AMMONIA ENERGY ASSOCIATION

AEA Principles Document

Preamble

Ammonia (NH_3) is one of the most abundant molecules on earth and is both naturally occurring and man-made. It is a vital product, used as a nitrogen fertilizer as well as for many industrial and consumer applications. In recent years, ammonia's potential role in a decarbonized society has come to the forefront of global discussions.

The Ammonia Energy Association (AEA) was founded in 2004 to promote the responsible use of ammonia in a sustainable economy. Its mission encompasses both the decarbonization of ammonia production and the use of low-emission ammonia as a fuel and energy carrier to decarbonize other sectors. The AEA is a global trade association whose members represent the full value chain of ammonia across multiple sectors. The AEA works with its member companies and partner organizations to share knowledge, foster collaboration, develop key programs, and engage in advocacy with industry, policy-makers, and the public for the safe and sustainable adoption of low-emission ammonia.

Background

In nature, ammonia is produced in living organisms, including humans, and in water, soil, and air. Ammonia is also the second most manufactured chemical in the world, with around 180 million metric tons produced each year in more than 70 countries. It has been produced industrially since the Nobel Prize-winning Haber-Bosch process was invented in 1913. Around 80% of manufactured ammonia is used as a building block for nitrogen fertilizers, supporting food production for half the world's population.

Beyond fertilizer, ammonia is used in a broad range of applications worldwide. It is a feedstock for manufacturing textiles, polymers, explosives, electronics, pharmaceuticals, and cleaning products; it is one of the world's most important refrigerants; it is used to reduce industrial and tailpipe NO_X emissions; and it is used to disinfect drinking water.

Ammonia (NH_3) is manufactured by fixing nitrogen from the air with hydrogen, which is largely produced using gas or coal today. As a result, fossil-based ammonia production currently accounts for a substantial amount of the world's global greenhouse gas emissions[1]. The Haber-Bosch process is often considered energy-intensive and cost-intensive but the vast majority of the energy inputs,

[1] The IEA *Ammonia Technology Roadmap* reports that ammonia production accounted for 450 million tons (1.3%) of global CO_2 emissions in 2021 (https://www.iea.org/reports/ammonia-technology-roadmap). According to the EU's *EDGAR - Emissions Database for Global Atmospheric Research*, if the global ammonia sector was a country, in 2021 it would have been the sixteenth highest CO_2 emitter, between Türkiye (467 million tons) and Mexico (442 million tons) (https://edgar.jrc.ec.europa.eu/report_2023?vis=co2tot#emissions_table).

CO_2 emissions, capital, and operational costs are actually related to hydrogen production – the synthesis of ammonia from hydrogen requires relatively small additional effort and investment.

The need for decarbonization

Left unchecked, the changing climate poses significant environmental, economic, public health, and security threats to countries and their populations around the world. As a result, governments, industry, and civil society are working to reduce emissions in line with the Paris Agreement, limiting global heating to 1.5°C and reaching net-zero emissions by 2050.

The AEA is committed to enabling the global ammonia value chain to achieve net-zero by 2050 and acts to accelerate the energy transition that is already underway.

The AEA and its members believe that ammonia, an energy-intensive commodity, will play a unique role in achieving net-zero. This includes not only the deep decarbonization of the existing ammonia sector by 2050 but also the adoption of low-emission ammonia in new applications, enabling other sectors to reach net-zero. This is a substantial undertaking.

To succeed, the nascent ammonia energy sector will require significant capital investment; increased availability of safe technologies for production, handling, and use of ammonia; improvement, expansion, and conversion of infrastructure; improved durability, consistency, and development of policies; and strong demand signals that develop swiftly into clear purchasing commitments.

Ammonia's role in achieving net-zero

While ammonia can enable deep decarbonization, it is not a silver bullet. To achieve net-zero, many levers of decarbonization must be applied together, including the massive and rapid expansion of renewable electricity generation and carbon sequestration.

