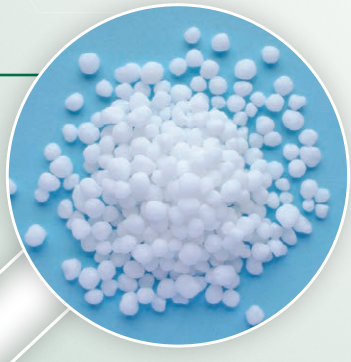
Sundyne®

Pumps & Compressors for Green and Blue Ammonia Production



Sundyne Pumps | Sundyne Compressors | ANSIMAG Sealless Pumps | HMD Kontro Sealless Pumps | Marelli Bombas | PPI Diaphragm Compressors | SUNFLO®

Ammonia Process

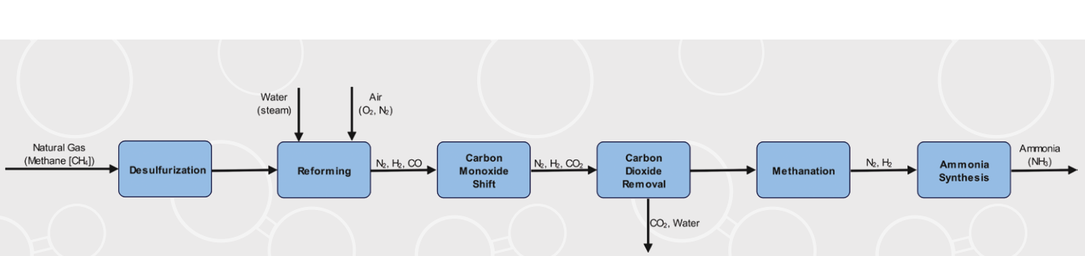
Ammonia (NH_3) is one of the most commonly produced industrial chemicals in the world. It is used in industry and commerce, and it exists naturally in humans and in the environment. Ammonia is essential for biological processes and it serves as a precursor for amino acid and nucleotide synthesis. In the environment, ammonia is part of the nitrogen cycle: it is produced in soil from bacteria. Ammonia is also produced naturally from the decomposition of organic matter, including plants, animals, and animal wastes.

About 80% of the ammonia produced by industry is used in agriculture as fertilizer itself or as the basis of upgraded nitrogen fertilizers, such as granular urea, urea ammonium nitrate (UAN), and ammonium nitrate (AN). Ammonia is also used as a refrigerant gas, for purification of water supplies, and in the manufacture of plastics, explosives, textiles, pesticides, dyes, and other chemicals.

Ammonia and its upgraded products, including diesel exhaust fluid (DEF), are also used in industrial processes for emissions reduction. Caprolactam is the precursor of a Nylon synthetic polymer used in the Textile and Automotive industries. Ammonia is found in many household and industrial-strength cleaning solutions. Household ammonia cleaning solutions are manufactured by adding ammonia gas to water – typically in concentrations of 5-10% ammonia. Ammonia solutions for industrial use may feature concentrations of 25% or higher and are corrosive.

Ammonia is produced commercially via the catalytic reaction of nitrogen and hydrogen at high temperature and pressure, known as the Haber-Bosch Process.

Traditional production of so-called grey ammonia consists of 6 steps as shown in the following process diagram:



Green Ammonia Process

What is Green Ammonia?

Ammonia can be made synthetically by combining nitrogen with hydrogen, in a process called ammonia synthesis. When this process is completed using renewable energy sources with zero carbon emissions (such as wind, solar, hydropower and geothermal energy) the result is green ammonia.

How is Green Ammonia Used?

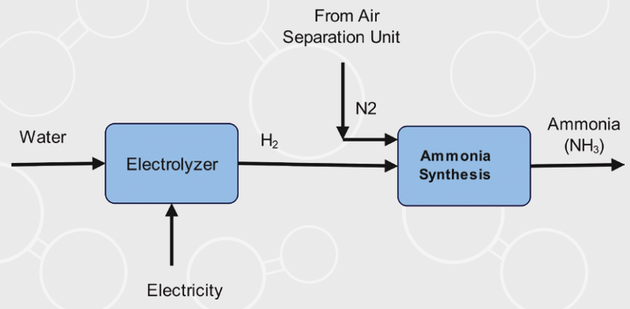
Green ammonia holds the potential to drastically reduce global carbon emissions if used as a:

- Hydrogen Carrier for large quantities of Hydrogen over long distances
- Fuel for engines, such as locomotives and ships, replacing diesel and marine fuel oil
- Fuel source for electricity power generation
- Building block to make fertilizers for use in agriculture
- Feedstock for industrial and manufacturing applications (such as water purification or pharmaceuticals).

