ISSN: 2692-5397
Modern Concepts in Material Science
DOI: 10.33552/MCMS.2021.04.000576
Iris Publishers

Review Article

Green Ammonia's Role in Decarbonizing Many Sectors: Its Global Impact and Optimization Associated With Renewable Energy Ammonia: Production and Diversity of Applications

Gabriel Winter[1]*, Antonio Pulido[1] and Lourdes Trujillo[2]

[1]*Institute of Intelligent Systems and Numerical Applications in Engineering (SIANI), ULPGC, Spain*

[2]*Research Team in Economics of Infrastructure, Transport and Tourism (EITT), ULPGC, Spain*

***Corresponding author:** Gabriel Winter, Institute of Intelligent Systems and Numerical Applications in Engineering (SIANI), ULPGC, Spain.

Received Date: June 04, 2021

Published Date: July 02, 2021

Abstract

Hydrogen is the fuel of the future, but it presents serious storage and transportation problems, one of the many solutions is to convert it into ammonia. Which was already used in buses in Belgium at the Second World War (1943). Nowadays, it is emerging as a fuel for certain applications, thermal power plants and vessels for long haul. It is produced via the conventional Haber-Bosch process, which was invented a century ago based on the chemical reaction between hydrogen and nitrogen. This reaction is easily reversible. Green ammonia is produced using renewable energy to produce hydrogen from water electrolysis and nitrogen easily captured from the air. All the aforementioned processes can be linked because of the high degree of complementarity between them. In striving to produce a 'complete installation' with high performance, optimization and artificial intelligence tools are needed to effectively produce, store and consume electric energy, desalinated water, H_2 , N_2 , O_2, and NH3. These facilities can be flexible, allowing a better use of the renewable energy fluctuating, contributing to its integration. The more chemical components to produce, use, store in the same facility and dispatch to the market, the more profitable it will be. It is vital to optimize from the sizing of all the components of the plant, to the decision-making of the quantities to be producing, storing and taking into account multiple technical restrictions, fluctuations in renewable energies production and prices in electricity market.

Keywords: Green ammonia; Hydrogen; Energy carrier; Renewable energy; Decarbonization; Sustainable; Optimal management

Green Ammonia: Production and Diversity of Applications

Storing and transporting hydrogen is very expensive, thus its conversion to ammonia is very useful, due to its capacity to be stored in liquid form (-33.4ºC), at atmospheric pressure, or at room temperature (20ºC) at 8.59 bar. When liquefied, ammonia contains near 50% more hydrogen by volume than liquid hydrogen. There are several methods to produce hydrogen [1].

Green ammonia is obtained from green hydrogen from water electrolysis, nitrogen achieve in an air separation unit. The reputable Haber Bosch synthesis process produces ammonia via the chemical reaction 3H2 + N2 → 2NH3 [2]. The conversion rate for obtaining ammonia, after several passes, is close to 97% [3]. The gases employed must have a high degree of purity [4]. The before chemical reaction is reversible, as ammonia can be dissociated or "cracked" back into hydrogen and nitrogen via endothermic reaction. The cracker efficiency is estimated at around 80% [5,6].

The electrolysis process consumes most electricity, by a considerable margin [7]. For this reason, it is both much more efficient to obtain green hydrogen in locations that have a high renewable resource, like sun or wind. Today in the Canary Islands, due to the little flexibility of conventional generation and the lack of energy storage systems, some of the renewable generation is wasted, which gives this installation added value.

To obtain high levels of decarbonization, green hydrogen and ammonia need to be produced in large quantities (currently, global ammonia production is high, around 176 million tons per year). In particular, this can then be used in the manufacturing of cement, steel, ethylene and fertilizers [2]. As well as many other applications such as cleaning products, refrigeration, pharmaceuticals, and textile manufacturing [8], [9]. Ammonia is expected to be a competitive carbon neutral marine fuel [10].

Furthermore, ammonia can be used in gas turbines, fuel cells or as a combustion group [11]. Recently considerable research effort has been dedicated to combustion engines and fuel cells that employ ammonia and produce H2O and N2; thereby avoiding any greenhouse gas. The emission of NOX is negligible when reduction catalytic selection and reused ammonia are employed.

We must aspire to a complete decarbonization, for this reason we must use renewable electricity to recharge vehicles and operate heat pumps with which to obtain low temperature at high performance. There are other types of transport, which due to their size, or route, will not be easy to be electric. Just as there will be thermal processes that, because they need medium or high temperature, it will not be possible to use a heat pump. In addition, natural resources follow a seasonality, so they will be more abundant at one time and less at another.

