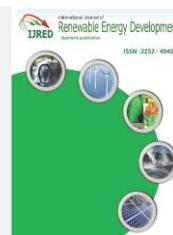




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Research Article

# The feed-in tariff (FIT) policy to improve renewable energy utilization: An analysis of FIT implementation in ASEAN countries from renewable energy growth, decarbonization, and investment perspective

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**Abstract.** The FIT policy are widely adopted in the world to promote the utilization of renewable energy technology (RET). Tariff rates, tariff regression mechanisms, contract term, and quota constraints are all components of the FIT policy. This policy has also been adopted by Association of Southeast Asian Nations or ASEAN countries to optimize their renewable energy (RE) potential. This paper examines the utilization of RET in power generation under the FIT policy from the perspective of the growth of renewable energy, environment, and investment which applied in five major ASEAN countries in term of the biggest generation capacity, such as: Indonesia Vietnam, Malaysia, Thailand, and the Philippines. This study shows that the FIT has been successful in accelerating renewable energy growth compared to pre-FIT, where annual RE capacity growth was 7.52% in Thailand (2007-2021), 16.38% in Vietnam (2011-2021), 4.56% in Indonesia (2012-2021) 2021), 9.11% in Malaysia (2012-2021), and 5.21% in the Philippines (2012-2021). FIT also managed to keep CO<sub>2</sub>/kWh emissions production stable in Vietnam, Malaysia, and Thailand while increasing RE production in their power systems. Otherwise, due to the low utilization of RET in Indonesia and the Philippines, CO<sub>2</sub> emissions in them has increased significantly, 6.67% per year at Indonesia, and 15.25% per year at the Philippines after the introduction of the FIT. Generally, FIT has succeeded in increasing the value of international funding investments in RE sector in Indonesia, Vietnam, Malaysia, Thailand, and the Philippines.

**Keywords:** Renewable energy, Renewable energy policy, Feed-in Tariff, Renewable energy growth, ASEAN



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## 1. Introduction

Entering the 20th century, climate change became a global issue. Climate change is causing damage to the earth's environment, leading to environmental problems, natural disasters, drinking water, food and social problems. Rising surface temperatures, increased droughts, sea level rise, floods, increased health risks, and poverty are the direct effects of climate change (European Commission, 2023; UN, 2023; WHO, 2003). Climate change is caused by an increase in the earth's temperature because of a greenhouse phenomenon. This phenomenon is caused by some gases (called greenhouse gasses) such as: nitrous oxide, fluorine gas, carbon dioxide (CO<sub>2</sub>), and methane (CH<sub>4</sub>). These greenhouse gases come from a variety of human activities, including electricity generation, transportation, commodity production, and deforestation (EPA, 2023a; European Commission, 2023; UN, 2023). Several studies have shown that increasing atmospheric CO<sub>2</sub> levels have a

significant impact on global temperature rise (Hannah Ritchie, 2020; NAS; The Royal Society, 2021). More than 65% of greenhouse gases are CO<sub>2</sub>. CO<sub>2</sub> is mainly formed by electricity and heat production, industry and agriculture (EPA, 2023b). By 2022, over 70% of the fuel used to generate electricity and heat will come from coal, 22% from gas and 5% from oil (IEA, 2023a). This type of power plant, which uses fossil fuels, produces very high CO<sub>2</sub> emissions. A pulverized coal fired power plant produces 760 gCO<sub>2</sub>eq/kWh and a combined cycle power plant (natural gas) produces 370 gCO<sub>2</sub>eq/kWh. This is very different from RE power generations which have very low emission such as geothermal, hydro, solar, and wind (IPCC, 2014). The RETs can reduce carbon emissions and climate change impacts while increasing gross domestic product (GDP) (Bilgili et al., 2016; Inglesi-Lotz & Dogan, 2018). In an effort to overcome environmental problems and climate change, in 1997 industrialized countries agreed to sign the Kyoto Protocol to

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reduce greenhouse gas emissions (UNFCC, 2023; Kyoto Protocol to the United Nations Framework Convention on Climate Change, 1998). With this emission reduction program, many industrialized countries have begun to demote their utilization of fossil fuels and switch to low-emission renewable energy.

