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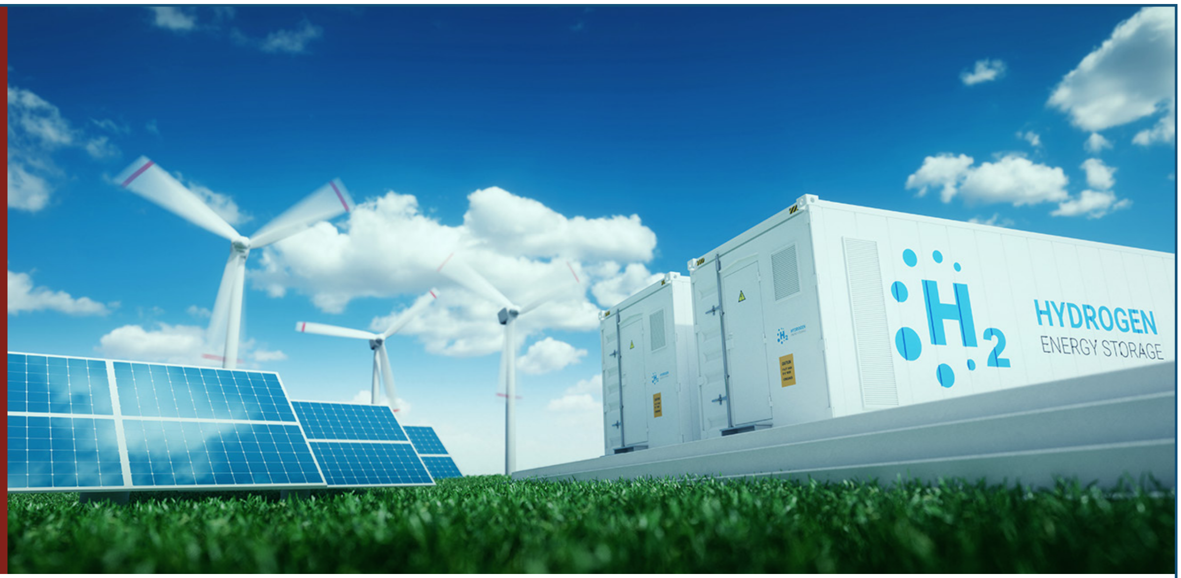

The Role of Hydrogen in ASEAN's Clean Energy Future

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The economic, social, and political dynamics of Southeast Asia have made it one of the fastest-growing regions in the world. However, the Association of Southeast Asian Nations (ASEAN) faces significant challenges in matching energy demand with sustainable supply during its transition to a lower-carbon economy. Reducing global greenhouse gas emissions is high on the global agenda under the Paris Agreement (COP21) and the upcoming UN Climate Change Conference (COP26) in November 2021. Leaders have pledged to pursue alternative fuel pathways, shifting from fossil fuel–based energy systems toward greener energy sources.

While countries in the Organisation for Economic Co-operation and Development (OECD) have achieved a rapid reduction of emissions in response to the climate commitments of COP21, developing Asia still has some way to go to achieve a balance of economic growth, energy affordability, and energy availability. Much of the future energy mix of emerging ASEAN countries will rely on fossil fuels to power economic development. However, there are pathways to ensure the future of economic development with sustainable energy use to harmonize economic growth, social well-being, and environmental sustainability. Renewable energy is a leading solution.

There are several challenges to increasing the share of renewable energy in all sectors at the current level, such as trade-offs between political issues, energy affordability, and access to technologies. Although wind and solar resources are rich, scalable electricity production from these resources faces tremendous challenges due to current practices of system integration in the ASEAN region. Investors in solar or wind farms will face high risks from electricity curtailment if surplus electricity is not used. While many countries have developed battery storage, it remains costly. Hydrogen presents additional opportunities to bridge the current gaps in renewable energy technologies and facilitate clean energy transitions.

This essay examines the potential of renewable or "green" hydrogen as a clean energy source for the ASEAN region's energy mix in the foreseeable future. It first provides context on the traditional production and uses of hydrogen and then outlines regional examples of the fuel's adoption and development. The essay next considers the role that hydrogen can play as an enabler of variable renewable energy deployment and examines questions regarding its cost competitiveness. Finally, it considers key policy implications to accelerate the deployment of hydrogen energy in ASEAN.

