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## Article

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# Opportunities for Production and Utilization of Green Hydrogen in the Philippines

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## ABSTRACT

The Philippines is exploring different alternative sources of energy to become energy-independent while significantly reducing the country's greenhouse gas emissions. Green hydrogen from renewable energy is one of the most sustainable alternatives with its application as an energy carrier and as a source of clean and sustainable energy as well as raw material for various industrial processes. As a preliminary study in the country, this paper aims to explore different production and utilization routes for a green hydrogen economy in the Philippines. Production from electrolysis includes various available renewable sources consisting of geothermal, hydropower, wind, solar, and biomass as well as ocean technology and nuclear energy when they become available in the future. Different utilization routes include the application of green hydrogen in the transportation, power generation, industry, and utility sectors. The results of this study can be incorporated in the development of the pathways for hydrogen economy in the Philippines and can be applied in other emerging economies.

**Keywords:** Green Hydrogen, Electrolysis, Renewable Energy, Energy Storage, Sustainable Energy

**JEL Classifications:** O13, Q01, Q42, Q43, Q48

## 1. INTRODUCTION

To limit the average global temperature rise below 1.5 degrees, different countries are taking rapid and far-reaching actions to reduce greenhouse gas (GHG) emissions toward achieving climate neutrality. Various climate mitigation strategies include but are not limited to the deployment of energy-efficient technologies, promotion of low-carbon fuels, optimization of power grid mix, incorporation of the carbon trade mechanism, development of low-carbon supply chain, advocating low-carbon lifestyles, among others (Geng et al., 2018).

Another promising technology is green or renewable hydrogen, from the electrolysis of water using renewable energy (RE), which can be substituted for fossil fuels. Theoretically, green hydrogen can store surplus RE, support decarbonizing hard-to-electrify sectors such as long-distance transport and heavy industry, and substitute fossil fuels as a zero-emission feedstock in chemicals

and fuel production (van Renssen, 2020). In recent years, the rapid growth in interest and investments in green hydrogen is observed in different countries due to stronger climate regulations, decreasing cost of producing hydrogen from clean sources, improvement in the cost and performance of hydrogen technologies, and the availability of technological infrastructure to support a hydrogen energy system (ESMAP, 2020).

Corresponding to the Sustainable Development Goal (SDG) 7 of ensuring access to affordable, reliable, sustainable, and modern energy for all, the country launched its medium-term Philippine Development Plan 2017-2022 of attaining a strongly rooted, comfortable, and secure life by 2040 via the adoption of innovative technologies while ensuring ecological integrity, clean, and healthy environment (NEDA, 2017). One of these technologies includes the use of green hydrogen as an energy source for electricity generation, utilities, and transportation. Recently, the Department of Energy (DOE) signed a Memorandum of Understanding

(MOU) with Star Scientific Ltd., an Australian-based research and development company, to facilitate the country's move towards the production of green hydrogen (DOE, 2021). The company offers its cutting-edge technology called Hydrogen Energy Release Optimizer (HERO) which transforms hydrogen into heat without combustion. With the potential benefits of green hydrogen, the collaboration promises various possibilities to addressing the increasing energy demand while reducing its GHG emissions.

At present, the Philippines is exploring the potential of all possible routes for green hydrogen pathways in the country. This paper aims to provide a primary investigation of the different production and application of green hydrogen in the Philippines. Specifically, we aim at addressing the questions: what are the possible sources of clean and sustainable energy for green hydrogen production; what are the different utilization pathways for green hydrogen; and what government policies facilitate the realization of a green hydrogen economy. We further aim to propose a framework for green hydrogen production and utilization that can be applied in the case country and other developing economies.

## 2. BACKGROUND OF ENERGY SOURCES IN THE PHILIPPINES

The Philippines is a developing country in Southeast Asia with a gross domestic product (GDP) of USD 360 billion and a 5-year average GDP growth rate of 6.56% before the pandemic. While the Philippines is an agricultural country, the agriculture, forestry, and fisheries sector only account for 10% of the economy. The service sector drives the economy with a 61% share followed by the industry sector at 29% share (PSA, 2021). Its main industries include manufacturing; construction; electricity, steam, water, and waste management; and mining and quarrying.

The archipelagic country is composed of 7641 islands interconnected by road and railway, aviation, and maritime transport (Guno, Collera, and Agaton, 2021). It has an almost 110 million population with a growth rate of 1.4% per year. The continuous growth in population and economic development has resulted in a consistently increasing demand for energy for various purposes including utilities, industry, and transportation. While the country has an ample amount of natural reserves of fossil fuels, it is still highly dependent on imported coal and oil resulting in unstable energy security and sustainability (Agaton, 2018).

