

Review

# The Status Quo, Dilemma, and Transformation Path of the Carbon Neutrality-Related Policy of the ASEAN

Fang Yang <sup>1,2</sup> and Chutong Li <sup>3,\*</sup> 

<sup>1</sup> Center for Southeast Asian Studies, Xiamen University, Xiamen 361005, China; yangfang@xmu.edu.cn

<sup>2</sup> Research School for Southeast Asian Studies, Xiamen University, Xiamen 361005, China

<sup>3</sup> Graduate Institute for Taiwan Studies, Xiamen University, Xiamen 361005, China

\* Correspondence: tylct@stu.xmu.edu.cn

**Abstract:** After joining the globalization initiative, countries from the Association of Southeast Asian Nations (ASEAN) have experienced an exponential growth in carbon emissions. The high carbon lock-in of the energy consumption structure and lagged energy infrastructure construction have led to high carbon emissions, which has put great pressure on ASEAN countries to reduce their carbon emissions. To achieve the goal of carbon neutrality by the middle of this century, ASEAN countries have successively formulated strategic guidelines for energy transformation and green development, focusing on the structural transformation of energy development and utilization, a coal decommissioning plan, grid interconnection, the electrification of urban transportation patterns, energy conservation, consumption reduction, and international technological cooperation. ASEAN countries still face many challenges in achieving their carbon neutrality targets, including unstable policies, poor environmental awareness among residents, poor guarantee for energy transformation, disconnection between technology and capital, and difficulties in regional coordination. These are reflected in the obvious carbon lock-in effect and the strong dependence on carbon in traditional industries. ASEAN countries are seeking a balance of interests in the Sino–US infrastructure game. In this context, China, as an advocate of South–South cooperation, is committed to expanding the cooperation with ASEAN countries on carbon neutrality in the following aspects: the development and utilization of renewable energy resources, formulation of a progressive grid interconnection plan, establishment of the green financial system, and research and development of green technologies. The purpose is to help ASEAN countries achieve their goals of carbon neutrality.

**Keywords:** ASEAN; carbon neutralization; policy evolution; energy transformation; green development



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## 1. Introduction

It has become the consensus of all countries in the world to jointly tackle global climate change. Since the 26th UNFCCC Conference of the Parties (hereafter referred to as COP26), countries have made emission reduction commitments and set carbon neutrality targets [1]. The 27th UNFCCC Conference of the Parties (COP27) held in 2022 once again urged countries to further implement emission reduction actions and climate goals, with a focus on helping developing countries better cope with climate disasters and achieve energy transition [2].

As the region most affected by climate change, the Association of Southeast Asian Nations (ASEAN) is under the greatest pressure to reduce carbon emissions in the future [3]. After ASEAN countries put forward the goal of achieving carbon neutrality, reducing carbon emissions through energy transformation and mitigating the negative impacts of climate change will become the focus of global climate governance. However, the fact is that ASEAN countries generally have problems, such as technological backwardness and

capital shortage. Therefore, extensive international cooperation is also needed in addition to their own active efforts.

Since the official dialogue between China and the ASEAN in 1991, the two sides have gradually formed a community of shared futures. Since 2009, China has been the ASEAN's largest trading partner, and by 2020, the ASEAN became China's largest trading partner as well. In addition to the economy, China and ASEAN also cooperate in the fields of climate governance and energy. As early as 2015, Chinese President Xi proposed at the United Nations Development Summit to "build a global energy internet and promote clean and green energy to meet global electricity demand." China and the ASEAN should accelerate their cooperation on green transformation, Chinese President Xi emphasized in 2021 at the summit commemorating the 30th anniversary of dialogue relations between China and the ASEAN. After setting the goal of achieving carbon neutrality, China and the ASEAN gained a great historical opportunity for a green and low-carbon transition cooperation, pointed out by the Belt and Road Green Development International Alliance in a report (*Green Low-Carbon Transformation of ASEAN Countries under the Belt and Road Initiative—Potential and Opportunities*) released in March 2022. As a responsible developing country, China has always been an active advocate and practical practitioner of the South–South cooperation on climate change and will continue to strengthen climate cooperations with other developing countries; China reaffirmed this later that year at the latest COP27 China Forum for South–South Cooperation on Climate Change.

Whether based on the development consensus of the UNFCCC Conference of the Parties or driven by such factors as geopolitical relations, economic cooperation, and cultural exchanges, China and the ASEAN are bound to cooperate in realizing the goal of achieving carbon neutrality. Therefore, to strengthen the energy cooperation between China and the ASEAN, it is necessary to determine the policy priorities, difficulties, and development space for ASEAN to achieve carbon neutrality.

The research on the ASEAN's climate and energy fields has been quite extensive, mainly involving the following three aspects: climate change, energy transformation, and energy cooperation between the ASEAN and China.

In terms of climate change, the existing research primarily focuses on the ASEAN's measures to address climate issues and the impact of climate issues on the economy. For example, Francisco et al. and Lian et al. [4,5] highlighted the implementation and evaluation of adaptive measures in Southeast Asian countries. Rasiah et al. [6] evaluated the cost of climate damage in Malaysia and ASEAN countries in the absence of climate policies and actions. Ding et al. [7] argued that, despite various adaptive measures, ASEAN countries' environmental performances regarding carbon reduction and addressing climate change remain poor. Amran et al. [8] analyzed the impact of extreme weather on economic development based on institutional and resource theories, and concluded that both internal resources and geographical regional effects can influence climate change business strategies. Some studies have also explored the impact of climate change on food security, and pointed out that climate change has changed the food system. Caballero et al. [9] emphasized the role of ASEAN mechanisms in considering food security issues comprehensively from economic, social, and cultural perspectives. Lassa et al. [10] further analyzed the specific evaluations and predictions of this impact.

In terms of energy transformation, the existing research primarily focuses on the current status of energy development, the development paths of clean energy, and the influencing factors of energy development and utilization. For example, Karki et al. [11] analyzed the energy resource management and energy utilization efficiency of ASEAN countries. Sovacool et al. [12] examined the challenges, implementation, and operation of the trans-ASEAN gas pipeline (TAGP) network. Additionally, Zheng, Nurdianto et al. and Kanchana et al. [13–15] compared the energy patterns, energy consumption patterns, and energy supply security of ASEAN countries to determine the driving measures for regional energy cooperation. Tongsopit et al. [16] evaluated the ASEAN's energy policies and found that the ASEAN made slow progress in energy security. Shi [17] pointed out that fossil

fuels still dominate in ASEAN countries despite the introduction of various energy policies, indicating the great potential for clean energy development. Some scholars have conducted detailed analyses of the clean energy potential, development paths, and obstacles in ASEAN countries [18–20], and evaluated the development and utilization of various types of clean energy in ASEAN countries from a technical perspective [21,22]. Additionally, scholars have also evaluated the flexibility of power grids in ASEAN countries and the feasibility of emission reductions in the power sector, and emphasized the importance of regional cooperation and clean energy development for achieving energy goals [23,24]. Heidari et al. [25] found that there was an inverted U-shaped relationship between economic growth and carbon dioxide emissions, and that per capita energy consumption significantly impacted carbon dioxide emissions. Zhu et al. [26] argued that, in high-emitting countries, greater economic growth and population size outcomes will reduce carbon emissions, as will higher levels of trade openness. However, Bakker et al. [27] argued that low-carbon transportation policies will reduce energy consumption and climate change. Furthermore, Husaini et al. [28] reported that the development of the digital economy could reduce energy consumption, and this effect would vary in different countries.

Hong [29] analyzed the energy cooperation and competition between ASEAN countries and China from the perspective of energy security. Liu et al. and Shi et al. [30,31] used the “sense of ownership” framework to analyze the success and failure of energy sector investments in the ASEAN, providing insights into the people-to-people bond under the BRI. Feng et al. [32] delved into the electricity cooperation between China and ASEAN countries. Deng [33] analyzed the cooperation between the ASEAN and China in the development of nuclear energy from clean energy. Liao et al. [34] evaluated the current status of the energy cooperation between China and ASEAN countries, emphasizing the need for China to strengthen its cooperation with the ASEAN regarding green energy. Scholars have also discussed energy finance and energy law from the perspectives of China and the ASEAN [35,36].

It is evident that there is a limited number of studies on the evolution and systematic characteristics of carbon neutrality policies in ASEAN countries. Particularly following the proposal of carbon neutrality goals by ASEAN countries, their measures involve not only energy transformations, but also multi-dimensional aspects, such as urban and rural developments, lifestyle transformations, and international cooperation. The policy logic and development evolution of these measures need to be investigated. This paper aims to analyze the carbon neutrality policies of ASEAN countries, identify their policy priorities while pursuing carbon neutrality goals, and analyze the challenges they face in this pursuit. Based on the above analysis, this paper proposes policy recommendations for the ASEAN to achieve energy transformation and carbon neutrality goals. Furthermore, with the official launch of the RCEP agreement, the energy cooperation between China and ASEAN countries has presented new development opportunities. This article proposes targeted policy recommendations in this regard.

