Economic and environmental assessment of small-scale Haber-Bosch and plasma-assisted ammonia production pathways

Jose Osorio-Tejada[a], Nam N. Tran[b], Volker Hessel[ab]

[a]*School of Engineering, University of Warwick, Coventry CV4 7AL, UK*
[b]*School of Chemical Engineering and Advanced Materials, University of Adelaide, Adelaide SA 5005, Australia*

Abstract

Ammonia synthesis using the Haber-Bosch (HB) process is one of the most important inventions of the last century due its contribution to agriculture. Yet, this process requires a lot of energy and releases carbon emissions since hydrogen input is obtained by steam methane reforming and the reaction performed in harsh conditions. In addition, given that this process highly depends on non-expensive natural gas, ammonia production is concentrated in few countries at large-scale plants, adding emissions due to transportation. Distributed plants next to farmers can reduce these impacts, as well as reduce large storage needs, shortage risks and price volatility of imported fertilizers, promote local employment and bespoke production. Mini HB plants have been proposed, but they still need high pressure and heat, mainly produced by fossil sources. A proposed alternative is a non-thermal (NT) plasma reactor operating under ambient conditions, using only electricity. Yet, this technology has only reached energy efficiencies below 20%, whereby its high electricity consumption makes it more expensive than the conventional pathway. The feasibility of these emerging technologies can be promoted by the internalization of environmental benefits of its products life cycles in their economic analyses. In this sense, a life cycle assessment of different ammonia production pathways is performed in order to quantify, from cradle-to-utilization, credits of avoided emissions in the production, storage and transportation phases, by-products utilization, use of local renewable resources, reduction of product wastes, and soil beneficiation. Different scenarios are analysed for centralized and distributed ammonia production in Australia for the conventional large-scale HB process, alternatives using mini-HB reactor supplied by hydrogen from water electrolysis and thermal plasma methane pyrolysis, and the NT plasma-assisted synthesis supplied by water electrolysis, using different renewable energy sources according to the location. The best energy sources and plant configurations for each environmental impact category would be identified and their characterized results monetized and internalized in costing analyses for each alternative, which can contribute to the deployment of green ammonia distributed production.

Keywords: Plasma; LCA; fertilizers; ammonia.