Indonesian Journal of Environmental Law & Sustainable Development
ISSN 2829-9582 (Print) 2829-9590 (Online)
Vol. 4 Issue 1 (2025) 153-179
DOI: https://doi.org/10.15294/ijel.v4i1.25457
Available online since: June 30, 2025

Indonesian Journal *of* Environmental Law and Sustainable Development

Green Hydrogen Management in ASEAN Countries from Investment Law Perspective

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Abstract

The development of green energy is a global priority in facing the challenges of climate change, where green hydrogen has emerged as a renewable energy that can be a sustainable solution. This article discusses the comparison of green hydrogen management in ASEAN countries from an investment law perspective. The main focus of this study is to analyze the regulations, incentives, and legal barriers faced by investors in the green hydrogen sector in various ASEAN member countries. The research method used involves a qualitative approach with a literature study and analysis of laws and regulations related to renewable energy investment. The results of the study show that there are policy disparities among ASEAN countries in supporting green hydrogen investment. Singapore and Malaysia, for example, have adopted more progressive policies, including fiscal incentives and ease of licensing, while other countries still face complex regulatory challenges and lack of supporting infrastructure. This article concludes that harmonization of the investment legal framework in ASEAN is needed to attract more investment in the green hydrogen sector. In addition, strong regional

collaboration can accelerate the development of green hydrogen technology and strengthen energy security in the region.

KEYWORDS *ASEAN, green hydrogen, investment, renewable energy*

Introduction

Various records show that humanity is facing a catastrophe in the form of a climate crisis.[1] Based on the IPCC report in 2023, human activities cause global temperatures to rise and can cause rising sea levels, droughts, floods, and other natural disasters.[2][3] This is caused by environmental damage, mainly due to the use of fossil fuels.[4] For this reason, many countries are currently starting to use hydrogen, as a renewable energy source to replace the use of fossil fuels. The potential of hydrogen is very large as an environmentally friendly alternative to fossil fuels because it only releases water when burned.[5]

The process of making hydrogen produces a lot of emissions, so currently, hydrogen is divided into three according to the emissions produced in the manufacturing process, namely green hydrogen, blue hydrogen, and gray hydrogen.[6] Gray hydrogen is produced from fossil

[1] Matt McGrath, "Perubahan Iklim: Ribuan Ilmuwan Sebut Kondisi Darurat Iklim Global 'Jelas Dan Tak Terbantahkan,'" BBC News Indonesia, 2019, https://www.bbc.com/indonesia/majalah-50297919.

[2] LindungiHutan, "Krisis Iklim – Penyebab Dan Fenomena Di Sekitar Kita," LindungiHutan, 2019, https://lindungihutan.com/blog/krisis-iklim-dan-dampaknya.

[3] Sophie Boehm and Clea Schumer, "10 Temuan Besar Dari Laporan IPCC 2023 Terkait Perubahan Iklim," WRI Indonesia, 2023, https://wri-indonesia.org/id/wawasan/10-temuan-besar-dari-laporan-ipcc-2023-terkait-perubahan-iklim.

[4] Perserikatan Bangsa-Bangsa di Indonesia, "Penyebab Dan Dampak Perubahan Iklim," Perserikatan Bangsa-Bangsa di Indonesia, 2021, https://indonesia.un.org/id/175273-penyebab-dan-dampak-perubahan-iklim.

[5] Ho Lung Yip et al., "A Review of Hydrogen Direct Injection for Internal Combustion Engines: Towards Carbon-Free Combustion," *Applied Sciences* 9, no. 22 (November 12, 2019): 4842, https://doi.org/10.3390/app9224842.

[6] Priyanka Saha et al., "Grey, Blue, and Green Hydrogen: A Comprehensive Review of Production Methods and Prospects for Zero-Emission Energy," *International Journal of Green Energy* 21, no. 6 (May 2, 2024): 1383–97, https://doi.org/10.1080/15435075.2023.2244583.

fuels with no carbon capture, leading to significant emissions.[7] Blue hydrogen is produced from fossil fuels but utilizes carbon capture and storage (CCS) technology to reduce emissions.[8] Green hydrogen is produced via electrolysis using renewable energy, resulting in a zero-emission process.[9] Hydrogen that has the lowest carbon emissions is green hydrogen, because of its clean nature, many countries focus on producing green hydrogen.[10] Currently, the production cost/levelized cost of hydrogen ranges from USD 4.3 to USD 8.3 per kilogram so that in its production, investment is needed for the utilization of green hydrogen and to cut the cost down.[11]

ASEAN is a group of countries in Southeast Asia with quite large fossil consumption, so in order to support energy security by reducing dependence on fossils, and to meet the net zero emission target in each country, several countries in ASEAN have tried to develop green hydrogen and programs to support the development of green hydrogen.[12][13][14] For this reason, this study compares each country in ASEAN in regulating green hydrogen. This study has a main issue in the form of how to compare ASEAN green hydrogen management in terms of investment perspective in each country in ASEAN, with the aim to

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[7] Seon-Yong Ahn et al., "From Gray to Blue Hydrogen: Trends and Forecasts of Catalysts and Sorbents for Unit Process," *Renewable and Sustainable Energy Reviews* 186 (October 2023): 113635, https://doi.org/10.1016/j.rser.2023.113635.

