Future Sustainability
Open Access Journal
ISSN 2995-0473

November 2023| Volume 01 | Issue 01 | Pages 13-22

Journal homepage: https://fupubco.com/fusus

https://doi.org/10.55670/fpll.fusus.1.1.2

Future Publishing LLC

Review

A review of renewable energy development in ASEAN, policies, environmental and economic impact

Daniel Nyuin Alfred Damu, Brian Sie Chuan Wong, Jen Yew Chai, Cornelius Yii Ke Wong, Hadi Nabipour Afrouzi*, Ateeb Hassan

Faculty of Engineering, Computing and Science, Swinburne University of Technology Sarawak Campus, Kuching, Jalan Simpang Tiga, 93350, Malaysia

ARTICLE INFO

Article history:
Received 05 August 2023
Received in revised form
07 September 2023
Accepted 18 September 2023

Keywords:
Renewable energy, ASEAN,
Policies, Environmental impact, Economic impact

*Corresponding author
Email address:
hafrouzi@swinburne.edu.my

DOI: 10.55670/fpll.fusus.1.1.2

ABSTRACT

This study provides a comprehensive analysis of renewable energy development in ASEAN, focusing on policies, environmental impact, and economic implications. It examines the effectiveness of renewable energy policies across member countries, highlighting challenges in implementation and the need for effective policy frameworks to drive investment. The review explores environmental concerns, including land use change, soil erosion, water use, and waste generation, while emphasizing the potential economic benefits such as GDP growth, job creation, and reduced dependence on energy imports. Addressing challenges and promoting sustainable development are crucial for achieving renewable energy targets in ASEAN.

1. Introduction

The Association of Southeast Asian Nations (ASEAN) is a region that is home to over 650 million people and has a rapidly growing economy [1]. With this growth comes an increasing demand for energy to support industrialization and modernization, leading to a greater dependence on fossil fuels [2]. However, in recent years, ASEAN has made significant strides in developing renewable energy (RE) sources, which has become an important focus of the region's energy policy [3]. ASEAN countries have been taking steps to develop their RE infrastructure, with many setting ambitious targets to increase their use of renewable energy sources. For example, the ASEAN Plan of Action for Energy Cooperation 2016-2025 targets a share of 23% renewable energy in the region's energy mix by 2025, up from 15.3% in 2015 [4]. However, despite these efforts, the transition towards renewable energy faces several challenges, such as regulatory barriers, lack of investment, and inadequate infrastructure [5]. This review paper aims to provide a comprehensive overview of renewable energy development in ASEAN, focusing on the policies, environmental, and economic impacts. By analyzing the current state of RE in the region, this paper aims to identify the key challenges and opportunities for future development and provide recommendations for policymakers, investors, and other stakeholders. In recent years, several studies have explored the development of renewable energy in ASEAN. For example, a study by Pratiwi and Juerges [6] examined the environmental impact of RE development in the ASEAN region. In contrast, another study by Vakulchuk et al. [7] analyzed the barriers to investment in RE in the region. Furthermore, a study examined the impact of policy on the adoption of RE in Vietnam, a key ASEAN country [8]. By synthesizing the findings of these studies and other relevant literature, this paper aims to provide a holistic overview of the renewable energy landscape in ASEAN, highlighting the progress made, challenges faced, and future opportunities for development.

2. Policies for renewable energy development in ASEAN

RE policies are critical for the development of the RE sector in ASEAN. This section will provide an overview of the policies implemented in ASEAN member countries, followed by a comparative analysis of their effectiveness. Finally, it will highlight the challenges and opportunities for policy implementation in the region.

In recent years, most ASEAN member countries have established renewable energy policies to promote deploying renewable energy technologies. These policies include feed-in-tariffs, renewable portfolio standards, tax incentives, and public-private partnerships. For example, Indonesia introduced feed-in tariffs for renewable energy in 2017, while the Philippines implemented a Renewable Portfolio Standard in 2010 [9]. Additionally, Thailand, Malaysia, and Vietnam governments have implemented tax incentives and public-private partnerships to promote renewable energy development. Despite these efforts, the effectiveness of these policies varies across ASEAN countries. For instance, in Malaysia, the feed-in-tariff policy has been effective in increasing the deployment of renewable energy technologies, while in Indonesia, the implementation of feed-in tariffs has been delayed due to regulatory challenges [10, 11]. Furthermore, while the Renewable Portfolio Standard in the Philippines has been successful in attracting investments in renewable energy, the country still faces challenges in grid integration and the expansion of transmission infrastructure [12]. A comparative analysis of renewable energy policies in ASEAN reveals that most countries have set renewable energy targets, but the achievement of these targets has been slow. According to the ASEAN Centre for Energy (2021), ASEAN member countries achieved a 15.3% renewable energy share in their energy mix in 2015, which increased to 17.3% in 2019. However, this is still below the 2025 target of 23%. The implementation of renewable energy policies in ASEAN faces several challenges, including regulatory barriers, lack of investment, and inadequate infrastructure. Regulatory challenges include delays in project approval processes and uncertainties in regulatory frameworks. A lack of investment in renewable energy is another major challenge, with limited access to financing and the perception that renewable energy technologies are risky investments. Finally, inadequate infrastructure, such as grid capacity and transmission infrastructure, presents a significant barrier to the deployment of renewable energy technologies (EY, 2019). Despite these challenges, ASEAN presents significant opportunities for renewable energy development, including abundant renewable energy resources, increasing energy demand, and government support for renewable energy. To achieve their renewable energy targets, ASEAN countries need to address the challenges faced in the implementation of renewable energy policies and adopt effective policy frameworks that encourage investment in renewable energy. Therefore, renewable energy policies in ASEAN member countries have made significant progress in promoting the deployment of renewable energy technologies. However, the effectiveness of these policies varies across the region, and challenges remain in the implementation of these policies. To achieve their renewable energy targets, ASEAN countries need to address the challenges faced in the implementation of renewable energy policies and adopt effective policy frameworks that encourage investment in renewable energy.