Multi-Generation Plant with Green Ammonia Production: Need of the Robust Multi-Objective Optimization

An installation where many chemical components linked in the aforementioned processes are produced simultaneously is of great interest. Some components are input to form other components, thus the diversification of both production and storage will lead to a more efficient and profitable installation. Recent publications present a study in this line, although still in the context of steady-state modelling and optimization, taking into account the fluctuations of renewable energies [12].

The energy in multi-production will be stored in various ways and for different time frames, using comprehensive management software, and a SCADA network that will monitor all production systems, making optimal decisions in real time. The products can go directly to the market or be used as 'ingredients' in a subsequent refurbishment. Fresh water, N2 and O2 wouldn´t be used for energy purposes; but specifically, it could use in business requirements. Anyway, it is easy to find many papers that link desalination and storing water, as a way to store energy. A complete experimental multi-production plant has been recently proposed for Gran Canary, because the island has a strong water shortage and an abundance of sun and wind resources with locations near to the port, to the airport, and to the electricity grid [13].

General Summary

Ammonia is an energy vector that is easy to market, store, transport and use in different ways and in many economic sectors. In order to achieve complete decarbonization, it is necessary to use sustainable electricity as renewable energy in all the processes involved in the production of ammonia. In particular, green hydrogen production. We emphasize that it is important to incorporate all the productions of the chemical components linked to the production of ammonia as possible. Optimal management of these integral installations requires the use of advanced multi-objective methods and artificial intelligence.

Acknowledgement

The author wishes to sincerely thank Canary institutions for their support.

Conflict of Interest

No conflict of interest.

References

1. Deepa Dumbre (2020) Hydrogen Production For Sustainable Environment: Perspective. Modern Concepts and Material Science 3(4): 1-2.
2. The Royal Society (2020) Ammonia: zero-carbon fertiliser, fuel and energy storage. The Royal Society, London.
3. Osman O, Sleptchenko A, Sgouridis S (2020) Scaling the production of renewable ammonia: A techno-economic optimization applied in regions with high insolation. Journal of Cleaner Production, 271.
4. Morgan E, Manwell J, McGowan J (2014) Wind-powered ammonia fuel production for remote islands: A case study. Renewable Energy 72: 51-61.
5. Giddey S (2017) Ammonia as a Renewable Energy Transportation Media. ACS Sustain. Chem Eng 5(11): 10231-10239.
6. Kojima Y, Adachi T (2018) Ammonia as a Hydrogen Carrier for PEM Fuel Cells. In Proceedings.
7. Matthew J Palys, Prodromos Daoutidis (2020) Using hydrogen and ammonia for renewable energy storage: A geographically comprehensive techno-economic study. Computers and Chemical Engineering 136: 106785.
8. Zhang H, Wang L, Van herle J, Maréchal F, Desideri U (2020) Techno-economic comparison of green ammonia production processes. Applied Energy, 259.
9. Palys MJ, Kuznetsov A, Tallaksen J, Reese M, Daoutidis P (2021) A novel system for ammonia-based sustainable energy and agriculture: Concept and design optimization. Chemical Engineering and Processing - Process Intensification 140: 11-21.
10. Korean Register (KR) (2019) Forecasting the alternative marine fuel: Ammonia. KR.

Citation: Gabriel Winter, Antonio Pulido, Lourdes Trujillo. Green Ammonia's Role in Decarbonizing Many Sectors: Its Global Impact and Optimization Associated With Renewable Energy Ammonia: Production and Diversity of Applications. Mod Concept Material Sci. 4(1): 2021. MCMS. MS.ID.000576. **DOI:** 10.33552/MCMS.2021.04.000576.

11. Zac Cesaro, Matthew Ives, Richar Nayak-Luke, René Bañares-Alcántara (2021) Ammonia to power: Forecasting the levelized cost of electricity from green ammonia in large-scale power plants. Applied Energy 282: 16009.

12. Kevin Verleysen, Diederik Coppitters, Alesandro Parente, Ward De Paepe, Francesco Contino (2020) How can power-to-ammonia be robust? Optimization of an ammonia synthesis plant powered by a wind turbine considering operational uncertainties. Fuel 266: 117049.

13. CEANI-SIANI Division of the Institute of Intelligent Systems of the University of Las Palmas de Gran Canaria (ULPGC).