[8] Robert W. Howarth and Mark Z. Jacobson, "How Green Is Blue Hydrogen?," *Energy Science & Engineering* 9, no. 10 (October 12, 2021): 1676–87, https://doi.org/10.1002/ese3.956.

[9] Jimena Incer-Valverde et al., "'Colors' of Hydrogen: Definitions and Carbon Intensity," *Energy Conversion and Management* 291 (September 2023): 117294, https://doi.org/10.1016/j.enconman.2023.117294.

[10] Ying Zhou et al., "Green Hydrogen: A Promising Way to the Carbon-Free Society," *Chinese Journal of Chemical Engineering* 43 (March 2022): 2–13, https://doi.org/10.1016/j.cjche.2022.02.001.

[11] Jinping Man et al., "Levelized Costs and Potential Production of Green Hydrogen with Wind and Solar Power in Different Provinces of Mainland China," *Journal of Renewable and Sustainable Energy* 16, no. 2 (March 1, 2024), https://doi.org/10.1063/5.0183511.

[12] ASEAN Centre for Energy, "8th ASEAN Energy Outlook: 2023–2050" (Jakarta, 2024), https://aseanenergy.org/publications/the-8th-asean-energy-outlook/.

[13] International Energy Agency, "Southeast Asia Energy Outlook 2024" (Paris, 2024), https://iea.blob.core.windows.net/assets/ac357b64-0020-421c-98d7-f5c468dadb0f/SoutheastAsiaEnergyOutlook2024.pdf.

[14] Christopher Len, "Green Hydrogen in Southeast Asia: Connecting National Strategies with Public Support," *ISEAS – Yusof Ishak Institute* 33 (2025).

compare green hydrogen management in supporting the use of renewable energy.

In writing this article, this research is involved with various previous studies that have been conducted. Kostyunina's research focuses more on the strategy/roadmap/regulation of each country regarding hydrogen and future prospects. This research focuses more on investment in green hydrogen.[15] The next research comes from Kumaraswamy et al which discusses the hydrogen supply chain modeling & optimization tool called HEART (Hydrogen Economy and Resource Assessment Tool).[16] Then, Li et al's research focuses more on the well-to-wheel (WTW) and Total Cost of Ownership (TCO) models in analyzing the costs and carbon emissions of hydrogen for ASEAN's energy supply and transportation sectors, and the prospects for hydrogen exports.[17] Nepal et al's research discusses more about the progress of green energy technology in dealing with climate change in the context of sustainable development in ASEAN.[18] Finally, Kim's research focuses more on the potential for green hydrogen exports based on the cost of green hydrogen production (Levelized Cost of Hydrogen/LCOH) in each country in ASEAN.[19]

This study will be given a limit in the form of green hydrogen regulation in ASEAN countries with the structure of the discussion article in each country in ASEAN regarding the regulation of green hydrogen in an investment perspective. That way, this research is expected to be able to provide new patterns in the discourse on green

[15] Galina Kostyunina, "Hydrogen Energy in ASEAN Countries," *SSRN Electronic Journal*, 2024, https://doi.org/10.2139/ssrn.4651485.

[16] Archana Kumaraswamy et al., "Hydrogen for Net-Zero Emissions in ASEAN by 2050," *International Journal of Hydrogen Energy* 90 (November 2024): 575–87, https://doi.org/10.1016/j.ijhydene.2024.09.277.

[17] Yanfei Li et al., "A Strategic Roadmap for ASEAN to Develop Hydrogen Energy: Economic Prospects and Carbon Emission Reduction," *International Journal of Hydrogen Energy* 48, no. 30 (April 2023): 11113–30, https://doi.org/10.1016/j.ijhydene.2022.12.105.

[18] Rabindra Nepal, Han Phoumin, and Abiral Khatri, "Green Technological Development and Deployment in the Association of Southeast Asian Economies (ASEAN)—At Crossroads or Roundabout?," *Sustainability* 13, no. 2 (January 14, 2021): 758, https://doi.org/10.3390/su13020758.

[19] Kim Hyeonjun, Song Gayoung, and Ha Yoonhee, "Green Hydrogen Export Potential in Each Southeast Asian Country Based on Exportable Volumes and Levelized Cost of Hydrogen," *Applied Energy* 383 (2025), https://doi.org/https://doi.org/10.1016/j.apenergy.2025.125371.

hydrogen in Indonesia and in ASEAN by involving an investment perspective in it.

This study applies normative research which will use two approaches, namely conceptual approach and comparative approach. The conceptual approach departs from the views and doctrines that develop in legal science and the comparative approach compares the implementation in Indonesia and other countries, especially in ASEAN.[20]

In conducting this study, the conceptual approach will provide a theoretical foundation by examining relevant legal principles, doctrines, and frameworks that underpin energy transition and decarbonization policies. This will help clarify the normative basis for regulatory measures and climate commitments within the context of international and regional law. Meanwhile, the comparative approach will analyze how Indonesia and other ASEAN countries have implemented these legal frameworks and policies in practice, identifying best practices, challenges, and lessons learned. By combining these approaches, the study aims to offer a comprehensive understanding of the legal and policy landscape surrounding energy transition in ASEAN and propose recommendations to strengthen regional cooperation and effective implementation.