To address this problem, the country is exploring all sustainable and alternative sources of energy including RE sources (RES). At present, RES accounts for 21% of the total energy mix dominated by geothermal (10%) and hydropower (8%) with limited utilization of wind (1%), solar (1%), and biomass (1%). Considering the geographic location in the Pacific, the country has vast potential of RES capacity from the ocean (170GW), wind (77GW), hydropower (10GW), geothermal (4GW), solar (1.5GW), and biomass (0.5GW) (Guno, Agaton, Villanueva, and Villanueva, 2021). In the 1970s, the Philippines built its first nuclear power plant but never operated after finishing the construction due to safety issues (Agaton, 2017).

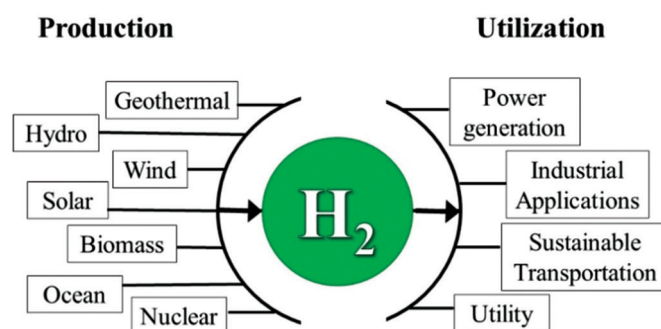
Recently, the DOE signed a deal to explore the potential of hydrogen as one of the alternative sources of energy and help the country address its issues in energy independence as well as reducing GHG emissions. The memorandum of understanding between the government and Star Limited aims to investigate how the HERO technology be used to convert the existing power assets to unlimited zero-emissions hydrogen assets; the viability of increased distribution of zero-emission power using the HERO's Super Critical CO<sub>2</sub> grid network; and desalination options for both existing and new systems throughout the Philippines using the HERO technology (DOE, 2021). Alongside the development of renewable energy infrastructures, the production of green hydrogen from electrolysis is expected to supply cheaper, cleaner, and more sustainable energy carriers for power generation in remote areas, household utility purposes, and as industrial raw materials.

## 3. GREEN HYDROGEN PRODUCTION

The biggest challenge to green hydrogen is that it will require vast amounts of renewable power (van Renssen, 2020). Complementarily, the Philippines' geographic advantage promises a huge potential for renewable energy generation which can be tapped for the production of green hydrogen. Figure 1 illustrates the possible production routes of green hydrogen which include geothermal, hydropower, wind, solar, biomass, ocean, and nuclear.

Geothermal is thermal energy generated and stored in the Earth. It originates from the geothermal gradient between the cooler surface of the Earth and the radioactive decay of minerals from the core producing thermal energy in the form of heat from the core to the surface (Jiang et al., 2017). Currently, it is the most abundant and cheapest RES in the Philippines due to its mature technology and the country's location in the Pacific ring of fire (Agaton, 2018). Additionally, the two most compelling advantages to using geothermal energy are the low or zero carbon emissions making it one of the cleanest energy sources and it can provide power for 24 hours in a continuous manner which other RES cannot (Jiang et al., 2017). Since it can only be used for electricity generation, direct use of heat, and heat pumps, it is reasonable to combine it with other solutions including the production of green hydrogen to store the underutilized energy for future use (Mostafaeipour et al., 2020). Continuous electricity generation at the lowest possible cost makes green hydrogen production from geothermal highly cost-effective and sustainable.

Figure 1: Hydrogen production and utilization



Hydropower is generated from the falling water from a reservoir or flowing water from streams and rivers which are employed to turn the blades of a water turbine to generate electricity (Heidari et al., 2020). Along with geothermal energy, hydropower dominates the RES in the Philippines given its mountainous terrain and abundance of rainwater (Agaton, 2018). Aside from biodiversity loss from the construction of dams, one problem with hydropower is the excess water directed to the spillway which causes erosion, landslide, and flooding the nearby communities especially during rainy seasons (Culaba and Marfori, 2020). On the other hand, this excess energy and water during high-throughput seasons can be tapped to produce green hydrogen, which could supply shortages of energy in remote areas in the country (Nadaleti et al., 2020). The main advantage of hydropower is its utilization at both base and peak load electricity generation as well as its reliability at fast startup which makes it a suitable source of renewable energy for peak load generation (Heidari et al., 2020).