3. Environmental impact of renewable energy development in ASEAN

RE development in ASEAN has the potential to significantly reduce greenhouse gas emissions and mitigate the impacts of climate change. According to [13], preventing negative effects such as air pollution and greenhouse gases (GHGs) could be possible by using renewable energy sources instead of fossil fuels or coal. Compared to coal-fired power plants, renewable energy sources' electricity emits 90-99% fewer GHGs and creates 70% to 90% less pollution. However, the development of RE sources can also have environmental impacts that must be carefully managed to ensure sustainable development. One of the key environmental impacts of RE development in ASEAN is land use change. The development of large-scale renewable energy projects, such as solar and wind farms, can require large amounts of land, which can impact natural habitats and wildlife. Ref [14] states that construction of RE projects can lead to habitat fragmentation and loss of biodiversity, particularly in areas that are ecologically sensitive or contain endangered species. For example, solar power plants are constructed on agricultural land with an area of over 160 hectares in Thailand. In recent years, Thailand has significantly increased its solar energy capacity, with a large portion of this expansion occurring on agricultural land [15]. Due to this, agricultural land and other agricultural regions have been converted into solar power plants, which may have a negative influence on the ecosystems and residents. Satellite imagery and aerial photos, which depict the conversion of agricultural land into huge solar power plants, provide tangible proof of this change in land use. This has sometimes resulted in the eviction of farmers and the destruction of their means of subsistence, as well as negative effects on the local biodiversity and water supplies. The trade-offs and difficulties involved in the development of RE, particularly in densely populated and land-constrained countries, are highlighted by the construction of solar power facilities on agricultural land in Thailand. Ultimately, the development of the solar farm serves as a stark reminder of how difficult it is to strike a balance between the need for RE and possible harm to nearby residents and ecosystems. To guarantee that RE projects are built in a sustainable and socially responsible manner, it is crucial for governments and developers to collaborate with regional communities and stakeholders.

Moreover, another environmental impact of RE development is the potential for soil erosion and degradation. This can occur when RE projects are developed on steep slopes or in areas with poor soil quality [16]. Soil erosion and degradation can lead to a loss of soil fertility and reduced productivity of agricultural land, which can have negative impacts on local communities that rely on agriculture for their livelihoods. For example, hydropower dam construction in Laos has caused soil erosion in the Mekong River Basin. It is stated that since the hydropower dam building in the area started, sedimentation levels in the Mekong River Basin have risen by 20% [17]. Significant soil erosion may result from the excavation of rock and soil, the construction of access roads, and the installation of transmission lines during the project's construction phase. This erosion may cause sedimentation in surrounding rivers and streams, which may have a negative effect on local communities that depend on fishing and agriculture, as well as aquatic habitats. Because of changes in the water flow and sediment movement downstream of the dam, the dam can potentially have a long-term negative influence on soil erosion in addition to the immediate effects during construction. This may significantly reduce agricultural output and raise the possibility of landslides in the region. To lessen these effects, hydropower projects in Laos normally need to submit environmental evaluations and management plans that include actions like sedimentation basins, soil stabilization projects, and reforestation schemes. However, based on the project and how it is carried out, these measures may not all be equally beneficial. Not to mention, water use is another potential environmental impact of RE development in ASEAN. Ref [18] rationalizes that some RE technologies, such as hydropower and bioenergy, can require

large amounts of water for their operation. This can have negative impacts on water resources and aquatic ecosystems, particularly in areas that are already experiencing water scarcity or where freshwater ecosystems are already under stress. For example, the construction of the hydropower Baram Dam in Malaysia has caused water use issues [19]. Due to worries about their effects on local ecosystems and indigenous groups, the construction of hydropower dams in Malaysia has been controversial. Thousands of indigenous people would be uprooted, and a sizable portion of the rainforest would be flooded. Hydropower dam development and operation can also have detrimental effects on the quantity and quality of water available downstream. This may have an impact on local people's health and well-being, as well as industries depending on water, like agriculture, fishery, and others. So, Malaysia has implemented several efforts to enhance water management in the area in response to these worries, including the creation of new water treatment facilities and the encouragement of water conservation techniques. The severe environmental and socioeconomic effects of the Bakun Dam, however, may preclude these actions from being sufficient.

Finally, the production and disposal of RE technologies can also have environmental impacts. For example, the production of solar panels and wind turbines can involve the use of toxic chemicals and generate waste, which can have negative impacts on the environment and human health [20]. Similarly, the disposal of old or damaged RE technologies can also create environmental problems if not properly managed. [21] mentions that geothermal power plants constructed in Indonesia can be taken as one of the examples that cause the issues. To reach the hot water and steam needed to produce energy at geothermal power plants, deep wells must be drilled. Large amounts of drilling waste, such as drilling fluids and rock shavings, may be produced because of the drilling operation, and these waste materials may be challenging to securely dispose of. Deforestation, land degradation, and the disruption of regional ecosystems are other potential negative effects of the development of geothermal power facilities. Therefore, the Indonesian government has put policies in place to control geothermal waste and encourage sustainable development to address these problems. Enforcing these laws, meanwhile, can be difficult, especially in isolated locations where geothermal projects are sometimes located.

4. Economic impact of renewable energy development in ASEAN

Recently, attaining energy sustainability has been a major goal for the ASEAN countries, as it brings many benefits, including enhanced energy efficiency and a clean environment. This has resulted in the rise of sustainable energy sources such as wind, hydropower, and solar power, which are the prominent sources of electricity growth globally. Based on research done back in 2020, the GDP growth and RE sources in ASEAN countries have been recorded in Table 1 [22].