At a compound annual growth rate (CAGR) method, the weighted installation costs of RETs such as solar photovoltaic (PV) have fallen 17% over the past ten years, from \$4,808/kWh in 2010 to \$857/kWh in 2021, while onshore wind decreases by 4% CAGR from 2044 USD/kWh in 2010 to 1325 USD/kWh in 2021 (IRENA, 2022). Levelized cost of energy (LCOE) is a formula that calculates the selling price of power generation so that the investment in a power plant will break even during its lifetime. LCOE is a commonly used metric to compare the cost of electricity generation from different types of electricity generation (Aldersey-Williams & Rubert, 2019; HM Government Department for Business, 2016; Wang & Barnett, 2019). The LCOE of RETs has decreased significantly over the past decade. For example, the LCOE of PV has decreased by 22% CAGR (2010-2021) from 0.415 USD/kWh to 0.048 USD/kWh. Meanwhile, the onshore wind decreased by 11% CAGR (2010-2021) from 0.102 USD/kWh to 0.033 USD/kWh (IRENA, 2022).

Renewable Energy (RE) has a vital function in decarbonizing and enhancing the security of energy supply. But, as a cutting-edge research and technology, renewable energy has several constraints from its higher total cost and lower efficiency compared to conventional or fossil fuel energy generations. Incentives for RE development should be adopted to attract investment interest and promote the application of RETs. Investment in the RE sector is expected to revitalize the global economy after the Covid-19 pandemic because the RE sector can create more jobs. Sustainable policies and incentives in this sector are critical to renewable energy development (Bull, 2001; Haas *et al.*, 2011; Jahangir *et al.*, 2021; Miguel Mendonça, 2007; Safrina & Utama, 2023; Tuan *et al.*, 2021; Wahyudi & Palupi, 2023). A typical example of an incentive policy of RE is the FIT policy. FIT is a government policy to encourage RE investment that provides funding to private company to optimize RE sources like photovoltaic (PV), hydropower, wind, and biomass (Sun, 2015). Energy reform policies such as FIT have a positive effect on environmental indicators like CO<sub>2</sub> emissions and the energy intensity. So there is empirical evidence that subsidy reform reduces fossil fuel consumption and affects emissions (Hartono *et al.*, 2020). However, one disadvantage of FIT policy is a disruption in the fair market competition since special treatment is given to specific technology sectors. Other disadvantages of FIT policy adoption include additional strain on the government budget, which affects taxpayers financial burden (Alishahi *et al.*, 2012).

In general, the parameter of the FIT policy especially tariff rates, contract duration in certain time, tariff degression policy, and quota limits (Ye *et al.*, 2017). How the government or authority applies the right FIT rate is a real challenge. This condition can be generalized based on the fact that higher tax rates can generate more foreign or local investors. However, this policy has the effect of reducing the financial efficiency of the government and increasing the cost of the policy. At the same time, a prudent policy regarding tax rates may not be sufficient to develop a customer-based market and limit the coverage of this most effective systematic technology (Alizamir *et al.*, 2016). The first FIT system was established in the US in 1978 as an "avoided cost" payment scheme. US electric utilities are required to purchase electricity generated by so-called "qualifying facilities", a designation for industrial plants that produce electricity using either co-generation technologies or

renewable resources such as wind, solar, and biomass. State energy regulators estimate the price to be paid and determine by estimating utilities' long-term avoided cost (Lesser & Su, 2008). A study comparing incentive schemes to promote renewable energy in Europe concluded that FIT schemes were more efficient than tender schemes, but emphasized the theoretical benefits of trading green certificates, should be validated in practice considering the effect of market structure, and regulations for practicing this approach (Menanteau *et al.*, 2010). In Europe, the success factors of FIT scheme are linked to customs systems, including transparent processes. The others factors such as a good commitment by the government, a low uncertainty about the conditions, and structure of the system are very important (Zhang *et al.*, 2020).

Spain and Germany are the leaders of European countries related of RE development, and both countries applied FIT mechanisms to achieve it (García-Alvarez & Mariz-Pérez, 2012). The FIT in Germany have existed since the 1980s replacing R&D programs that were intended to promote renewable energy. In its implementation, there are two important features in the FIT design that are applied: degression of tariffs, where since 2002, every new installation will receive a lower tariff, and tariff differences based on the technology used (Ragwitz & Huber, 2005). Whereas in Spain, FIT has succed in optimizing the utilization of wind power, although it has shown less impact for other technologies. FIT prices are reviewed and revised every 4 years following the conditions of the electricity market. The consumer pays this price through the distributor, and then it is passed on to the generator (del Río & Gual, 2007).