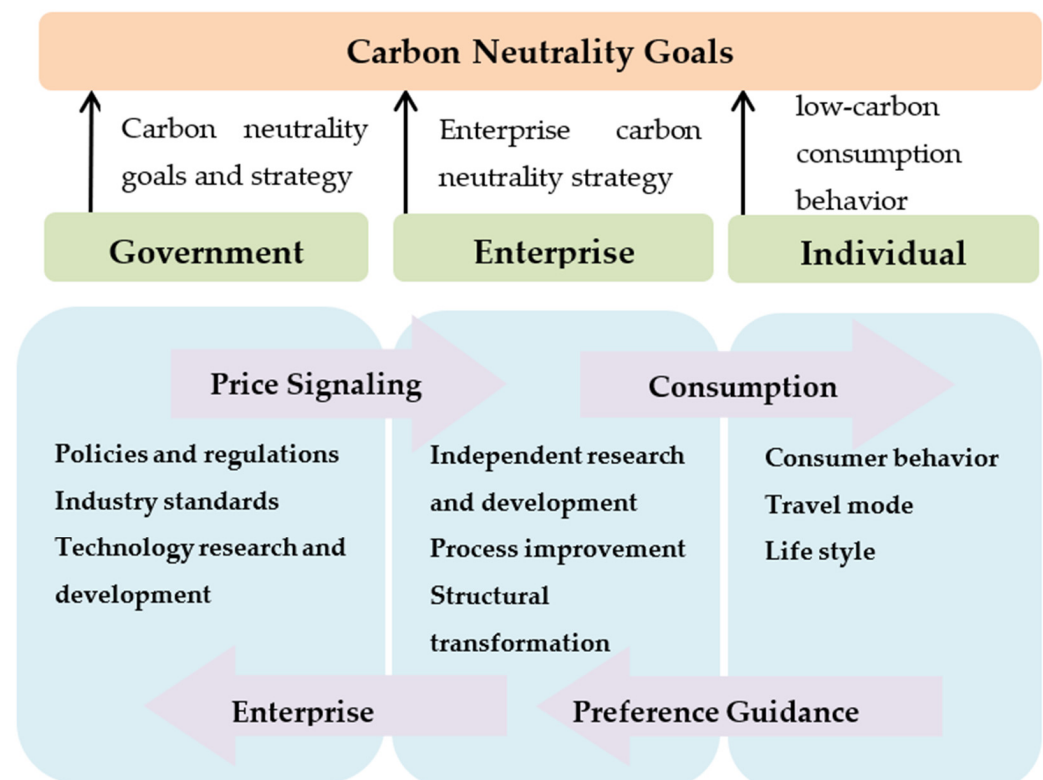
The subsequent sections are organized as follows. Section 3 introduces the carbon emissions trajectory of ASEAN countries. Section 4 summarizes the evolution of carbon neutrality policies in ASEAN countries. Section 5 analyzes the challenges faced by ASEAN countries and Section 6 presents the conclusion and policy suggestions.

## 2. Theoretical Framework for Achieving Carbon Neutrality Goals

The achievement of carbon neutrality goals cannot be separated from the positive interaction of society, and governments, enterprises, and individuals play a crucial role in advancing towards the vision of achieving carbon neutrality. Referring to Wang and Zhang [37], we constructed the following theoretical framework, as shown in Figure 1.

As the leader, supervisor, and policy maker of carbon neutrality actions, the government incorporates carbon neutrality goals into national economic and social development plans, formulates emission reduction policies, establishes industry standards, supports research and development, and fully plays its role in promoting energy conservation and

emissions reductions throughout society [5,7,11,22,24]. As the main actors in carbon neutrality practices, enterprises should actively respond to government policies; improve their overall efficiency through technological innovations, process improvements, supply chain management, and other measures; achieve low-carbon production; and form a positive interaction with consumers to promote green consumption [20,38,39]. Individuals are the main body implementing low-carbon consumption practices and practicing low-carbon concepts, and their interaction with the government and enterprises will promote the implementation of low-carbon policies and the development of low-carbon industries. At the same time, individuals play a supervisory role and provide suggestions for building an efficient carbon neutrality policy system [40,41].



**Figure 1.** Theoretical framework for achieving carbon neutrality goals.

The abovementioned theoretical framework is beneficial for us to analyze the policy system related to carbon neutrality in the ASEAN and the challenges of achieving carbon neutrality goals, as it comprehensively considers the main roles of the government, enterprises, and individuals in achieving their carbon neutrality goals, combines the behavioral advantages of each subject, and leverages the linkage between subjects. We can systematically analyze the relevant issues through this theoretical framework and provide targeted suggestions.

### 3. Trajectory and Characteristics of the ASEAN's Carbon Emissions

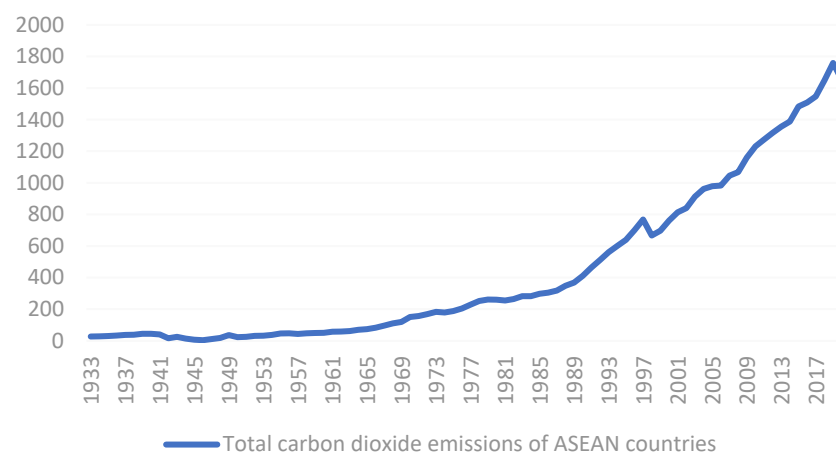
The carbon emissions trajectory is the most important determinant for predicting global temperature rise, and carbon emissions are the results of the complex interactions among social, political, economic, and technological systems [42]. The carbon emissions trajectory of ASEAN countries is closely related to the economic development, energy consumption structure, and energy infrastructure construction in different stages.

#### 3.1. Main Driver of High Carbon Emissions in ASEAN Countries: Industrial Transfer

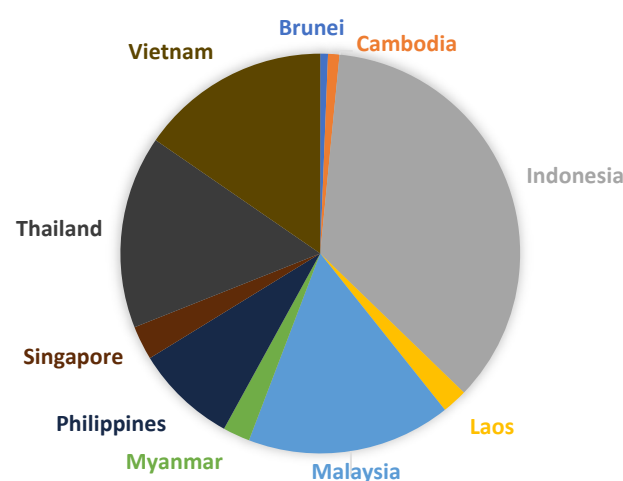
The ASEAN's overall carbon emissions show an annual increasing trend, especially after industrialization [26,43,44]. Since 1965, ASEAN countries have gradually shifted

to an export-oriented strategy by undertaking the transfer of primary processing and manufacturing industries and high-pollution heavy industries from Western countries and Japan. The introduction of production factors, such as high-density capital and advanced technologies, has considerably shortened the industrialization process of ASEAN countries and improved their industrialization efficiency. However, rapid industrial developments have also led to an exponential increase in carbon emissions.

On the whole, the ASEAN's share of global carbon emissions rose from 0.65% to 4.74% between 1965 and 2020, with an annual growth rate of 5.8%, well above the global value of 2.1%. Since the 21st century, the accelerated industrialization and urbanization processes in construction, transportation, and domestic electricity have greatly increased the energy demand, resulting in a sharp increase in carbon emissions (see Figure 2). Carbon emissions from emerging industrial countries, such as Indonesia, Malaysia, Thailand, and Vietnam, are particularly high, accounting for 85% of the ASEAN's total emissions (see Figure 3).



**Figure 2.** Total CO<sub>2</sub> emissions from ASEAN countries from 1933 to 2020. Data source: Our World in Data, CO<sub>2</sub> emissions by country. Website: <https://ourworldindata.org/> (accessed on 25 December 2023).



**Figure 3.** Proportion of CO<sub>2</sub> emissions from ASEAN countries in 2020. Data source: Our World in Data, CO<sub>2</sub> emissions by country. Website: <https://ourworldindata.org/> (accessed on 25 December 2023).

Developed countries and newly industrialized countries in the ASEAN have taken the lead in joining the globalization trend. In the 1960s and 1980s, Singapore's carbon emissions increased at an average annual rate of 16.68%, and in the late industrialization stage, it plummeted to about 2%. At present, the carbon emissions growth curve has



shown a turning point, and the carbon emissions growth rate has entered a negative value in the informatization stage. In Malaysia, the growth rate of carbon emissions in the industrial embryonic stage was close to 10%. As the economic growth slowed down, the growth rate of carbon emissions gradually declined. The less-developed countries mainly participated in the fourth industrial transfer after the financial crisis, so the peak of carbon emissions growth appeared relatively late. For example, when Cambodia transitioned from the agricultural stage to the industrial stage, its annual growth rate of carbon emissions soared to 10% from 1% (see Table 1). In general, the newly industrialized countries in the ASEAN have a larger carbon emissions base, the less-developed countries have a higher carbon emissions growth rate, and the developed countries have a lower base and smaller growth rate.

