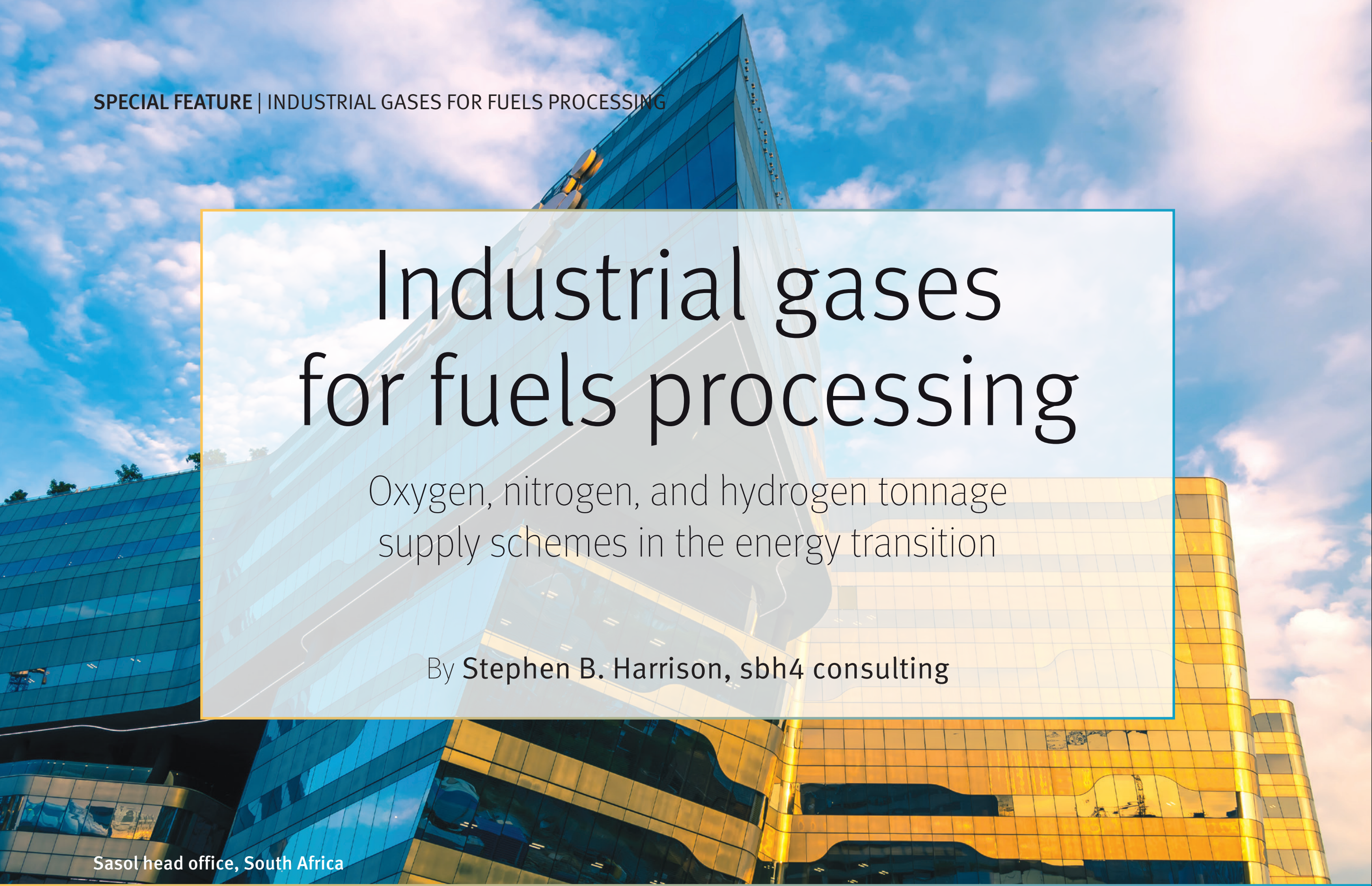

Industrial gases for fuels processing

Oxygen, nitrogen, and hydrogen tonnage supply schemes in the energy transition

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Industrial gases have been at the heart of fuels production for decades. Thousands of tonnes of oxygen have been used on refineries all around the world for catalyst regeneration on fluidised catalytic cracking (FCC) units. The FCC unit upgrades heavier molecules to increase the production of high-value gasoline. Oxygen is also integral to the gas to liquids and methanol to gasoline processes, where it is required as a feedstock to Auto Thermal Reformers (ATRs).

