

Submission: Australia's transition to a green energy superpower (Nov 2022)

1. Ammonia is Ready

The [Ammonia Energy Association](#) (AEA) is a global non-profit industry association that promotes the responsible use of ammonia in a sustainable energy economy.

AEA Australia Ltd is a subsidiary of AEA Global and has close working relationships with several key groups, including the Clean Fuel Ammonia Association (CFAA) of Japan, the Korea Clean Ammonia Association, the Europe-based NH3 Event, the Australian Hydrogen Council, the Smart Energy Council and the CSIRO.

Our mission encompasses both the decarbonisation of ammonia in its existing applications, and the adoption of low-carbon ammonia in new applications. New applications include direct use of ammonia as a fuel for power generation or maritime transport, and indirect use as a hydrogen carrier and carbon-free energy commodity.

Our vision for Australia is to enable and accelerate the energy transition through the development and deployment of a decarbonised ammonia ecosystem. Leveraging Australia's abundant natural resources, major resource project capability, and proximity to and trading relationships with energy-importing nations, we see the potential for an enormous clean energy manufacturing industry, with ammonia plants to be powered by our abundant renewable electricity resources. This will mean Australia's wind, solar and hydro potential will be converted to carbon-free liquid fuel for domestic use and for export.

When Australia's fossil fuel exports are inevitably replaced by cleaner options over the coming decades, ammonia is ready to step up and fill the gap. We estimate Australia's current LNG exports (80 million tpa in 2021) could be replaced by 200 million tpa of liquid ammonia, and thermal coal exports (200 million tpa in 2021) could be replaced by 300 million tpa of liquid ammonia. The ocean-going trade of chemical fuels must be replaced with low and zero-carbon alternatives for the world to achieve net zero emissions by 2050, and ammonia is a ready-made replacement.

2. The advantages of ammonia

Compared to alternatives, ammonia is a superior hydrogen carrier

- Liquid ammonia carries 1.69 times more hydrogen per litre than liquid hydrogen does.
- For a given volume, liquid ammonia carries 1.69 times the energy of liquid hydrogen, and more than 2.5 times the energy of compressed hydrogen.
- Liquid ammonia has been safely manufactured, stored and transported in commercial volumes for more than a century.
- Of the possible alternatives (transmission of energy by power lines, liquid hydrogen, compressed hydrogen, liquid organic hydrogen carriers and liquid ammonia), ammonia is demonstrably the most flexible, lowest cost, energy efficient and “ready now” option.

Ammonia can be directly used as a fuel

- **Bunker fuel for large ocean-going ships.** The first retrofit technology platforms to allow the main engines for such vessels to run on ammonia fuel will be commercially available next year. New build engines able to run on ammonia fuel will follow shortly thereafter.
- **Fuel for gas turbines.** Current utility-scale gas turbine models that run on natural gas are being modified to run on ammonia fuel. Japan & Singapore both envisage a big role for ammonia-fuelled gas turbines for power generation needs in the years to come.
- **Co firing existing coal fired power stations.** Currently, the co-firing of 20% liquid ammonia – 80% pulverised coal fuel is being demonstrated at the Hekinan Thermal Power Station in Japan. The % of ammonia fuel in coal power station boilers can theoretically approach 100%. Co-firing trials are soon to begin in Korea, India, Indonesia and Malaysia.
- **Firing industrial furnaces.** Similar to coal co-firing, ammonia fuelled industrial burners are under development in Japan.
- **Fuel for solid oxide fuel cells.** Many fuel cell applications require ammonia to be “cracked” back into high purity hydrogen, which is then consumed as a fuel. In contrast, solid oxide fuel cells use ammonia fuel directly to produce power.

3. Emerging and Future Trends

The deployment of ammonia into new industries is dependent on the development of new technologies to utilise ammonia as an energy source and hydrogen carrier. Numerous technology pathways are under development to service various elements of the overall addressable energy market.