**Table 1.** Economic growth and carbon emissions growth of typical ASEAN countries in different development stages.

Development Stage	Year	Average Annual Growth Rate of GDP (%)	Average Annual Growth Rate of Carbon Emissions (%)	Average Annual Growth Rate of per Capita Carbon Emissions (%)
Advanced Economies: Taking Singapore as an Example				
Industrialization stage	1960–1980	9.06	16.68	14.43
Late industrialization stage	1980–2000	7.40	2.35	−0.25
Informatization stage	2000–2020	4.44	−0.31	−2.15
Emerging Industrializing Economies: Taking Malaysia as an Example				
Industrial embryonic stage	1960–1980	7.37	9.96	7.10
Industrialization stage	1980–2000	6.54	7.81	5.05
Late industrialization stage	2000–2020	4.30	3.93	2.21
Underdeveloped Economies: Taking Cambodia as an Example				
Agricultural stage	1960–1974	−0.57	1.01	0.24
Equal emphasis on the industry and agriculture stage	1974–1992	/	10.14	6.86
Industrialization stage	1993–2020	8.81	10.79	9.05

Data source: the division of industrialization stages is compiled based on the literature and carbon emissions data, and other data are calculated and organized by the author.

### 3.2. Energy Structure of ASEAN Countries

The energy consumption structure of ASEAN countries is characterized by high carbon lock-in. The energy consumption structure of major ASEAN countries has always been dominated by fossil fuels, with renewable energy consumption accounting for almost no more than 20% of the total consumption (see Table 2). Currently, about 75% of the ASEAN's electricity supply comes from fossil fuel facilities, while coal provides over 50% of the total electricity supply [45]. The statistics from the International Energy Agency (IEA) predict that three-quarters of the growth in energy demand will still be met by fossil fuels by 2030 [38].

**Table 2.** Energy consumption structure of ASEAN countries in 2021.

Country	Oil	Gas	Coal	Renewable Energy
Indonesia	34.06%	16.00%	39.47%	10.35%
Malaysia	34.84%	35.32%	21.24%	8.59%
Thailand	44.03%	33.07%	15.85%	7.04%
Vietnam	21.76%	6.02%	49.77%	22.69%
Philippines	41.84%	6.12%	40.31%	12.24%
Singapore	84.68%	13.87%	0.87%	0.29%

Data source: World Energy Statistical Yearbook 2022, which only counts the six ASEAN countries in the table above for the ten ASEAN countries. <https://www.vzkoo.com/document/202207113cf714b0dc4481cd505a20c3.html> (accessed on 25 December 2023).

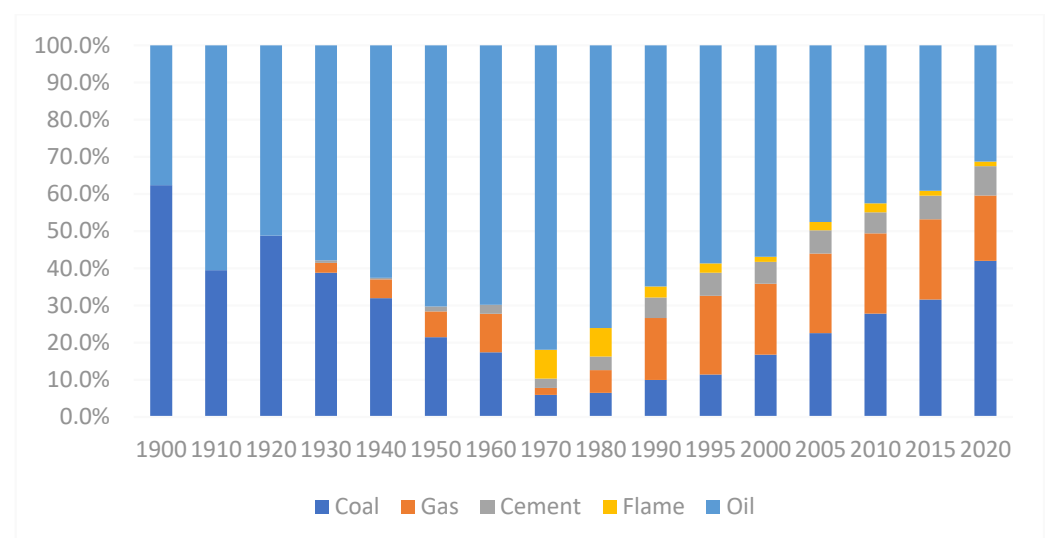
Although ASEAN countries are abundant in energy resources, it is difficult to develop and utilize clean energy, and there are still a large number of potential resources that have not been developed (see Table 3), making it difficult to break through the high carbon lock. According to the 2019 G20 Climate and Environment Report, the ASEAN lags behind other regions with the same energy endowment in clean energy development, and its solar power accounts for only 0.5% of total power, far below the European (10%) and world (1.3%) levels. Wind power accounts for only 0.2% of the total power generated, and its rich wind-energy resources have barely been developed.

**Table 3.** Development and regional distribution of renewable energy resources in ASEAN countries.

Country	Developed Renewable Energy Sources (MW)	Technology Preference-Based Renewable Energy and Development Goals	Overall Development Goals for Renewable Energy
Malaysia	6.286	Solar energy (18.7 MW), Hydropower	21.37 MW (2050)
Indonesia	6.68	Water energy (21.3 MW), Geothermal energy	46.307 MW (2025)
Brunei	1.67	Solar energy (954 GWH)	954 GWH (2025)
Singapore	5.898	Hydropower (8.937 MW), Solar energy	15.306 MW (2030)
Myanmar	3.204	Small hydropower (472 MW)	472 MW (2020)
Thailand	7.901	Solar energy (6 MW), Biomass energy (5.57 MW), Wind energy	19.684 MW (2036)
Philippines	33.1	Solar energy (350 MWP), Wind energy	350 MWP (2020)
Cambodia	0.952	Water energy (2.241 MW), Biomass energy	2.241 MW (2020)
Vietnam	17.14	Water energy (27.8 MW), Wind energy	45.8 MW (2030)
Laos	3.348	Small hydropower (543 MW), Wind energy, Biomass energy	951 MW (2025)

Data source: based on the research of Erdiwansyah et al. (2020) [46].

In summary, ASEAN countries are far from reaching the peak of the environmental Kuznets inverted “U” curve, so energy-intensive consumption will inevitably increase carbon emissions levels. The data show that, although ASEAN countries tend to diversify their energy consumption structures, the main sources of carbon emissions are still coal and oil. From the 1970–2020 period, following the oil crisis and integration into globalization, the proportion of carbon emissions caused by coal use in the total emissions increased from 5.9% to 42%, and that of petroleum carbon emissions remained above 30% (see Figure 4).



**Figure 4.** Sources of CO<sub>2</sub> emissions from ASEAN countries from 1900 to 2020. Data source: our World in Data, CO<sub>2</sub> emissions by source. <https://ourworldindata.org/> (accessed on 25 December 2023).

### 3.3. Backward Energy Infrastructure and Oversupply of Energy

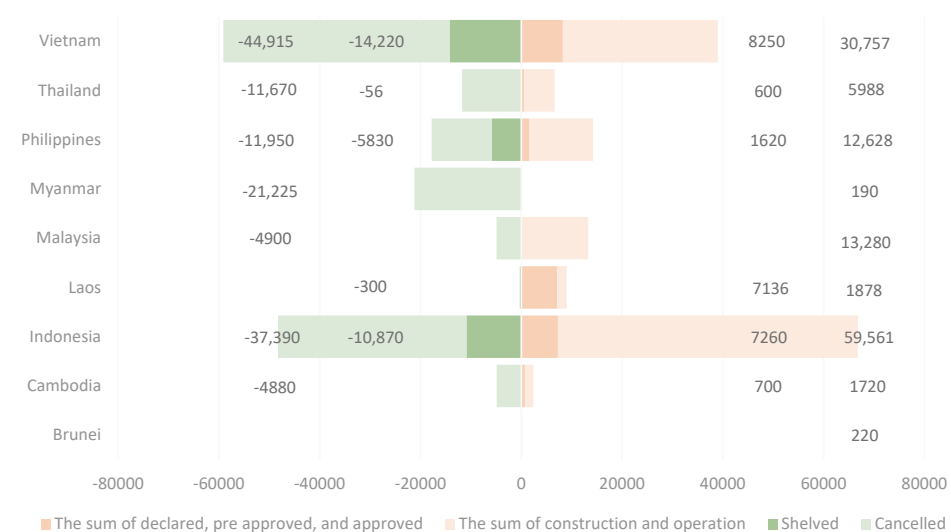
The energy infrastructure in most ASEAN countries is poor and below the world average level. There is an oversupply of energy and a significant gap between countries within the region. Most ASEAN countries consume more energy than they can produce and thus need to import energy. According to Zhang and Wang [20], the ASEAN population accounted for 8.5% of the world's total in 2017, but electricity consumption only accounted for 3.9% of the global electricity consumption. The per capita electricity consumption was 1350 kWh, far below the world average of 4616 kWh. In addition, the per capita electricity consumption of some ASEAN underdeveloped countries, such as Myanmar and Cambodia, was significantly different from that of Brunei and Singapore (see Table 4). This shows that there is a significant gap in ASEAN energy levels.

