Ammonia as a power generation fuel

The advantages and challenges on the use of Ammonia (NH_3) as fuel for stationary utility-scale gas turbine power generation

The growing global interest in carbon-free fuels has opened the door for range of hydrogen alternatives, including ammonia, whose primary use today is in the production of fertilizer. There are potential advantages to using ammonia as a hydrogen carrier instead of transporting liquid hydrogen, but there are significant technical issues and safety risks associated if using ammonia as a gas turbine fuel.

Given the costs and complexities of producing ammonia, GE does not see a viable business case in the near-term for using ammonia as a gas turbine fuel. In addition, development of an ammonia capable gas turbine that meets critical operational and safety requirements will require a multi-year combustion and balance of plant development program.

WHAT IS AMMONIA?

Ammonia is one of the most widely produced chemicals in the world today, with more than 170 million tonnes being produced each year; more than 85% of this goes into production of fertilizer. Ammonia is carbon-free, being composed of hydrogen and nitrogen. It is more energetic (on a volume basis) than hydrogen, but still contains about 2.5 less energy than methane (natural gas). It is less reactive than methane which could create combustion operability issues.

	Methane	Hydrogen	Ammonia
Formula	CH_4	H_2	NH_3
Temperature to condense to a liquid	-258.7° F -161.5° C	-423.2° F -252.9° C	-28° F -33.3° C
Lower flammability limit	4.4%	4%	15%
Lower heating value	911.6 BTU/scf 35.8 MJ/Nm^3	274.4 BTU/scf 10.8 MJ/Nm^3	360 BTU/scf 14.1 MJ/Nm^3

PROS

- **Reduced carbon footprint –** If ammonia is synthesized from either blue or green hydrogen, along with nitrogen produced from zero carbon electricity, it can be labeled as green ammonia. Ammonia produced with blue hydrogen may be labeled as blue ammonia, but there could still be carbon emissions tied to the production of nitrogen.
- **Easier to transport –** Ammonia can be liquefied at a higher temperature than either hydrogen or natural gas, meaning less energy is spent in creating a cryogenic liquid (see table at left). Ammonia must be cooled below -28° F (-33° C) to liquefy, whereas hydrogen requires cooling below -423° F (-253° C) which is 37 °F (20° C) above absolute zero. Whereas hydrogen would require a fleet of new cryogenic tanker ships for transport, there is potential to use existing ships to transport ammonia.
- **Already used in power plants –** Ammonia is a key chemical used in SCR systems to reduce NO_x emissions in many power plants around the world.