There will be a significant role for fuel molecules in the net-zero economy. The simplest carbon-free fuel molecule is hydrogen, but hydrogen is difficult to store and move. This is why hydrogen derivatives like ammonia have such an important role to play.

As an energy-dense molecule, ammonia can be used to move hydrogen or electricity (an "energy carrier"). Compared to shipping hydrogen or using a high-voltage transmission line, ammonia is often easier and more efficient to transport over long distances. Similarly, storing hydrogen or electricity in batteries for long durations can be very difficult, whereas ammonia can be stored indefinitely at a low cost. The ammonia molecule enables us to move energy to the place and time that it is needed.

As a carbon-free molecule, ammonia can be combusted or converted to produce power without causing CO_2 emissions. While this has the potential to produce pollutants such as NO_X, N_2O, and unburnt NH_3, mature technologies will mitigate these emissions to meet existing regulatory thresholds. The optimal applications for ammonia energy will vary by region but may include power generation (peaking, seasonal, and off-grid); industrial heat (steel, cement, glass); heavy

transportation (rail, trucks, and off-road vehicles), maritime shipping (deep-sea and inland waterways), hydrogen imports, and energy storage and stockpiles.

Prioritizing safety and environmental stewardship

As we work toward net-zero, the ammonia energy sector faces broader sustainability imperatives beyond CO_2 emissions. Safety is essential throughout the entire value chain because of the hazardous properties of ammonia. We have been producing, distributing, and using ammonia for more than 100 years, so these hazards are well known. Mature technologies, best practices, standards, and regulations are established that minimize both the likelihood and the consequence of ammonia incidents.

Environmental safety is also a prerequisite for the adoption of ammonia energy. Some of these issues are well understood and regulated already, providing technology developers with clear targets for environmental performance (for example, atmospheric emissions of NO_X and N_2O). Other issues require further research (for example, a large-scale ammonia spill in open water). With models, tests, pilots, and demonstrations, these hazards can be identified and mitigation measures developed – and, throughout, valuable experience can be applied from the existing industry.

This transfer of knowledge is essential for the responsible adoption of ammonia in new applications. The AEA plays an important role by facilitating this knowledge transfer, enabling all participants in the value chain to understand and manage the hazards of ammonia, and supporting the development of standards and regulatory frameworks in these sectors.

The role of the AEA

Consistent with global antitrust standards, the AEA's activities are organized across four strategic pillars:

Knowledge stewardship

- Creating, collecting, organizing, and disseminating relevant information;
- Providing thought leadership around key issues;
- Developing materials and toolkits for communicating with decision-makers, researchers, and the general public;
- Educating via publications, presentations, and events.

Collaboration

- Providing opportunities for member companies and partner organizations to connect and collaborate;
- Supporting public-private partnerships between governments, international organizations, industry, and other stakeholders.

Program development

- Developing strategic programs that unlock potential for ammonia energy, including:

- Establishing an Ammonia Certification System to enable differentiation in the marketplace for low-emission ammonia, enhance credibility throughout the supply chain, facilitate cross-border trade, and support alignment between multiple certification schemes, standards, and regulations;
- Sharing and amplifying best practices around safety and supporting the development of new best practices where there are gaps.

Advocacy

- Promoting the continued safe use of ammonia, from production and storage through transportation and end use;
- Promoting alignment and mutual recognition between certification schemes and regulatory frameworks;
- Engaging with governments, regulatory bodies, and intergovernmental agencies;
- Supporting the creation of durable and supportive policy frameworks that:
  - establish consistent, stable, and clear environmental targets supported by appropriate regulations;
  - recognize the roles of ammonia in achieving net zero;
  - support the advancement and deployment at scale of relevant technologies;
  - stimulate supply and demand for low-emission ammonia, both within countries and across borders;
  - encourage long-term investment throughout the ammonia value chain.