Blue Ammonia

Towards a sustainable, reduced carbon economy

What is **Blue Ammonia**?

Ammonia is manufactured by converting gaseous nitrogen and hydrogen ("synthesis gas" or "syngas") at the right temperature and pressure, and in the presence of a catalyst. Syngas can be produced from hydrocarbon feedstock and fuel or from renewable sources. Almost all ammonia is currently produced from hydrocarbon feedstock and fuel, accounting for around 1.8% of global CO_2 emissions[1].

Blue ammonia is produced from hydrocarbons but the CO_2 emitted during production is sequestrated via carbon capture utilization & storage (CCUS) technology and/or offset by planting trees to become carbon neutral.

KBR offers blue ammonia technology for grassroot or existing plant revamping projects to achieve significant reductions of CO_2 generated per ton ammonia and effective CCUS.

TOWARDS A SUSTAINABLE, REDUCED CARBON ECONOMY

With over 100 years of history providing innovative solutions and 50+% market share in commercial ammonia synthesis plants, KBR offers its technology solutions to produce **Blue Ammonia**.

Ammonia has various advantages as a carbon-free fuel and as a medium for storage and transportation of energy.

- High energy density
- Feedstock widely available
- Low carbon fuel
- Infrastructure for storage and delivery technologies in place
- Can be used directly in fuel cells and thermal engines

1 Ammonia: Zero-carbon fertilizer, fuel and energy store, Issued: February 2020, The Royal Society

MINIMIZING AND OPTIMIZING CO_2 GENERATION

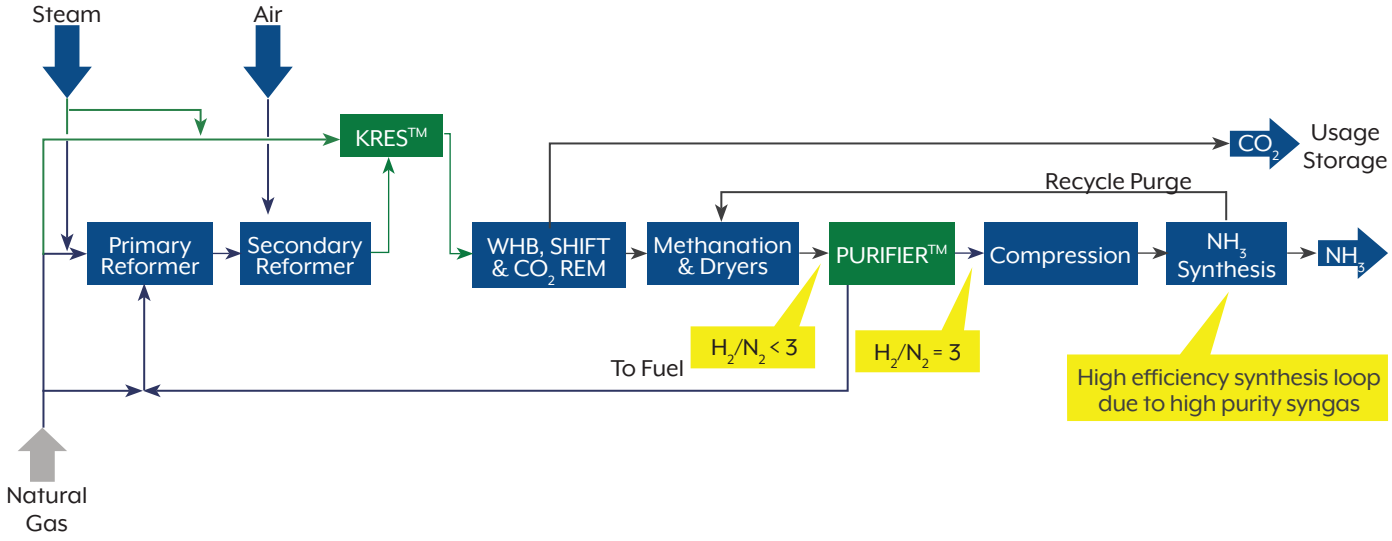
KBR's ammonia technology offers various technical options to minimize and optimize CO_2 generation and distribution in ammonia production process

- Thanks to KBR's inherent high energy efficient PurifierPlus™ technology, total CO_2 produced per ton of NH_3 is reduced about 15% in comparison with that of the conventional SMR process
- Almost 80% of the total CO_2 produced is recovered at higher pressure (process side) vs. less than 70% in a conventional SMR process
- KBR can also cost-effectively offer over 80% or even 100% CO_2 recovery with further integration, depending on project/client requirements