A. Energy Transition In ASEAN

ASEAN is an association of 11 countries in Southeast Asia with quite high energy needs in each country due to quite rapid economic development. Currently, energy use in ASEAN is dominated by fossil fuels, which in 2017 reached 80% and is estimated to be 82% in 2050 if ASEAN countries do not make the transition from fossil fuels to cleaner and renewable energy.[21] In its commitment to support the change in energy to renewable energy and carbon neutrality in order to support the Paris Agreement to prevent climate change, ASEAN member countries each set ambitious goals such as net zero emissions and increasing the use of renewable energy.[22]

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[20] P.M. Marzuki, *Penelitian Hukum* (Jakarta: Kencana, 2005).

[21] Han Phoumin, Fukunari Kimura, and Jun Arima, "Potential Green Hydrogen from Curtailed Electricity in ASEAN: The Scenarios and Policy Implications," 2021, 195–216, https://doi.org/10.1007/978-981-16-2000-3_8.

[22] Kamia Handayani et al., "Moving beyond the NDCs: ASEAN Pathways to a Net-Zero Emissions Power Sector in 2050," *Applied Energy* 311 (2022), https://doi.org/https://doi.org/10.1016/j.apenergy.2022.118580.

To address the growing challenge of fossil fuel dependency, ASEAN countries have increasingly prioritized energy transition policies focused on reducing reliance on fossil fuels and promoting renewable energy sources such as solar, wind, hydro, and biomass.[23] This shift is driven not only by environmental concerns and commitments to global climate goals but also by the need to enhance energy security and mitigate economic risks associated with volatile fossil fuel markets.[24] Regional initiatives like the ASEAN Plan of Action for Energy Cooperation (APAEC) play a crucial role in fostering collaboration on renewable energy development, energy efficiency improvements, and the adoption of innovative technologies such as green hydrogen and carbon capture.[25]

In practice, ASEAN member states are implementing various measures to accelerate decarbonization, including deploying carbon capture and storage (CCS) and carbon capture, utilization, and storage (CCUS) technologies, promoting the transition to electric vehicles, and establishing carbon taxes and emissions trading schemes to incentivize low-carbon practices.[26] The development of carbon markets is also gaining traction, alongside efforts to utilize green hydrogen and ammonia as clean alternatives to fossil fuels.[27] While these initiatives show promise, overcoming challenges related to financing, infrastructure, and regulatory frameworks remains essential. Success will depend on strong public-private partnerships and enhanced international cooperation to ensure a sustainable, secure, and low-carbon energy future for the region.

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[23] J. Aleluia et al., "Accelerating a Clean Energy Transition in Southeast Asia: Role of Governments and Public Policy," *Renewable and Sustainable Energy Reviews* 159 (May 2022): 112226, https://doi.org/10.1016/j.rser.2022.112226.

[24] Ashutosh Yadav, "Promoting Economic Stability: The Role of Renewable Energy Transition in Mitigating Global Volatility," *International Journal of Energy Sector Management*, January 2, 2025, https://doi.org/10.1108/IJESM-06-2024-0032.

[25] Hazleen Aris and Bo Nørregaard Jørgensen, "ASEAN Power Grid 20 Years after: An Overview of Its Progress and Achievements," *IOP Conference Series: Earth and Environmental Science* 463, no. 1 (March 1, 2020): 012055, https://doi.org/10.1088/1755-1315/463/1/012055.

[26] Hon Chung Lau and Xianlong Lin, "Pathways to Achieve Rapid Decarbonization of ASEAN," in *Day 3 Wed, May 04, 2022* (OTC, 2022), https://doi.org/10.4043/32016-MS.

[27] Sapto Hermawan and Febrian Indar Surya Kusuma, "Navigating the Complexities of Carbon Markets Policy in ASEAN: Challenges and Opportunities," *Environment, Development and Sustainability*, August 9, 2024, https://doi.org/10.1007/s10668-024-05268-z.

CCS (Carbon Capture and Storage) is the process of capturing carbon dioxide (CO2) emissions from emission sources and storing them permanently, while CCUS (Carbon Capture, Utilization and Storage) is the same process, but also involves the use of captured CO2 to produce value-added products such as fuel or chemicals.[28]
Furthermore, in the transition of vehicles that initially used gasoline to use electric energy, these vehicles do not have batteries and use hydrogen as their fuel. FCEV will react hydrogen with air to produce power that can drive electric motors and dispose of waste in the form of water vapor.[29]

One method of funding for the massive and structured implementation of CCS is sustainable funding and incentives for its adapters. Carbon tax is one effective and sustainable method for providing funding for green technology.[30] A carbon tax is a fee imposed by a government on any company that emits carbon emissions, particularly those that burn fossil fuels such as coal, oil, gasoline, and natural gas.[31] A carbon tax can help the adoption of carbon capture and storage (CCS) in several ways. First, by making it more expensive to burn fossil fuels, a carbon tax provides an economic incentive for companies to reduce their carbon emissions. This can encourage companies to invest in CCS technology as a way to avoid the tax.[32] Second, the revenue generated from a carbon tax can be used by governments to subsidize the development and deployment of CCS technology. This can help make CCS more affordable and therefore more widely used.[33]

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[28] Qiao Deng et al., "CCS and CCUS Technologies: Giving the Oil and Gas Industry a Green Future," *Frontiers in Energy Research* 10 (June 17, 2022), https://doi.org/10.3389/fenrg.2022.919330.