Wind energy is another prime candidate for green hydrogen production specifically from onshore wind farms. Wind energy is produced from the kinetic energy of the natural wind converted into mechanical energy by the wind turbine which generates electric power (Salam et al., 2018). At present, wind energy, albeit with huge potential, makes up a small percentage of the total energy generation mix in the Philippines. With the archipelagic nature of the country, islands with high potential for wind energy production are not connected to the national grid limiting the mass development of wind infrastructures. However, this curtailment can be tapped with the conversion of excessive RE into other types of energy such as green hydrogen (Yan et al., 2018). Additionally, given the intermittent production of RE from wind due to fluctuations in wind speed, green hydrogen can be used to store excess RE as well as to provide additional service to the grid for power balance smoothing (Abdelghany et al., 2020). This sets an advantage of hybrid systems which improve the reliability of the whole system, decrease the cost of implementation and maintenance, and reduce GHG emissions (Rezaei et al., 2019).

Solar energy is another promising source of green hydrogen which could be economically competitive and commercially viable in the next years (Burton et al., 2021). In this system, PV cells are used to create electrical energy and an electrolyzer passes this electric current through water, causing the water molecules to separate into hydrogen and oxygen gases (Ture, 2007). While the neighboring countries in Asia embraced solar energy, the Philippines still underutilized this energy source despite its location advantage in the tropics and great potential to harness solar energy (Guno, Agaton, Villanueva, and Villanueva, 2021). In line with the government's aim to tap this potential by awarding micro- to mini-grid solar projects particularly in remote areas (Agaton and Karl, 2018), this can also be used to produce green hydrogen to provide an additional energy source, household use, as well as a transportation fuel. With the decreasing trend in the cost of solar PV and electrolyzers, hybrid solar-hydrogen energy systems have significant potentialities in electrifying remote communities with low energy generation costs, as well as a contribution to the reduction of their carbon footprint (Dawood et al., 2020).

Ocean energy could be another source of green hydrogen, however, it seemed to be delayed in development in terms of capacity as compared with other renewables. At present, the DOE has identified possible sites for Ocean Thermal Energy Conversion (OTEC), tidal-in-stream, and wave energy in different locations in the Philippines. Ocean wave energy is considered a concentrated form of solar energy as the waves produced by the winds are created from the pressure differences in the earth's atmosphere which are a product of differential solar heating (Quitoras et al., 2018). In this method, a wave energy converter system interacts with the sea waves, converts the kinetic energy into electricity which will be fed in the hydrogen generation system where the received energy is used in the electrolysis of the pre-processed sea water (Yavuz, 2020). While the OTEC is still not mature compared with the wind or solar, co-producing green hydrogen makes electricity production cost from the ocean much cheaper (Banerjee et al., 2017).

Biomass is another renewable and sustainable source of energy that can replace fossil fuels for hydrogen production. As an agricultural country, the Philippines has a great potential to produce hydrogen from biomass as the country is abundant in various agricultural wastes such as livestock manure and plant residues of rice, corn, sugarcane, and coconut; as well as agro-industrial and municipal organic wastes with millions of tons generated per year (Ventura et al., 2021). Various processes for hydrogen production include biomass gasification, pyrolysis, reforming, fermentation, among others (Baeyens et al., 2020; Shahabuddin et al., 2020). These processes may produce CO<sub>2</sub> which is arguably acceptable considering the life cycle analyses of the production is carbon-neutral (Valente et al., 2020). Compared with other hydrogen production routes (including those from fossil fuels), hydrogen from biomass is still considered an economical and promising technology due to its carbon neutrality, environmentally friendly, sustainability, and renewable characteristics (Tan et al., 2020).

Nuclear energy is one of the most economically attractive options for hydrogen production. A nuclear hybrid energy system has the potential to capitalize the production of multiple commodities (electricity and hydrogen) and allowing electricity grid load to produce hydrogen during low electricity prices. Hence, the nuclear reactor can continuously operate at full capacity and can utilize the excess heat and electricity towards hydrogen production which can either be sold for other purposes or converted back to electricity using fuel cells during periods with a higher price (Pinsky et al., 2020). While the Philippines constructed its first nuclear power plant in 1973, it was never operated due to numerous protests related to the threat of nuclear disasters following the Long Mile Island accident, controversies on corruption and substandard quality, and nuclear safety (Agaton, 2017). In recent years, the government is considering rehabilitating the mothballed plant and construct four additional nuclear power plants as a long-term option for an energy source in the country that could also be tapped for the production of green hydrogen.

#### 4. UTILIZATION OF GREEN HYDROGEN

The country's DOE considers a lot of potentials for green hydrogen for the local industry given that it is seen as the fuel of the future.



In line with the Philippine Energy Plan 2012-2030 and the recent MOU, we illustrate in Figure 1 the possible utilization pathways for green hydrogen. These include the transport, power generation, industry, and utility sectors.