KBR'S BLUE AMMONIA PROCESS

KBR's blue ammonia process is based on its successful PurifierPlus™ technology, which offers advantages including:

- **Highest energy efficiency and low CO_2 generation**
- **Lowest CAPEX**
  - Single train design
  - Reduced equipment count
  - 60% smaller primary reformer
  - No purge gas recovery unit
  - No ASU — inherently safer with no pure oxygen in system
- **Lowest OPEX**
  - Most energy efficient technology
  - Less CH_4 consumption means less CO_2 production
- **Highest Reliability**
  - Well-proven technology
  - Mild (low temperature) primary reformer
  - Secondary reformer with no metallic burner
  - Purifier stabilizes entire plant operation
  - Simple and precise control of H_2/N_2 ratio
  - Cold wall horizontal ammonia converter
  - Maintain production despite catalyst deactivation
  - 13 days more online time per year on average



KBR PURIFIERPLUS™ TECHNOLOGY

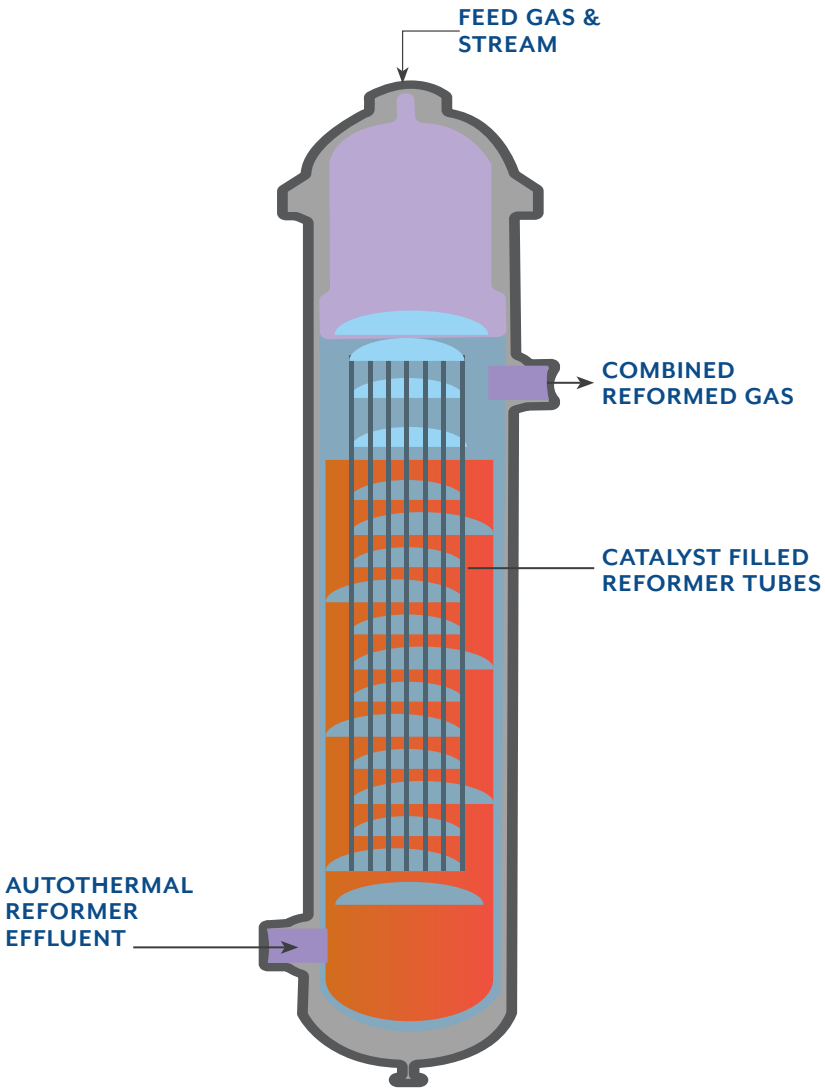
KBR PurifierPlus™ technology combines:

- KBR's cryogenic Purifier™ syngas technology, the most cost-effective route to high purity synthesis gas in ammonia manufacturing plants, which simultaneously removes impurities (i.e. methane, argon) from syngas by stripping it with excess nitrogen while adjusting the hydrogen to nitrogen (H_2/N_2) ratio to 3
- KBR's Reforming Exchanger System (KRES™), which offers the potential for reforming up to 30% of the total natural gas fed to the plant by using high temperature process waste heat exiting the secondary reformer (or auto-thermal reformer) instead of burning fuel