[29] Fuad Un-Noor et al., "A Comprehensive Study of Key Electric Vehicle (EV) Components, Technologies, Challenges, Impacts, and Future Direction of Development," *Energies* 10, no. 8 (August 17, 2017): 1217, https://doi.org/10.3390/en10081217.

[30] Joshua Meltzer, "A Carbon Tax as a Driver of Green Technology Innovation and the Implications for International Trade," *Energy Law Journal* 35, no. 1 (2014).

[31] Kian Mintz-Woo, "Carbon Tax Ethics," *WIREs Climate Change* 15, no. 1 (January 6, 2024), https://doi.org/10.1002/wcc.858.

[32] Minghai Shen et al., "Carbon Capture and Storage (CCS): Development Path Based on Carbon Neutrality and Economic Policy," *Carbon Neutrality* 1, no. 1 (November 30, 2022): 37, https://doi.org/10.1007/s43979-022-00039-z.

[33] Susana Silva, Isabel Soares, and Carlos Pinho, "Green Tax Reforms with Promotion of Renewable Energy Sources and Carbon Capture and Sequestration:

A carbon market is a trading system that allows carbon credits to be traded.[34] Companies or individuals can use the carbon market to offset their greenhouse gas emissions by purchasing carbon credits from entities that remove or reduce greenhouse gas emissions.[35] One tradable carbon credit is equal to one ton of carbon dioxide or the equivalent amount of various greenhouse gases reduced, sequestered, or avoided. When a credit is used to reduce, sequester, or avoid emissions, it becomes an offset and is no longer tradable.[36]

Then, ammonia has an important role as a hydrogen carrier.[37] Hydrogen carrier compounds are compounds that can be cracked to become hydrogen. Ammonia production for this purpose can be done using green hydrogen or blue hydrogen as raw materials.[38] Ammonia produced from green hydrogen is called green ammonia while ammonia produced from blue hydrogen is called blue ammonia.[39]

In addition to these activities, one of the main focuses of ASEAN countries in decarbonization is the development of green hydrogen, because in the development of technology, consideration of the energy trilemma is needed, namely sustainability, security, and affordability in each ASEAN member country.[40]

Comparison of Different Alternatives," *Energy Reports* 6 (February 2020): 620–25, https://doi.org/10.1016/j.egyr.2019.09.036.

[34] Michael G. Pollitt, "A Global Carbon Market?," *Frontiers of Engineering Management* 6, no. 1 (March 12, 2019): 5–18, https://doi.org/10.1007/s42524-019-0011-x.

[35] Anhua Zhou, Ling Xin, and Jun Li, "Assessing the Impact of the Carbon Market on the Improvement of China's Energy and Carbon Emission Performance," *Energy* 258 (November 2022): 124789, https://doi.org/10.1016/j.energy.2022.124789.

[36] Nimanthika Lokuge and Sven Anders, "Carbon-Credit Systems in Agriculture: A Review of Literature," *The School of Public Policy Publications* 15, no. 12 (2022).

[37] Yoshitsugu Kojima and Masakuni Yamaguchi, "Ammonia as a Hydrogen Energy Carrier," *International Journal of Hydrogen Energy* 47, no. 54 (June 2022): 22832–39, https://doi.org/10.1016/j.ijhydene.2022.05.096.

[38] Wai Siong Chai et al., "A Review on Ammonia, Ammonia-Hydrogen and Ammonia-Methane Fuels," *Renewable and Sustainable Energy Reviews* 147 (September 2021): 111254, https://doi.org/10.1016/j.rser.2021.111254.

[39] Yunliang Qi et al., "A Review on Ammonia-Hydrogen Fueled Internal Combustion Engines," *ETransportation* 18 (October 2023): 100288, https://doi.org/10.1016/j.etran.2023.100288.

[40] Leonid M. Grigoryev and Dzhanneta D. Medzhidova, "Global Energy Trilemma," *Russian Journal of Economics* 6, no. 4 (December 14, 2020): 437–62, https://doi.org/10.32609/j.ruje.6.58683.

The practical application of energy transition in ASEAN varies across countries based on their unique energy landscapes, economic capacities, and policy frameworks.[41] For example, Indonesia and the Philippines are actively investing in large-scale solar and geothermal projects to diversify their energy mix and reduce reliance on coal.[42][43] Vietnam has rapidly expanded its solar and wind capacity, becoming a regional leader in renewable energy deployment.[44] Thailand is focusing on bioenergy and smart grid development to enhance energy efficiency and grid integration.[45] Meanwhile, Singapore, despite its limited land area for renewables, is investing heavily in clean energy research, regional power grid interconnectivity, and the development of low-carbon technologies such as green hydrogen and carbon services. Regional initiatives, such as the ASEAN Power Grid, aim to facilitate cross-border electricity trade, allowing countries to optimize renewable energy resources and improve energy security. Additionally, the growing emphasis on electric vehicles (EVs) and energy efficiency standards in buildings and industry demonstrates ASEAN's multi-sectoral approach to energy transition.[46] However, scaling up these applications will require consistent regulatory frameworks, substantial investment, and enhanced

[41] Mukesh Shankar Bharti, "An Evolution of ASEAN Energy Policy on Renewable Energy Transition and Energy Sustainability for Carbon Neutrality," 2024, 373–94, https://doi.org/10.4018/979-8-3693-6740-7.ch015.