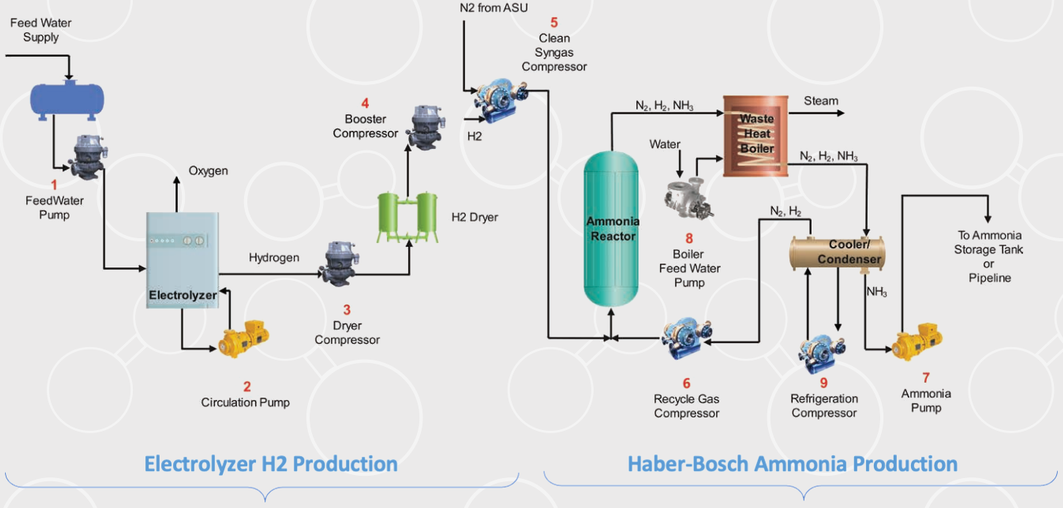
How is Green Ammonia Made?

Nitrogen can be extracted from the Earth's atmosphere using an air separation unit. Hydrogen can be generated through electrolysis, which splits water into hydrogen and oxygen using electricity. Ammonia synthesis is achieved by combining and reacting green hydrogen and nitrogen at high temperature and pressures (modified Haber-Bosch Process).

The production features 2 steps, shown in the process diagrams below and on the next page.

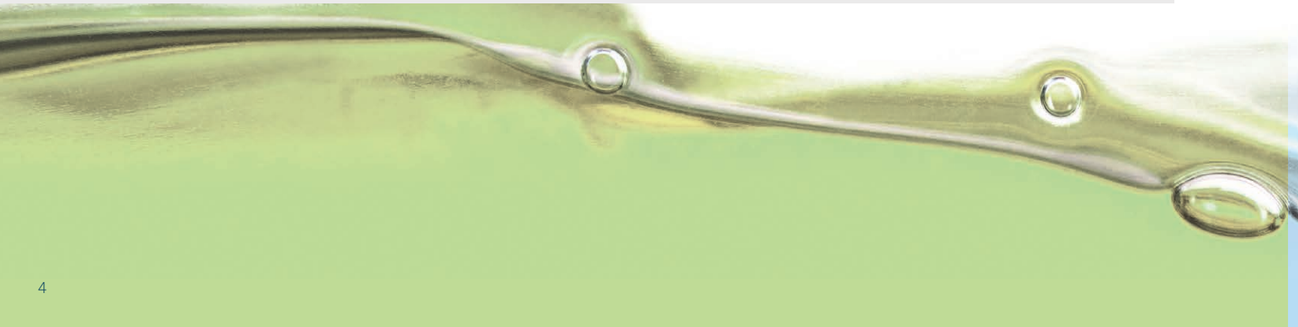


Green Ammonia Process



Equipment List

Location	Service	Equipment Type	Medium
1	Feedwater Supply Pump	Sundyne LMV, Marelli OH or VS	Water
2	Circulation Pump	Sundyne HMD, Ansimag or Marelli	PEM = deionized water Alkaline = KOH Electrolyte
3	H_2 Dryer Compressor	Sundyne BMC, LMC	Wet H_2
4	Booster Compressor	Sundyne LF-2000, LMC or BMC	Wet H_2
5	Syngas Compressor	Sundyne LF-2000	H_2 + N_2
6	Recycle Gas Compressor (separate or integrated in Syngas compressor 5)	Sundyne LF-2000	H_2 + N_2
7	Ammonia Pump	Sundyne LMV,HMD or Marelli VS6	Liquid NH_3
8	Boiler Feedwater Pump	Sundyne LMV, HMP, or Marelli BB3	H_2O
9	Refrigeration Compressor	Sundyne LF-2000	NH_3



Blue Ammonia Process

In order to meet Paris Agreement commitments, many countries are turning to blue ammonia projects as a medium-term solution for ammonia mass production, while also developing green ammonia for future production. Almost all ammonia is currently produced from hydrocarbon feedstock, accounting for around 1.8% of global CO_2 emissions.

