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Carbon and Nitrogen Footprint Optimization of Ammonia as an Automotive Fuel

D. Angeles1, K.A. Are1, L. Razon1, R.R. Tan*1

1De La Salle University, Philippines

Abstract

The transportation sector is one of the primary contributors to the global CO₂ emissions. Recent research suggests that ammonia is a potential alternative automotive fuel due to its favorable storage properties and the mature infrastructure for its production and distribution. However, there remains the question of whether ammonia can be a sustainable alternative automotive fuel on a life-cycle basis. The energy-intensive production process and the need for a secondary fuel are two major issues with the use of ammonia. A comparative well-to-wheel life cycle assessment of selected ammonia-based fuel cycles is done. Two conventional fossil fuel-based ammonia production processes and two proposed biomass-based processes are considered, namely: steam reforming, partial oxidation, a cyanobacterial (Anabaena) process, and a willow-based (Salix) process. The end-use is propulsion of a light-duty internal combustion engine vehicle, and the functional unit is 1 km of distance driven by a such a vehicle. Three types of secondary fuels are considered: gasoline, diesel, and dimethyl ether. Using the carbon and nitrogen footprint as the primary environmental performance indicators, fuzzy life cycle optimization is applied to determine the optimal system configuration. Results show that ammonia produced from the biomass-based process with dimethyl ether as the secondary fuel results in the best well-to-wheel fuel pathway. Sensitivity analysis shows that the end-user vehicle fuel economy has the most significant influence on the optimal solution, which means that concerted efforts to improve ammonia-based fuel cycles must be focused on the end-use phase.