[42] Marnel Arnold Ratio, Jillian Aira Gabo-Ratio, and Yasuhiro Fujimitsu, "Exploring Public Engagement and Social Acceptability of Geothermal Energy in the Philippines: A Case Study on the Makiling-Banahaw Geothermal Complex," *Geothermics* 85 (May 2020): 101774, https://doi.org/10.1016/j.geothermics.2019.101774.

[43] Juergen Stich and Thomas Hamacher, "The Cost-Effectiveness of Power Generation from Geothermal Potentials in Indonesia and the Philippines," in *2016 IEEE Innovative Smart Grid Technologies - Asia (ISGT-Asia)* (IEEE, 2016), 177–82, https://doi.org/10.1109/ISGT-Asia.2016.7796382.

[44] Xuan Phuong Nguyen et al., "Mission, Challenges, and Prospects of Renewable Energy Development in Vietnam," *Energy Sources, Part A: Recovery, Utilization, and Environmental Effects* 47, no. 1 (December 31, 2025): 10367–79, https://doi.org/10.1080/15567036.2021.1965264.

[45] Kampanart Silva et al., "Enhancing Resilience of Sustainable Energy Infrastructure: Best Practices in Thailand," 2024, 73–85, https://doi.org/10.1007/978-981-97-4174-8_6.

[46] Calin-Cristian Cormos, Loredana Petrescu, and Ana-Maria Cormos, "Green Hydrogen Production Based on Biogas Reforming Integrated with Carbon Capture and Storage," Chemical Engineering Transactions 114 (2024), https://doi.org/https://doi.org/10.3303/CET24114058.

regional cooperation to ensure an equitable and effective transition across all member states.

B. Decarbonization In ASEAN

Indonesia ranked first in ASEAN countries regarding CO2 emissions from fuel combustions in 2022 with 652 Mt CO2 contributing 1.91% of global emissions which increased 156% since 2000. Coal is the largest contributor of CO2 emissions with 57,5%, followed by oil with 32,9%, and natural gas with 9,5%.[47] The second place is Vietnam with 287 Mt CO2 contributions, third is Thailand with 250 Mt CO2, closely followed by Malaysia with 242 Mt CO2, Philippines in the fifth place with 138 Mt CO2, then with quite gap Singapore in the sixth place with 47 Mt CO2, Myanmar with 26 Mt CO2, Laos with 19 Mt CO2, Cambodia with 17 Mt CO2, and lastly Brunei Darussalam with 10 Mt CO2.[48] In 2023, data from Timor Leste shows that the latest country to join ASEAN is within 0.703 Mt CO2.[49]

Indonesia's position as the largest emitter of CO2 in ASEAN highlights the urgent need for targeted policies and investments to reduce fossil fuel dependency, especially coal, which remains the dominant source of emissions. The rapid increase in emissions since 2000 underscores the environmental challenges posed by Indonesia's expanding industrial and energy sectors.[50] Meanwhile, other major emitters like Vietnam, Thailand, Malaysia, and the Philippines also face similar pressures to balance economic growth with sustainable development.[51] The relatively lower emissions from smaller ASEAN members such as Singapore, Myanmar, and Brunei reflect differences in population size, industrialization levels, and energy profiles, but these countries too are integral to regional climate efforts.

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[47] International Energy Agency, "Indonesia – Emissions," accessed May 23, 2025, https://www.iea.org/countries/indonesia/emissions.

[48] International Energy Agency, "Asia Pacific – Emissions," n.d.

[49] Countryeconomy.com, "Timor-Leste – CO_2 Emission 2023," n.d.

[50] Martha Maulidia et al., "Rethinking Renewable Energy Targets and Electricity Sector Reform in Indonesia: A Private Sector Perspective," *Renewable and Sustainable Energy Reviews* 101 (March 2019): 231–47, https://doi.org/10.1016/j.rser.2018.11.005.

[51] Habib Zafarullah and Monami Mehnaz, "Balancing Economic Growth and Sustainability for Environmental Protection in Southeast Asia: A Regional Perspective," *Southeast Asia: A Multidisciplinary Journal*, April 1, 2025, https://doi.org/10.1108/SEAMJ-01-2025-0003.