What is Blue Ammonia?

Blue ammonia is the low-carbon alternative to conventional grey ammonia, where CO_2 emitted during production is sequestrated via carbon capture technology and/or offset by planting trees to become carbon neutral.

Blue ammonia is made from nitrogen and blue hydrogen derived from natural gas feedstocks, with the carbon dioxide by-product from hydrogen production captured and utilized or stored (CCUS).

Blue ammonia has various advantages as a medium for industrial feedstock, storage and transportation of energy. The product characteristics of blue ammonia are identical to conventionally produced ammonia. Since the CO_2 generated in the production process is captured and not released to the atmosphere, blue ammonia plays a significant role in the transition to alternative, less carbon-intensive products.

How is Blue Ammonia Used?

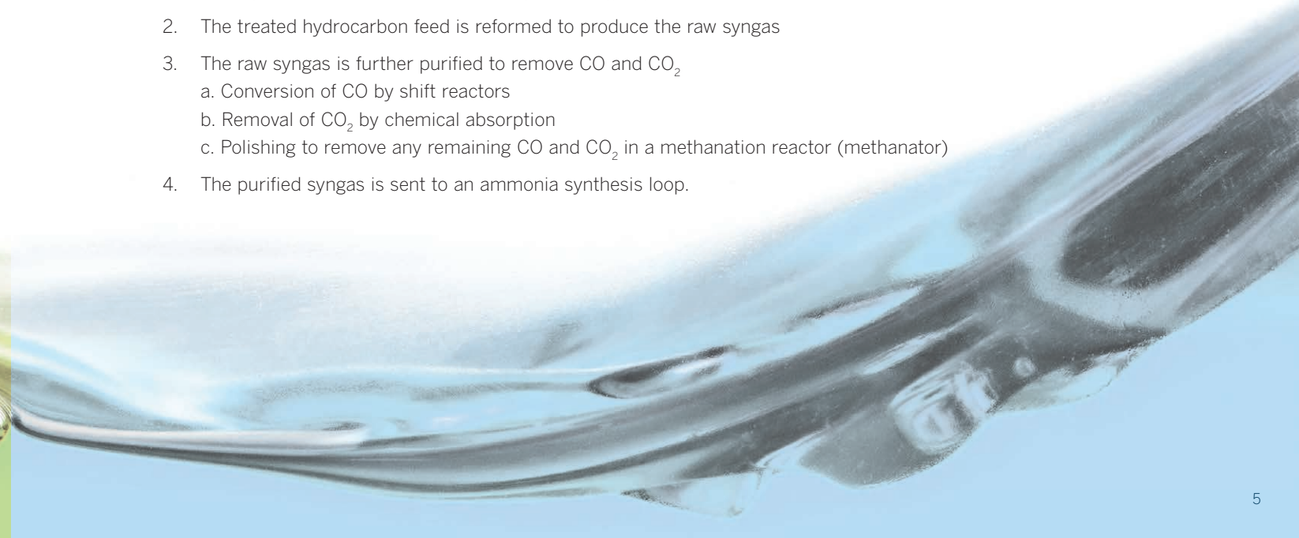
Blue ammonia is a carbon-neutral transportable form of energy. Being a carrier of hydrogen energy, blue ammonia helps hard-to-abate sectors decrease their carbon intensity, such as transportation and power generation.

How is Blue Ammonia Made?