In Asia, Japan has implemented FIT since July 2012, with a target to achieve a 20-30% RE ratio. The introduction of FIT in Japan has enabled investors to build a RET mainly in solar PV caused by high FIT prices (nearly double compared in Germany). The fund of FIT incentive is charged by consumers. Electricity costs go up about 100 ¥/month (F Muhammad-Sukki, 2014). The Philippines is another example of an Asian country that has succeeded in implementing FIT, as evidenced by the high growth of RE penetration. The installed capacity of RET has increased from only less than 200 MW in 2013 to almost 1600 MW in 2017 (Guild, 2019). The introduction of FIT began in China in 2011, hence the amount of solar PV increased significantly. Tariff adjustments continue to be made to allow investors to achieve an attractive internal rate of return (IRR) of around 8-12% (Fang *et al.*, 2016; Ye *et al.*, 2017).

Summarizing the prior studies mentioned in this section, four points were purposefully developed in the present study. The first concerns regulations in the FIT of the governments of ASEAN countries. Because the regulations of each country are different, the results of FIT promotion also have different results. These results are then compared to determine the optimal incentive in each country. Second, is it the energy production corresponded to the RE resources of each ASEAN country?. These data have been aggregated and described to fill in the lack of research-related FITs in ASEAN countries. Third, a country-by-country comparison has been listed before, which can help better understand where each country's conditions differ. Fourth is about evaluation that the government cost spends to stimulate the use of RE is very important points. Using evaluation, a government incentive can be assessed whether the incentive is on target. For these reasons, the destination of this research is to present an analysis on the regulations and characteristics of FIT policy, in accelerating the growth rate of RE use in the ASEAN. The application of FIT in ASEAN is still questionable, FIT is a form of government incentive to create an economic boost in the ecosystem of RET. However, the effectiveness of this policy from an environmental, the capacity

growth of RETs, and the attractiveness of investments point of view are still subject to debate.

Each program in each country is broken down into several key parameters, and then an assessment is conducted to specify which factors may contribute to the success of the FIT. To know the impact this would have, we linked data on the growth of renewable energy and its potential impacts about 5 years before and after the introduction of FIT pricing. In 2006, Thailand became the first country in ASEAN to implement FIT to support the growing PV array system. Renewable energy use for electricity in Thailand increased significantly by 18 kilowatts per capita within 5 years after the adjustment was made. After the successful implementation of FIT in Thailand, other ASEAN countries have begun to follow in Thailand's footsteps by adopting the FIT policy as a tool to accelerate the growth of RETs utilization. The RETs growth has led to a positive impact on the environment like the reduction of CO<sub>2</sub>, which, after the application of FIT has decreased to 5% per year. This study aims to provide an overview of different strategies of FIT implementation in ASEAN, and which of these strategies work better than other.

## 2. Methods

The method of this study is shown in Fig. 1. The papers that listed in the journal database, which are ScienceDirect and google scholar are selected. The keyword is listed as follow: Feed in Tariff; ASEAN; Renewable energy; renewable energy policy, and government incentive. The results are then selected based on the title, where the title that is closed with the keyword are selected for further analysis. The present study also searches related documents published by the government in each ASEAN country. These documents then studied and compared with the existing papers published by researchers. Thus, the present paper summarizes and compare the FIT design and implementation in several ASEAN countries and discuss their impacts on accelerating the growth of RET, as well as reducing Greenhouse Gas (GHG) emissions. Indonesia, Malaysia,

Philippines, Thailand, and Vietnam are chosen to be the sample of ASEAN countries in this study. The FIT scheme is summarized from past papers and government published regulations regarding FIT in the representative ASEAN countries. The LCOE data of RET in several countries were obtained from past studies. While the data of the RE installed capacity and CO<sub>2</sub> emissions were mainly taken from public reports and databases of UNECAP.

The comparative analysis of FIT regimes in ASEAN countries was conducted by using an international benchmark method. Profiles of each FIT design were compiled to assess the similarities and differences between the FIT patterns. Economic analysis was performed by comparing FIT calculations with LCOE at different times and places. These FIT designs and practices are then linked to the utilization of RET and reduction of CO<sub>2</sub> emissions in those countries, as expected results and parameters of a successful FIT implementation. Finally, this comparative analysis will provide a comprehensive of RE supplies in the tariff systems of ASEAN countries, their impact, and empirical evidence on success rates in terms of achieving the main objectives of the FIT implementation. The limitation of this document stems from the data collected among publicly available government documents. Unpublished documents are expelled. Furthermore, the research literature was also limited to the policy used by the ASEAN government, which does not include the FIT-related policy of other countries.