In response to these emission levels, ASEAN countries have committed to the Paris Agreement, which requires nations to regularly update and enhance their nationally determined contributions (NDCs) every five years.[52] These NDCs outline each country's climate action plans, including emission reduction targets and strategies to achieve them.[53] Given the diversity of economic development and energy usage across the region, ASEAN countries are adopting tailored approaches that combine renewable energy expansion, energy efficiency, carbon pricing, and emerging technologies such as green hydrogen and carbon capture. Strengthening implementation of NDCs through regional cooperation and international support will be crucial to ensuring that ASEAN collectively meets its climate commitments and contributes meaningfully to global efforts to limit temperature rise.[54]

Indonesia's first NDC was published in November 2026 with a target of reducing greenhouse gas emissions with two approaches, namely unconditional by 29% and with international support (conditional) by 41%, and reach net zero emissions by 2060 or sooner.[55] Unconditional means that with the resources owned by each country, such as funding, technology, and capacity, the country can reduce greenhouse gas emissions to a certain level, and conditional means that if there is external or international support in the form of funding, technology, and capacity, efforts to reduce greenhouse gas emissions can be increased.[56] This increase is measured in the form of an additional

[52] United Nations Framework Convention on Climate Change (UNFCCC), "Nationally Determined Contributions (NDCs)," accessed May 23, 2025, https://unfccc.int/process-and-meetings/the-paris-agreement/nationally-determined-contributions-ndcs.

[53] Angel Hsu et al., "Exploring Links between National Climate Strategies and Non-State and Subnational Climate Action in Nationally Determined Contributions (NDCs)," *Climate Policy* 20, no. 4 (April 20, 2020): 443–57, https://doi.org/10.1080/14693062.2019.1624252.

[54] Jiahui Qiu, Sharon Seah, and Melinda Martinus, "Examining Climate Ambition Enhancement in ASEAN Countries' Nationally Determined Contributions," *Environmental Development* 49 (March 2024): 100945, https://doi.org/10.1016/j.envdev.2023.100945.

[55] Djoko Santoso Abi Suroso et al., "Revisiting the Role of International Climate Finance (ICF) towards Achieving the Nationally Determined Contribution (NDC) Target: A Case Study of the Indonesian Energy Sector," *Environmental Science & Policy* 131 (May 2022): 188–95, https://doi.org/10.1016/j.envsci.2022.01.022.

[56] United Nations Development Programme (UNDP), "NDCs (Nationally Determined Contributions) and Climate Change: What You Need to Know,"

percentage of greenhouse gas emission reduction above the level achieved with own resources or unconditionally.[57] This NDC covers five sectors, namely forestry, energy, agriculture, industrial processes and product use, and waste & sewage, showing a comprehensive approach in efforts to address climate change in Indonesia.[58]

Several ASEAN countries have outlined specific targets in their Nationally Determined Contributions (NDCs) to address climate change and reduce greenhouse gas emissions. Vietnam aims to reduce emissions by 15.8% unconditionally and up to 43.5% with international support, with a net-zero target set for 2050. Malaysia has committed to an unconditional 45% reduction in emissions intensity by 2030, compared to 2005 levels. Thailand targets a 20% unconditional and 25% conditional reduction, with a carbon neutrality goal by 2050 and net-zero emissions by 2065. The Philippines has pledged a 2.71% unconditional reduction and a significant 72% reduction conditional on international support. Singapore, meanwhile, plans a 36% reduction in emissions intensity from 2005 levels by 2030, aims to peak emissions at 65 $MtCO_2e$ or less by 2030, and achieve net-zero by 2050. Myanmar has committed to a 50% reduction conditionally, while Laos and Cambodia have pledged 60% and 42% unconditional reductions, respectively. Brunei has set an unconditional emissions reduction target of 20%.[59] These varied commitments highlight the region's collective ambition toward decarbonization, while also reflecting differences in national capacities and development stages.

These NDC commitments reflect both the diversity and complexity of the ASEAN region's path toward climate mitigation. Countries like Singapore and Malaysia, with relatively higher capacities and more developed infrastructure, are focusing on emission intensity

accessed May 23, 2025, https://climatepromise.undp.org/news-and-stories/NDCs-nationally-determined-contributions-climate-change-what-you-need-to-know.

[57] Indonesia Research Institute for Decarbonization, "NDC_29JUN-FINAL," accessed May 23, 2025, https://irid.or.id/wp-content/uploads/2023/06/NDC_29JUN-FINAL.pdf.

[58] Madani Berkelanjutan, "Understanding the Nationally Determined Contribution (NDC)," accessed May 23, 2025, https://madaniberkelanjutan.id/mengenal-nationally-determined-contribution-ndc/.

[59] ASEAN Climate Change and Energy Project (ACCEPT), "ASEAN Country Profiles," accessed May 23, 2025, https://accept.aseanenergy.org/country/.

reductions and technological innovation to meet their goals.[60] In contrast, nations such as Laos, Cambodia, and Myanmar, which contribute less to global emissions but are highly vulnerable to climate change, emphasize unconditional targets, often relying on international support to enhance implementation.[61] The distinction between unconditional and conditional targets is crucial, as it underscores the importance of climate finance, technology transfer, and capacity-building from developed countries to enable more ambitious climate actions. Additionally, while some countries like Vietnam and Thailand have set long-term net-zero or carbon neutrality goals, achieving these targets will require overcoming substantial challenges, including fossil fuel dependence, policy gaps, and financing constraints.[62] Regional cooperation, knowledge sharing, and support mechanisms will be essential to ensure that ASEAN countries can collectively meet their climate commitments while pursuing sustainable and inclusive development.

Despite progress, the path to decarbonization in ASEAN faces several challenges. Many countries still rely heavily on coal and face difficulties in securing sufficient investment for clean energy infrastructure. Policy and regulatory frameworks vary widely across the region, creating gaps in implementation and enforcement. Furthermore, ensuring a just transition that supports economic inclusion and job creation remains essential. To overcome these barriers, ASEAN must enhance regional cooperation, foster innovation, and strengthen public-private partnerships, ensuring that decarbonization is both equitable and effective across all member states.