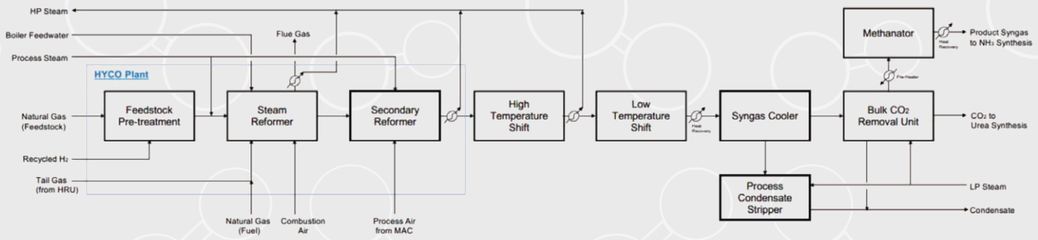
Blue Ammonia is manufactured by converting gaseous nitrogen (N_2) and hydrogen (H_2) in synthesis gas (Syngas) with a typical molar ratio of approximately 3:1 at the right temperature and pressure, and in the presence of a catalyst.

Syngas for Blue Ammonia production comes from Blue Hydrogen, which is produced by reforming or gasification of fossil feedstocks combined with CO_2 Capture.

1. The Hydrocarbon feed is pre-treated by removing any sulfur and chloride
2. The treated hydrocarbon feed is reformed to produce the raw syngas
3. The raw syngas is further purified to remove CO and CO_2
   a. Conversion of CO by shift reactors
   b. Removal of CO_2 by chemical absorption
   c. Polishing to remove any remaining CO and CO_2 in a methanation reactor (methanator)
4. The purified syngas is sent to an ammonia synthesis loop.



Blue Ammonia Process



Generic Block Flow Diagram of the syngas generation

IEAGHG, "Techno-Economic Evaluation of Hyco Plant Integrated to Ammonia/Urea or Methanol Production with CCS", 2017/03, February, 2017

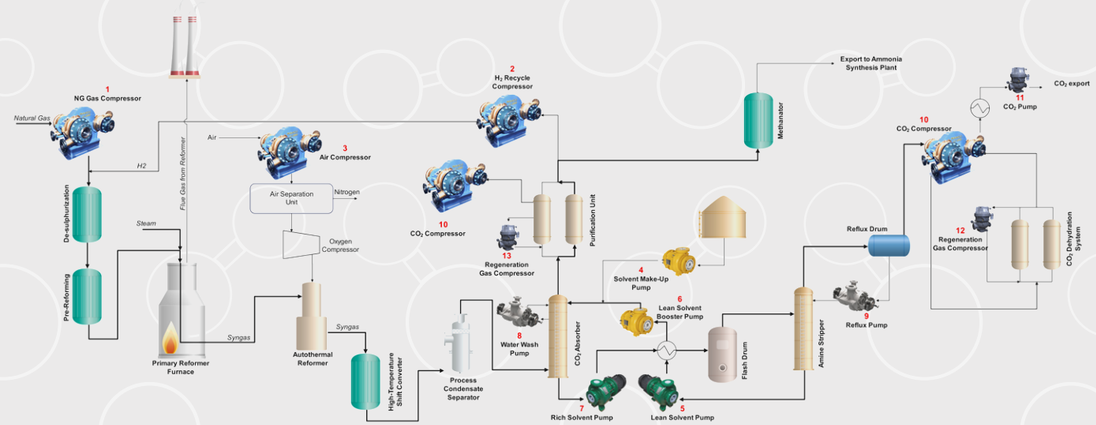
Three main blue-H_2 production technologies exist:

- **Steam Methane Reforming (SMR):** is the most widely deployed technology. SMR involves reacting natural gas with steam in the presence of a catalyst at high temperature to produce hydrogen. Approximately two-thirds of the CO_2 is in concentrated form during hydrogen production. The remaining third is generated in dilute form in the flue gas from burning natural gas for heating purposes. Post-combustion carbon capture can be retrofitted to convert grey hydrogen production to blue.
- **Autothermal Reforming (ATR):** improves the cost-effectiveness of SMR by adding Oxygen to the process and a higher overall energy efficiency. In ATR, pure oxygen is supplied for combustion which results in a concentrated and high-pressure stream of CO_2, making carbon capture integration easier. This requires a substantial feed gas pretreatment investment and the fired heater produces CO_2 emissions.
- **Partial Oxydation (POX):** reaction happens between oxygen and hydrocarbons in the reformer and produce H_2 rich syngas. It is a noncatalytic process that does not consume steam and has no direct CO_2 emissions. With no need for feed gas pretreatment, POX technology is simpler than ATR.