Overview of Hydrogen Fuel

For the past two decades, hydrogen has rarely been mentioned by proponents of renewable energy, even as it is frequently used in the ammonia-production, petrochemical, and oil-refining industries. However, its adoption has been accelerating in all sectors. Hydrogen is a versatile fuel that can be produced from many energy sources. It thus presents untapped potential as a clean energy source.

Currently, annual global production of hydrogen is around 120 million tons, of which two-thirds is pure hydrogen and one-third is mixed with other gases.[1] Hydrogen can be produced from either fossil fuels or renewables. As of today, about 95% of hydrogen is produced from coal and gas without carbon capture and sequestration/storage (CCS), known as "gray" hydrogen. Only small amounts are produced with CCS, known as "blue" hydrogen. The gasification of coal can also be used to produce hydrogen, but in terms of its carbon footprint, this process emits roughly four times as much carbon dioxide per kilogram (kg) of hydrogen as using natural gas feedstock. Around 5% of total hydrogen production is from renewables, or green hydrogen.

Two well-known processes to extract hydrogen fuel are steam methane reforming, mainly applied to extract hydrogen from fossil fuels, and electrolysis of water, applied to extract hydrogen from water using electricity. Steam methane reforming is the process used to harvest hydrogen from methane through high temperature steam at 700–1,000 degrees Celsius. Most hydrogen production occurs through this process, which is the most mature technology. Given access to cheap natural gas in the United States and other parts of the world, hydrogen offers a pathway toward

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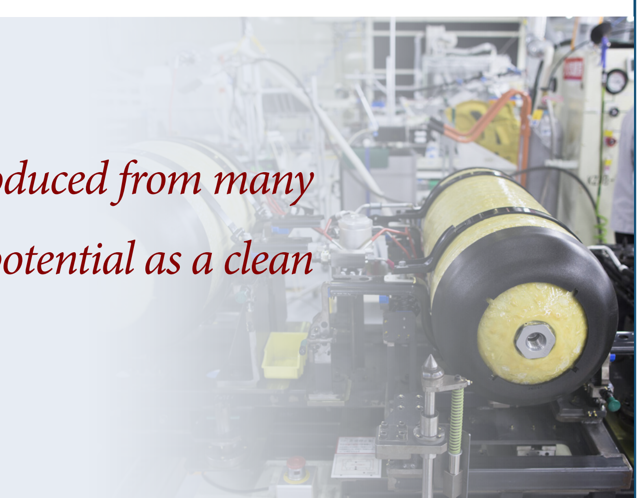

a cleaner economy if steam methane reforming can be augmented with carbon capture and storage.

Green hydrogen is made through electrolysis of water, where electricity is used to split water into hydrogen and oxygen atoms. Hydrogen produced from electrolysis has many advantages that complement battery storage. In particular, it can be stored as a liquid gas, which is suitable for uses in many sectors and is easy to transport.

Examples of Hydrogen Adoption and Development

Although hydrogen fuel is only a small proportion of total global energy consumption, it holds great potential to help abate climate change. Hydrogen has enjoyed political support in many advanced countries, including Germany, the Netherlands, and many other members of the OECD. The European Union's ambition to make Europe the first climate-neutral continent in the world by 2050 will assign a large role for hydrogen fuel. Many hydrogen projects in the OECD will be launched by 2023, including electrolyzers and pipelines for distribution of hydrogen to end users.

The Economic Research Institute for ASEAN and East Asia's research on hydrogen energy over the past two years has identified significant potential for hydrogen energy supply and demand in East Asia. In the ASEAN region, however, hydrogen has yet to formally enter the policy agenda as an alternative fuel.

East Asia. Japan is currently pioneering the renewable hydrogen economy. The production of hydrogen through electrolysis of electricity from renewable sources such as wind, solar, and nuclear could be a game changer to decarbonize emissions. Japan is also the first country in East Asia to adopt a basic hydrogen strategy to ensure that hydrogen production will reach cost parity with gasoline fuel and power generation in the long term.