NOx emissions can be safely mitigated

A critical point here is that combustion of ammonia is carbon-free, but not emissions free. NOx emissions can be formed in ammonia fuel combustion, and this family of molecules has a higher global warming potential than carbon dioxide or methane. Luckily, NOx capture/abatement technology already exists and is available off-the-shelf to deal with NOx emissions produced in conventional fuel combustion (including in the exhaust system of all passenger vehicles). These technologies are being further honed for use in new ammonia applications, particularly gas turbines for power generation. **Many of these Nitrogen pollutant abatement systems already use ammonia or urea (AdBlue) to remove the pollutants from the exhaust stream.**

Fuel ammonia applications in key addressable markets

- **Key addressable market – maritime transport fuel**, displacing diesel/Heavy Fuel Oil for maritime applications.
- MAN Energy Solutions is finalising preparations for its large bore, two stroke diesel marine engines to run on ammonia fuel. These engines should be available for dual fuel (HFO + NH₃) applications by 2024.
- Major international ports including Singapore and Rotterdam are studying in detail the progression towards bunkering ammonia fuel in the near future. There is work to be done on properly assessing and then mitigating the safety hazards of large-scale use of ammonia fuel. A recently released safety report from Nanyang Technological University in Singapore “Ammonia as a Marine Fuel” is publicly available (<https://www.ntu.edu.sg/mesd-coe/publications>).
- Wärtsilä is developing a range of its four stroke diesel engines to run on ammonia fuel. These will be available in future for marine, rail and stationary power applications.
- CFAA members are developing gas turbines to run on ammonia fuel. Already they have mid-sized prototypes running (10's of megawatts) and will progress to much larger units (one hundred-plus megawatts) in the near future.
- **Key addressable market – stationary energy** displacing coal/oil in existing thermal power stations for electricity generation.
- CFAA members already have a prototype power station running on 20% ammonia co-fired with 80% pulverised coal which commensurately reduces carbon emissions.
- The next stage for this project is to move to 50/50 co-firing which will substantially reduce emissions.
- The aim is to increase the ammonia co-firing percentage as high as possible, ultimately approaching 100%
- This technology will be offered to other countries including those in SE Asia which will mean the development of a market for Australia's green ammonia close to home.

Efficiency improvements in “green” ammonia manufacture

- More efficient manufacturing technologies will hasten adoption of clean ammonia across all applications, both traditional and emerging. Current technology requires ~10MWh per tonne of ammonia produced with ~5% of this required for the ammonia synthesis reaction.
- Current manufacturing technology requires a hydrogen gas stream generated by the electrolysis of water and a nitrogen gas stream generated by an air separation unit (ASU) These two gas streams are fed into a Haber Bosch process to produce renewable ammonia, assuming all three of these processes are powered by renewable electricity.
- Hydrogen production by electrolysis consumes the majority of the electrical energy.
- There are a number of research projects in progress globally, investigating significant improvements in manufacturing efficiency. One such project at [Monash University](#) is pursuing the manufacture of ammonia by direct nitrogen reduction using electrochemical means, which has the potential to bypass current manufacturing technology and greatly reduce the required electrical energy input per unit of ammonia produced. This technology has the potential to significantly reduce the cost of production for renewable ammonia and would therefore be a game changer.

4. Trade and Investment

The opportunities for Australia to produce & export ammonia as an energy commodity is there for the taking. Production potential at locations around Australia is matched by the forecast fuel ammonia demand for some of our closest trading partners in Asia.

“Green” Ammonia Manufacture Potential in Australia

- Businesses are proposing to manufacture up to 400,000 tpa green ammonia in Tasmania (Bell Bay).
- There are a number of green ammonia production plants proposed on the mainland ranging in size from 1 million tpa up to 15 million tpa of ammonia (Pilbara, Esperance, Gladstone, Eyre Peninsula and Murchison to name a few of the proposed locations).

Ammonia Fuel Potential Markets in Asia

- Japan has signalled that it wishes to be importing 5 million tpa by 2030 (government roadmap target).
- JERA is currently conducting a tender process for the supply of 500,000 tpa fuel ammonia, starting in 2027.
- South Korea has signalled that it wishes to be importing 10 million tpa by 2030 (again, a government roadmap target).
- And there are positive signs from Singapore that it is starting to seriously consider using ammonia as a significant bunker fuel for the shipping sector, and also potentially for turbine-based power generation in Singapore.

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