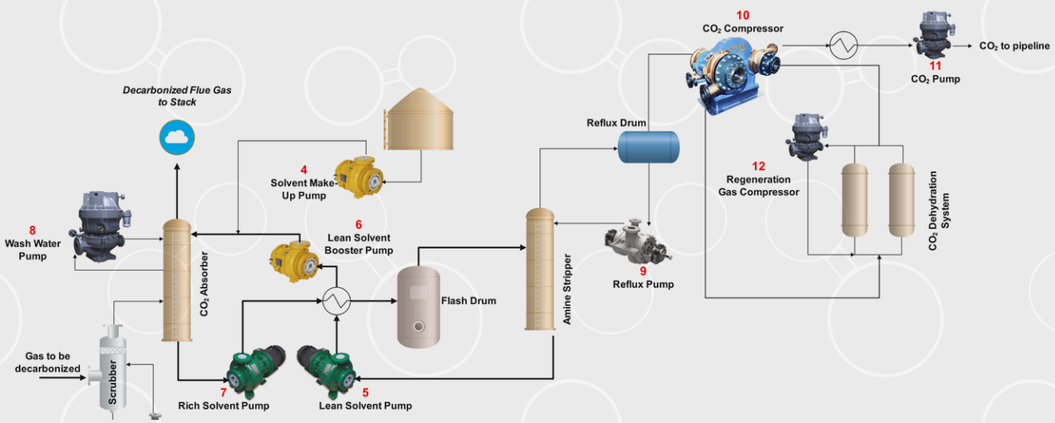
The blue syngas is further processed to adjust gas mixture composition in two shift sections. It is then purified in a CO_2 removal section to produce blue hydrogen-rich syngas, and it also goes through a methanator unit which removes the remaining CO and CO_2.

Finally, Blue Ammonia synthesis is achieved by combining and reacting blue H_2 rich syngas and nitrogen at high temperature and pressure (modified Haber-Bosch Process).

Autothermal Reforming (ATR)