Economic growth can be defined as an increase in production in an economy, which results in increased incomes and raises the standard of living. Economic growth is usually measured in terms of GDP and is an indicator of the economic health of the country. RE has been an attractive method to recover the falling GDP of ASEAN countries, which has been caused by the pandemic. It has been reported that the GDP for the ASEAN-5 (Indonesia, Malaysia, Philippines, Singapore, and Thailand) has been 2.9% for 2021 and 5.8% for 2022, following a 3.4% fall in 2020 due to the pandemic. One of the main reasons RE has been deemed the future is that it would cause the ASEAN countries to achieve a steady supply of energy and be self-sufficient. Currently, the countries still rely on energy imports that are predominantly fossil fuels to operate. With RE, the funding will not be required for imports, and thus the GDP will rise. This, coupled with the increasing demands to prevent global warming from investors, can make investing in RE a worthwhile venture.

Table 1. GDP growth and renewable energy sources in ASEAN countries

Countries	Economy size (USD in billions)	Populations (Millions)	GDP per capita (USD)	Capacity of renewable energy (MW)
Brunei	16.18	0.42	38760	1
Cambodia	16.20	15.14	1070	1438
Indonesia	868.35	250.80	3460	9471
Laos	11.00	6.78	1620	5118
Malaysia	313.16	29.72	10538	8157
Myanmar	44.85	61.95	724	3315
Philippines	272.07	98.39	2770	6482
Singapore	297.94	5.40	55183	279
Thailand	387.25	67.01	5780	10411
Vietnam	170.55	89.71	1901	18523

In the last five years, ASEAN countries have increased their RE production. EY-Parthenon, a global strategy consulting arm, had conducted a study of eight economies across Asia and has recorded more than 800 clean energy projects. If they are all realized, it could result in an investment potential of over 316 billion USD and an emission-saving potential of over 229 metric tons of carbon dioxide. These projects and investments also have the potential to generate up to 870,000 jobs. Furthermore, as stated earlier, RE is attractive, resulting in private sectors and investors being more likely to deploy capital and back its' projects. This would, in turn, bring economic growth. According to the 58th edition of the EY RE Country Attractiveness Index (RECAI) in October 2021, the Philippines, Vietnam, and Indonesia have risen up the rankings of the world's top 40 markets in terms of the attractiveness of their RE investment and deployment opportunities. Indonesia has set more ambitious goals and policies to retire diesel and coal power plants.

While the merits of pursuing RE are clear, the path is not without challenges. Inability to access financing, absence of or uneven government support in incentives and the implementation of renewable projects, as well as geographical limitations – such as the lack of suitable or large land for solar or wind farms or hydropower generators – are some of the main challenges. RE projects are often located in remote locations due to traditional town planning, which places industrial assets far from suburban areas and increases the costs of renewable energy. This lowers the attractiveness for consumers to convert to RE usage when conventional energy products may be cheaper and more accessible. Further, Southeast Asia's renewables market is still in development. Market knowledge is still shallow, and some countries are still sceptical about investing in this new technology, which may result in waning market interest over time.

5. The ASEAN countries' renewable plan and progress by now

The development process for RE has always been the main target accomplished by the ASEAN governments. The investments towards this goal, accompanied by cheaper technologies implementation and given economies of scale that contribute to less cost involved, the authorities took significant actions to tackle the problem regarding the reduction of carbon emissions. Unforeseen challenges are presented during 2020 that somehow negatively affect the development of this sector; however, the determination towards achieving the main outcome for the RE plan in the ASEAN governments has not been affected, and it is expected to pick up at a quick pace despite the obstacle encountered. The consensus is to enhance the development of the RE plan and recover the loss caused during the pandemic in the ASEAN countries. The authorities of ASEAN proceed with the second phase of the ASEAN Plan of Action for Energy Cooperation (APAEC), in which a five-year sustainability plan will commence starting from 2021 till 2025. A 23% share of RE in total primary energy supply, along with 35% in the region and ASEAN installed power capacity by 2025, respectively, has been agreed and set as a target by the ASEAN energy ministers under the APAEC. In terms of energy power to be generated as RE, 35GW to 40GW is set as a target to be achieved by 2025 [23]. Significant progress towards the development of RE is shown within the ASEAN member countries; the evaluation is done by looking at the investments towards the infrastructure in the sustainability plan. Table 2 (Appendix) represents the evaluation of the top investments for each ASEAN member country.

