# Sustainable Production of Ammonia solely using Solar Power, Water, and Air


## Summary

A process is proposed capable to produce ammonia solely from sun, water and air and therewith promising to replace the million-ton consumption of natural gas with solar production of hydrogen and nitrogen. While several routes for solar hydrogen production were important research subjects for decades, an innovative and sustainable nitrogen generation is still missing. Our approach to produce nitrogen is based on a novel air separation: a thermochemical cycle based on a redox material driven thermally by concentrated solar radiation. The results of the redox material, which was carried using numerical methods and experimentally with a TGA, will be discussed as well as the results of modelling key components and the description of the entire process.



KEYWORDS: fertilizer, hydrogen, solarthermal, thermochemical, redox material, air separation


## 1. Introduction

The yearly demand for cereals for both, food and animal feeding, is projected to reach some 3 billion tonnes by 2050, up from today's nearly 2.1 billion tonnes [Toml-13]. Food production is strongly associated with the use of synthetic fertilizers that mainly rely on ammonia which, up to now, is produced almost exclusively from fossil fuels in the Haber-Bosch process [Toml-14]. With a global production capacity of almost 200 million tonnes per year, ammonia is the most produced chemical substance. Facing fossil fuel depletion and upcoming CO2-emission goals, on the one hand, and increasing ammonia consumption due to global population growth and biomass-based fuels, on the other hand, emphasize the demand of a sustainable way to produce ammonia that solely relies on renewable energy sources. We propose a novel process that produces the precursors nitrogen and hydrogen solely from air and water, respectively, using solar heat.

## 2. Discussion

The process consists of two thermochemical cycles based on redox materials and provides the gases $N_2$ and $H_2$ to a Haber-Bosch process (see Figure 1).

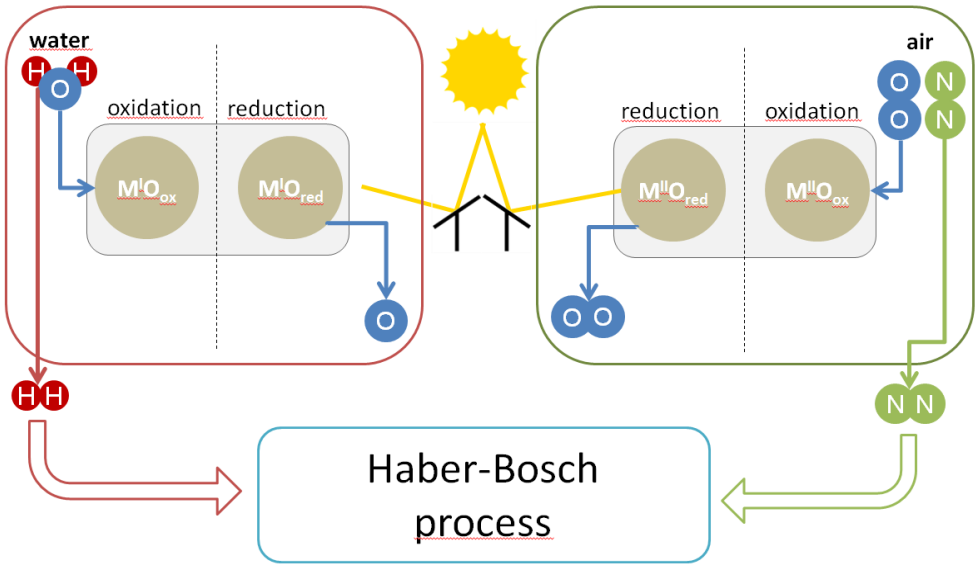


**Figure 1: Schematic of the two redox cycles solarthermally producing the precursors nitrogen and hydrogen for a Haber-Bosch process.**

From a research perspective, identification and further development of materials suitable to perform the redox reactions at feasible conditions is one of the current tasks. This is especially the case for the innovative step of thermochemical nitrogen production. Based on thermodynamical calculations, a comprehensive assessment of suitable redox materials will be presented. The hydrogen production step is already investigated for years and successfully tested on a pilot scale. However, further development of the material and the reactor technology is required. Besides this experimental work, a comprehensive model of the entire process will be presented that determines the potential of this concept but also identifies the major research questions concerning the implementation of a sustainable nitrogen and hydrogen production in existing ammonia production plants.

## 3. Conclusions

The proposed concept opens up a novel research field that combines the upcoming technologies of solarthermal chemistry based on redox materials with industrial scale chemical processes. Research on both, suitable materials and reactor concepts provides a basis for this novel technology and allow for establishing the overall process, which integrates the Haber-Bosch process as well as further downstream processing. Hence, solely using air, water and solar power, this technology enables the sustainable production of fertilizer.

## 4. References

Tomlinson, I; Doubling food production to feed the 9 billion: A critical perspective on a key discourse of food security in the UK; Journal of Rural Studies; 29(0):81-90; 2013.

Tomlinson, I; Agriculture: sustainable crop and animal production to help mitigate nitrous oxide emissions; Current Opinion on Environmental Sustainability; 9-10:46-54; 2014