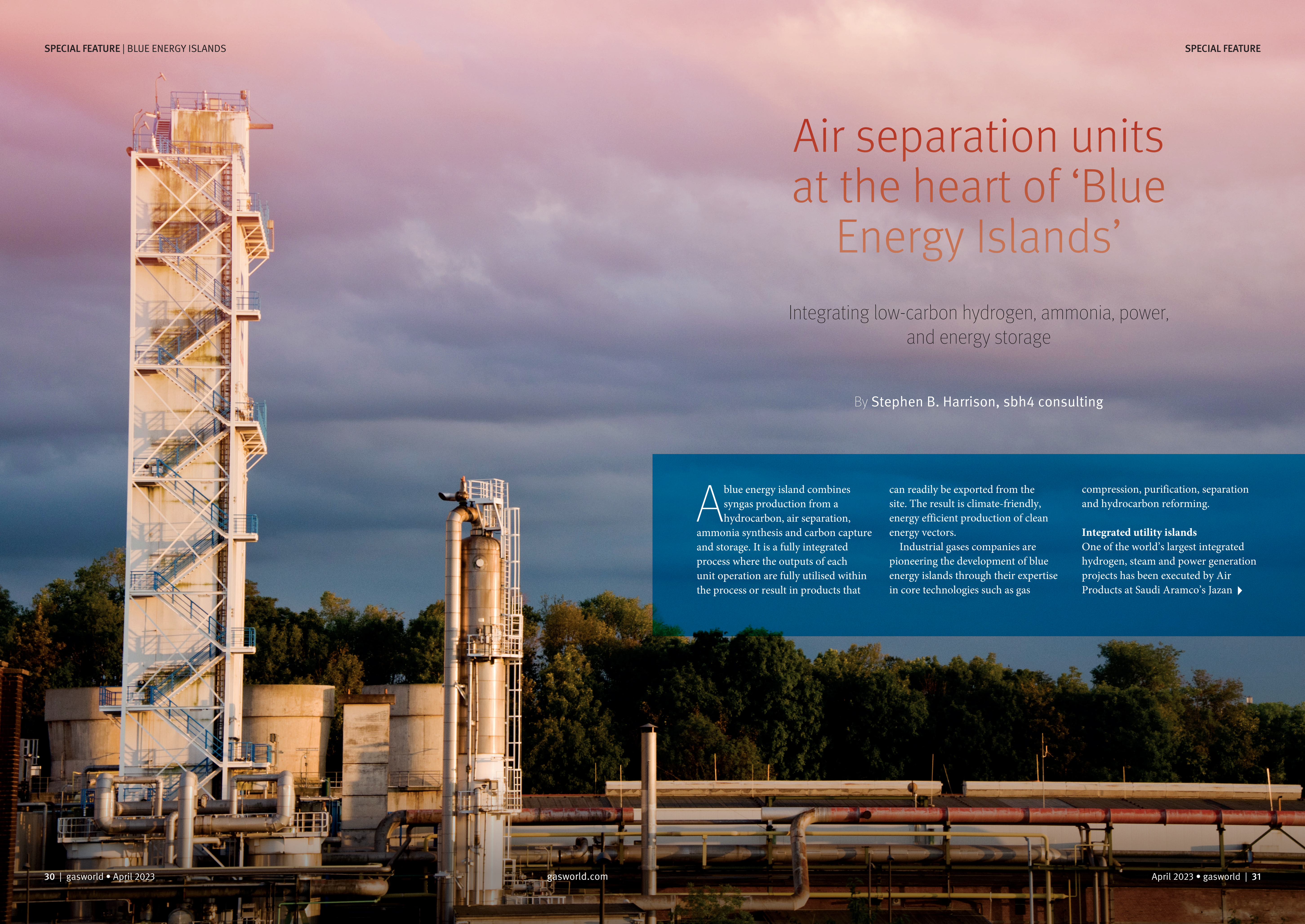

Air separation units at the heart of 'Blue Energy Islands'