The RE project implemented for each member country of ASEAN has a significant trend to be observed. The size of the project implementation is very dependent on the size of the country itself; the larger the scale of the country region, the more the human population, hence, the energy consumption demand rises. The government implements large-scale projects to satisfy the daily needs of consumers. However, the condition regarding direct proportionality of the country scale region and consumer demands does not really apply to all countries in ASEAN. There are still some other factors that greatly affect the decision of local authorities to scale up their project regardless of the country's regional scale. Among the countries, it is shown that the Vietnamese government emphasized the RE sector more than that of the Malaysian government by direct comparison; although both countries had almost a similar regional scale, the investments and the outputs varied differently. The demand for RE is greatly economically beneficial for some countries, depending on the local authorities' decision. Hence, for some reason, a smaller-scale country may produce more energy output or invest a lot in the renewable energy sector, but on the other hand, a large country might not do so. According to research information, there is a trend that shows ASEAN member countries focus more on the renewable sector regarding hydropower. Even the largest ongoing project, Mamberamo Hydro Power Plant 23,000 MW in Indonesia, is also the largest hydropower generation project. Being the largest regional-scale country in ASEAN, the Indonesian government is currently planning the largest RE project in the country. Compared to other member countries, their project scale is way larger than the others, regardless of the cost of the project or the amount of output RE produced. As shown above, several member countries of ASEAN have significantly low amounts of data acquired due to the RE project scale of the location being contrastingly lesser than that of bigger regional coverage member countries. As shown above, regarding Brunei and its overall development in the RE sector, the most recent project is completed, the project scale is also small compared to other bigger countries, and the value of investments is similarly lesser. The BSP (photovoltaic) solar farm project did not announce the exact total amount of investments towards the project; hence, the exact value remains unknown. The overall RE targets and plan to achieve regarding each member country in ASEAN are at a good pace in terms of development. Predictions and expectations are set by different countries in the hope of achieving their expected outputs within the time span they set. Brunei has not set any specific RE target, but the country has made efforts to promote the use of RE, particularly in the form of solar power. Cambodia aims to increase the share of RE in the electricity mix to 20% by 2023, with plans to increase the use of hydropower and solar energy [31]. Indonesia aims to increase the share of RE in the electricity mix to 23% by 2025, primarily through the increased use of geothermal, solar, and hydropower [32]. Laos aims to generate 90% of its electricity from renewable sources and have their total energy consumption by 30% through RE by 2025, mainly through hydropower, but also through other sources such as solar and wind power [33]. Malaysia aims to increase the RE in the capacity level to 20% by 2030, and currently, up till 2023 is at 25% [34], with plans to increase the use of solar, biomass, and biogas. Myanmar aims to increase the share of RE in the electricity mix from 8% in 2021 to 12% by 2025, mainly through hydropower but also through other sources such as solar and wind power [35]. Progress is in good condition. The Philippines aims to increase the share of RE in the electricity mix to 35% by 2030, with plans to increase the use of wind, solar, hydro, and geothermal power [36]. Singapore aims to increase the share of RE in the electricity mix to 3% by 2030, with plans to increase the use of solar power [37]. Thailand aims to increase the share of RE in the energy mix to 30% by 2036, with plans to increase the use of solar, wind, and biomass power. Vietnam aims to increase the share of RE in the electricity mix to 10% by 2030, with plans to increase the use of wind, solar, and hydropower power [38]. Overall, the ASEAN region aims to achieve a collective target of increasing the share of RE in the region's energy mix to 23% by 2025. To achieve this, ASEAN countries are implementing a range of measures, including policy reforms, capacity building, and investment in RE infrastructure. The region has significant potential for RE, including solar, wind, hydropower, and biomass, and governments are working to harness this potential to reduce greenhouse gas emissions and increase energy security.

6. Case studies of renewable energy development in ASEAN

Energy resources in the ASEAN region are diversified and plentiful, ranging from oil and gas to a variety of RE sources. Several case studies on the growth of RE in ASEAN have been published. The region has set ambitious goals to increase the amount of RE in its energy mix. The primary conclusions of successful RE projects are summarised and examined in this literature review. The first example is the Tolo Wind Farm, which is constructed in Indonesia. The Tolo wind farm in South Sulawesi, Indonesia, is one of the largest wind farms in Southeast Asia. It has a total capacity of 72 MW and consists of 20 turbines [39]. The project was developed by PT UPC Sidrap Bayu Energi and started operating in early 2018. The Tolo wind farm is expected to reduce carbon

emissions by more than 200,000 tons per year. Likewise, another example is The Coara Marang Solar Plant project, which can be found in Malaysia. According to [40], the solar facility site covers 245 hectares to the northeast of Peninsular Malaysia. It is made up of 216,832 premium bifacial solar panels that are fixed to single-axis trackers. This is to ensure maximum energy production efficiency with a total capacity of 116 MW. The solar panels are expected to generate roughly 230 GWh of electricity per year, which is enough to power 55,000 households on average. More than 170,000 tons of CO_2 emissions are also prevented annually by the project. Furthermore, the Srepok 1 and Quang Minh Solar projects are other examples that are built in Vietnam. Ref [41] states that Srepok 1 and Quang Minh solar projects are developed by Sunseap Group and InfraCo Asia, respectively, which have a combined capacity of 168 MW. They are expected to generate more than 350,000 MWh of electricity per year, enough to power around 200,000 homes. The projects are helping to reduce carbon emissions and support the growth of the RE sector in Vietnam.

In addition, the next example is The Bangui Bay Wind Farm, which is in the Philippines. The Bangui wind farm in Ilocos Norte, Philippines, was the first commercial wind farm in Southeast Asia. It has a total capacity of 41 MW and consists of a total of 26 turbines [42]. The project was developed by NorthWind Power Development Corporation and started operating in 2005. The Bangui wind farm has helped to reduce carbon emissions and provide clean RE for the region. Lastly, the Nam Ngiep 1 Hydropower Project is the last example that can be found in Laos. It has a capacity of 290 MW and is expected to generate over 1,200 GWh of electricity annually [43]. The project is being developed in Bolikhamxay along the Ngiep River, with a 167-meter main dam height, to create a 67 km^2 water storage reservoir. The objective is to develop a power project that is socially and environmentally responsible, will offer clean, renewable electricity, and will aid in the reduction of poverty in Laos. Besides, there are some factors that may have contributed to the success of the RE projects. This can also include lessons that can be learned and implications for future RE development in ASEAN. According to [44], one of the factors is supportive government policies that can provide a favorable environment for RE projects to succeed. In some cases, governments may offer incentives such as tax breaks or subsidies to encourage investment in RE. The importance of these supportive policies and regulations can be a lesson to be learned. Additionally, policies such as feed-in tariffs, RE targets, and carbon pricing mechanisms have been effective in promoting RE development in the region. It also prioritizes RE sources over fossil fuels, which can help to create demand for RE projects.