Transportation is a key sector in the Philippines that connects its islands through road, rail, maritime, and aviation (Guno, Collera, and Agaton, 2021). At present the country, the sector contributes to 18% of the country's total GHG emissions. In line with the PEP and public utility modernization program, the country is decarbonizing the transport sector by replacing old vehicles with electric, hydrogen-fueled, hybrid, and other low-carbon vehicles in the transport system (Guno, Collera, and Agaton, 2021). For hydrogen-powered vehicles or fuel cell vehicles, the hydrogen can be used as a fuel in a traditional engine which is combusted in a chamber, or used in fuel cells to generate energy that drives an electric motor (Turoñ, 2020). The same mechanism is also applicable for battery-electric and fuel cell maritime transport vehicles which will connect the Philippine islands with zero emissions. On the other hand, its application in the aviation community continues to face complex challenges including the lack of infrastructure required to provide hydrogen fuel for the industry as well as alteration of both aircraft designs and airport operations (Baroutaji et al., 2019). Therefore, the short- to medium-term application in the aviation industry is still not included in the utilization pathways for green hydrogen in the case country.

The power sector dominated by fossil fuels is the main contributor to GHG emissions. Along with the development of localized RES to reduce the emissions from the power sector, the government plans to transform the old coal plants with the HERO systems to green hydrogen plants (DOE, 2021). The MOU with Star also explores the possibilities of co-producing electricity and green hydrogen at onshore wind farms. With the expected penetration of RE, energy storage should also be developed at equal magnitudes. During periods of high supply and low demand, electricity can be transformed into an energy carrier such as green hydrogen which can be tapped during high demand and for several applications in other sectors as needed by different end-users.

The industry sector is another major contributor to the country's GHG emissions. Among the major industries include manufacturing, construction, mining and quarrying, and electricity, gas, and water supply (PSA, 2021). The petroleum refining industry has the highest demand for hydrogen, followed by the production of several chemicals such as ammonia, fertilizer, methanol, and other petrochemical products, and industrial heat source. At present, Pilipinas Shell is constructing integrated blue hydrogen (from fossil fuels with carbon capture) manufacturing facility to improve the competitiveness of the refinery and a dedicated carbon recovery facility will also be set up to convert the by-product of carbon dioxide for industrial purposes or for selling to manufacturers of dry ice or carbonated drinks. The said blue hydrogen will serve as an enabler to green hydrogen utilization when the latter becomes readily available in the Philippine market soon.

The country's dependence on imported fossil fuels, unstable electricity supply, and unreliable power infrastructures have caused longstanding problems in power outages in several

areas in the Philippines particularly the households from remote islands (Agaton and Karl, 2018). Green hydrogen as the energy storage medium can provide a reliable supply of electricity, especially for the communities inhabiting distant locations (Widera, 2020). As a fuel source, it can replace natural gas for household cooking and heating purposes (Scott and Powells, 2020). Finally, it can be used to provide safe and clean water through a hybrid hydrogen-desalination plant which will be particularly beneficial to remote communities with a lack of drinking water.

## 5. CONCLUSION AND RECOMMENDATION

Green hydrogen as an energy carrier and fuel plays a crucial role in total decarbonization towards achieving the climate targets. With the country's abundance of sustainable energy sources, the Philippines sees a huge potential for green hydrogen production. The current study identified various production routes including the electrolysis from geothermal, hydropower, wind, solar, and biomass as well as ocean and nuclear energies once they become available in the country. Complementary to the deployment of different renewable energy sources, green hydrogen can be utilized for the decarbonization of various sectors such as transportation, power generation, industry, and utility.

With the Philippine government's goal of attaining continuous economic growth by 2040 through the adoption of innovative technologies while ensuring ecological integrity, a healthy, and clean environment, the utilization of green or renewable hydrogen as added renewable energy sources could not be timelier and more significant. Moreover, this will be the Government's initiative in attaining Sustainable Development Goal #7 for affordable and clean energy. However, its realization also rests on sustainable governance –leadership anchored into looking after the welfare of the present generation without compromising the well-being of the future generations resulting in the crafting of long-term public policies.

The adoption of this new technology in the Philippines entails the formulation of policies, programs, and initiatives, in addition to the existing renewable energy law and the Philippine Energy Plan 2017-2040, that will facilitate the utilization of these renewable energy sources. To enable the realization of a green hydrogen economy in the country, the government must first intensify the development of infrastructures for renewable energy sources for green hydrogen production; strictly enforce the transport modernization program with the use of more sustainable fuel for transportation; encourage different industry for a circular economy with sustainable production; and accelerate the consumption of more sustainable fuels for household utilities and energy generation particularly in remote communities in the country.

Despite the research's limited analysis, this preliminary study can be used as a basis for further development to investigate various aspects of the green hydrogen roadmap for the Philippines as well as for other developing countries.

## 6. ACKNOWLEDGEMENT

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