Pipeline supply of hydrogen to refineries is required to desulphurise crude oil and produce clean-burning, low-sulphur diesel and gasoline. Hydrogen is also used for hydrotreating heavy fractions of crude to generate higher value, lighter products. On bio-refineries, hydrogen is required to hydrogenate vegetable oils to enable them to be used as sustainable bio-diesel.

The energy transition of the past has seen liquid fuels production diversify from crude oil as the main feedstock to include natural gas and coal. As the world embraces the next energy transition, thousands of tonnes of new air gases production capacity will be required to make clean fuels such as blue hydrogen and ammonia.

Gas-to-Liquids and Coal-to-Liquids

In Q4 2021, natural gas prices in Europe hit an all-time high. Crude oil prices, on the other hand remained at a moderate level, around $60 per barrel. The crude-gas price spread has not always been like this. A decade ago, crude oil was more than $100 per barrel and natural gas was cheap. The disparity between gas and crude prices in the years around 2010 led to several major investments in Gas-to-Liquids facilities (GTL).

GTL converts natural gas to syngas on an ATR, which must be fed with oxygen. The syngas is then converted to gasoline, diesel and aviation kerosene using the Fischer-Tropsch process. Some of the world's largest air separation units (ASUs) have been built for this value chain, for example Shell's Pearl GTL complex, at Ras Laffan in Qatar, where 8 ASUs produce 30,000 tonnes per day of oxygen for the ATRs. Sasol also operates GTL at the Oryx project in Qatar and oxygen is supplied by GASAL, a joint venture company involving Air Liquide.

The world's largest oxygen supply scheme is now operated by Air Liquide at Sasol's Secunda site in South Africa. It produces 42,000 tonnes per day of oxygen on 16 ASUs. Secunda converts coal to syngas, which is converted to liquid fuels in a process is known as CTL. In a similar CTL scheme, four large Air Products ASUs feed coal gasification reactors with 10,000 tonnes per day of oxygen at Lu'an in China.

Low carbon methanol

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

ATRs are used in combination with steam methane reformers (SMRs) for methanol production in a process known as 'combined reforming'. The mix of reforming techniques ensures the syngas composition is ideal for the subsequent methanol synthesis. Whilst SMRs do not consume oxygen for their operation, ATRs do.

Methanol is biodegradable and yields no sulfur dioxide (SOx) emissions. It also emits significantly less nitrogen oxide emissions (NOx), and particulate matter than liquid fuels derived from crude oil.

Existing infrastructure, such as ships, terminals, and pipelines, could enable speedy scale up of methanol as a clean fuel. In addition to being an energy vector that can be readily transported across the oceans, methanol itself is being lined up as a marine fuel. The container shipping giant A.P. Moller – Maersk plans to launch the world's first carbon-neutral container ship powered by renewable methanol in 2023.

Methanol to gasoline

Hydrogen mobility and battery electric vehicles are experiencing fantastic growth. However, the global vehicle fleet is still overwhelmingly dominated by gasoline or diesel-fuelled cars. Methanol has many attractions as a fuel of the future, but for most people it is not the fuel of today. This is the driver behind the methanol to gasoline (MTG) process.

One of the world's largest MTG facilities is operated by Turkmengaz Gas at Ashgabad in Turkmenistan. The technology used is Haldor Topsøe's TIGAS™ process, which enables the conversion of natural gas to gasoline, via methanol. An ATR is used to generate the syngas and an ASU is integrated into the facility to supply oxygen for the ATR.

Blue and purple hydrogen

Decarbonisation of hydrogen production from natural gas or LNG can be achieved using CCS. The resulting low-carbon hydrogen is referred to as 'blue' and modern ATRs are the most suitable technology for new on-purpose blue hydrogen production. This is due to the high CO_2 capture rate which is achievable with good energy efficiency.