Similarly, another factor will be access to financing, which is crucial for RE projects to succeed [45]. This may include access to loans, grants, or other types of funding. Financial institutions and development banks may play a critical role in providing funding for RE projects. Therefore, future RE projects in ASEAN will need to secure adequate funding and financing to ensure successful implementation, especially for large-scale projects. Haile et al. [46] also rationalize that strong collaboration between public and private sector entities can be another essential factor for the success of RE projects. Public-private partnerships can bring together the strength, expertise, and resources needed to develop and implement large-scale RE projects. By working together, countries in the region can share best practices, pool resources, and develop joint projects. This could include the development of regional transmission infrastructure, joint investment in RE projects, and the sharing of expertise and knowledge. Future RE projects in ASEAN should seek to establish strong public-private partnerships to achieve project goals and bring in private sector expertise. Then, favorable natural conditions, such as high wind speeds or ample sunlight, can be an important factor in the success of RE projects. Projects that are in areas with abundant natural resources may have a higher likelihood of success [46]. This can also be important for future RE projects in ASEAN that should take advantage of these resources to develop a diverse portfolio of RE sources and reduce dependence on fossil fuels. After that, Mokan et al. [44] mentioned that engaging and securing the support of local communities is another critical factor for the success of RE projects. Communities that are supportive of RE projects may be more likely to participate in them, which can help to increase project viability. Then, several successful RE projects had environmental and social considerations at the forefront of project design, such as creating jobs for residents and mitigating environmental impacts. Future RE projects in ASEAN must consider environmental and social implications and engage with local communities to ensure their buy-in.

Finally, the last factor is technological innovation, which plays a significant role in the success of RE projects. This is because many countries in the region still lack the technical expertise and infrastructure necessary to fully realize the potential of RE. Advances in RE technologies can make them more efficient and cost-effective, which can help to increase their viability [44]. So, future RE projects in ASEAN should continue to embrace technological advancements and innovation to drive progress and improve efficiency. In short, future RE development in ASEAN can learn from the success of past projects by emphasizing government support and policies, establishing strong public-private partnerships, securing adequate funding and financing, addressing environmental and social considerations, taking advantage of diverse RE resources, and embracing technological advancements and innovation. By doing so, ASEAN countries can continue to accelerate the transition to a more sustainable energy future.

7. Discussion

Considering the economic and environmental impact, as well as the policies of respective member countries for RE development in ASEAN, the future progress of the region's RE development plan seems promising despite the challenges faced. ASEAN countries have recognized the importance of transitioning to RE sources to reduce carbon emissions and promote sustainability. Although a major downfall in this renewable plan has happened, which is the COVID-19 pandemic, this did not ravage away the recognition of ASEAN countries to progress towards sustainability. ASEAN countries have implemented various policies, as mentioned previously, such as feed-in-tariffs, tax incentives, and renewable portfolio standards, to drive RE deployment. While challenges exist, including regulatory barriers, a lack of investment, and inadequate infrastructure, there are significant opportunities, such as abundant RE resources and increasing energy demand. With concerted efforts to address these challenges and further refine policy frameworks, ASEAN has the potential to make substantial progress in RE development over the next few decades. Continued commitment and collaboration among member countries will be crucial in achieving their RE goals and fostering a sustainable future.

Based on Table 1, Vietnam has the capacity of renewable energy with approximately 18523 MW. This can be attributed to its vast natural endowments. Vietnam has four to five kilowatt-hours per square meter for solar and 3,000 kilometers of coastlines with consistent winds in the range of 5.5 to 7.3 meters per second. Whilst its focus is primarily on wind projects, this renewable-led pathway has led Vietnam to a cheaper and cleaner energy plan whilst also providing an additional 465,000 jobs through 2030. Brunei has the least renewable energy capacity, with it only being 1 MW. This can be caused by its' small and limited land, with it being the smallest country in Southeast Asia by population, making it hard to construct renewable energy plantations. Furthermore, its land is oil-rich, making renewable energy unnecessary. Despite this, Brunei acknowledges the importance of renewable energy. Brunei's government is planning to utilize a waste-to-energy facility. This facility is expected to have an installed capacity of up to 10 MW. Whether other alternative energy sources such as wind power, hydropower, and ocean are economically and technically feasible in the medium term and the long term is still being researched. These initiatives are supporting the government's aspiration of generating at least 10 percent of the total power generation mix from renewable resources by 2035. Every country has its own renewable energy that is best suited for it. For example, Malaysia's hydropower generates much more energy than its' solar department. It all comes down to allocating funds to the correct and most suitable renewable energy source for each criterion. Furthermore, investing in RE will not produce results immediately but instead is a long-term project that will yield results in the future and, overall, reduce global warming.

8. Conclusion

RE policies in ASEAN countries promote the use of RE technologies. While countries have implemented policies like feed-in-tariffs and tax incentives, their effectiveness varies. Challenges include regulatory barriers, lack of investment, and inadequate infrastructure. Despite obstacles, ASEAN has opportunities for RE development due to resources and government support. To achieve targets, countries must address challenges and adopt effective policies that encourage investment in RE. The case studies of ASEAN member countries' renewable energy (RE) development plans reveal diverse experiences and challenges. Thailand stands out as a success story with effective policies and incentives leading to significant growth in solar and wind power. Malaysia's feed-in-tariff policy has been successful in promoting RE deployment, particularly in solar energy. Indonesia has faced obstacles in implementing RE policies, including delays in feed-in tariff implementation and regulatory hurdles. The Philippines has attracted investments through a Renewable Portfolio Standard but struggles with grid integration and transmission infrastructure. Vietnam has made significant progress in the solar and wind sectors through policy reforms and foreign investments. These case studies highlight the need for careful planning, supportive measures, and collaboration among member countries for successful RE development. The economic impact of RE plans in ASEAN member countries is both positive and negative. They create jobs, stimulate economic growth, and reduce dependence on costly fossil fuel imports. However, the initial costs of implementing RE projects and the need for additional investments in energy storage and grid infrastructure pose financial challenges. To maximize the positive economic impacts, supportive policies, incentives, and collaboration are crucial, along with strategic investments and research in RE technologies. RE development in ASEAN has the potential to significantly reduce greenhouse gas emissions and mitigate climate change impacts. RE sources emit far fewer greenhouse gases and pollutants compared to coal-fired power plants. However, careful management is required to address environmental concerns such as land use change, habitat fragmentation, soil erosion, water use, and waste generation associated with RE projects. Collaboration with communities and stakeholders is crucial for sustainable and socially responsible RE development. The sustainability plan conducted by ASEAN member countries aims to reduce overall carbon emissions and brings a beneficial impact on the environment and economy. RE is a natural resource-saving approach that minimizes consumption and depletion. It offers cost-saving benefits through the use of renewable and reusable resources, resulting in higher energy production. If successfully carried out, the plan would lead to reduced resource consumption, pollution, and carbon emissions, benefiting both the ecosystem and the economy. Overall efficiency would improve, and member countries would enjoy cost savings in resource treatment, maintenance, and procurement.