Integrating low-carbon hydrogen, ammonia, power, and energy storage

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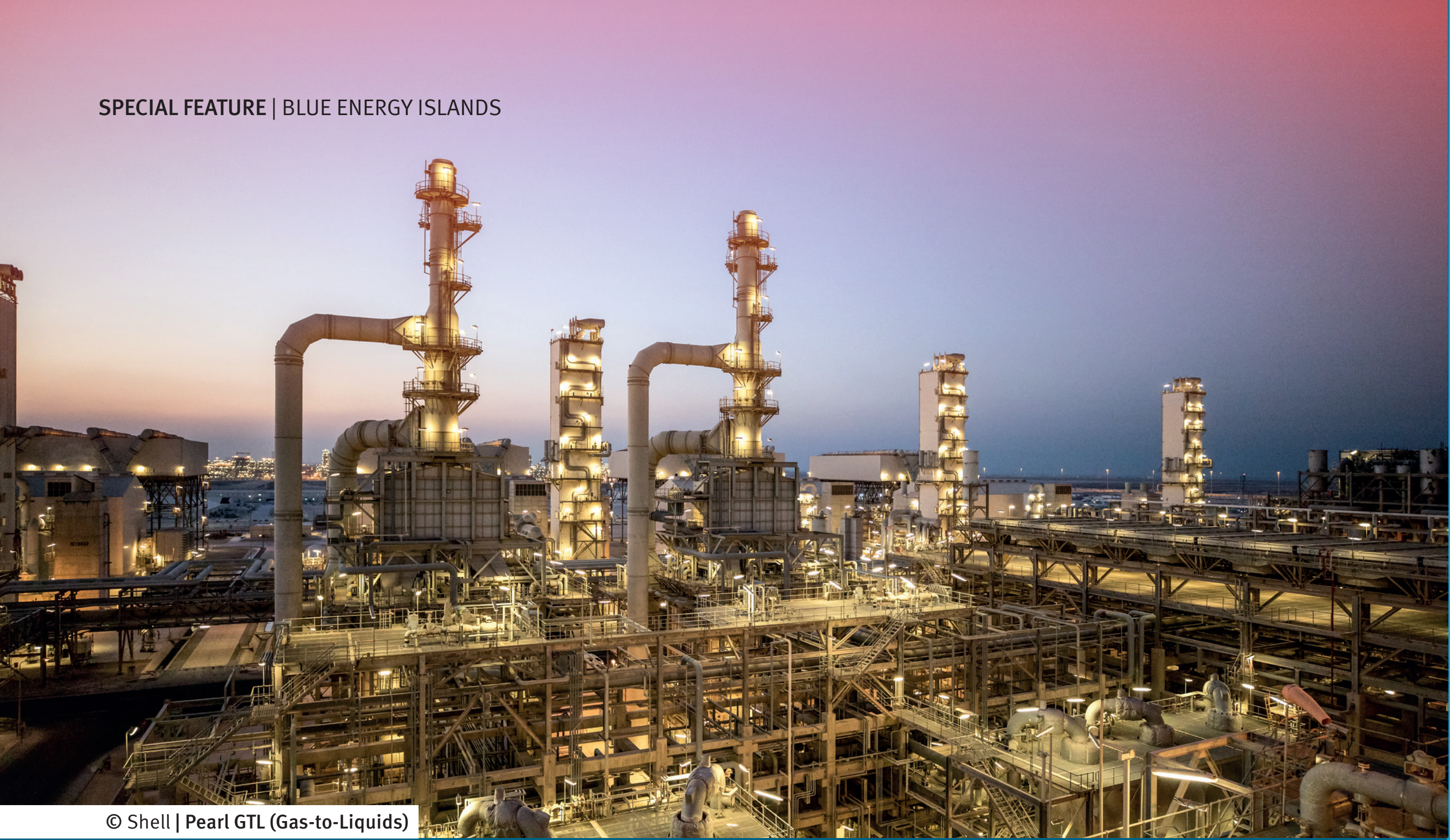
A blue energy island combines syngas production from a hydrocarbon, air separation, ammonia synthesis and carbon capture and storage. It is a fully integrated process where the outputs of each unit operation are fully utilised within the process or result in products that can readily be exported from the site. The result is climate-friendly, energy efficient production of clean energy vectors.

Industrial gases companies are pioneering the development of blue energy islands through their expertise in core technologies such as gas compression, purification, separation and hydrocarbon reforming.

Integrated utility islands

One of the world's largest integrated hydrogen, steam and power generation projects has been executed by Air Products at Saudi Aramco's Jazan ▸



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refinery in Southeastern Saudi Arabia. More than a dozen gasifiers produce syngas from a heavy refinery residue.

The gasifiers at Jazan are based on Shell's partial oxidation (POx) technology. POx converts a hydrocarbon feedstock to syngas using a combination of reforming and oxidation reactions. It is a thermolysis process, like steam methane reforming (SMR) or autothermal reforming (ATR). POx is ideally suited to heavy liquid feedstocks. Compared to an SMR or ATR; the syngas produced from a POx reactor is generally richer in CO and the process generates more steam.

The Jazan gasifiers can produce 2,110,000 Nm^3 per hour of syngas which is fired directly on gas turbines which produce 2.4 GW of electricity in an integrated gasification combined cycle (IGCC) power plant. Some of the electrical power is used on the refinery for motors in pumps and compressors. Process control equipment and instrumentation also require power. However, much of the generated power is fed onto the local grid.

The syngas-island also provides hydrogen and steam for the refinery. Hydrogen is recovered from the syngas. It is used for hydrotreating and desulfurisation of the crude feedstock to yield low-sulfur refined products. Steam is an essential utility on the refinery and is required for distillation column reboilers and process heating applications.

Gasification consumes a controlled amount of oxygen to achieve partial oxidation of the feedstock. Some gasifiers draw in air to supply the oxygen requirement. This is common in smaller biomass gasification processes. The gasifiers at Jazan are fed with pure oxygen to avoid introducing nitrogen into the gasifiers and downstream equipment. This reduces the equipment size and energy losses. It also simplifies management of nitrogen oxide emissions.

