Power-to-ammonia pathways to decarbonize the agriculture, transportation, and energy sectors

Xiao-Yu Wu*, Carlo Cunan, Milind Jain
Department of Mechanical and Mechatronics Engineering, University of Waterloo, Waterloo, Canada
*xiaoyu.wu@uwaterloo.ca

ABSTRACT

Ammonia is a versatile chemical that is distributed and traded widely as a commodity for the fertilizer and refrigeration industries, and it also has the potential to be a low-emission fuel, hydrogen carrier and energy storage medium. Converting clean electricity to ammonia (i.e., power-to-ammonia, or P2A) is a critical process to decarbonize the use of ammonia in agriculture, transportation, and energy sectors. To understand the viability of P2A, we conducted a techno-economic analysis to study the electrified ammonia production process. The levelized cost of ammonia was found to be highly dependent on the electrolyzer efficiency and the plant’s capacity factor. Then, we designed a P2A plant using offshore wind power from Sable Island, Nova Scotia. Even though the offshore wind farms in Atlantic Canada are expected to have high-capacity factors, we still found it necessary to connect the plant with the electrical grid to maintain high ammonia outputs. Grid-connection, however, may raise the carbon intensities of the P2A process to a higher level than the conventional fossil-fuel based ammonia production. Furthermore, we studied the potential economic benefits and risks of using excess electricity for P2A in a combined ammonia use scenario, including local fertilizer sales, export, and energy storage. Results show that with higher prices and larger export demands for low-carbon ammonia, as well as technology development, the combined use scenario will be profitable compared with selling excess electricity at low prices.