## 3. Results

### 3.1. Electricity in ASEAN

#### 3.1.1. Electricity condition

Over the past 20 years, ASEAN's electricity generation has increased by more than 5% annually (S&P Global, 2022). As shown in Figure 2, most energy sources are natural gas and coal. Figure 3 shows that the largest electricity production in 2020 come from Indonesia, Vietnam, Malaysia, Thailand and the Philippines. Indonesia accounts for over 35% of the energy in

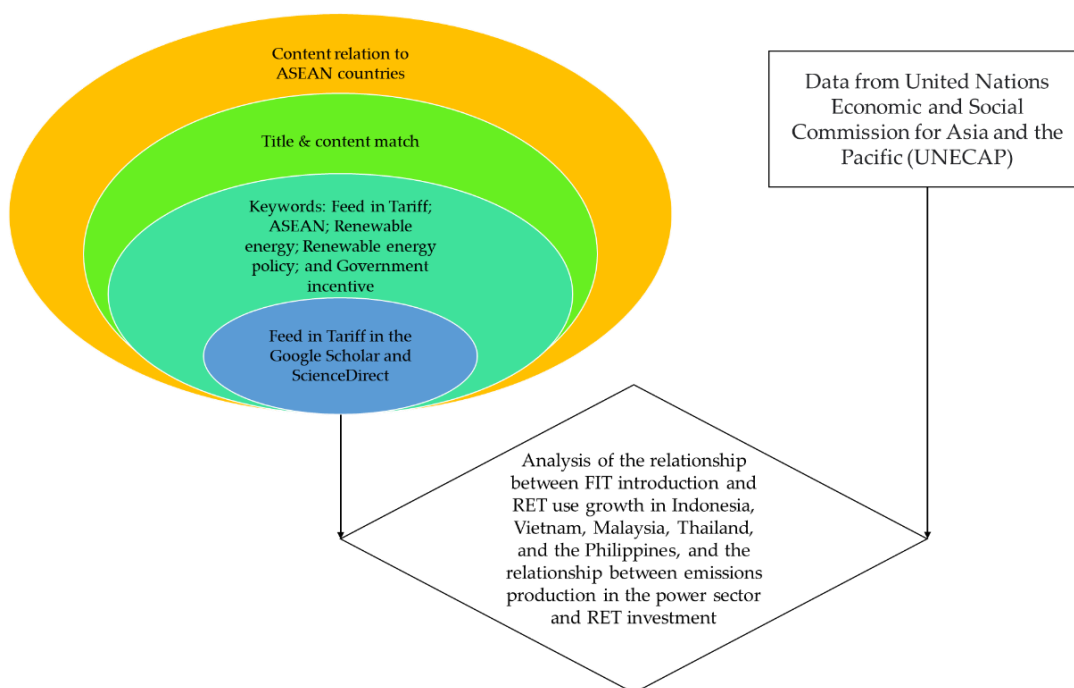


Fig. 1 Method for the paper clustering process & analyzing.

