blue Hydrogen Energy Complex in Louisiana, US. Industrial gases are certainly at the forefront of the clean energy transition. gw