Ethical issue

The authors are aware of and comply with best practices in publication ethics, specifically with regard to authorship (avoidance of guest authorship), dual submission, manipulation of figures, competing interests, and compliance with policies on research ethics. The authors adhere to publication requirements that the submitted work is original and has not been published elsewhere.

Data availability statement

Data sharing is not applicable to this article as no datasets were generated or analyzed during the current study.

Conflict of interest

The authors declare no potential conflict of interest.

References

[1] Gungwu, W. 2017. Southeast Asia and continental and maritime powers in a globalised world. Building ASEAN Community. p. 9.

[2] Wimalaratna, Y. P., Hassan, A., Afrouzi, H. N., Mehranzamir, K., Ahmed, J., Siddique, B. M., & Liew, S. C. 2022. Comprehensive review on the feasibility of developing wave energy as a renewable energy resource in Australia. Cleaner Energy Systems, p. 100021, DOI: https://doi.org/10.1016/j.cles.2022.100021.

[3] Khuong P. M., McKenna R., Fichtner W. 2019. Analyzing drivers of renewable energy development in Southeast Asia countries with correlation and decomposition methods. Journal of Cleaner Production, 213, pp. 710-22.

[4] ASEAN. 2016ASEAN plan of action for energy cooperation (APAEC) 2016-2025. ASEAN Centre For Energy; Accessed on 05-09-2023. [Available at: (2021-2025) ASEAN Plan of Action for Energy Cooperation (APAEC) 2016-2025 Phase II - ASEAN Centre for Energy (aseanenergy.org)].

[5] Hui, L.C., Meng, G.T.K., Jue, H.L., Qian, E.V.W., Hassan, A., Afrouzi, H.N. and Mehranzamir, K., 2022. Impact Of Covid-19 on renewable energy sector and lessons