Similarly, coal gasification with CCS can be used to generate syngas which can yield purple hydrogen. This is the idea behind the Hydrogen Energy Supply Chain (HESC) or HySTRA project that is piloting the export of liquid hydrogen from Australia to Japan.

In the Latrobe Valley in the State of Victoria in Australia, J-Power operates a brown coal gasifier. The Australian industrial gases company, Coregas, is involved in hydrogen liquefaction at the Port of Hastings. A small liquid hydrogen tanker, the Suiso Frontier, ships the hydrogen to the port of Kobe in Japan.

At this stage, the scheme is operating at pilot scale. The Suiso Frontier has a storage capacity of 1,250 cubic metres of liquid hydrogen, which is only 90kg. When the project scales up, CO_2 emissions from the gasification process will be captured in the CarbonNet CCS scheme. Kawasaki Heavy Industries (KHI), who are playing a leading role in the HESC, plans to build a much larger liquid hydrogen tanker, the Asahi Shimbun which will be able to carry 75 tonnes of liquid hydrogen.

At Kobe, the hydrogen is decanted into one of the largest liquid hydrogen spherical storage tanks in the world. In the future, KHI plans to build larger flat-bottomed liquid hydrogen storage tanks that resemble LNG tanks that have become a familiar sight at LNG storage and regasification terminals around the world.

Blue ammonia from blue hydrogen

Ammonia terminal infrastructure and shipping fleets are established worldwide. Ammonia is a widely traded bulk chemical commodity with strong links to the urea fertiliser value chain. The use of ammonia as an energy vector will leverage existing infrastructure and enable an affordable transition to ▶

Air separation plant at one of the methanol plants operated by Petronas in Labuan, Malaysia.

clean energy.

Ammonia has the potential to be produced with minimal CO_2 emissions. Renewable power can feed electrolysers for hydrogen generation and ASUs for nitrogen production. Alternatively, blue hydrogen can be produced from natural gas on an ATR. This process has the benefit that the oxygen from the ASU can feed the reformer and nitrogen from the ASU can be reacted with hydrogen from the ATR to make ammonia.

Combustion of ammonia results in zero CO_2 emissions. In Japan, there is a target to admix 20% of ammonia onto existing coal-fired power plants by 2035 to reduce their CO_2 emissions. Japan's national fuel-ammonia demand is projected to grow to be three million tonnes per year by 2030. Gas turbine manufacturers, such as Mitsubishi Power are also developing ammonia fired turbines that will be able to produce electricity with zero CO_2 emissions. JERA, Japan's biggest power generator, plans to be using pure ammonia-fired turbines for power generation by 2040.

Many international shipping operators and marine engine developers are considering ammonia as a bunker fuel. For example, the Finnish engine maker Wärtsilä and the Korean shipbuilding company Samsung Heavy Industries are collaborating in this field. Also, Maersk is investing in research into ammonia as a bunker fuel, in addition to their focus on reneable methanol.

Biomethane

Despite its high global warming potential, methane is likely to be used as an energy vector for many decades. Best operating practices for Leak Detection and Repair (LDAR), the use of modern methane monitoring instrumentation and a zero-tolerance approach to methane emissions will ensure that it can be used sustainably.

Many industrial gas operating companies are active in the field of compressed biomethane distribution from biogas reactors. On these facilities, CO_2 is often recovered in parallel to the biomethane for commercial utilisation as an industrial gas. Equipment suppliers to the industrial gases sector such as SIAD Macchini Impianti and Pentair Haffmans are leading providers of biogas to biomethane upgrading equipment for such applications.

Biomethane can be used in compressed natural gas (CNG) powered vehicles. In Europe alone there are 2,700 CNG fuelling stations for buses, trucks, and cars. In Asia there are many more; India, for example, has around 2,200. CNG can also be blended with 18% of hydrogen to yield hythane, which can be used on CNG vehicles to reduce their CO_2 emissions. gw

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Maersk container ship at Yangshan, Shanghai, China.