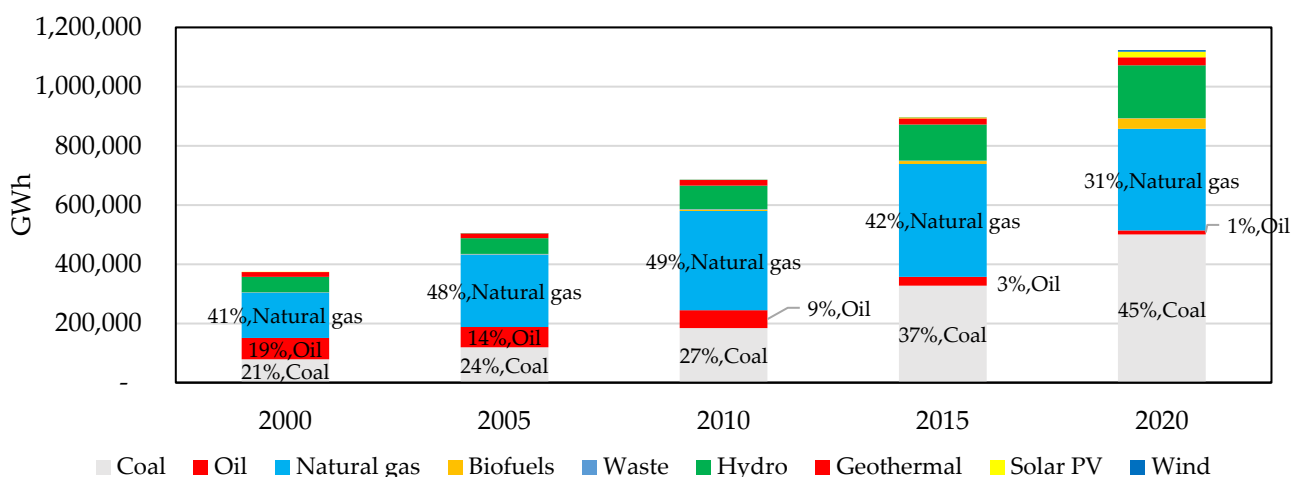


Fig 2. The trend of electrical energy production in ASEAN (adequate from ref. (ASEAN Energy, 2023; IEA, 2023b)).

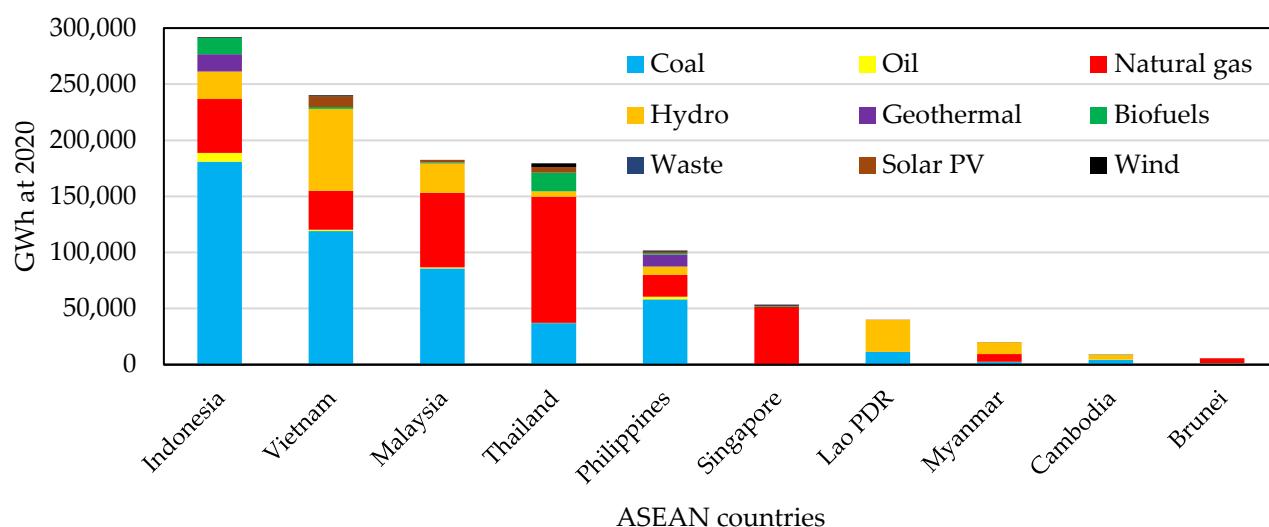


Fig 3. The condition of electricity energy sources in ASEAN countries in 2020 (reprinted from ref. (ASEAN Energy, 2023; IEA, 2023b)).

ASEAN (Lau, 2023; Liu & Noor, 2020). In view of ASEAN's large generation capacity, this study only discusses the introduction

of FIT in these five countries. Over the past decade, Vietnam's electricity production growth has been the highest in the