**Table 4.** Current situation of energy and electricity production and consumption levels in ASEAN countries.

Country	Energy Output Value (Thousand Tons)	Energy Consumption (Thousand Tons)	Per Capita Electricity Consumption in 2020 (KWH)	Net Energy Import (%)
Indonesia (2020)	2,990,402.4	1,001,672.9	882.6	−112.28
Malaysia (2019)	186,009.4	207,266.4	4782.9	−5.76
Philippines (2020)	17,350.4	41,850.3	759.6	45.32
Cambodia (2020)	NA		675.8	31.64
Brunei (2020)	5418	7779	9001.3	−458.37
Myanmar (2019)	670,696	157,428	354.8	−39.82
Singapore (2020)	NA		8927.6	97.56
Thailand (2020)	4504	78,941	2679.8	42.47

Data source: Asian Development Bank database; World Bank database.

The development of clean energy is not only difficult, but also takes a long period of time. Therefore, ASEAN countries tend to choose cheap and low-technology fossil fuels to meet the electricity demands, leading to a continuous increase in carbon emissions. Currently, ASEAN countries have a large number of coal power plants approved, under construction, or in operation. It can be observed that Indonesia and Vietnam have a large base of coal power plants, while Malaysia, Laos, and Indonesia are still in an growing stage of coal power utilization (see Figure 5). It is expected that carbon emissions from the power sector could decrease by 2050, but it is difficult to achieve net zero.



**Figure 5.** Current situation of coal power plants in ASEAN countries. Data source: Global Energy Monitoring's global coal-fired power plant tracker, with data from 2010 to 2022 removed and construction data from 2022. <https://globalenergymonitor.org/projects/global-coal-plant-tracker/dashboard/> (accessed on 25 December 2023).



#### 4. Evolution and Characteristics of Carbon Neutrality-Related Policies

As parties to the Paris Agreement, all ASEAN countries have submitted National Independent Contribution (NDC) commitments to reduce greenhouse gas emissions while limiting global warming to 1.5 °C. To this end, the ASEAN Energy Cooperation Action Plan (2016–2025) proposes to increase the share of clean energy in the regional primary energy supply structure to 23% by 2025, including increasing the share of renewable energy in an installed capacity to 35% by 2025, and increasing the target of reducing energy intensity levels to 32% by 2025, demonstrating the determination to achieve a low-carbon transformation. The 2021, COP26 further demonstrated the ASEAN’s growing energy transformation ambitions. By the end of COP26, all ASEAN countries, except the Philippines, had explicitly proposed carbon neutrality targets. Singapore, Indonesia, Cambodia, and Thailand submitted long-term strategies for achieving carbon neutrality to the United Nations by December 2022.

Despite the different carbon neutrality targets, ASEAN countries have many similarities in their policies and measures to achieve carbon reduction goals. It is, therefore, necessary to analyze the existing carbon neutrality policies in ASEAN countries, summarize the commonalities and differences of national policies and dynamic mechanisms of emissions reduction behavior, and determine the current and future development priorities of ASEAN countries in achieving carbon neutral goals. Based on the theoretical analysis framework mentioned above, we comprehensively analyzed the evolution and future implementation priorities of carbon neutrality policies in ASEAN countries, with policies, enterprises, and individuals as the main analysis subjects, their behaviors as the policy orientation, and their interactions as the policy framework.

##### 4.1. Carbon Decoupling by Setting Carbon Neutrality Targets and Accelerating Energy Structure Transformation

The key to realizing the goal of achieving carbon neutrality is to promote energy transformation, that is, to replace fossil energy with renewable energy on both the supply and demand sides. ASEAN countries have made specific commitments based on their energy endowments in the types and intensity of renewable energy consumption, the capacity share of renewable energy power, and the application of renewable energy in transportation fuels, and have specified a time point for achieving carbon neutrality (see Table 5). ASEAN countries have actively deployed energy transformations before making carbon neutral commitments. They have made great efforts to develop clean energy in various ways.

**Table 5.** Summary of energy transformation goals of ASEAN countries.

Country	Energy Transformation Goals	Climate Change Goals	Net-Zero Emissions Target
Brunei	By 2035, 30% of electricity by renewable energy will be achieved.	By 2035, the carbon dioxide, CO <sub>2</sub> , emissions generated from vehicle use during peak hours will be reduced by 40% compared to BAU levels.	2050
Cambodia	By 2030, the total installed capacity will reach 55% hydroelectric power generation, 6.5% biomass power generation, and 3.5% solar photovoltaic power generation.	With international support, Cambodia aims to reduce its greenhouse gas emissions from baseline emissions by 27% by 2030.	2050
Indonesia	An increase in the share of renewable energy in the primary energy supply will rise to 23% by 2025 and 31% by 2050.	With international support, Indonesia aims to reduce its greenhouse gas emissions at the BAU level by 41% by 2030.	2060

Table 5. Cont.

Country	Energy Transformation Goals	Climate Change Goals	Net-Zero Emissions Target
Laos	From 2021 to 2030, renewable energy will account for 52% of the newly added electricity capacity.	/	2050 (additional conditions)
Malaysia	By 2025, renewable energy will account for 30% of the total energy consumption.	By 2030, Malaysia proposes to reduce the intensity of greenhouse gas emissions in GDP by 35% from the 2005 levels and increase this to 45% with international support.	2050
Myanmar	By 2025, Malaysia aims to achieve 20% of renewable energy and 31% of renewable energy installed capacity in the electricity capacity portfolio.	/	2050
Philippines	By 2025, the proportion of the renewable energy installed capacity will reach 20%.	With international support, the Philippines pledges to reduce its greenhouse gas emissions from BAU levels by 70% by 2030.	/
Singapore	By 2030, the installed capacity of solar photovoltaic energy will be 2 GW.	By around 2030, the carbon peak will be achieved, and the emissions peak will not exceed 65MtCO <sub>2</sub> . By 2050, emissions will be reduced by half from their peak, reaching 33MtCO <sub>2</sub> , to achieve net-zero emissions by the second half of this century.	2050–2011
Thailand	By 2037, Thailand aims to increase the proportion of renewable energy in the total final energy consumption to 30%, the capacity of renewable energy electricity to 36%, and the proportion of power generation to 20%.	By 2030, Thailand proposed to reduce its greenhouse gas emissions from BAU levels by 20% and increase them by 25% with international support.	2065
Vietnam	By 2036, Vietnam will increase the proportion of its renewable energy in transportation fuel consumption to 25%. By 2030, renewable energy will account for 15–20% of the primary energy consumption and 25–30% by 2050. The installed capacity of solar photovoltaic and wind energy is in the range of 31–38 GW. The installed capacity of offshore wind power is 4 GW, which will be 36 GW by 2045.	With international support, Vietnam aims to reduce its greenhouse gas emissions by 9% and 27% at the BAU level by 2030.  By 2035, the carbon dioxide, CO <sub>2</sub> , emissions generated from vehicle use during peak hours will be reduced by 40% compared to BAU levels.	2050

Data source: compiled by the author based on “Southeast Asia Energy Outlook 2022”.

To achieve a low-carbon transformation of the energy system, ASEAN countries have adopted three policy models. The first is to establish an energy committee specifically responsible for the formulation, implementation, and supervision of renewable energy policies and projects, to ensure that renewable energy development policies are following economic developments. Studies have shown that the insufficient development of clean energy in ASEAN is partly ascribed to policy deficiencies at the national and regional levels [18]. However, the clean energy development funds provided by ASEAN countries will facilitate the energy transformation [19]. The second is to focus on policy continuity, that is, follow-up policies should try to improve the weak points of the previous policies. The third is to allow local governments to formulate energy policies and regulations specific to regions and industries under the guidance of central policies.

In addition, to realize the positive effect of “policy signals–investment confidence–price advantages”, ASEAN countries fully stimulate the economic benefits of their clean energy endowments through three types of incentive policies. One is to reduce or exempt

the enterprise's income and import taxes or provide production incentives for clean energy development, as well as import raw materials and equipment. Some studies have pointed out that tax incentives are conducive to the investment environment and the development of the geothermal industry in the ASEAN region [47]. The second is to establish a special renewable energy fund or green climate fund to encourage investments in technological innovations in clean energy developments, energy storage, energy internet, etc., and to provide financing services for private enterprises in the research, development, utilization, and promotion of renewable energy. The third is to comprehensively utilize the "Feed in Tariffs" mechanism and the "Net Metering" plan. Government subsidies are used to encourage enterprises to develop and utilize clean energy, ensuring sustainable investments in renewable energy [48,49], and create employment opportunities. In addition, individuals are encouraged to carry out clean energy power generation projects and achieve a stable supply of electricity through public and private energy lending schemes to achieve peak shaving and valley filling results.

Furthermore, ASEAN countries have established a standard system for renewable energy development to provide guidance for a zero-carbon transition. The standards of ASEAN countries were formulated mainly based on their energy endowments. Based on the existing system framework, some technical processes were modified to ensure the adaptability of the modified processes to the existing system [39]. They underwent a development process of "integration–coordination–comprehensive innovation". In order to better understand the renewable energy development policies in ASEAN countries, we provide some typical cases in Table 6.