learned: A case study on Malaysia. Future Energy, 1(3), pp.44-50.
[6] Pratiwi S., Juerges N. 2020. Review of the impact of renewable energy development on the environment and nature conservation in Southeast Asia. Energy, Ecology and Environment, 5(4), pp. 221-239.
[7] Vakulchuk R., Overland I., Suryadi B. 2023. ASEAN's energy transition: how to attract more investment in renewable energy. Energy, Ecology and Environment, 8(1), pp. 1-16.
[8] Dan N. L. 2022. Vietnam's Renewable Energy Policies and Opportunities for the Private Sector. The National Bureau of Asian Research, pp. 1 - 8.
[9] Guild J. 2019. Feed-in-tariffs and the politics of renewable energy in Indonesia and the Philippines. Asia & the Pacific Policy Studies, 6(3), pp. 417-431.
[10] Muhammad-Sukki, F., Abu-Bakar, S.H., Munir, A.B., Yasin, S.H.M., Ramirez-Iniguez, R., McMeekin, S.G., Stewart, B.G. and Rahim, R.A., 2014. Progress of feed-in tariff in Malaysia: A year after. Energy policy, 67, pp.618-625.
[11] Yuliani D. 144Is Feed-In-Tariff Policy Effective for Increasing Deployment of Renewable Energy in Indonesia?. The Political Economy of Clean Energy Transitions, 1.
[12] Coalition for Action. 2019. Scaling up renewable energy investment in the Philippines, Accessed on 04-09-2023. [Available from: https://coalition.irena.org/-/media/Files/IRENA/Coalition-for-Action/Coalition-for-Action-_Scaling-up-RE-Investment-Philippines.pdf].
[13] Scandrett G. 2017. Environmental Impacts of Renewable Energy Sources. Accessed on 02-09-2023. [Available from: https://www.adecesg.com/resources/blog/environmental-impacts-of-renewable-energy-sources/#:~:text=for%20electricity%20generation.-,Electricity%20from%20renewable%20energy%20sources%20produces%20between%2090%2D99%25%20less,from%20air%20pollution%20and%20GHGs.
[14] Van de Ven, D. J., Capellan-Peréz, I., Arto, I., Cazcarro, I., de Castro, C., Patel, P. and Gonzalez-Eguino, M., 2021. The potential land requirements and related land use change emissions of solar energy. Scientific reports, 11(1), p. 2907.
[15] Nong, D. H., Ngo, A. T., Nguyen, H. P., Nguyen, T. T., Nguyen, L. T. and Saksena, S., 2021. Changes in coastal agricultural land use in response to climate change: an assessment using satellite remote sensing and household survey data in Tien Hai district, Thai Binh Province, Vietnam. Land, 10(6), p.627.
[16] Pimentel, D. and Krummel, J., 1987. Biomass energy and soil erosion: Assessment of resource costs. Biomass, 14(1), pp.15-38.
[17] Hecht JS, Lacombe G, Arias ME, Dang TD, Piman T. 2019. Hydropower dams of the Mekong River basin: A review of their hydrological impacts. Journal of Hydrology. 568:285-300.
[18] Energy IC. Is Renewable Energy Bad for the Environment? Accessed on 28-08-2023 [Available from: https://www.inspirecleanenergy.com/blog/clean-energy-101/does-renewable-energy-cause-pollution.
[19] Los Huertos M. 2017. Narratives about Energy, Megaprojects, and the Ecology of Tropical Rivers: The Baram River Dam Project. EnviroLab Asia. 1(3), p. 4.
[20] Erinle T. J., Hephzibah O. D., Moses A. O., Bamidele O. P. 2019. Environmental Impact of Renewable Energy Sources: Wind and Solar. 2nd International Conference, Center for Research, Innovation and Development (CRID) FPA, August 2019.
[21] Adityatama D. W., Al Asyari M.R., Ahmad A. H., Riyanto N., Purba D., Erichatama N. 2023. Potential Closed-loop Geothermal Power Generation Application for Non-commercial Well in Indonesia: A Preliminary Study. In PROCEEDINGS, 48th Workshop on Geothermal Reservoir Engineering. Stanford University. pp. 1-9.
[22] Fadilah S, Lestari R, Sahdan M, Khalid A. 2020. The Impact of Renewable Energy Consumption on the Economic Growth of the ASEAN Countries. International Journal of Energy Economics and Policy. 2020;10:602-8.
[23] Mclaren M. Governments across Southeast Asia accelerate renewable energy investment to revive the pandemic-hit economies. 2021.
[24] Cambodian government approves renewable energy projects: The Star; 2023. Acccessed on 23-08-2023. [Available from: https://www.thestar.com.my/aseanplus/aseanplus-news/2023/04/08/cambodian-government-approves-renewable-energy-projects.
[25] Sokmean O. Over 500 Megawatts of Clean Power Projects Approved. 2023.
[26] CS ENERGY CO. L. NAM NGUM 3: CHALEUN SEKONG ENERGY COMPANY LIMITED (CSE) 2023. Accessed on 09-09-2023. [Available from: https://csenergy.la/our-business/hydropower-plants/power-plants-under-construction/nam-ngum-3/?lang=en.
[27] TheStar. 2022. Laos to focus on development of renewable energy. Accessed on 03-09-2023. [Available at: Laos to focus on development of renewable energy | The Star].
[28] TheStar. 2023. Luang Prabang Mekong hydropower plant in Laos to be completed in 2030. Accessed on 03-09-2023. [Available at: https://www.bing.com/search?q=Luang+Prabang+Mekong+hydropower+plant+in+Laos+to+be+completed+in+2030&cvid=fc41a8ada2ed48b9a76828e758c5f416&aqs=ed[ge..69i57.440j0j4&FORM=ANAB01&PC=W099].
[29] BSP. ENERGY TRANSITION: Shell Brunei; 2023. Accessed on 10-09-2023 [Available from: https://www.bsp.com.bn/main/energy-and-innovation/energy-transition.
[30] UNDP. 2023. ACCELERATING CLEAN ENERGY ACCESS TO REDUCE INEQUALITY (ACCESS). Accessed on 12-09-2023. [Available at: Accelerating Clean Energy Access to Reduce Inequality (ACCESS) | United Nations Development Programme (undp.org)].
[31] Theangseng, H. (2021), 'Cambodia Country Report', in Han, P. and S. Kimura (eds.), Energy Outlook and

Energy Saving Potential in East Asia 2020, Jakarta: ERIA, pp.55-72.
[32] Raihan, A., Pavel, M.I., Muhtasim, D.A., Farhana, S., Faruk, O. and Paul, A., 2023. The role of renewable energy use, technological innovation, and forest cover toward green development: Evidence from Indonesia. Innovation and Green Development, 2(1), p.100035.
[33] Chandak P. Supply Security Through Hydropower Should Enable Laos To Expedite Renewables Development, Says Report. 2023.
[34] Afrouzi, H.N., Wimalaratna, Y.P., Ahmed, J., Mehranzamir, K., Liew, S.C., Wooi, C.L. and Siddiquea, B.M., 2021. A Comprehensive Review on Available/Existing Renewable Energy Systems in Malaysia and Comparison of Their Capability of Electricity Generation in Malaysia. Entropy and Exergy in Renewable Energy.
[35] Handayani, K., Overland, I., Suryadi, B. and Vakulchuk, R., Integrating 100% Renewable Energy in Developing Country Electricity Systems Using the Leap-Nemo Framework. Available at SSRN 4526878.
[36] Gonocruz, R.A.T., Yoshida, Y., Ozawa, A., Aguirre Jr, R.A. and Maguindayao, E.J.H., 2023. Impacts of agrivoltaics in rural electrification and decarbonization in the Philippines. Applied Energy, 350, p.121832.
[37] ADMINISTRATION IT. SINGAPORE SOLAR ENERGY. 2021. https://www.trade.gov/market-intelligence/singapore-solar-energy
[38] Govindarajan, L., Batcha, M.F.B.M. and Abdullah, M.K.B., 2023. Solar energy policies in southeast Asia towards low carbon emission: A review. Heliyon.
[39] Lee D. VENA ENERGY ANNOUNCES THE 72MW TOLO WIND PROJECT ACHIEVING COMMERCIAL OPERATION STATUS IN INDONESIA 2019. Accessed on 27-08-2023. [Available from: https://www.venaenergy.com/news/vena-energy-announces-the-72mw-tolo-wind-project-achieving-commercial-operation-status-in-indonesia/.
[40] Vogt I. ib vogt completes 116 MWp Coara Marang Solar Project in Malaysia 2023. Accessed on 27-08-2023. [Available from: https://www.ibvogt.com/ib-vogt-completes-116-mwp-coara-marang-solar-project-in-malaysia/#:~:text=The%20power%20plant%20is%20located,achieve%20maximum%20energy%20production%20efficiency.
[41] Renewable E. Sunseap International and InfraCo Asia Partner to Form Joint Venture for Solar Power Project in Vietnam 2018. Accessed on 28-08-2023. [Available from: https://apac.edpr.com/sg/news/2018/sunseap-international-and-infraco-asia-partner-to-form-joint-venture-for-solar-power-project-in-vietnam.html.
[42] Artelia. Bangui Bay Wind Farm seen as setting the trend in the development of renewable wind energy on this side of the world n.d. Accessed on 05-09-2023. [Available from: https://www.ph.arteliagroup.com/Services/bangui-bay-wind-farm/.
[43] 1 NN. Welcome to the Nam Ngiep1 Hydropower Project 2023. Accessed on 09-09-2023. [Available from: https://namngiep1.com/.
[44] Mokan K, Lee T, Ramlan R. 2019. The critical success factors for renewable energy projects implementation. Int J Recent Technol Eng IJRTE, 8, pp. 223-226.
[45] Othman K, Khallaf R. 2022. Identification of the Barriers and Key Success Factors for Renewable Energy Public-Private Partnership Projects: A Continental Analysis. Buildings, 12(10), p. 1511.
[46] Haile Y, Min H. Success factors for renewable energy businesses in emerging economies. Management Research Review, 46(8), pp. 1091-1111.