Table 1  
RE target in ASEAN members

Countries	Target	Year	Policy approaches	Ref.
Indonesia	23% RE share in energy mix 2025, additional cap. 20.9 GW RE until 2030	2030	FIT	(President of Republic Indonesia, 2022; Government Regulation of the Republic of Indonesia Number 79 of 2014 On National Energy Policy The President of the Republic of Indonesia, 2014; PT. PLN (Persero), 2021)
Vietnam	27 GW RE installation (12 GW PV)	2030	FIT, permit, incentives	(Approval of the Revised National Power Development Master Plan for the 2011-2020 Period with the Vision to 2030, 2016)
Malaysia	Additional cap. 10.8 GW RE Installed	2040	FIT, capital subsidies	(National Energy Policy 2022-2040, 2022; Yeap, 2022)
Thailand	30% (RE) Annual energy of share in total energy consumption	2037	FIT, permit, incentives	(Renewable and Alternative Energy Development Plan 2018 - 2037, 2018; UNFCCC, 2022)
Philippines	15 GW installed capacity	2030	FIT, permit, incentives, capital renewable standards	(National Renewable Energy Program (NREP) 2020-2040, 2020)

Source: "Asean Feed-in-Tariff (FiT) Mechanism Report," 2018; IRENA, 2017, 2023; Mamat et al., 2019; Rahmadi et al., 2017; Shukla et al., 2017; The World Bank, 2018

**Table 2.** FIT policies in ASEAN countries (Source: ACE & CREEL, 2018)

Country	Start	Regulator	Information	Funding
Indonesia	2017	Ministry of Energy and Mineral Resources (MEMR)	Selling price is set at 85% of the local cost of electricity	<p>the government is given Vietnam Environment Protection Fund (VEPF) to help pay some percentages of FIT. For instance, to pay for wind power plants FIT, which is 7,8 USD/kWh, 1 USD/kWh is paid by VEPF while 6,8 USD/kWh is paid by Electricity of Vietnam (EVN)</p> <p>A total of RM 300 million was released by the government as the initial fund. Besides that, 1% incentive was generated from electricity sales. The program was set with the rule for consumer limit 300kWh per month or RM77 per month. The incentive was then changed to 1.6%, and implemented in January 2014. This program can absorb 44% of total sales</p> <p>The FIT mechanism in Thailand was implemented to electricity consumers with a fix and flat fee for all consumers. This program was called Fuel Adjustment Cost (FAC)</p>
Vietnam	2017	Ministry of Industry and Trade	Based on location and types of technology used, 20 years contract duration	
Malaysia	2012	Sustainable Energy Development Authority (SEDA) Malaysia	FIT prices vary depending on power plant capacity and generation potential. Some bonuses are provided for plants that meet some specific criteria. Contract duration: 16 years for biomass and biogas, 21 years for the rest RE	
Thailand	2006	Electricity Generating Authority Thailand, MEA	Divided into 3 stages:  1. Plant capacity is not necessarily high and FIT rate high.  2. FIT degression  3. When the capacity has already met the target, FIT will be changed into SPP Hybrid-firm bidding.	
Philippines	2012	Ministry of Energy  National Renewable Energy Board (NREB), Philippines Department of Energy	1) Open for newly built power plants with 10-50 MW capacity 2) Power plant should be operating 100% during peak time, and the reduced with 65% for off-peak time. 3) Fossil fuel or conventional fuel was banned (except for start-up or emergency condition). 4) The cost of 3.66 baht (B)/kWh was implemented. ERC has the right to review and change prices either when the installation meets the target within a certain period, or when the target is not met. The last review is conducted in 2015 by ERC, i.e., tariff reduction for solar and wind power plants. Contract duration: 20 years, but it will be made to be 12 years in the future	

ASEAN region, exceeding 10% (S&P Global, 2022). The industrial and commercial sector is the prime mover of the

growth of electricity demand in Vietnam (Rosado, 2022). Thailand and the Philippines are leaders in the ASEAN region in

terms of solar PV and wind power deployment. In 2017, wind power production exceeded 1000 GWh. The amount of electricity produced by solar PV generation was over 4,000 GWh in Thailand and over 1,000 GWh in the Philippines in 2017 (Diaz-rainey *et al.*, 2021). In 2020, Vietnam experienced a big change in the use of solar power. Vietnam is the ASEAN's largest user of solar power, with additional capacity of 16.5 GW (2010-2020) (Govindarajan *et al.*, 2023; IRENA & ACE, 2022; Sreenath *et al.*, 2022). Vietnam is one of the best examples of policy implementation on renewable energy, especially solar power, in the ASEAN region (Do *et al.*, 2021; Fahim *et al.*, 2023; Qureshi *et al.*, 2023; Thanh *et al.*, 2023; Vakulchuk *et al.*, 2020). In geothermal sector, Indonesia has over 2,300 MW and the Philippines has over 1,900 MW installed capacity. In term of world's biggest installed capacity of geothermal power plants, the United States rank 1, Indonesia rank 2 and the Philippines rank 3 (Richter, 2023; Theglobal economy, 2022).

