Life Cycle Assessment of Green Ammonia in Solid Oxide Fuel Cells for Sustainable Heat and Power Generation

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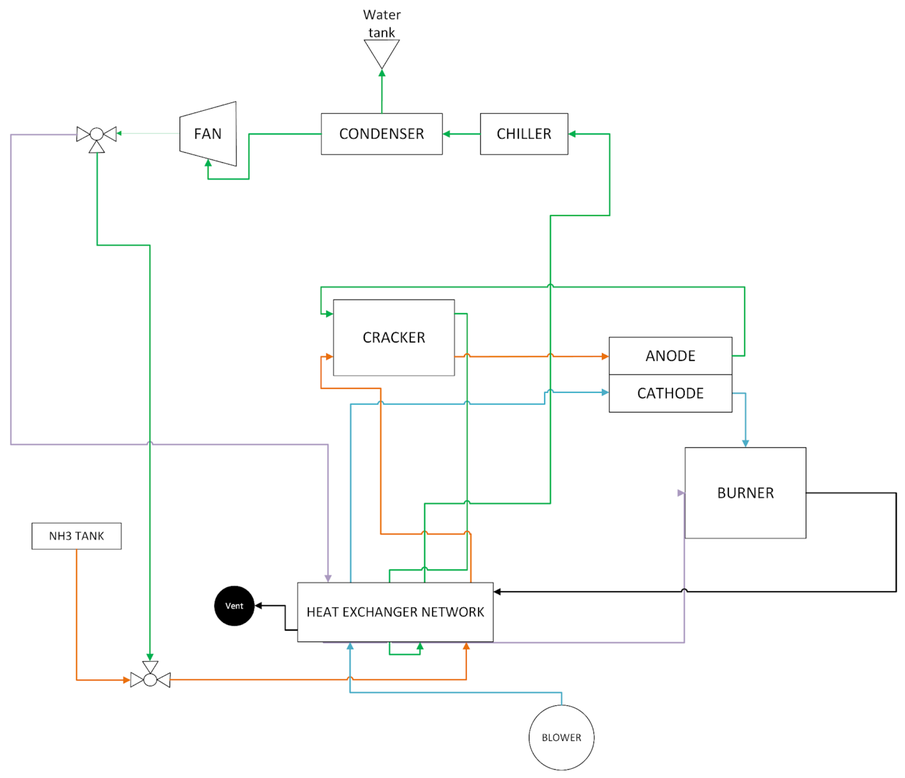
Abstract

This study assesses the environmental impacts of utilizing green ammonia in Solid Oxide Fuel Cells (SOFCs) for sustainable heat and electricity generation. A cradle to gate Life Cycle Assessment (LCA) is performed using OpenLCA, utilizing ReCiPe2016 midpoint (H) methodology for a functional unit of 1 kWh of electricity generated. Results show that SOFC powered by green ammonia has lower climate change impact and reduced fossil resources use compared to fossil fuel-based electricity generation. However, material resource use is higher due to the green ammonia production and the manufacturing of the system components. Future technological improvements could enhance the sustainability of green ammonia-based power generation.