While the Japanese government and businesses are making efforts to kick-start hydrogen adoption and usage, the realization of a hydrogen society in Japan will largely depend on the competitive cost of hydrogen production and society's willingness to pay. Japan is actively promoting the global adoption of hydrogen for vehicles, power plants, and other potential uses. Likewise, South Korea has set bold targets for hydrogen use, seeking to reach 10% of total energy consumption by 2030 and 30% by 2040 to power select cities and towns.[2]

China has some of the greatest potential to become a major producer and consumer of hydrogen energy in the foreseeable future. It has recently accelerated hydrogen investment support to local industries, with an expected $2 billion to be invested in the next few years.[3] China plans to put in place three hundred hydrogen fueling stations by 2025 and scale up to one thousand stations by 2030 to support the deployment of as many as one million fuel cell electric cars from 2025 to 2030.[4]

United States. In the United States, more than ten million metric tons of hydrogen are produced annually to meet demand, mainly in oil refining for petroleum and ammonia for fertilizer industries. About 95% of hydrogen produced in the United States comes from natural gas feedstock.[5] In January 2020 the U.S. Department of Energy announced that up to $64 million in funding would be made available to support R&D that will encourage market expansion and increase the scale of hydrogen production, storage, transport, and use.

ASEAN. Brunei is taking the lead in ASEAN's hydrogen supply chain, having supplied liquefied hydrogen from the port of Muara to Japan since late 2019. The liquefied hydrogen process involves more energy consumption to cool gaseous hydrogen into liquid hydrogen at -253 degrees Celsius. However, Brunei's hydrogen exports to Japan demonstrate an alternative form of shipping hydrogen using a new technology called liquid organic hydrogen carrier. If the cost of this technology is economically viable, it can pave ways for global market access and address the challenges of hydrogen supply chain barriers. Singapore is also working closely with Japanese companies to explore the development of hydrogen as a new clean fuel to stimulate the economy and reduce carbon emissions. The use of hydrogen is gaining momentum in the transportation sector as well.

Unfortunately, hydrogen has yet to enter the policy agenda in many ASEAN countries as an alternative fuel. The ASEAN Plan of Action for Energy Cooperation (APAEC) Phase II (2021–2025), which was endorsed at the 38th ASEAN Ministers on Energy Meeting in November 2020, provides policy measures to address emerging and alternative technologies, such as hydrogen storage, in order to accelerate the region's energy transition and strengthen energy resilience through innovation and cooperation. APAEC will enable member states to increase their adoption of hydrogen for the foreseeable future, with the goal of fulfilling the OECD's action plan to expand the share of hydrogen in the energy mix.

Hydrogen as an Enabler of Variable Renewable Energy

In ASEAN, intermittent renewables like solar and wind have so far contributed a negligible amount to power generation, standing at only 1.3% in 2017.[6] In optimistic projections, ASEAN's share of wind and solar power is set to rise to 12.3% by 2050. If hydrogen (17.6%) and geothermal (2.2%) sources are included, the overall proportion of energy from renewable sources used in ASEAN stood at 21.1% in 2017. However, wind and solar are the most abundant and promising resources for ASEAN.

Although the production cost of variable renewable energy has drastically dropped in recent years, grid operators still have many misperceptions about these sources being overly expensive and risky. The levelized cost of electricity (LCOE) for solar photovoltaic (PV) farms dropped from 37.8 cents per kilowatt-hour (kWh) in 2010 to 4.3 cents per kWh in 2020 in some places. Similarly, all LCOE for wind and concentrated solar power dropped drastically from 2010 to 2020. Solar PV farm and onshore wind sources have already reached cost levels of 2–3 cents per kWh in some locations with abundant sunshine, such as Saudi Arabia.[7] These misperceptions come from a concern that variable renewable energy production is intermittent and will add costs to grid system stability by requiring backup capacity from conventional gas power plants.[8]

This risk of variable energy output can be minimized if power systems are largely integrated within the country and region.[9] However, plans for an integrated ASEAN power grid and market are progressing slowly due to several reasons, such as regulatory and technical harmonization issues within power grids and utilities. While many member countries are endowed with abundant natural resources for wind, solar, hydropower, or geothermal electricity production, these resources are often far away from demand centers and would require significant investment in undersea transmission cables to transport electricity if developed. In such cases, hydrogen development has the potential to turn 100% of renewably sourced energy into hydrogen for versatile uses in many sectors.