KRES™

KBR's proprietary Reforming Exchanger System features:

- Effluent gas from the ATR/ secondary reformer provides heat for the reforming reaction occurring inside the catalyst-filled reforming tubes
- Heat energy that would otherwise be used to generate possibly unneeded steam in a waste heat boiler downstream of the reformer is instead used to replace fuel as the source of heat to drive the reforming reaction
- Tubes are open-ended and hang from a single tube sheet at the inlet cold end to minimize expansion problems
- Easy load through a removable top head
- The tubes are accessible and removable as a bundle for maintenance



CARBON CAPTURE UTILIZATION & STORAGE (CCUS)

KBR offers a unique value proposition in CCUS application to fertilizer and processing industries thanks to its extensive technical and commercial knowledge across the CCUS value chain having been involved in a number of notable CCUS projects in recent years spanning from feasibility studies to engineering (sample references: Statoil's Northern lights, JX Nippon, Gorgon LNG). KBR has specific experience with CO_2 capture, use and/or sequestration from NH_3 production facilities (sample references: Ras Laffan, Woodside and Jianfeng).

KBR is experienced in green and blue hydrogen development and its derivatives, e.g. ammonia (sample references: Singapore Government, Sunshot Energy); KBR has vast experience on carbon capture and Natural Gas Processing Activities utilizing CO_2 injection for enhanced oil recovery (EOR) and long-term storage (sample references: Browse FLNG, Confidential UAE study).

KBR can help with investment strategy in CCUS including deal sourcing, feasibility studies, transaction advisory, market/regulation support, technical support, asset performance, asset design/commissioning and more.

KBR EXPERIENCE IN CCS PROJECTS

ADNOC SHAH GAS CCS PROJECT

Project: 2.3 MTPA of carbon capture utilization and storage at ADNOC's Shah ultra-sour gas production facilities

Location: Shah, Abu Dhabi, UAE

Year: 2019

Client: ADNOC

KBR's Scope: FEED aims to assess the project techno-economic feasibility

NORTHERN LIGHTS PROJECT

Project: 1.5 MTPA onshore CO_2 receiving and storage terminal, offshore pipeline and CO_2 injection and subsea storage

Location: Eastern Norway

Year: 2017

Client: Equinor

KBR's Scope: Feasibility study, front-end engineering design for onshore CO_2 storage terminal, import jetty topside, CO_2 injection lines and associated utilities

QUEST CCS PROJECT

Project: 1.1 MTPA carbon capture facility installed at the stream methane reformer for Shell's Scotford complex. CO_2 is sent 80km from the facility to a 2,300m underground storage facility

Location: Fort Saskachewan, Canada

Year: 2013

Client: Shell, Canada

KBR's Scope: Off-site modularization and pipe fabrication, off-site testing and commissioning services

GORGON PROJECT

Project: One of the world's largest CCS project capable of injecting 3.4-4.0 MTPA of CO_2 extracted from gas production and liquefaction operations. CO_2 is injected and stored 2.3km underground into a saline aquifer via a 7km pipeline.

Location: Barrow Island, Western Australia

Year: 2005

Client: Gorgon Joint Venture

KBR's Scope: FEED, EPCm and commissioning of 3x5.2 MTPA LNG plants including CCS facility