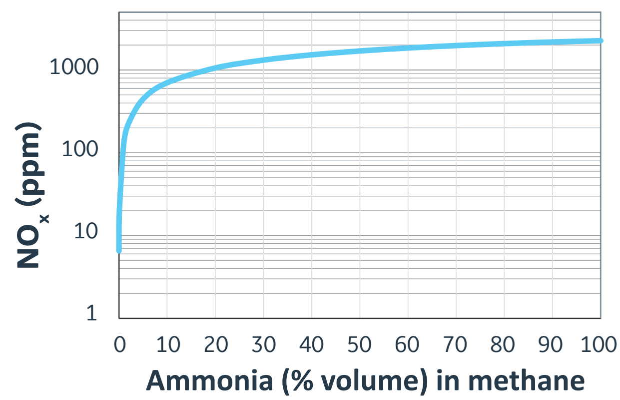
OVER

Ammonia as a power generation fuel

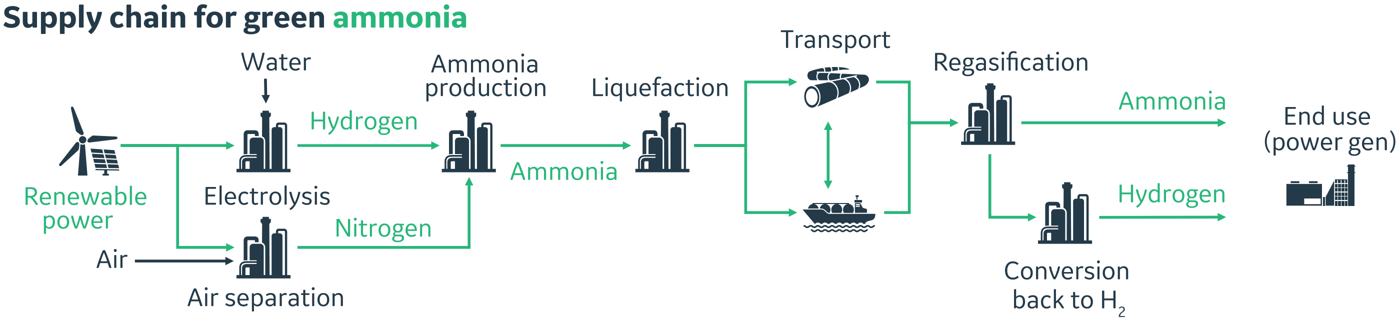
CONS

- **Very high rates of NO_x production –** During the process of combustion in a gas turbine configured with a current DLN (dry low NO_x) combustion system, the nitrogen in ammonia tends to convert to nitric oxides (NO_x) at a rate of ~100X more than in methane or hydrogen flames at the same flame temperature. This will yield NO_x emissions in excess of 1000ppm. This is even true with blends of ammonia and natural gas (see figure below).
- **LCOE penalty –** Using ammonia in existing power plants could increase the levelized cost of electricity (LCOE). Today, ammonia produced from hydrogen ranges in price from \$300–\$600 per metric tonne (equivalent to \$17 and \$34/MMBTU), which is 3–11X more expensive than natural gas. These prices are based on grey hydrogen; using green hydrogen (which may cost 3–6X more than grey hydrogen) will drive the price of green ammonia even higher.
- **Combustor operability challenges –** Ammonia has lower reactivity which might reduce flame stability. Its lower flammability limit is ~3X higher than methane's, implying there might be challenges in getting reliable ignition.
- **Ammonia is classified as acutely toxic –** It interacts with available moisture in the skin, eyes, mouth, respiratory tract, and particularly mucous surfaces leading to chemical burns. As an example, OSHA defines the Immediately Dangerous to Life or Health (IDLH) limit for ammonia at 300ppm, which is equivalent to 0.03%.
- **Large increases in usage rates at power plants –** Using ammonia as a fuel would increase required amounts (relative to SCR flow rates for natural gas systems) by roughly 400–600X, depending on the gas turbine and plant configuration.
- **Supply chain energy penalty –** Multiple chemical conversions are required to achieve power-to-ammonia-to-power. These steps degrade the overall process round-trip efficiency. Aside from creating green hydrogen, nitrogen must be separated from air. Energy is required to combine these into ammonia and to liquefy. (This last step uses less energy than liquefying hydrogen.) After transport, ammonia could potentially be used as fuel, or it could be split back into hydrogen and nitrogen. Not counting any losses during transport, due to the increased number of conversion steps, the round trip process for ammonia has ½ the efficiency of the hydrogen path.[1]

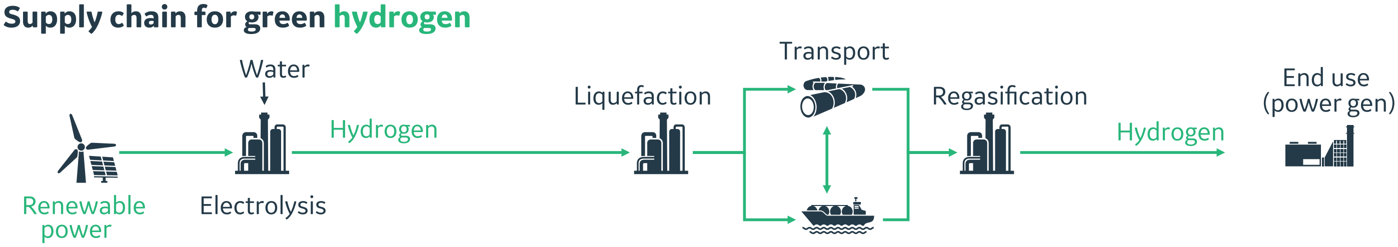
[1]Production efficiency defined as the % of energy input remaining after conversion steps on a per kWh basis. This includes production and liquefying green H_2. For ammonia, this also includes the production of nitrogen, reacting hydrogen and nitrogen to make ammonia, liquefying ammonia, and cracking ammonia back into hydrogen and nitrogen.



Supply chain for green ammonia



Supply chain for green hydrogen



For more information contact: Dr. Jeff Goldmeer | Senior Product Manager, GE Gas Power

GEA34985 (06/21)