Given the scale of operation, six very large ASUs designed and built by Air Products are required to feed oxygen to the gasifiers at Jazan. Each ASU is rated at 3,000 tonnes per day (tpd) of oxygen. Nitrogen from these ASUs is also supplied to the refinery as a utility gas for inerting and purging operations to ensure safe operations across the site.

The gasifiers, power plant and air separation units at Jazan can be referred to as a syngas island, or integrated utility island. To earn the title of 'blue energy island' most of the carbon dioxide (CO_2) that is generated on the gasifiers and power plant would need to be captured and sequestrated. At present, this is not the case.

Cost-effective carbon capture

A blue energy island builds on the concept of an integrated utility island but operates with comparatively low CO_2 emissions to atmosphere. Carbon capture and storage (CCS) is the key differentiator that makes the blue energy island 'blue'. The need to capture CO_2 changes the optimal layout of the process flowsheet and favours some technologies ahead of others.

SMRs operate at around 25 bar. An ATR operates at a higher pressure, perhaps 40 bar. The POx reactor is generally designed to operate at 60 bar. As the pressure increases, the CO_2 capture equipment size can be reduced and when using an amine absorption type system, the energy requirement for CO_2 capture is also reduced.

For large-scale carbon capture, the most economic means of exporting CO_2 from the site will be by pipeline. The CO_2

must be compressed to around 100 bar, at which point it exists as a supercritical fluid, above its triple point on the phase diagram. Feeding the compressor with high pressure CO_2 from a CO_2 capture plant that is operating at high pressure reduces the CO_2 pipeline compression power requirement.

The burners in an SMR are generally air-fed. Not so in the ATR and POx units. These technologies lend themselves to a pure oxygen feed. Again, the use of pure oxygen instead of air avoids the introduction of a huge amount of nitrogen ballast gas to the system, keeping equipment size and cost to a minimum.

The various OPEX and CAPEX savings in the CCS element of the process flowsheet favour the selection of ATR and POx over SMR for blue energy islands. Air Products has announced the development of two blue energy islands in North America. One in western Canada will utilise an ATR. The other in Louisiana, US will use a POx reactor.

Making full use of the air

For several reasons, the ATR or POx technologies are favoured for syngas generation in the blue energy island concept. This means that an ASU is required for oxygen.

Profitable industrial gases operations rely on full use of the products from an air separation unit to leverage the invested capital and electrical power that they consume during operation. So, utilisation of the nitrogen from the ASU could potentially improve the blue energy island's economic profile.

Ammonia, as a hydrogen derivative, is increasingly recognised for its value as a super-fuel. Undoubtedly, ammonia will play a leading role in the energy transition. It is more readily transported over long distances than hydrogen due to its superior volumetric energy density. Its ease of storage has also led to testing its suitability as an aviation fuel. In this case, a small portion of the ammonia is partially cracked to hydrogen and nitrogen prior to the ammonia and cracked gas mixture being blended and fed to the jet engine.

On arrival at its destination, ammonia can either be used directly as ammonia, for example co-firing with coal for power generation or partially, or wholly cracked to hydrogen. Ammonia-fired gas turbines are in development, these will enable ammonia to be used in a value chain almost identical to the current LNG supply and utilisation business model.

Production of ammonia is achieved by reacting nitrogen with hydrogen in the Haber Bosch process. Some very large ammonia plants draw in air to provide the nitrogen. In these cases, unfortunately oxygen is introduced as a ballast gas. The process flowsheet for modern small and mid-scale ammonia plants has converged to using a nitrogen fed ammonia synthesis loop and eliminating the oxygen.

The emergence of nitrogen-fed ammonia production means that the nitrogen co-product from the ASU that is required for the gasifier has an immediate value and application. Fortunately, the mass balance across an integrated blue energy island where the ASU is feeding oxygen to the gasifiers and nitrogen to the ammonia plant works well and the oxygen to nitrogen production ration from the ASU is well aligned to the requirements of each process. Every MW of power supplied to the air compressor is being used productively

Blue Power

As with the case at Jazan, syngas or hydrogen from the ATR or POx reactors in a blue energy island can be used for power generation. If the CO_2 emissions from syngas combustion during power generation are captured or the turbine is fired with pure hydrogen, the result is low-carbon thermal power generation, or blue power.

On the blue energy island, the air separation unit will be a major power consumer. It can either be run from blue power, or in a further degree of process integration a hydrogen or syngas fired turbine can drive the air separation unit's main air compressor directly. The conversion of gas to power and power to pressure results in more energy losses than the directly coupled system.

However, if the blue energy island is connected to the local power grid, the use of power in the process can increase the flexibility of operation. This is achieved because power can be exported to the grid if the ASU is not operating, and power can be imported from the grid to start up the ASU prior to the gasification unit generating syngas.

Cryogenic energy storage can be implemented. During periods when power generation on the blue energy island exceeds the requirement to dispatch power to the local grid, excess power can be supplied to a nitrogen or air liquefier. The cryogenic liquid can be stored in insulated tanks for several days or weeks. When the grid needs a surge of power the liquid air or nitrogen is pumped to high pressure, vaporised, and fed to an expansion turbine to generate additional power. gw

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