Hydrogen is a potential game changer for the world to reduce emissions, especially in sectors like cement and steel production where decarbonization is difficult. Hydrogen can also allow wind, solar, and other renewable resources to be fully developed. This opportunity yields higher penetration of renewables into the grid; at the same time, surplus electricity during hours of low demand can be used for hydrogen production. A hybrid energy system with other baseload power plants such as hydropower, geothermal, or nuclear is the perfect energy choice. Since hydrogen is a clean energy carrier and can be stored and transported for use in hydrogen vehicles, ammonia and fertilizer, metal refining, heating, and other products and services, hydrogen development is an ideal pathway to a sustainable clean energy system in the ASEAN region as well as the rest of the world.

Hydrogen's Cost Competitiveness

The cost competitiveness of producing green hydrogen is key for the wide adoption of hydrogen in the foreseeable future. The current cost of supplying hydrogen is about three to five times the cost of gas, mainly due to the limited investment in hydrogen supply chains and the lack of a wider adoption strategy for hydrogen use. A large-scale hydrogen-based energy transition from gray and blue hydrogen toward green hydrogen could facilitate a global shift to renewables.

Green hydrogen production costs dropped drastically from $10–$15 per kilogram of hydrogen gas (kg H2) in 2010 to $4–$6 per kg H2 in 2020, and by 2040 the cost of hydrogen could decrease by more than 50% if it is adopted across all sectors.[10] Costs are expected to decline to as low as $2 per kg H2 in 2030, which is competitive with steam methane reforming through CCS and the price of gasoline. The

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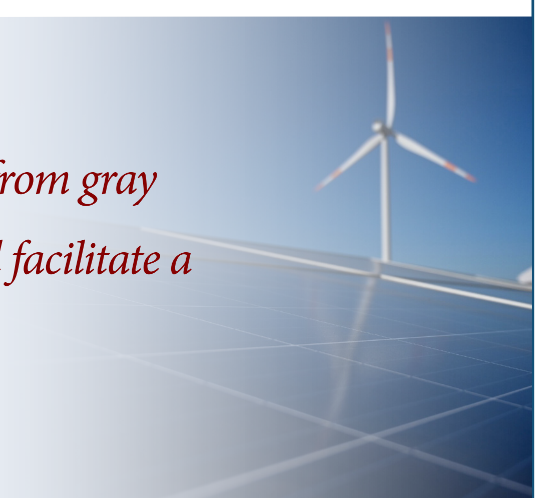

International Renewable Energy Agency (IRENA) also predicted that the cost of electrolyzers will drop by 50% by 2040.[11] If coupled with the falling cost of renewables in general, renewable hydrogen could be the cheapest energy option in the future.

Moreover, the cost of green hydrogen production could decline even more quickly to lower than $2 per kg H2 if the government, business players, and stakeholders join hands to promote the wider use of green hydrogen by allowing more investment and R&D in hydrogen fuels. Investors may look into the industrialization of electrolyzer manufacturing; improvements in electrolyzer efficiency, operations, and maintenance; and the use of low-cost renewable power as hydrogen as enablers to increase the penetration of variable renewable energy into the power grid.

Policy Implications

The energy transition in Southeast Asia will largely depend on the clean use of fossil fuels as the bridge to a clean energy future. Although hydrogen itself is a clean fuel, how that hydrogen is produced is important. As shown above, hydrogen, especially green hydrogen, has a bigger role to play. In particular, it is important for enabling a greater share of intermittent renewable energy such as wind and solar into the power mix and further accelerating the use of other renewable energy such as geothermal, hydropower, biomass, nuclear, wind, and solar in a hybrid energy system.

Therefore, leaders around the world need to focus on promoting hydrogen development and adoption. The full participation of governments, business players, and stakeholders can make hydrogen a bridge fuel to enable the scaling up of renewable energy penetration into all sectors, thereby reducing global emissions.

