Power to Ammonia - Gasoline synthesis from H_2 and N_2 by using water electrolysis and Air Separation

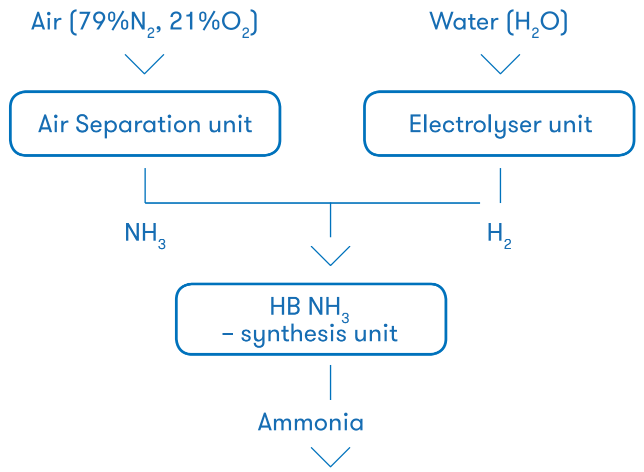
European Association for Storage of Energy

Chemical Energy Storage

1. Technical description

A. Physical principles

Hydrogen is produced by water electrolysis while nitrogen is separated from air via an Air Separation Unit. Both gases are converted to ammonia by using the Haber Bosch reaction. The efficiency is up to 50-55%.



B. Important components

The main components are the following:

- Electrolyser unit:
  - Pressurised alkaline electrolyser, or
  - High-temperature solid oxide electrolyser, or
  - Proton exchange membrane (PEM) electrolyser
- Air Separation unit:
  - Amine based absorption/desorption process as known from chemical processes
- HB NH_3 - synthesis unit:
  - Conversion of hydrogen and nitrogen to ammonia via Haber Bosch process

C. Key performance data

Power range	1MW-1GW
Energy range	1MWh-several GWh
Discharge time	n.a.
Operating hours	8500h/year
Life Cycle	30 years
Reaction time	Sec
Efficiency	50-55%
Energy density	5,2MWh/t
CAPEX: energy	n.a.
CAPEX: power	1,9 – 2,9 m€/MW

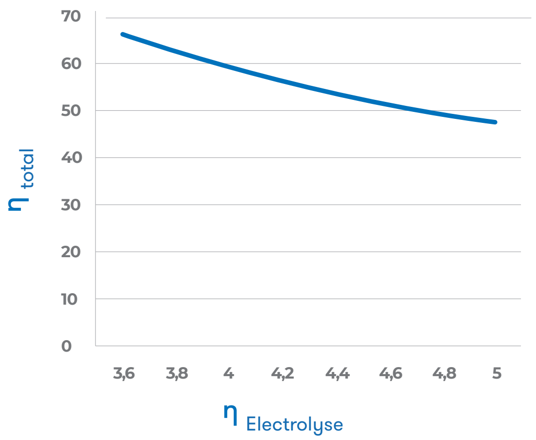
D. Design variants

Different design variants of the power to ammonia process are mainly defined according to the on-site availabilities of the feed stocks hydrogen and nitrogen, respectively. The Haber Bosch reactor is the core component and therefore always needed.

2. State of the art

The concept of hydrogen to ammonia by using water electrolysis and the Haber Bosch chapter would be a first-of-its-kind plant. However, the technology is fully developed and almost all necessary sub-units have references at industrial scale with sufficient operational experience. The only unit which is not already in industrial operation related to the needed size for future plant designs is the Haber Bosch reactor. Consequently, several reactor units have to be operated in parallel in order to achieve higher production rates.

So it can be stated that the technical risk can be reduced to a scale which is in the same range as it is normal for complex industrial plants. The efficiency of the whole process is directly correlated to the efficiency of the electrolyse unit – see the graph below.



3. Future developments

- Haber Bosch reactor unit: up-scaling and further development in order to achieve higher product capacities.
- Plant: build first-of-its-kind plant in order to achieve experience for future plants and improvement of the total process.
- Similar technology for gasification plants using biomass: Increasing of the carbon conversion to nearly 100% by addition of hydrogen to raw syngas (Power to fuel as a sustainable business model for cross-sectoral energy storage in industry and power plants).
- The stored ammonia will be used as fuel instead of natural gas. No CO_2 will be released when ammonia is burned.
- Development of new reactor designs for process intensification, leading to improvements in reaction kinetics, energy efficiency and decrease in capital costs.
- Development of new catalysts for more durable and cost-effective processes.

4. Relevance in Europe

The EU has recently adopted changes [i, ii] to the Renewable Energy Directive (RED) and Fuel Quality Directive (FQD). The amended directives now include a new category of renewable fuels from "non-biological sources" other than biofuels. Member States are each required to have at least 10% of their transport fuels come from renewable sources by 2020 according to the RED; the amended RED version made it possible for renewable fuels from "non-biological sources" as well as Carbon Capture and Utilisation (CCU) using renewable energy sources to count twice their energy content towards this target. The FQD demands a 10% reduction of CO_2 emissions from fuels and electricity used in transport before 2020. The mismatch between demand for electricity and the supply of renewable electricity increases the pressure on regulators and generators to expand transmission grids to transport electricity from regions with oversupply to regions with high demand or provide energy storage to shift the supply of renewable energy from hours with excess supply to hours or establish energy storage to shift the supply of renewable energy from hours with excess supply to hours with excess demand. Storing excess hydrogen as ammonia is a possibility to simplify the transport and make it more economical. Ammonia does not release CO_2 when it gets burned, which supports the aims from the EU.

5. Applications

- Balance excess capacity and RES from power plants, waste incineration or industry with existing technology.
- Provide flexibility services to the grid through a smart management of process energy consumption.
- Build power to ammonia plants next to an existing industrial operation.
- Achieve the targets of the Renewable Energy Directive (RED) and Fuel Quality Directive (FQD)
- Find the right fit between available power, utilisation factors, CO_2 sources, infrastructure, and offtake distribution.

6. Sources of information

- Analysis of Islanded Ammonia-based Energy Storage Systems, René Bañares-Alcántara[1], Gerard Dericks III[2], Maurizio Fiaschetti[2], Philipp Grünewald[3], Joaquín Masa Lopez[1], Edman Tsang[4], Aidong Yang[1], Lin Ye[4], Shangyi Zhao[1]
- Über die Verwendung von Ammoniak als Treibstoff, Rudolf Tanner
- Green Ammonoia, Tim Hughes[5], Ian Wilkinson[5], Edman Tsang[6], Ian McPherson[6], Tim Sudmeier[6], Josh Fellowes[6], Fenglin Liao[6], Simson Wu[6], ,Augustin Valera-Medina[7], Sebastian Metz[8]

i Council Directive (EU) 2015/652 of 20 April 2015 laying down calculation methods and reporting requirements pursuant to Directive 98/70/EC of the European Parliament and of the Council relating to the quality of petrol and diesel fuels

ii Directive (EU) 2015/1513 of 9 September 2015 amending Directive 98/70/EC relating to the quality of petrol and diesel fuels and amending Directive 2009/28/EC on the promotion of the use of energy from renewable sources

[1] Department of Engineering Science
[2] Smith School of Enterprise and the Environment
[3] Environmental Change Institute
[4] Department of Chemistry
[5] Siemens Corporate Technology
[6] University of Oxford
[7] University of Cardiff
[8] STFC