

# Accepted Manuscript

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Donna A. Angeles, Raymond R. Tan, Kathleen B. Aviso, Kristian Ray Angelo G. Are,  
Luis F. Razon



PII: S0959-6526(18)30804-7

DOI: [10.1016/j.jclepro.2018.03.143](https://doi.org/10.1016/j.jclepro.2018.03.143)

Reference: JCLP 12401

To appear in: *Journal of Cleaner Production*

Received Date: 20 December 2017

Revised Date: 6 March 2018

Accepted Date: 14 March 2018

Please cite this article as: Angeles DA, Tan RR, Aviso KB, Are KRAG, Razon LF, Fuzzy optimization of the automotive ammonia fuel cycle, *Journal of Cleaner Production* (2018), doi: 10.1016/j.jclepro.2018.03.143.

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## Fuzzy Optimization of the Automotive Ammonia Fuel Cycle

Donna A. Angeles, Raymond R. Tan,  
Kathleen B. Aviso, Kristian Ray Angelo G. Are, Luis F. Razon\*

Department of Chemical Engineering  
De La Salle University,  
2401 Taft Avenue, 0922 Manila, the Philippines

\*corresponding author; e-mail: [luis.razon@dlsu.edu.ph](mailto:luis.razon@dlsu.edu.ph), ORCID: 0000-0002-0918-4411

### Highlights

- The fuel cycle of ammonia fuel is optimized.
- Four alternative production pathways and two secondary fuels are considered.
- All ammonia pathways have higher nitrogen footprint than conventional fuels.
- Ammonia pathways from biomass have lower carbon footprint than fossil fuels.
- The optimal path uses cyanobacteria-based syngas production with diesel co-fuel.

### Abstract

Ammonia has favorable properties for use in automotive fuel applications, such as good storage properties and mature production and distribution infrastructure. However, the sustainability of ammonia as an alternative automotive fuel remains in question, due to the significant environmental impact of conventional production technology and the need for a secondary hydrocarbon fuel to promote combustion when used in internal combustion engines. The two commercially implemented processes for ammonia: steam reforming and partial oxidation, a wood-based syngas process and a cyanobacterial process combined are considered in the life cycle optimization of the ammonia-based fuel system. It is assumed that the functional unit is 1 km travelled by a representative light-duty internal combustion engine vehicle. Two conventional fuels are also considered as secondary fuel in this study, namely, gasoline and diesel. Fuzzy linear programming is applied using carbon and nitrogen footprint as environmental objectives. The cyanobacteria-based process combined with gasoline as the secondary fuel was identified as the optimal solution. The most significant parameter was the end-user vehicle fuel economy. Hence, more attention must be given to the improvement of vehicle technology to enable the sustainable use of ammonia for transportation.

**Keywords:** ammonia, fuel, life-cycle optimization, carbon footprint, nitrogen footprint

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