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[60] Asif Raihan et al., "Relationship between Economic Growth, Renewable Energy Use, Technological Innovation, and Carbon Emission toward Achieving Malaysia's Paris Agreement," *Environment Systems and Decisions* 42, no. 4 (December 19, 2022): 586–607, https://doi.org/10.1007/s10669-022-09848-0; Qinqin Chen and David Taylor, "Economic Development and Pollution Emissions in Singapore: Evidence in Support of the Environmental Kuznets Curve Hypothesis and Its Implications for Regional Sustainability," *Journal of Cleaner Production* 243 (January 2020): 118637, https://doi.org/10.1016/j.jclepro.2019.118637.

[61] Norio Saito, "Mainstreaming Climate Change Adaptation in Least Developed Countries in South and Southeast Asia," *Mitigation and Adaptation Strategies for Global Change* 18, no. 6 (August 26, 2013): 825–49, https://doi.org/10.1007/s11027-012-9392-4.

[62] Kampanat Thapmanee et al., "Measures to Promote Renewable Energy and Energy Efficiency Towards Net-Zero Carbon Emissions," *PaperASIA* 41, no. 3b (May 15, 2025): 45–54, https://doi.org/10.59953/paperasia.v41i3b.383.

C. Green Hydrogen Investment In ASEAN

Indonesia ranked first in ASEAN countries regarding CO2 emissions from fuel combustions in 2022 with 652 Mt CO2 contributing 1.91% of global emissions which increased 156% since 2000. Coal is the largest contributor of CO2 emissions with 57,5%, followed by oil with 32,9%, and natural gas with 9,5%. Green hydrogen is emerging as a critical component in ASEAN's long-term strategy to decarbonize its energy systems and meet climate targets.[63] Produced through electrolysis using renewable energy sources like solar and wind, green hydrogen offers a clean alternative to fossil fuels, particularly for hard-to-abate sectors such as heavy industry, transportation, and power generation.[64] As ASEAN countries seek to diversify their energy mix and reduce reliance on imported fuels, green hydrogen presents a promising solution for both energy security and emissions reduction. While still in its early stages, green hydrogen is gaining policy attention and attracting growing investment interest across the region.[65]

Several ASEAN member states have begun integrating green hydrogen into national energy and climate roadmaps. Singapore has positioned itself as a potential hub for hydrogen trade and bunkering services, supported by its strong regulatory environment and research capabilities.[66] Indonesia and Malaysia have announced intentions to develop green hydrogen projects, leveraging their vast renewable energy

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[63] Bijay B. Pradhan et al., "Role of Green Hydrogen in the Decarbonization of the Energy System in Thailand," *Energy Strategy Reviews* 51 (January 2024): 101311, https://doi.org/10.1016/j.esr.2024.101311.

[64] M. Jayachandran et al., "Challenges and Opportunities in Green Hydrogen Adoption for Decarbonizing Hard-to-Abate Industries: A Comprehensive Review," *IEEE Access* 12 (2024): 23363–88, https://doi.org/10.1109/ACCESS.2024.3363869.

[65] H.B. Aditiya and Muhammad Aziz, "Prospect of Hydrogen Energy in Asia-Pacific: A Perspective Review on Techno-Socio-Economy Nexus," *International Journal of Hydrogen Energy* 46, no. 71 (October 2021): 35027–56, https://doi.org/10.1016/j.ijhydene.2021.08.070.

[66] Karl Schönsteiner, Tobias Massier, and Thomas Hamacher, "Sustainable Transport by Use of Alternative Marine and Aviation Fuels—A Well-to-Tank Analysis to Assess Interactions with Singapore's Energy System," *Renewable and Sustainable Energy Reviews* 65 (November 2016): 853–71, https://doi.org/10.1016/j.rser.2016.07.027.

potential.[67] At the regional level, the ASEAN Plan of Action for Energy Cooperation (APAEC) has recognized hydrogen as a strategic technology for the future, encouraging collaboration and knowledge-sharing among member countries.

ASEAN's abundant renewable energy resources make the region well-suited for large-scale green hydrogen production. Investment opportunities span the entire value chain—from electrolyzer manufacturing and renewable power generation to storage, transport, and end-use applications. Industrial decarbonization, clean shipping, and hydrogen-powered vehicles are seen as potential early markets. As global demand for clean hydrogen rises, ASEAN also has the potential to become an exporter to energy-hungry markets such as Japan and South Korea. Governments and private sector players are increasingly forming joint ventures, conducting feasibility studies, and launching demonstration projects to assess commercial viability.

Several pioneering green hydrogen projects are already taking shape across ASEAN. In Malaysia, Sarawak is positioning itself as a green hydrogen hub, with government-supported pilot plants and plans to export hydrogen to East Asia.[68] Indonesia has initiated projects to produce hydrogen using geothermal and hydropower resources. Singapore's Energy Market Authority (EMA) and the Maritime and Port Authority (MPA) are collaborating on hydrogen bunkering trials, while private firms are testing fuel cell technologies.[69] These early initiatives are essential for building local capacity, testing regulations, and creating the infrastructure needed to support a broader hydrogen economy.