**Table 6.** Summary of typical cases corresponding to renewable energy development policies in ASEAN countries.

Policy Formulation Model	Typical Cases and Explanations
Policy timing	Brunei's "Strategic Plan 2018–2023" (2018) established an energy database that enables information and technology sharing and cross-departmental collaborations, and established regulatory departments to test verify the effectiveness of policy implementations based on the data, and to dynamically improve and modify policy frameworks.
Policy adaptability	Both Brunei's Energy White Paper (2014) and Myanmar's Energy Master Plan (2016) emphasize at the start that energy development must be in line with its suitability for economic development.
Policy continuity	Indonesia's Regulations on Household Electricity Subsidies (2016) and the National Energy Master Plan (2017) were implemented under the guidance of the energy law (2007).
Income tax incentives	Vietnam's Electricity Law provides tariff preferences for the import of energy-saving equipment or production materials.
Green fund	The Philippines' Renewable Energy Plan (2011–2030) established a Renewable Energy Trust Fund to support the research, development, and utilization of renewable energy.
Feed in tariffs	In 2013, Thailand implemented the feed-in tariff rules for solar energy projects, with a feed-in period of 25 years. The feed-in tariff was THB 6.96 per unit for residential unit buildings with a capacity of less than 10 KWP, THB 6.55 per unit for small commercial buildings with a capacity of below 250 KWP, and THB 6.16 per unit for large- and medium-sized commercial buildings/factories with a capacity of less than 1 MWP.
Net metering	Singapore's "Strengthening the Regulatory Framework for Intermittent Generation Resources in the National Electricity Market" (2017) implemented the "net settlement" and simplified the process for individuals to receive payments for excess electricity payments sold to the grid.

Data source: the author compiled the data based on the "ASEAN Energy Database" and the "Asia Pacific Energy Portal". It should be noted that, due to the varying policies of ASEAN countries and the lack of specific implementation rules, despite some countries proposing relevant policies, this article only lists and issues typical policy rules with commonalities to reflect policy characteristics. <https://aeds.aseanenergy.org/> and <https://asiapacificenergy.org/> (accessed on 25 December 2023).

#### 4.2. “A Firm Attitude and Lagging Action” toward the Coal Decommissioning Plan

Among ASEAN countries, only Indonesia, Malaysia, the Philippines, and Singapore committed to coal decommissioning in COP26. However, it is worth noting that Brunei, Indonesia, the Philippines, Singapore, and Vietnam all signed the Coal to Clean Energy Transition Agreements during COP26. In addition, Indonesia, the Philippines, and Vietnam also participated in coal early withdrawal plans under the leadership of the Asian Development Bank. Coal accounts for the largest proportion of the ASEAN’s energy structure and is a key driving force for industrial development. It is extremely difficult to achieve complete decarbonization within the target period. In view of this, major industrial ASEAN countries have reservations about coal removal plans [17], and their policies are more focused on promoting clean coal technology to reduce the negative impacts of high carbon emissions. For example, Thailand’s Power Development Plan 2012–2030 (2012) requires new coal-fired power plants to carry out clean coal technology research and development. Nevertheless, only 31 out of the 97 power generation projects predicted in the Plan for the 2015–2025 period are renewable energy projects, while the rest are new and expanded coal power plants. In the future, clean coal technology cooperation will also be the focus of ASEAN countries in the energy transformation process.

#### 4.3. Electrification Reform Based on “Fairness” and “Efficiency”

ASEAN countries are committed to achieving 100% electrification between 2025 and 2030 by increasing the electrification rate. They hope to achieve the goal of carbon neutrality by changing the economic development model and the lifestyles of residents [50,51]. To accelerate electrification, they have introduced countermeasures in electricity pricing and power grid construction.

In the formulation of electricity prices, ASEAN countries are addressing the challenges related to significant industrial power waste and substantial urban–rural electricity price differences [52]. In response, ASEAN countries are returning to market pricing in industrial and urban electricity consumption practices to mitigate the environmental pollution stemming from energy waste. In addition, subsidies will be provided for rural residents’ electricity consumption behaviors to narrow the gap between urban and rural electricity prices. For example, in addition to the National Energy Efficiency Act for raising the low utilization rate of industrial energy, Indonesia has also introduced the Domestic Electricity Subsidy Mechanism Act, which provides electricity price subsidies to rural, poor households with less than a 900 volt ampere capacity and adopts the time-of-use electricity pricing model. This model meets the requirements of the Pareto efficiency and has been widely applied in ASEAN countries. The Philippines, for example, established a rural electrification fund to subsidize rural solar power generation projects while carrying out industrial electricity price reforms.

In power grid construction, the main shift is from off-grid power to grid-connected power. The series connection of domestic grid-connected power lays the foundation for the on-demand distribution and dispatching of domestic power and cross-regional power cooperation between countries. In the past, policies promoting electrification primarily encourage rural and remote areas to utilize local resources to generate electricity for the self-supply of clean energy through small power generation and distribution systems comprising distributed power sources, energy conversion and storage, and protection devices [53]. Governments also encouraged the construction of small power generation facilities in urban communities to achieve internal resource mobilization. In recent years, however, grid-connected power has gradually become the mainstream source. Therefore, countries are determined to promote the extension and series connection of power network systems. For example, the “Support Mechanism for the Development of Solar Energy Projects in Vietnam” (2017) stipulates that Vietnam’s support mechanism is only applicable to grid-connected projects, and its policy favors promoting the construction of a national grid interconnection system to replace off-grid electricity as soon as possible.

#### 4.4. Electrification Transformation of the Urban Transportation Pattern

The Urban Sustainable Development Low-Carbon Transportation (LOTUS) proposed at COP27 demonstrates the continued interest in decarbonizing and transforming urban transportation patterns [54]. To achieve carbon emissions reductions on the consumption side of the transportation sector, ASEAN countries have made great efforts to develop the electric vehicle market. Moreover, infrastructure constructions supplemented by electric vehicle operations have also been added to the agenda, and ASEAN countries have proposed corresponding commitments and measures to strengthen the construction of charging stations and the rational layout of electric resources (see Table 7). The first is to accelerate the promotion of new energy vehicles by formulating strict emissions standards and fuel efficiency standards and determining the shutdown time of fuel vehicles. The second is to replace diesel locomotives by encouraging the use of public transportation. The third is to improve the penetration rate of new energy vehicles and the construction of a charging infrastructure supporting system by incentives, such as car purchase subsidies and financial support.

**Table 7.** Electrification transformation goals of ASEAN countries.

Country	Electrification Transformation Goals
Brunei	By 2035, electric vehicles will account for 60% of the total annual car vehicle sales.
Cambodia	By 2030, the engine efficiency of passenger cars will increase by 15%.
Philippines	Specify the minimum proportion of electric vehicles in the total number of vehicles owned by companies, local government units, and public transportation operators; encourage commercial institutions to provide dedicated exclusive parking spaces and charging stations for electric vehicles.
Malaysia	By 2025, 9000 AC charging stations and 1000 DC charging stations will be installed.
Singapore	Expand the scope of vehicle emissions taxation; launch a subsidy plan for purchasing electric vehicles; increase the number of electric vehicle charging infrastructures from 1600 to 28,000.
Thailand	An 80% reduction in road traffic tax for electric vehicles and exemption from tariffs on imported automotive batteries; by 2036, there will be 1.2 million electric vehicles and 690 charging stations.

Data source: compiled by the author based on policy documents and news reports.

#### 4.5. Systematic Energy Conservation and Consumption Reduction

To achieve carbon neutrality, ASEAN countries are committed to reducing their energy intensity and energy consumption levels and have proposed targeted consumption reduction goals (see Table 8). COP27 once again emphasized the responsibility of the emissions reduction industry and the construction of the next generation of sustainable urban. In practice, this is reflected by the multi-dimensional emissions reductions in the areas of industrial production, urban construction, and lifestyle [40,41].

**Table 8.** Consumption reduction goals of ASEAN countries.

Country	Consumption Reduction Goals
Brunei	By 2035, total energy consumption by 63% from the BAU level will be achieved.
Cambodia	By 2035, the total energy consumption will be reduced by 20% from the BAU level.
Indonesia	By 2025, the energy intensity will be reduced by 1% every year.
Laos	The total final energy consumption will be reduced from the BAU level by 10% by 2030 and by 20% by 2040.
Myanmar	By 2030, the demand for primary energy will be reduced by 8% from the 2005 level, and energy consumption will be reduced by 20%.
Philippines	By 2030, the energy intensity will be reduced by 40% from the 2010 level and the energy consumption will drop by 1.6% annually compared to the baseline forecast. By 2040, the energy intensity and total energy consumption will be reduced by 24% from the BAU level.
Singapore	By 2030, the energy intensity will be reduced by 35% from the 2005 level.
Thailand	By 2030, the energy intensity will be reduced by 35% from the 2005 level.

Data source: compiled by the author based on the “Southeast Asia Energy Outlook 2022”.



Energy mismatch within the industry leads to a decrease in energy efficiency, while environmental regulations can improve the carbon emissions efficiency [55]. ASEAN countries have introduced a series of measures to improve industrial energy efficiency. Specifically, ASEAN countries have reduced industrial energy intensity and energy consumption levels by utilizing raw materials with lower carbon intensity outcomes, optimizing process flow, eliminating inefficient production equipment, and recycling by-products in the production process. In terms of soft environment construction, ASEAN countries have taken measures to support the development of energy service companies, strengthen the training of energy efficiency technicians, and conduct energy efficiency audits. As for the development and application of emission reduction technologies, ASEAN countries have adjusted the future energy structure; conducted preliminary research on emission reduction technologies, such as carbon capture, utilization, and sequestration (CCUS) [56–58]; adopted an innovative subject cooperation mode; and provided innovation subsidies and formulated technological innovation action plans for energy conservation and emission reduction purposes.