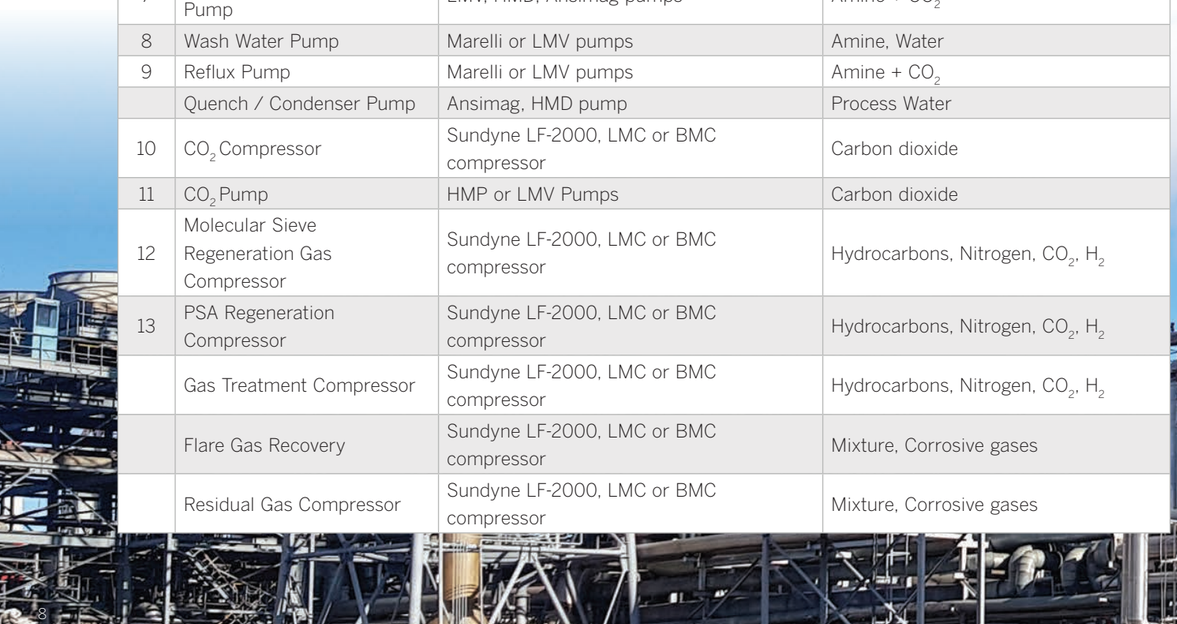


CO_2 Capture



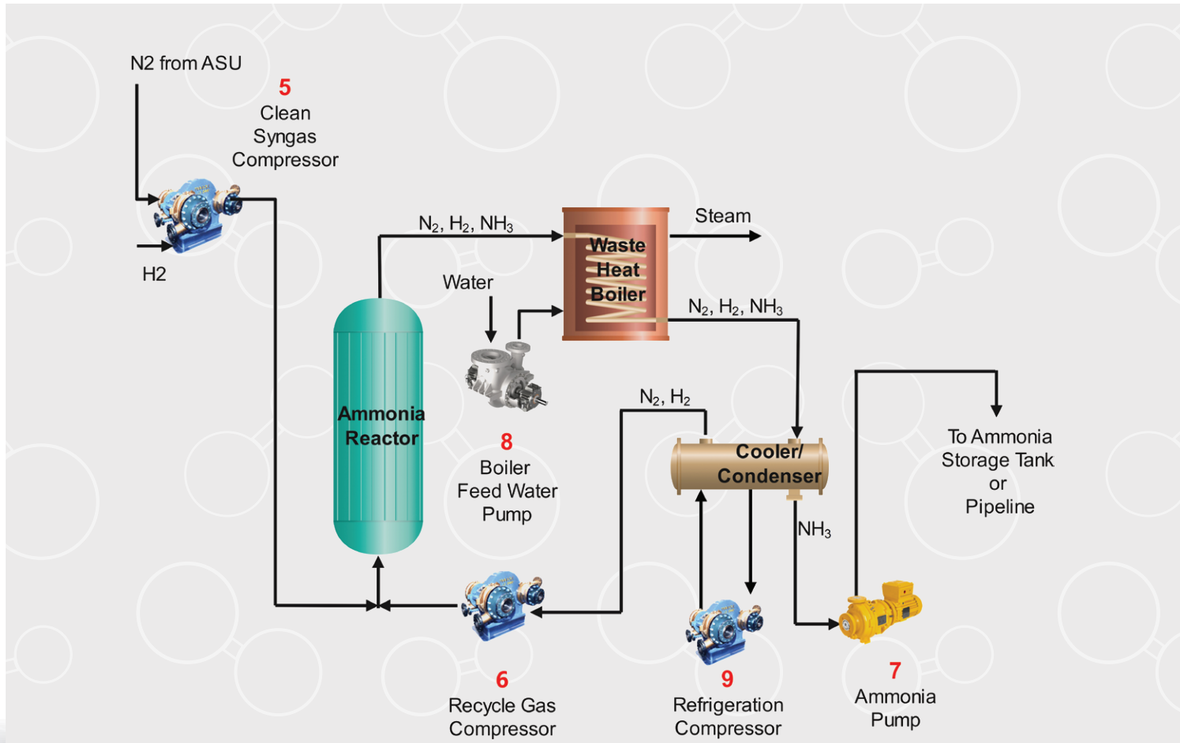
Recommended Sundyne Equipment

Loc	Service	Equipment Type	Medium
1	Natural Gas Feed Compressor	Sundyne LF-2000 compressor	Natural Gas
	Boiler Feed Water Circulation Pumps	Marelli, LMV, HMP, Sunflo pump	Water
	Boiler Feed Water Feed Pumps	Marelli, LMV, HMP, Sunflo pump	Water
2	Hydrogen Recycle Compressor	Sundyne LF-2000, LMC or BMC compressor	Hydrogen
	Condensate Pump	Marelli, LMV, HMP, Sunflo pump	Water
	Sea Water Pump	Marelli pump	Water
	Closed Cooling Water Pumps	Marelli pump	Water
	Corrosion Inhibitor Pumps	HMD, Ansimag pump	Alkaline compounds, Amine, Hydrazine
3	Air Compressor	Sundyne LF-2000, LMC or BMC compressor	Air
	Demi Water Feed Pumps	Marelli, LMV, HMP, Sunflo pump	Water
	Demi Water Circulation Pumps	Marelli, LMV, HMP, Sunflo pump	Water
	Refrigerant Gas Compressors	Sundyne LF-2000, LMC or BMC compressor	HCFC or CFC, Hydrocarbons, CO_2, Ammonia
	Flare KO Drum Pumps	LMV, HMD pumps	Hydrocarbons, Water, various
	Fuel Gas Compressors	Sundyne LF-2000 compressors	Natural Gas
4	Solvent Make-Up Pump	LMV, HMD pumps	Amine solvent
5	Lean Amine Circulation pump	LMV, HMD, Ansimag pumps	Amine + CO_2
6	Lean Amine Booster pump	LMV, HMD pumps	Amine + CO_2
7	Rich Amine Circulation Pump	LMV, HMD, Ansimag pumps	Amine + CO_2
8	Wash Water Pump	Marelli or LMV pumps	Amine, Water
9	Reflux Pump	Marelli or LMV pumps	Amine + CO_2
	Quench / Condenser Pump	Ansimag, HMD pump	Process Water
10	CO_2 Compressor	Sundyne LF-2000, LMC or BMC compressor	Carbon dioxide
11	CO_2 Pump	HMP or LMV Pumps	Carbon dioxide
12	Molecular Sieve Regeneration Gas Compressor	Sundyne LF-2000, LMC or BMC compressor	Hydrocarbons, Nitrogen, CO_2, H_2
13	PSA Regeneration Compressor	Sundyne LF-2000, LMC or BMC compressor	Hydrocarbons, Nitrogen, CO_2, H_2
	Gas Treatment Compressor	Sundyne LF-2000, LMC or BMC compressor	Hydrocarbons, Nitrogen, CO_2, H_2
	Flare Gas Recovery	Sundyne LF-2000, LMC or BMC compressor	Mixture, Corrosive gases
	Residual Gas Compressor	Sundyne LF-2000, LMC or BMC compressor	Mixture, Corrosive gases