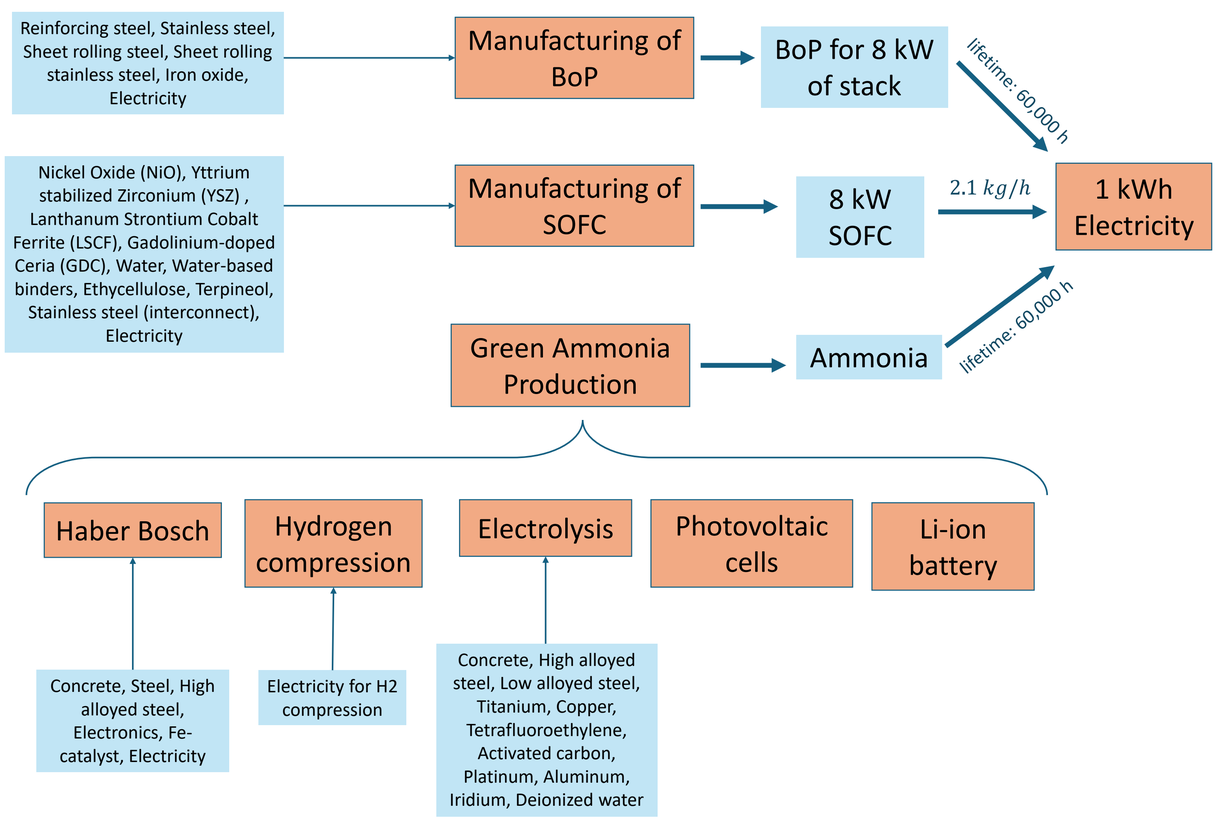
Introduction

Green ammonia, produced from renewable hydrogen, is a promising energy carrier for decarbonizing power generation. The project AMON "Development of a next generation AMmONia FC system" is aimed at developing a novel system for the utilization and conversion of green ammonia into electric power at high efficiency using a solid oxide fuel cell system. The innovative system includes the fuel cell (operating at temperatures in the range 650-750 °C), ammonia cracker, burner, and anode gas recirculation, as well as the whole balance of plant (BoP). The SOFC employed is based on an 8 kW G8x stack by SolydEra.



Methodology

This cradle to gate LCA uses OpenLCA based on Ecoinvent database and applies ReCiPe 2016 midpoint (H) methodology. Data for the 8 kW SOFC is based on SolydEra's technology, with material substitutions where used materials are missing in the database [1]. Green ammonia production is modeled using PV powered electrolysis and the Haber-Bosch process according to the literature [2]. Moreover, missing BoP data was adapted from the literature [3].