The key to achieving emissions reductions in the construction sector is to enhance energy use efficiency and adjust the energy structure of buildings to meet the development requirements of green and low-carbon cities [59–61]. In terms of the energy efficiency policies, ASEAN countries have formulated green building standards and energy efficiency building codes, which provide detailed specifications for building emissions and consumables use. ASEAN countries also emphasize the implementation of low-carbon operations throughout the entire cycle from construction to completion. At the same time, they have established a green building rating system and the mandatory disclosure of building performance. Additionally, they require buildings to meet the minimum green standards. Furthermore, ASEAN countries have established energy manager certification programs that monitor building equipment and propose energy-saving strategies based on the habits of building users. In terms of adjusting the energy structure of buildings, ASEAN countries have implemented electricity substitution policies, which require increasing the proportion of the renewable energy supply and heating by installing photovoltaic photothermal devices and using efficient electric heating pumps, to achieve low-carbon operations in the construction sector.

Alternatively, the focus of energy reduction actions in urban life is to reduce emissions from the electrical sector, mainly aimed at improving the energy efficiency of end-user products and reducing household electricity consumption. Currently, Singapore, Thailand, Malaysia, the Philippines, Vietnam, and Cambodia have all adopted MEPS energy efficiency labels to control energy consumption from the end of products.

#### *4.6. International Cooperation for Achieving Institutional Transformation and Technological Upgrading*

Over the years, the ASEAN has repeatedly urged developed countries to provide full consideration of the specific needs and conditions of developing countries. International communities should provide ASEAN countries with adequate, sustained financial and technical support to help the ASEAN realize the low-carbon development goals [3]. Cambodia, Indonesia, the Philippines, and Thailand have all proposed to seek international support when formulating the carbon neutrality goal. With the assistance of international communities, they set further goals to encourage major countries to invest in more factors in addressing global climate issues. This approach will become a new driving force for the sustainable development of industries in ASEAN countries. At the same time, the transformation and upgrading of the industrial structure will fully leverage the “feedback effect” to drive the efficient use of energy and the transformation of economic growth patterns. At present, ASEAN countries have reached technical cooperation agreements with many foreign companies. For example, Singapore Jurong Port signed agreements with Mitsubishi Heavy Industries and JERA Asia for technical cooperation on ammonia direct combustion. Moreover, Vietnam plans to collaborate with Norwegian energy companies to develop offshore wind power and strengthen CCUS cooperation regarding hydrogen and



ammonia. Furthermore, the Philippines has collaborated with Shell to develop, operate, and maintain renewable energy and to develop green power.

## 5. Challenges in ASEAN's Carbon Neutrality Progress

Although the carbon neutrality targets reflect the determination of ASEAN countries to achieve energy transformation and provide scientific guidance for ASEAN's energy transformation, there are still political, economic, social, and other challenges in the policy implementations, which can affect the progress of achieving carbon neutrality. Based on the theoretical analysis framework mentioned above, we analyzed the challenges faced by ASEAN countries in the process of achieving their carbon neutrality goals through the respective roles of government, enterprises, and individuals, as well as their interaction effects.

### 5.1. Energy Transformation Hindered by Carbon Lock-in and Dependence on Traditional Industries

Since ASEAN countries have not yet met the environmental Kuznets inverted "U" curve peak, their consumption rates of fossil fuels will continue to increase until there is positive feedback from their carbon neutrality actions. It is impossible to change the lock-in effect of high-carbon energy structures in ASEAN countries in the short term. Therefore, sudden changes in the energy structure and the large-scale deployment of low-carbon technologies can create potential cross-system and nonlinear risks. The government must establish regulatory and bankruptcy mechanisms to achieve a smooth transition of energy transformation. In Vietnam, for example, coal-fired power presently accounts for half of its total power. Coal imports are predicted to increase significantly in the next 12 years [62]. If coal power plants are shut down in large numbers, this will create huge economic losses and potential financial risks, affecting social stability. In addition, with the increasingly complex international situation, ASEAN countries could face a serious oil energy crisis, which would also slow down the progress of achieving carbon neutrality. Affected by the COVID-19 pandemic and the Russia–Ukraine conflict, the Philippines, Thailand, and Vietnam have increased the subsidies for fossil fuels to stabilize their economies, and Indonesia has scrapped its plan to stop selling low-grade (high-emission) gasoline products. The IEA predicted that oil production in Southeast Asia is expected to fall from approximately 2 million barrels per day in 2020 to 400,000 barrels per day in 2050, and the oil demand will reach 9 million barrels per day by 2040. Almost all of the ASEAN's annual net energy trade deficit will then be used for oil imports [63].

To reduce the lock-in effect of carbon, ASEAN countries have proposed measures on carbon market construction and to realize electricity decarbonization through carbon tax and carbon pricing. However, only Singapore has officially imposed carbon tariffs; other ASEAN countries are considering or have not yet considered formally implementing carbon pricing plans. This means that it is still unrealistic for the carbon market to have a positive effect. Moreover, the construction of the carbon market is still in its early stages, and mechanisms, such as offset strategies, credit generation and purchase, and monitoring, and the verifications of credit, project financing, credit scrapping, and reporting are still incomplete. For example, Singapore's carbon tax rate is USD 5 per ton of emissions, which is expected to rise to USD 50 to 80 per ton by 2030. Under high taxes and fees, the government allows companies to partially offset domestic taxes with international carbon credits [64]. The possible risk is that companies can purchase inferior carbon credits internationally to offset domestic emissions. The poor regulation could increase carbon emissions and cause enterprises to invest less in decarbonization projects.

### 5.2. Investment Enthusiasm Limited by the Unstable Business Environment and Policies

Social instability and a poor business environment in ASEAN countries have become the biggest risk and challenge for foreign investments in ASEAN energy developments. From 1970 to 2018, all ASEAN countries experienced terrorist activities. On average, the Philippines and Thailand were attacked by more than 100 terrorist activities each year.

The average number of days of terrorist activities was basically over 15 (see Table 9), directly affecting the business environment in ASEAN countries. Foreign investment in the energy infrastructure in ASEAN countries is likely to encounter sudden events, such as strikes, smashing, looting, and burning. And, there is no stable property protection mechanism in the case of a regime change. Consequently, energy cooperation agreements and energy construction projects previously signed by these countries are likely to be invalidated, which will greatly weaken the enthusiasm of foreign investors in the energy field in ASEAN countries.

**Table 9.** Terrorist activities in ASEAN countries.

Country	Number of Terrorist Activities from 1970 to 2018	The Average Number of Days
Cambodia	260	15
Indonesia	831	16
Laos	27	19
Malaysia	108	15
Myanmar	678	17
Philippines	7976	16
Thailand	4162	15
Vietnam	13	14
Brunei	6	19
Singapore	7	19

Data source: Global Terrorism Database established by the START team at the University of Maryland, United States, <https://www.start.umd.edu/gtd/> (accessed on 25 December 2023).

In addition to the political risks, ASEAN countries also lack policy stability and execution capabilities. ASEAN countries have designed a complete policy system that emphasizes the post-supervision of policies, but such post-supervisions can deteriorate into abrupt policy changes that lack consistency and continuity during policy implementations. Arbitrary policy changes will seriously impact the confidence of foreign investors and weaken the investment attractiveness of the local energy industry. For example, in April 2017, the Vietnamese government issued the Resolution on Encouraging Mechanisms to Promote the Solar Power Generation Industry, promising to purchase electricity generated by solar power projects at a guaranteed price of 0.0935 USD/kWh. After causing severe overcapacity outcomes, in November 2019, the Vietnamese government abrogated this policy and adjusted the grid electricity price to a competitive grid. Then, the enterprises that have been incentivized to invest in photovoltaic projects in Vietnam are likely to suffer economic losses as a result of the policy adjustments. In addition, the challenge of an inefficient policy formulation is also quite prominent. The Philippines first proposed to implement the feed-in tariff (FIT) system in the Renewable Energy Act of 2008, but it was not officially approved until 2012. For large-scale solar photovoltaic projects in Indonesia's public utilities, the cost associated with consulting services, manufacturing, licensing, as well as land acquisition and development, accounted for a significant proportion [65,66]. This indicates that, due to policy uncertainty and cumbersome procedures, the efficiency of project approvals is low and the costs are high. In the case of Cambodia, solar energy was initially not included in the Master Energy Plan released in 2017. However, in response to increased investor interests in developing solar energy, the Cambodian government quickly announced in mid-2017 that the next version of the energy plan would incorporate solar energy. While this measure aims to promote rational energy development, frequent policy changes have also raised the cost of market research for investors. Thailand, on the other hand, implemented a renewable energy grid pricing policy in 2007 and adjusted their photovoltaic grid pricing in 2013 and 2014. Nevertheless, since 2018, Thailand has announced a suspension of its solar grid electricity pricing policy, leading to a rapid slowdown of the growth rate of photovoltaics [67]. These policy changes do not contribute to a stable policy environment for ASEAN countries to achieve carbon neutrality.