Ammonia Synthesis for Green & Blue Ammonia

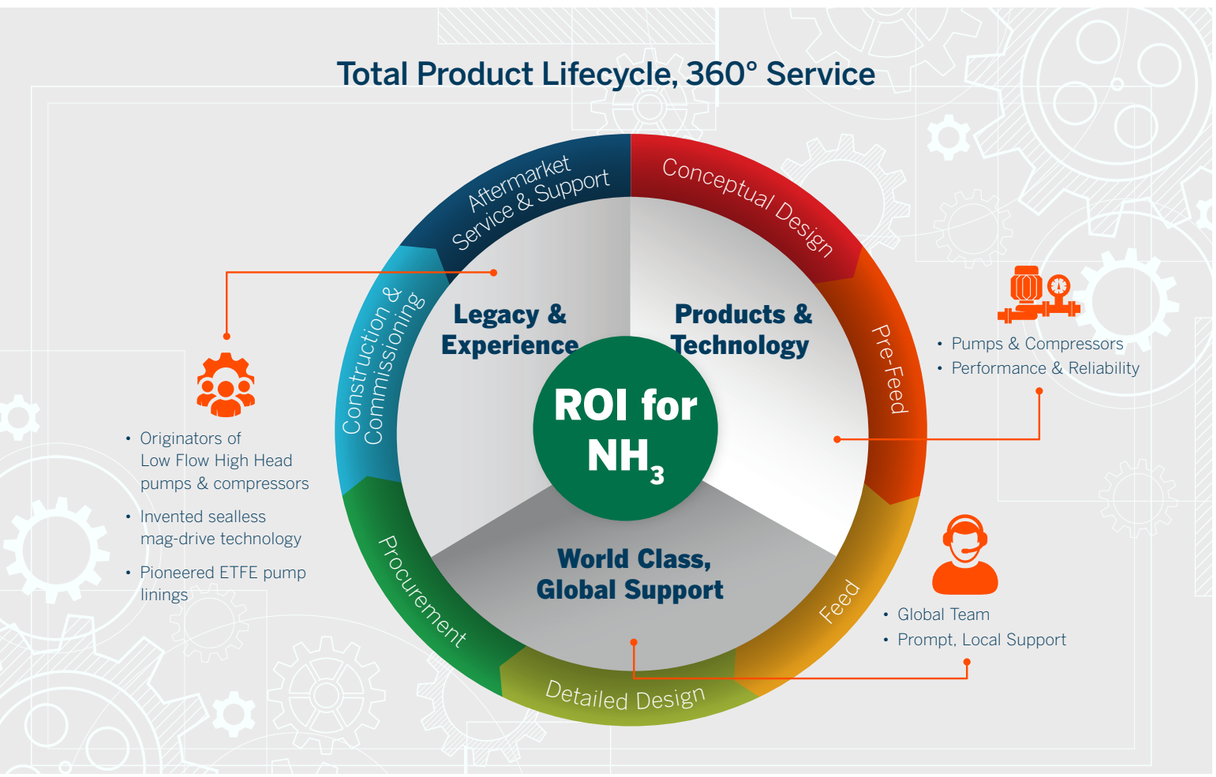
Ammonia is synthesized industrially through the Haber Bosch process, which involves reacting a nitrogen molecule with three hydrogen molecules over a bed of catalysts. The reaction takes place at high pressures and relatively low temperatures, which maximizes the ammonia yield to 15-20%.