ASEAN leaders can promote hydrogen adoption through the following actions:

- *Demonstrate a strong commitment to promoting a hydrogen society in ASEAN through energy policy.* Using the ASEAN Ministers on Energy Meeting facilitated by the ASEAN Secretariat, a clear and actionable hydrogen development roadmap needs to be developed with a general agreement on policy incentives to promote hydrogen development and adaptation.
- *Develop a clear strategy for how to promote hydrogen use in the transportation, power, and other hard-to-abate sectors like the iron and steel industries.* Singapore, Malaysia, Thailand, Indonesia, and the Philippines could take the lead by investing in R&D for hydrogen produced from both renewables and nonrenewables and setting targets and learning from OECD countries to guide investment. Investment in industries that can adopt hydrogen energy provides strong potential, but ASEAN should accelerate plans and fine-tune strategies to embrace hydrogen use.
- *Develop a clear investment policy for promoting hydrogen development and adoption.* The right policy, as discussed above, will enable economies of scale; improvements in electrolyzer efficiency, operations, and maintenance; and the use of low-cost renewable power. Hydrogen could thus become a bridge fuel to enable the scaling up of renewable energy penetration into all sectors.

- *Help reduce the overall cost of managing the energy system by improving the electricity governance system among ASEAN's developing countries.* Energy remains expensive in some ASEAN countries, despite investment in low-cost and high-emission power-generation technologies, while countries in the region that have invested in more complex technologies have lower electricity tariffs than some developing countries in ASEAN. This dynamic highlights the need for transparency in the power sector and suggests that the high prices of energy and electricity tariffs are partly a governance issue that could be addressed through better management of the energy system. ~

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Note: This essay draws from Han Phoumin, Fukunari Kimura, and Jun Arima, "Potential Renewable Hydrogen from Curtailed Electricity to Decarbonize ASEAN's Emissions: Policy Implications," *Sustainability* 12, no. 24 (2020), https://www.mdpi.com/2071-1050/12/24/10560; and Han Phoumin, "Hydrogen: A Game-Changer for Asean," *Bangkok Post*, June 25, 2020, https://www.bangkokpost.com/opinion/opinion/1940744/hydrogen-a-game-changer-for-asean.

Endnotes

1 Fatih Birol, "Global Energy Prospects and Their Implications for Energy Security and Sustainable Development," International Energy Agency, February 24, 2020.

2 David Malone, "South Korea Plans to Build Three Hydrogen-Powered Cities by 2022," Building Design and Construction, November 8, 2019, "https://www.bdcnetwork.com/south-korea-plans-build-three-hydrogen-powered-cities-2022.

3 Shigeru Kimura and Yanfei Li, eds., "Demand and Supply Potential of Hydrogen Energy in East Asia," Economic Research Institute for ASEAN and East Asia (ERIA), Project Report, May 2019, https://www.eria.org/publications/demand-and-supply-potential-of-hydrogen-energy-in-east-asia.

4 Hydrogen Council, "Hydrogen for Policymakers," February 1, 2019, https://hydrogencouncil.com/en/hydrogen-for-policymakers.

5 "Hydrogen and Fuel Cell Technologies Office," Office of Energy Efficiency and Renewable Energy, U.S. Department of Energy, https://www.energy.gov/eere/fuelcells/hydrogen-and-fuel-cell-technologies-office.

6 Shigeru Kimura and Han Phoumin, eds., *Energy Outlook and Energy Saving Potential in East Asia 2020* (Jakarta: ERIA, 2021), https://www.eria.org/publications/energy-outlook-and-energy-saving-potential-in-east-asia-2020

7 International Renewable Energy Agency (IRENA), *Hydrogen: A Renewable Energy Perspective* (Abu Dhabi: IRENA 2019).

8 Paul Denholm and Jaquelin Cochran, "Wind and Solar on the Power Grid: Myths and Misperceptions," National Renewable Energy Laboratory, May 2015.

9 Ibid.

10 IRENA, *Renewable Power-to-Hydrogen: Innovation Landscape Brief* (Abu Dhabi: IRENA, 2019); and Hydrogen Council, "Path to Hydrogen Competitiveness: A Cost Perspective," January 20, 2020, https://hydrogencouncil.com/en/path-to-hydrogen-competitiveness-a-cost-perspective.

11 IRENA, *Hydrogen from Renewable Power: Technology Outlook for the Energy Transition* (Abu Dhabi: IRENA, 2020).

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