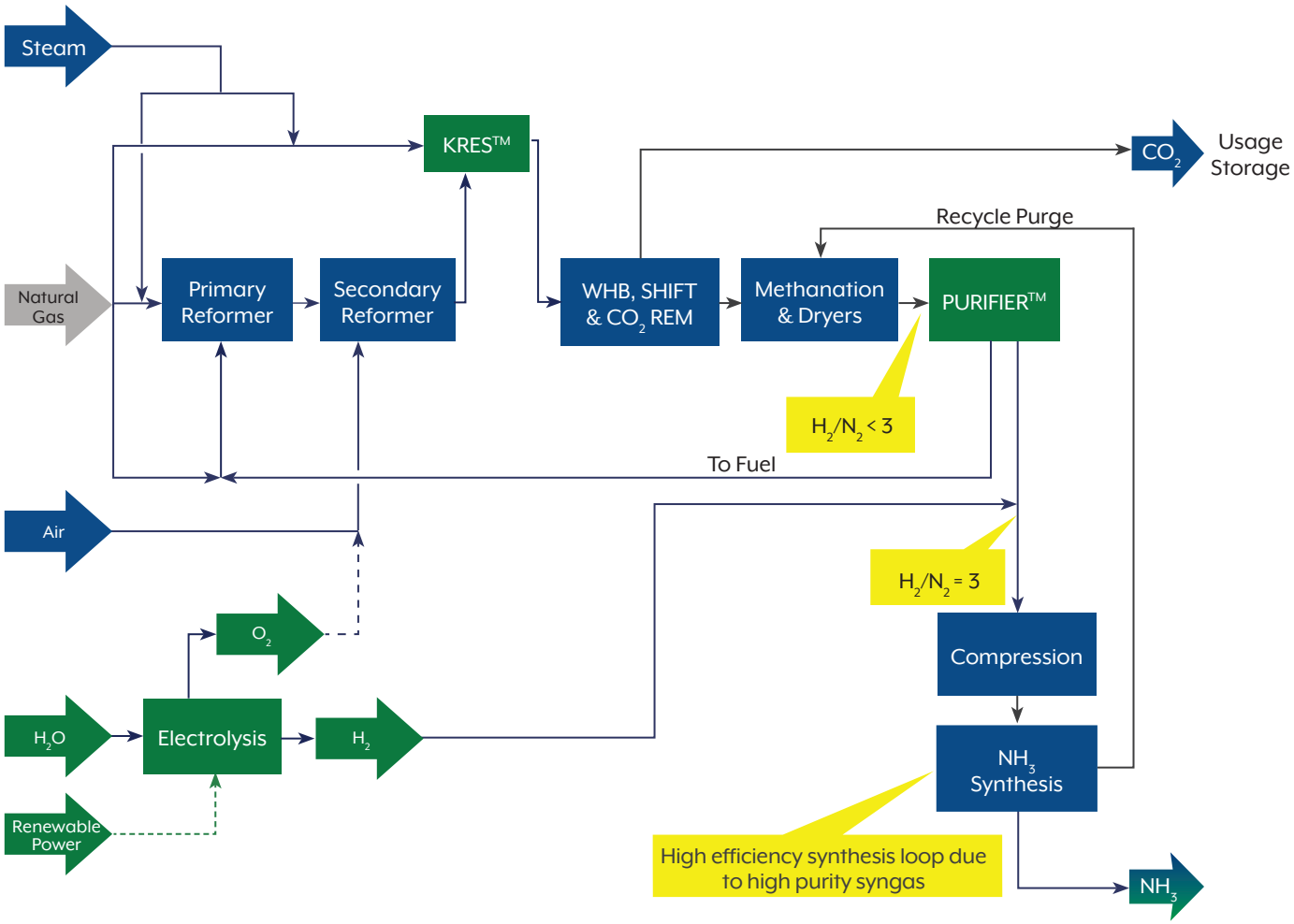
BLUE-GREEN AMMONIA COMBINATION

Depending on the client need, KBR offers **Blue-Green ammonia combination** as a feasible near-term solution.

- Low-cost add-on electrolyzer unit to any existing ammonia plant with no ASU required to co-produce some green ammonia
- Ammonia from renewable energy sources can be increased incrementally

KBR also offers **K-GreeN**®, a green ammonia technology, which consists of a fully integrated solution from the electrolysis of water, separation of air to produce green hydrogen and nitrogen to the synthesis of green ammonia.

Green ammonia is emerging as the preferred energy carrier to store and transport renewable energy for use either as energy or feedstock.



KBR AMMONIA EXPERIENCE

- Licensed, designed and/or built more than 250 plants
- KBR has licensed, designed and/or built plants from 300-6000 MTPD
- Experience with wide variety of feeds
- Reliable plants
- Highest on-stream days
- Maximum production rates

AMMONIA TECHNOLOGY — WORLD RECORDS

- Largest plant with single converter
- Most energy efficient plant
- Most reliable plant

In addition to providing technology, equipment and services for Blue Ammonia, KBR Technology Solutions provides an optimal mix of domain expertise with technology across its businesses, including;

- Advisory Consulting services for M&A, financial advisory, CAPEX evaluation, human performance and energy transition advisory
- Technology-Led Industrial Solutions including digital solutions for operating facilities, improved production, maximized reliability and optimized energy consumption at reduced OPEX
- Asset Solutions covering digitally enabled front-end engineering, detailed engineering, procurement services, construction management services and program management

ABOUT KBR, INC.

We deliver science, technology and engineering solutions to governments and companies around the world. KBR employs approximately 28,000 people performing diverse, complex and mission critical roles in 34 countries.

KBR is proud to work with its customers across the globe to provide technology, value-added services, and long- term operations and maintenance services to ensure consistent delivery with predictable results.

At KBR, We Deliver.

Scan for more information about KBR Technology Solutions

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