### 5.3. Policy Efficiency Affected by Residents' Weak Environmental Awareness

ASEAN countries have introduced relevant laws to strengthen the public recognition of green consumption. For example, Vietnam and Thailand encourage people to use electricity during off-peak periods and support local people to build self-circulating hydropower systems, and Cambodia strengthens training for farmers. Weak environmental awareness and cultural barriers are still important reasons for the poor effect of carbon reduction practices. Poor people in the remote areas of Southeast Asia are not aware of the benefits of renewable energy utilization, renewable energy power generation, and green technologies. In addition, no consensus has been reached on how to coordinate land use with tropical rainforest protection and safeguard the rights and interests of indigenous peoples in the construction of the project.

In recent years, ASEAN countries realized that, in addition to promoting energy conservation and carbon reduction from the perspective of energy structure reform, they also needed to improve the behavioral response of energy consumption entities. Survey results indicate a gradual increase in environmental awareness in ASEAN countries, even in underdeveloped countries, such as the Philippines and Cambodia [68]. Additionally, there is a growing belief that both central governments and non-governmental organizations play a crucial role in promoting public environmental awareness. The ASEAN Environmental Education Action Plan 2014–2018 established a comprehensive environmental education plan that outlined the specific requirements for policy systems, education programs, community promotion, and other aspects. In addition to collective action, ASEAN countries have actively introduced relevant measures [69]. For example, as early as 1991, the Education Planning Commission of the Malaysian Ministry of Education incorporated environmental education into the national education system and environmental subjects into textbooks, assignments, and activity books [70]. Similarly, Myanmar's Climate Change Master Plan and Cambodia's Basic Energy Plan incorporated energy efficiency improvement and climate change into the educational curriculum. Furthermore, the proposal of the carbon peak and neutrality goals will force the whole society to strengthen its awareness of temperature and carbon control and cultivate green and low-carbon concepts in various aspects of consumption and production. From the central government to local governments, from developed to less-developed areas, and from urban to rural areas, a consensus should be reached among various parties on green development, to ultimately achieve the sustainable development of society.

ASEAN countries have also made notable progress in environmental education initiatives. For example, the ASEAN Eco-Schools Program and the ASEAN Eco-School Award, presented every four years, have been launched to promote environmental awareness and recognize the achievements of environmental education. Additionally, the ASEAN Plus Three Youth Environment Forum, initiated by Brunei, aims to strengthen youth participation and cooperation in environmental protection efforts. The Philippines identified sustainable and eco-friendly schools to support environmental education initiatives, awarding honorary titles to nine schools at the primary, high, and university levels. Moreover, the ASEAN Green Higher Education Program, initiated by the Philippines and Thailand, assessed the environmental status of educational institutions and established ecological school guidelines [71]. These measures have enhanced the environmental awareness in ASEAN countries and reshaped energy consumption concepts, promoting the sustainable development of the environment.

### 5.4. Insufficient Transformation Guarantee Due to the Disconnection of Technological and Financial Elements

The main reasons for the low utilization rate of renewable energy in ASEAN countries are the low technology level and financing constraints. In terms of the technological innovations, ASEAN countries still lack the R&D capability of new technologies, including offshore wind energy, island geothermal energy, hydropower, and other development technologies, as well as the application of low hydrocarbon and ammonia develop-

ment technologies and carbon capture, utilization, and sequestration (CCUS) technologies. In 2006, Cambodia identified a total of 60 hydroelectric development sites with a power generation potential of up to 10,000 megawatts. However, due to the geographical constraints of hydropower development, only about 1330 megawatts were developed by 2019, accounting for only 13% of the potential electricity development [72]. Indonesia is also unable to build a unified national power grid owing to the geographical constraints, which poses a technical obstacle to the grid connection of renewable energy generation. Additionally, talent shortage is also a major challenge for ASEAN's energy transformation. The renewable energy industry is weak in ASEAN countries. Most countries lack senior technicians, and research, development, and management professionals, which hinders the large-scale application of renewable energy.

In terms of green finance, ASEAN countries have problems in the process of promoting green finance, including the solidification of the capital source structure and the inability of the financing scale to meet the financing needs. From 2016 to 2020, about half of the energy investment in the Eastern Alliance was from state-owned funds, with private capital accounting for 60% of the low-carbon electricity expenditure and 45% of fossil fuel power generation, lower than 90% in developed countries [38]. In addition, ASEAN countries also have the problem of an uneven allocation of funds during the energy transformation process, with more funds allocated to the central region. In Cambodia and Myanmar, for example, poor credit ratings make it difficult for small- and medium-sized enterprises and rural households to gain financial support, even though both countries have encouraged remote areas to establish their small-scale power generation systems. Moreover, the long-term investments in renewable energy development and technology research and development cannot be immediately converted into zero-emissions benefits or economic benefits. The sustainability of such investments may not be guaranteed when under financial pressure.

ASEAN countries can enhance technological innovations through several key initiatives.

First, ASEAN countries can establish inclusive green finance-inclusive products, such as loans tailored to low-carbon and emerging industries, for traditional high-carbon industries undergoing transformations, as well as for enterprises with technological innovation capabilities. These loans promote the application and pre-research of emerging technologies, accelerate industrial transformations and low-carbon productions, and help address technological challenges and create tailored technology models. Second, ASEAN countries should introduce incentive policies for foreign investments. This includes reducing soft barriers in land approval processes, local protection, and investment proportion restrictions, and attracting large, foreign, manufacturing enterprises through government subsidies, grid electricity prices, and open bidding. It is also important for ASEAN countries to capitalize on the development opportunity of the RCEP, enhance their connections with neighboring and developed countries, and explore the potential for localizing power equipment manufacturing [73]. Third, unifying technical standards is essential for a widespread technology adoption. ASEAN countries should accelerate the improvement of energy development and electricity standards in the ASEAN, considering the national and resource conditions, and aligning with the existing international standards. They should also establish technical standards throughout the entire processes of operation scheduling, model selection, and environmental protection.

##### *5.5. Regional Power Grid Interconnection Affected by Difficulties in Coordinating the Interests of All Parties*

Electricity has long been in short supply in ASEAN countries, and the power development capacity is unevenly distributed within this region. Therefore, regional grid interconnection and cross-border electricity trade are necessary means to meet the electricity demands and achieve the regional energy transformation goals. The interconnection of regional power grids needs to proceed through the development process of

“domestic power grid interconnection—cross-border bilateral interconnection—sub-regional interconnection—integrated power grid system”. Currently, the interconnection of power grids in ASEAN countries has not yet broken through the link of the domestic power grid interconnection. To achieve the integration of integrated power grid systems, two problems need to be addressed. First, the progress of ASEAN cross-border power grid projects is slow. Due to the small number of implemented projects, it is difficult for ASEAN countries to coordinate their policies and interests and to compromise on the overall interest. The “Laos–Thailand–Malaysia–Singapore” networking project promoted by ASEAN has presently become the “Laos–Thailand–Malaysia” networking project, with a signed trade volume of only 300 megawatts [20]. Second, ASEAN countries have a lot of work to do in promoting clean energy-oriented electricity market operations, technology supply chain constructions, and infrastructure investments. ASEAN’s energy infrastructure is generally rapidly aging. The intermittent, random, and volatile characteristics of wind power and photovoltaic power generations will lead to fluctuations in the grid voltage, current, and frequency after large-scale wind and photovoltaic power stations are connected to the grid, thereby affecting the power quality of the grid. To eliminate the adverse effects, power grid enterprises need to increase their additional backup capacity, which will increase the operating costs of the power grid and indirectly affect the extension and development of the power grid.

#### 5.6. ASEAN Seeks a Balance of Interests in the Sino–US Infrastructure Game

The conflict of infrastructure construction is mainly reflected in the competitive strategy of great powers. In response to China’s Belt and Road Initiative, the United States has designed a set of infrastructure strategies and attached more importance to overseas infrastructure construction, especially in the Indo-Pacific region. The competition between China and the United States has led to different security and foreign policy choices among ASEAN countries, making it difficult for ASEAN countries to seek the maximum benefits and experience the minimum number of risks. The Biden government put forward a series of alternative plans related to The Belt and Road Initiative and infrastructure cooperation in the RCEP agreement, such as the B3W framework. In addition, the Biden government proposed to focus on green energy infrastructure cooperation in the “Indo-Pacific Strategic Framework Agreement” and emphasized the discourse power game of infrastructure standards in the “Blue Point Network” plan. In the future, ASEAN countries are highly likely to take sides between China and the United States with two distinctly different development models and technological standards.

## 6. Conclusions

ASEAN countries have committed to achieving carbon neutrality by the mid-21st century. It is imperative to summarize the evolution of the policies related to achieving carbon neutrality in ASEAN countries and address the challenges associated with achieving net-zero emissions. This paper aimed to refine the evolution and characteristics of ASEAN countries’ carbon neutrality policies and identify the current obstacles they could encounter in the pursuit of achieving carbon neutrality, based on their carbon emissions trajectories. This paper constructed a theoretical framework for achieving carbon neutrality goals, which clarified the main positions and responsibilities of the government, enterprises, and individuals, and formed a path planning strategy from macro to micro, and from policy to practice, through the interaction between the government, enterprises, and individuals. This theoretical framework made it reasonable to analyze the carbon neutrality policies and challenges of ASEAN countries. Finally, to achieve carbon neutrality, ASEAN countries require international cooperation. As members of the RCEP, China and ASEAN should strengthen their cooperation for promoting carbon neutrality. Therefore, this article put forward policy suggestions for fostering a carbon neutral cooperation between China and ASEAN countries.



