Plasma-assisted Processes for the Transformation of Ammonia Manufacturing towards Local, On-Demand Manufacturing

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The Haber-Bosch (HB) process, the main method for ammonia (NH_3) production, contributes to near 2% of the global carbon emissions. The global supply chains recently has come to the edge of disruption. This asks for alternative ways of production with low emission of carbon dioxide and more resilient production. Plasma processing uses renewable energy and activates renewable, hardly otherwise reactive molecules, and this part of the concept for electrification of chemistry. Yet, plasma suffers from low energy efficiency. One way of out this problem might be a micronisation of plasmas to 'microplasmas'.

The presentation will provide examples of using different kind of microplasma designs for the synthesis of ammonia and other products from renewable sources such as air and water and using renewable energies such as wind, solar and biomass. The microplasma reactors include a multipyramid microvolume reactor for electrical field intensification at the tips, a microjet plasma reactor for submerged jet gas-liquid operation, and a gas-liquid 'microbubble plasma reactor'. The latter does produce directly ammonium- and nitrate containing fertilizing solutions opening the door to an at-farm net-zero fertigation production.

In the context of what has been mentioned above, distributed plants next to farmers and fed by renewable energy can reduce emissions from transport, as well as NH_3 storage, shortage risks, and price volatility. Multi-objective optimization was used to address the economic potential of distributed plants across Australia. Results showed that ammonia can be produced at $317/ton at a regional scale using high temperature plasma hydrogen generation which could be competitive to the conventional production model if credits in terms of lead time and carbon footprint were considered, Fig. 1 [1]. Considering that the economic viability of small-scale plants can be promoted by their environmental benefits, life cycle assessments of the different NH_3 supply chains were performed (Fig. 1). The carbon footprint of centralized production was up to 2.96 kg.CO_2- eq/kg.NH_3, where 29.3% corresponded to transport. Local plants using electrolysis and HB loops obtained rates of 0.12, -0.52, and -1.57 kg.CO_2-eq/kg.NH_3 using solar, wind, and biogas sources, respectively [2]. Regional plants using high temperature plasma instead of electrolysis obtained its best rate of -0.65 kg.CO_2-eq/kg.NH_3 using biogas. At farm electrolysis-based plants feeding novel non-thermal plasma NH_3 synthesis reached a rate of -1.07 kg.CO_2-eq/kg.NH_3, using solar energy.

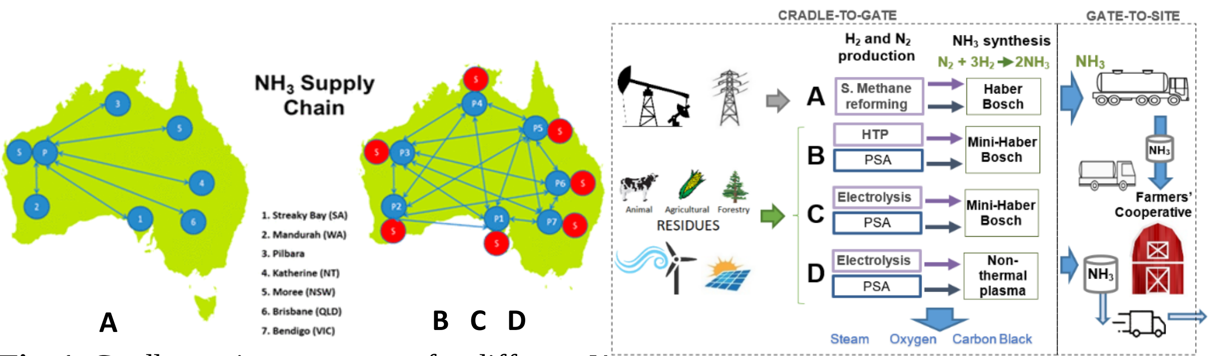

Fig. 1. Cradle-to-site assessment for different NH_3 production pathways in Australia

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[3] J. Osorio-Tejada, N.N. Tran, V. Hessel, STOTEN 826 (2022) 154162.