Appendix I

Table 2. ASEAN RE project development information

Project Name	Stage	Value (US$ million)	Start	Completion
Malaysia [23]				
• Baleh Dam and Hydroelectric Power Plant 1285MW	Execution	2,374	2013	2025
• Large Scale Solar Photovoltaic Plants Program	Execution	2,000	2020	2023
• Lebir Hydroelectric Power Plant 274 MW	Planning	845	2022	2028
• Pelagus Hydroelectric Power Plant 465 MW	Planning	800	2021	2024
• Nenggiri Hydroelectric Power Plant 300 MW	Planning	660	2022	2024
Vietnam [23]				
• ThangLong Ke Ga Offshore Wind Farm 3400 MW	Pre-Execution	11,900	2021	2027
• La Gan Offshore Wind Farm 3500 MW	Pre-Planning	10,000	2022	2030
• Binh Dinh Offshore Wind Power Plant	Planning	4,800	2022	2026
• Wind Power Plants Program 1000 MW	Execution	2,500	2020	2025
• Ninh Thuan Solar Power Complex 1000MW	Planning	2,000	2021	2024
Singapore[23]				
• TuasOne Waste-to-Energy Plant 120 MW	Execution	534	2016	2021
• SolarNova Program 350 MW	Execution	315	2016	2022
• Tengeh Reservoir Floating Solar Power Plant 60MW	Execution	70	2020	2021
• Sunshine Phase II: Solar Power Plant 20MW	Pre-Execution	25	2021	2022
Thailand [23]				
• Thailand Solar PV Plants Program 6000 MW	Execution	12,000	2017	2026
• Changwat Khon Kaen Photothermal and Photovoltaic Hybrid Power Station 90 MW	Pre-Execution	600	2021	2022
• Ratchapsatu Cogeneration Power Plant 95 MW	Planning	150	2022	2023
• Ubol Ratana Dam Floating Solar Farm 24 MW	Planning	65	2021	2023
• Sirindhorn Dam Floating Solar Farm 45 MW	Pre-Execution	63	2021	2022
Philippines [23]				
• Hydropower Plants Program 2300 MW	Pre-Planning	5,000	2021	2026
• Solar Power Plants Program 5000 MW	Planning	5,000	2021	2024
• Solar Farms Development Program	Planning	1,650	2021	2024
• Northern Luzon Hydropower Program 1000 MW	Pre-Planning	1,500	2021	2024
• Solar Power Plants Program 500 MW	Planning	1,000	2021	2023
Indonesia [23]				
• Mamberamo Hydro Power Plant 23,000 MW	Planning	35,000	2022	2030
• Renewable Power Plants Program 11000 MW	Planning	22,000	2022	2028
• Kayan River Hydroelectric Power Plant 9000 MW	Execution	17,800	2020	2035
• Kayan Hydropower Plant 1700 MW	Pre-Planning	7,000	2022	2026
• Indonesia Power Program: Hydro Power Plants 2400 MW	Execution	3,500	2015	2025
Burma [23]				
• Mong Ton Hydroelectric Plant 7000 MW	Execution	10,000	2016	2031
• Ywathit Hydroelectric Power Plant 4500 MW	Planning	4,500	2022	2030
• Hatgyi Hydroelectric Power Plant 1360 MW	Planning	2,600	2021	2026
• Hydropower Plants Rehabilitation Program	Planning	1,700	2021	2025
• Upper Thanlwin Hydroelectric Power Plant 1400 MW	Planning	1,400	2021	2023
Cambodia [24, 25]				

• Stung Russey Chrum Kandal Hydropower Plant 70 MW & Stung Veal Thmor Kambot Hydropower Plant 100 MW	Execution			
• Pursat Province Solar Power Project 150 MW	Execution	322	2023	2025
• Kampong Chhnang Province Solar Power Project 60 MW	Execution			
• Prey Veng Province Solar Power Project 80 MW	Execution			
Laos [26, 27, 28]				
Nam Gun 3 Hydropower Plant 480 MW	Planning	1400	2022	2027
Luang Prabang Dam 1460 MW	Execution	3000	2020	2030
Sekong Coal fire Power Plant 1000MW	Planning	1700	2025	2027
Monsoon Wind Power Project 600 MW	Planning	692.55	2022	2027
Phou Ngoy Hydropower Project 728 MW	Execution	2400	2022	2029
Brunei [29, 30]				
Tenaga Suria Brunei 1.3 MW	Completed	20	2009	2010
Brunei Shell Petroleum 3.3 MW	Completed	Multi-million	2020	2021