### 6.1. Carrying out Scientific and Efficient Energy Utilization Cooperations

The above analysis revealed that the energy structure of ASEAN was predominantly reliant on fossil fuels, with limited capabilities for energy development, hindering the transition to a greener economy. Therefore, it is essential for China and ASEAN to enhance the development of clean energy and promote emerging industries as substitutes for traditional sections in the future.

ASEAN countries have good renewable energy endowments and a large space for development. If properly developed and utilized, this will greatly accelerate the carbon neutrality process in ASEAN countries. China and ASEAN countries have complementary resources and distinct industrial advantages, and thus can learn from each other's development experiences. There is great potential for cooperation in the development of offshore wind energy, solar energy, and geothermal energy, as well as clean coal technology, hydrogen energy utilization, and ammonia value chain construction. Through the cooperation regarding clean coal technology, China and ASEAN countries aim to reduce the environmental pollution from fossil fuels. China is also assisting ASEAN countries in assessing the risks, benefits, and spatiotemporal distributions of renewable energy, formulating reasonable cooperative development strategies, and accelerating the planning, construction, and utilization of clean energy infrastructures, especially in rural and remote areas. In this process, China can also learn from the incentive policies and local differentiation policies introduced by ASEAN countries and give full play to the role of local governments in formulating preferential policies, coordinating cultural and religious conflicts, and promoting the awareness of green energy consumption. Through PPP and joint ventures, as well as the combination of public welfare and commercial benefits, China can participate in renewable energy development projects.

The operation of most low-carbon, zero-carbon, and negative-carbon technological equipment and the production of electric vehicles need to use key metals and mineral resources. It is therefore urgent for energy transformation to shift the physical foundation of the energy system from carbon to metals (from coal and oil to rare earth or lithium, etc.) [74]. Southeast Asia has an abundance of key energy minerals, such as nickel (Indonesia), tin (Indonesia and Myanmar), and rare earth (Myanmar), and produces mineral products, such as cobalt (the Philippines), manganese (Myanmar and Malaysia), graphite (Vietnam), and silicon (Malaysia). The ASEAN has the potential to establish a complete supply chain for electric vehicles and develop industries, such as photovoltaic and wind power. China holds a leading position in the production, sales, and ownership of electric vehicles, the development of solar and wind energy, as well as the recycling and remanufacturing of products, materials, and components. To better achieve a coordinated development, it is crucial to focus on the key areas and industries, accelerate the transformation and upgrading of industrial structures, and build a clean and low-carbon energy system [75]. If China and ASEAN countries can combine their strengths in industrial development and resource endowments under the RCEP framework, there will be great development potential for green transportation and clean energy infrastructure construction. In the expansion of the Southeast Asian market for new energy vehicles, China needs to maintain a good communication with the local government to seek preferential policies, such as tariff reductions and car purchase subsidies.

In addition, China and the ASEAN can integrate a trilateral cooperation between China, Russia, and the ASEAN to build a stable supply chain in the region. At present, China and ASEAN countries are in desperate need of raw materials to develop the electric vehicle market. And, ASEAN countries urgently need to transition their energy consumption structure from fossil fuels to natural gas, to progress to renewable energy. Cooperation in such areas cannot be realized without the support of Russia. If China, as the communication channel between Russia and ASEAN countries, promotes tripartite cooperation, reasonably develops and utilizes regional resources, opens up resource circulation channels between China, Russia, and ASEAN, and establishes a stable energy and resource supply chain, it



will greatly promote the tripartite economic transformation and accelerate the process of achieving carbon neutrality.

### 6.2. Building a Gradual Grid Interconnection System

Based on the analysis, it is evident that ASEAN countries' regional power cooperation encountered significant challenges, including the slow progress of power cooperation projects and a pressing need for financial and technical assistance. Therefore, it is imperative for China to support ASEAN countries in improving the regional power cooperation mechanisms and facilitating efficient power allocations within the ASEAN region.

The construction of the ASEAN power grid can adopt progressive and conditional coupling development strategies. ASEAN countries should actively establish an inter-governmental coordination and promotion mechanism. First, ASEAN countries can establish growth in central cities and then construct networking facilities around the central cities to achieve the optimal allocation of electricity within the region. Second, ASEAN countries can establish a bilateral interconnection of power grids in the border areas of member states according to the strategy of similar geographical and energy storage conditions. These remote areas are generally rural areas, which can meet the electricity demands of rural areas and also achieve bilateral power interconnections. The trans-regional power grids in border areas can be gradually extended to a larger region, with Laos, Myanmar, Cambodia, and Vietnam as the western sub-regions, and Brunei, the Philippines, Indonesia, Malaysia, and Singapore as the eastern subregions, so that an integrated power grid system across ASEAN conditions is finally formed. In addition, ASEAN regional power integration and multilateral power trade should be gradually standardized by developing unified power grid codes for transmission interconnections, establishing a unified operating fee system, formulating guidelines for third-party access to regional markets, establishing a collaborative mechanism for ASEAN's smart grid and network security technology and policies, establishing a mechanism for evaluating the stability of the power system and the contribution of renewable energy to the power grid.

ASEAN countries and China have similar development processes and geographical conditions. Under the framework of the RCEP agreement, China can cooperate with ASEAN countries in the planning of power grid interconnections and the construction of power grid infrastructures in special terrains. In terms of the mechanism cooperation, China can assist ASEAN countries in establishing a multilateral communication and negotiation mechanism for clean power grid interconnections. For example, through institutions, like the Asian Investment Bank, China can make feasible investments in renewable energy power generation in ASEAN countries, and share its experiences of clean energy development and applicable technologies (such as ultra-high-voltage technologies and large-scale infrastructure-related technologies). By providing support to energy development technology, infrastructure construction technology, and management experience, China can help ASEAN countries realize trans-regional power transmissions.

### 6.3. Deepening Cooperation in the Green Finance System

The above analysis reveals that ASEAN countries faces challenges, such as weak environmental awareness and insufficient funding, for clean energy development projects, particularly in impoverished areas. These obstacles hinder the energy transformation of the whole society and create an unfavorable business environment. To address this, China should cooperate with ASEAN countries to enhance the infrastructure of ASEAN cities and expedite the deployment of energy infrastructures in the underdeveloped areas of ASEAN countries through diverse financial support channels.

After setting the goals of achieving carbon neutrality, ASEAN countries gradually improved their business environment, and adjusted policies that seriously impeded foreign investment, such as land acquisition permits, special protection for domestic enterprises, and financing constraints. For example, Indonesia lowered the standards for technology transfer and land acquisition licenses to reduce investment restrictions; the Philippines cur-

rently allows foreign capital to establish wholly owned companies to develop its geothermal energy; and Vietnam implemented monetary indexation policies and government guarantees policies to deal with foreign exchange risks faced by foreign capital and the corporate default risks faced by banks. Moreover, many countries have released energy documents in English in addition to local languages. While improving the business and investment environments, ASEAN countries should make active use of the preferential loans provided by international organizations, such as the Asian Investment Bank, the World Bank, and the Asian Development Bank, and cooperate in developing financial tools to mobilize domestic and international commercial and private investments. China can cooperate with ASEAN countries to further promote the “Belt and Road” green financing system, including establishing various financing channels and assistance funds, promoting the simultaneous construction of large and small infrastructures in less-developed areas in ASEAN countries, and establishing an energy infrastructure evaluation system to guide funds to support large infrastructure projects. In addition, China should give full play to the positive role of financial entities, such as the Asian Investment Bank, the Export–Import Bank of China, and commercial banks in allocating resources, formulating specific financing application standards, simplifying application procedures, and establishing project supervision and environmental and climate risk response mechanisms, to ensure the smooth flow of the project funding chain, while balancing sustainability and environmental friendliness.

#### *6.4. Strengthening the Cooperation Regarding Green and Digital Technology*

The abovementioned analysis highlights the deficiency in technology and equipment within ASEAN countries to facilitate the advancement of new energy, especially the limited construction capacity for large-scale projects. To address this, China should bolster its technical cooperation with ASEAN countries and offer technical assistance to ASEAN countries through collaborative project developments and scientific research initiatives.

ASEAN countries are faced with various technical constraints in the process of achieving carbon neutrality. One is to reduce carbon emissions by promoting digital changes in urban lifestyles, such as administrative operations, autonomous driving, green buildings, and urban cooling systems. The second is to promote the cooperative research and development of new technologies, such as carbon capture, utilization, and sequestration in low-carbon emissions reductions, forest protection, and geological exploration, and promote the application of China’s ultra-high-voltage technologies for green power generation and a stable power supply in Southeast Asian countries. The third is to build an information-sharing platform integrating forest dynamic detection and protection and clean resource exploration, utilization, and application to improve the data processing capabilities. In recent years, China has accumulated a lot of practical experience and applied technologies in the development of the digital economy, the construction and operation of big data platforms, and the construction of low-carbon green cities. If ASEAN countries can cooperate with China through The Belt and Road Initiative and the RCEP agreement, the two sides will lower their production costs and improve the urban operation efficiency through technological progress. Moreover, the cooperation is conducive to the “Matthew effect” and “scale effect”, and will help tap into the potential of ASEAN countries in the development and utilization of clean energy, new energy vehicles, and low-carbon electrical appliances, as well as in green city constructions.

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