Despite promising developments, several challenges hinder large-scale green hydrogen investment in ASEAN. High production costs

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[67] Nor Arina Syazwani Jumaat and Azianabiha A Halip Khalid, "A Comprehensive Review of Challenges, Prospects, and Future Perspectives for Hydrogen Energy Development in Malaysia," *International Journal of Hydrogen Energy* 55 (February 2024): 65–77, https://doi.org/10.1016/j.ijhydene.2023.11.058; Muhammad Helmi Prakoso, Muhammad Bahrul Ulum, and Adetya Niam Saksama, "Case Study of a Potential Green Hydrogen Plant in Indonesia," in *2024 6th Global Power, Energy and Communication Conference (GPECOM)* (IEEE, 2024), 387–93, https://doi.org/10.1109/GPECOM61896.2024.10582660.

[68] Tenaga Nasional Berhad (TNB), "TNB Newsclip 15072024c1," 2024, https://www.tnb.com.my/assets/newsclip/15072024c1.pdf.

[69] Bryan Low Kai Sheng et al., "Envisioning a Decision Support System for the Planning of Alternative Fuel Bunkering Operations in Singapore," *Journal of Physics: Conference Series* 2867, no. 1 (October 1, 2024): 012013, https://doi.org/10.1088/1742-6596/2867/1/012013.

remain a major barrier, driven by the expense of electrolyzers and the intermittency of renewable energy. Infrastructure for storage, transportation, and distribution is still underdeveloped, and regulatory frameworks specific to hydrogen are either lacking or in their infancy.[70] Additionally, financing remains a hurdle, as investors seek clear policy signals, bankable project models, and stable long-term returns. Addressing these challenges will require coordinated government action, regional cooperation, and international support through funding, technology transfer, and capacity building.

International cooperation plays a vital role in accelerating green hydrogen investment in ASEAN.[71] Partnerships with countries such as Japan, South Korea, Germany, and Australia are helping ASEAN nations access cutting-edge technology, expertise, and financing. Multilateral institutions like the Asian Development Bank (ADB) and the International Renewable Energy Agency (IRENA) are also supporting feasibility studies, policy development, and pilot projects.[72] These collaborations not only help reduce the risks associated with early-stage investment but also foster standards and best practices that can be adopted across the region.

The future of green hydrogen in ASEAN holds significant promise, with the potential to transform the region's energy systems, stimulate economic growth, and reinforce climate commitments. To realize this potential, ASEAN must continue strengthening policy frameworks, incentivizing investment, and investing in workforce development. Regional coordination through platforms like APAEC can accelerate technology deployment and harmonize standards. With the right support, ASEAN can position itself as a competitive player in the global hydrogen economy, turning its renewable energy potential into a long-term strategic advantage.

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[70] Rabindra Nepal, Han Phoumin, and Abiral Khatri, "Green Technology Development and Deployment in the ASEAN—Lessons Learned and Ways Forward," 2021, 217–38, https://doi.org/10.1007/978-981-16-2000-3_9.

[71] Khairul Fahim et al., "An Evaluation of ASEAN Renewable Energy Path to Carbon Neutrality," *Sustainability* 15, no. 8 (April 20, 2023): 6961, https://doi.org/10.3390/su15086961.

[72] Dan Millison, "The Asian Development Bank's Energy Sector Operations in the Twenty-First Century," in *The Elgar Companion to the Asian Development Bank* (Edward Elgar Publishing, 2024), 249–62, https://doi.org/10.4337/9781800882966.00028; Elisa Asmelash et al., "Role of IRENA for Global Transition to 100% Renewable Energy," 2020, 51–71, https://doi.org/10.1007/978-3-030-40738-4_2.

Conclusion

ASEAN is advancing its energy transition and decarbonization efforts through ambitious climate commitments, renewable energy expansion, and emerging technologies like carbon pricing, CCS, and green hydrogen. With diverse Nationally Determined Contributions (NDCs) and net-zero targets, member states are implementing projects that range from solar and wind deployment to energy efficiency and clean mobility. Green hydrogen, in particular, holds significant promise for decarbonizing hard-to-abate sectors and fostering economic diversification, supported by pilot initiatives and international partnerships across the region. Growing green hydrogen investment is crucial to overcoming current technological and financial barriers, enabling large-scale production and infrastructure development. Despite challenges such as high costs, infrastructure gaps, and policy inconsistencies, ASEAN's coordinated approach—integrating renewable energy growth with hydrogen development and regional cooperation—can accelerate a sustainable, secure, and low-carbon energy future, positioning the region as a key player in the global clean energy transition.

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DECLARATION OF CONFLICTING INTERESTS

The author(s) declared that there is no competing interest in this article.

FUNDING INFORMATION

This article is funded by the Research and Community Service Unit of Universitas Negeri Semarang.

ACKNOWLEDGMENT

The author(s) would like to thank Universitas Negeri Semarang and Faculty of Law Universitas Negeri Semarang to make this research possible.

HISTORY OF ARTICLE

Submitted : May 23, 2025
Revised : July 08, 2025
Accepted : July 28, 2025
Published : July 30, 2025