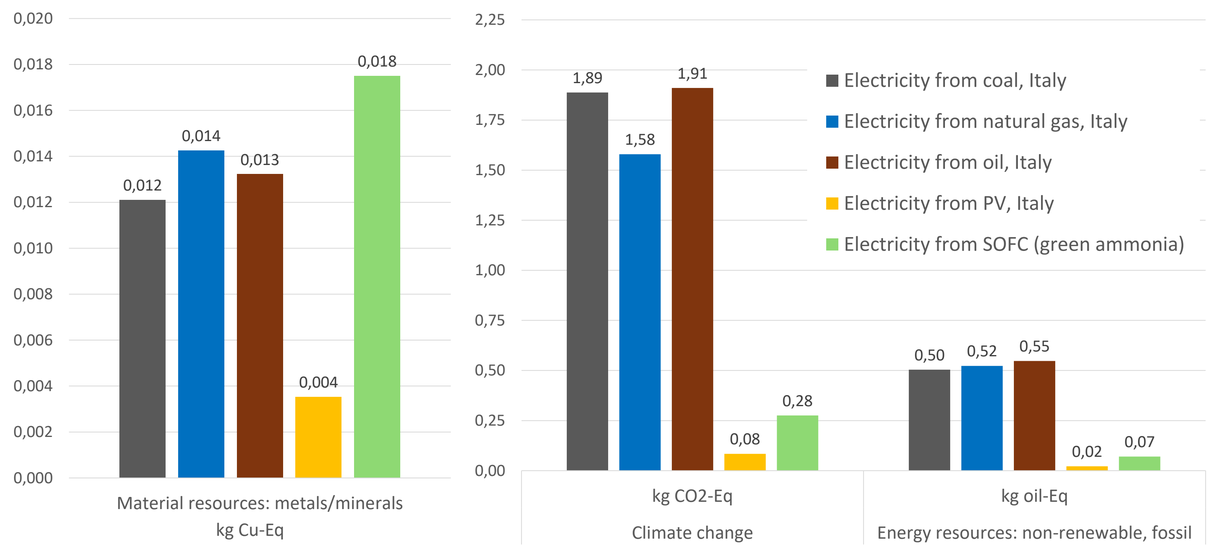


Results

The results show that producing 1 kWh of electricity from green ammonia in a SOFC system has lower environmental impacts compared to fossil fuel-based low voltage electricity (including transformation losses). Particularly, SOFC fed by green ammonia is more environmentally friendly in terms of climate change and fossil resources use. However, the material resources use is higher than that of fossil fuels, with the most significant impacts stemming from green ammonia production (99.2% compared to 0.58% from SOFC and 0.22% from BoP).

Impact category	Reference unit	Result
Acidification: terrestrial	kg SO2-Eq	0.001198
Climate change	kg CO2-Eq	0.275495
Ecotoxicity: freshwater	kg 1,4-DCB-Eq	0.060265
Ecotoxicity: marine	kg 1,4-DCB-Eq	0.079413
Ecotoxicity: terrestrial	kg 1,4-DCB-Eq	5.31947
Energy resources: non-renewable, fossil	kg oil-Eq	0.07062
Eutrophication: freshwater	kg P-Eq	0.00014
Eutrophication: marine	kg N-Eq	2.10E-05
Human toxicity: carcinogenic	kg 1,4-DCB-Eq	0.171479
Human toxicity: non-carcinogenic	kg 1,4-DCB-Eq	0.888513
Ionising radiation	k Bq Co-60-Eq	0.018066
Land use	m^2 *a crop-Eq	0.095507
Material resources: metals/minerals	kg Cu-Eq	0.017497
Ozone depletion	kg CFC-11-Eq	1.11E-07
PM formation	kg PM2.5-Eq	0.000575
Photochemical oxidant formation: human health	kg NOx-Eq	0.0007376
Photochemical oxidant formation: terrestrial ecosystems	kg NOx-Eq	0.0007775
Water use	m^3	0.009187

Material resources, climate change and fossil energy resources for 1 kWh low voltage electricity



Conclusion

Green ammonia is a sustainable energy carrier for long-distance transport. When used in SOFC for electricity generation, it reduces fossil resources use and helps mitigating climate change. However, this technology has high materials usage, primarily in green ammonia production. With future technological improvements, this can be reduced. Overall, this approach has the potential to be a green solution, especially for remote areas, as both SOFC and the balance of plant components can be environmentally friendly.

References

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