Sundyne's Value Proposition for Ammonia Production

Sundyne's portfolio of pumps & compressors is specifically designed to address green and blue hydrogen production and ammonia synthesis applications. Sundyne's unique combination of technology, expertise and support provides a 360-degree, full lifecycle service that spans everything from project pre-feed to comprehensive 24x7 support, utilizing a global network of Authorized Service Centers and aftermarket specialists.

Total Product Lifecycle, 360° Service



Sundyne LMV Pumps

Integrally geared pumps are designed for low-flow high-head applications such as pumping ammonia into a pipeline or pumping boiler feed water. The LMV pump features a single impeller running at high speed to produce high heads. This compact and simple design requires fewer spare parts than a multistage pump while offering much easier maintenance. Sundyne LMV pumps offer the highest efficiency in the low flow range. Sundyne's advanced inducer technology solves situations where the NPSH available is limited.

Sealless Magnetic Drive Pumps – HMD and ANSIMAG

Sundyne sealless pumps provide optimum safety and environmental protection for a wide range of ammonia applications. They are designed for hazardous and corrosive liquids, and applications that are difficult to seal. HMD Kontro metallic and Ansimag ETFE-lined sealless pumps ensure total product containment, increased reliability and uptime and simplified maintenance with no seals or seal support systems, whilst meeting industry standards such as ASME, ISO and API.

Marelli Pumps

Marelli pumps leverage a track record of more than 60 years in centrifugal pump design, development, manufacturing and service, to fulfill the latest standards for oil & gas, petrochemical and green markets, including carbon capture, H_2, green and blue ammonia and biofuels processing. Marelli pumps are designed for extreme reliability and a wide range of flow rates, to accommodate the most stringent customer specifications.

Sundyne Compressors

Sundyne compressors leverage more than 60 years of experience and innovation from thousands of deployments in some of the world's most demanding environments. Sundyne compressors feature single- and multi-stage centrifugal designs that are custom built to provide pulsation- and vibration-free operation, and to deliver oil-free process gas with zero emissions. Sundyne compressors offer the performance envelope, broad feature set and the reliability needed to address the B.E.P. for any application.

Criteria for Selecting Pumps and Compressors Used for Ammonia Production

- **Reliability**: ammonia plants are built to run for 20-50 years. Sundyne equipment has a service life of 30 years and some units have operated for more than 50 years.
- **Efficiency:** The footprint of Sundyne equipment allows users to install additional equipment in less space, like the addition of CO_2 capture on existing plants. Sundyne's 70-plus year track record makes it easy for operators to run equipment at B.E.P.
- **Worker Safety Via Leak Free Operation:** Ammonia compressors are subject to strict safety regulations. Sundyne liquid mechanical seals and dry-gas seals are proven for use in the petroleum, chemical and gas industry services. Ansimag and HMD sealless pumps are leak-proof by design, with fully enclosed wet-ends that eliminate leakage.
- **Superior Chemical Resistance:** Ammonia processing can wreak havoc on a pump's internals. A wide range of metallic and ETFE materials are available to address any process requirement.
- **Simplified Maintenance:** The global volume of ammonia production illustrates the need for reliable equipment that minimizes plant downtime. Sealless pumps have fewer parts and no seal support systems, which increases Mean Time Between Maintenance (MTBM), and minimizes costs.

For decades, Sundyne has worked with the world's largest ammonia producers, pioneering many of the technologies that are commonplace today. Sundyne's value proposition for ammonia production is represented by reliable technology that's easy to install and meets the toughest certifications in the industry. Sundyne's factory service centers and Authorized Service Centers around the world deliver the expertise and responsiveness needed to streamline maintenance, maximize plant uptime and ensure that equipment is always running at peak efficiency.

When it comes to Ammonia applications, Sundyne is the **Safer, Better, Best** choice.

Safer for Operations

Better for the Environment

Best Total Lifecycle Value

For more information please visit www.sundyne.com and fill out the Contact Me form. A Sundyne representative will contact you.

Sundyne Headquarters:
Sundyne, LLC
14845 West 64th Avenue
Arvada, Colorado 80007 USA

marketing@sundyne.com
Phone: 1 303 425 0800
Fax: 1 303 425 0896
www.sundyne.com

Dijon, France
Eastbourne East Sussex, UK
Madrid/Toledo, Spain
Tokyo, Japan
Pune, India