### 3.1.2. Renewable energy target

From 2010 to 2020, the power and energy mix has continued to increase due to the introduction of RET in ASEAN. The share of RE increased from 11.7% in 2010 to 14.2% in 2020 (ACE, 2023). This is far from the target of 23% renewable energy use in ASEAN in 2025. A target of 23% requires an annual investment of approximately US\$27 billion. Annual investment in renewable energy in ASEAN is only about \$8 billion (2016-2021). They should have more practical experience in bidding, feed-in tariffs and managing auctions (Vakulchuk *et al.*, 2023). Table 1 shows the RE utilization targets of the five ASEAN countries in terms of the biggest electricity production.

### 3.2. FIT Policies in ASEAN

Table 2 gives information about FIT schemes applied in ASEAN countries. Furthermore, policies related to FIT in each country along with its economic aspects, will be discussed and compared to provide a general overview of renewable energy development policies in Southeast Asia.

#### 3.2.1. Indonesia

PT Perusahaan Listrik Negara (Persero) or PLN, an Indonesian state-owned enterprise, is obligated to buy RE sources that been used to generated the electricity. This obligation started when the government enacted Ministry of Energy and Mineral Resources (MEMR) Regulation No. 17 in the year of 2013 on electricity that should be purchased by PT PLN (Persero) from Solar Photovoltaic. Later on, in 2014, the MEMR also enacted hydro, bioenergy, and geothermal regulations. The implementation of FIT in Indonesia was strengthened by the enactment of the Minister (EDSM) No. 50 of 2017 regarding the Utilization for the Provision of Electricity of non-conventional (Renewable) Energy Sources. Through this regulation, the funds of FIT are guaranteed by the government using the state budget, of which 85% of them comes from the taxpayer. In 2017, it was recorded that subsidy disbursed for the sector of energy reached USD 5,57 million in total. PLN was applied with several incentive to boost this energy by implementing subsidy to develop renewable energy sector of electricity in the country (Bakhtyar *et al.*, 2013; Boly & Sanou, 2022). Indonesia's FIT has increased investment in renewable energy in Indonesia since 2010. Even if the investment or tariff rates are attractive, many of these projects have slowed development in line with their goals (Rahmanta *et al.*, 2022). Grid issues, project permits, and land acquisition restrictions are some of the issues in this area (Yuliani, 2016). In the case of FIT geothermal power plants, despite attractive tariffs, restrictions on conversion of forest functions, grid networks, and permission to clear land remain investment barriers. In addition, short-term policy

disagreements represent another risk factor for investors (Hasan & Wahjosudibjo, 2014). Considering the level of economic development and characteristics of the power system, the price adjustment model used in East Asia is more suitable for application in Indonesia than other models. (Supriyanto *et al.*, 2022).

#### 3.2.2. Vietnam

Vietnam is currently implementing feed-in tariffs for several categories of RE, namely biomass, PVs, and wind resource. The tariffs' determination is not dependent on the area measurement or the electric capacity of the plant, but it is set to a fixed amount for different kinds of powerhouses. Recently, Vietnam's government is conducting research regarding FIT for geothermal and biogas powered electricity. To support the FIT implementation, the government is being helped by other parties, such as the Vietnam Environment Protection Fund (VEPF) who is paying some percentage of wind power plants FIT to help the government with the tariff. In Vietnam, FIT was introduced for wind power generation in 2011 and for solar power generation in 2017.

The FIT for solar power from 2017 to 2020 is between 7 and 9.35 USD cents/kWh (Decision 13/2020/QD-TTg on Mechanism for Encouragement Of the Development Of Solar Power in Vietnam, 2020; On the Support Mechanisms for the Development of Solar Power Projects in Vietnam, 2017; Amending and Supplementing Some Articles of Decision No. 11/2017/QD-TTg Dated 11 April 2017 by the PM on Mechanism for Encouragement of the Development of Solar Power Projects in Vietnam, 2019). In this case, the FIT for wind powerhouses cost 7.8 USD/kWh. Majority the tariff was paid by a government electricity corporation called Electricity of Vietnam (EVN) and then the rest, VEPF pays 1 USD/kWh out of the total tariff (Azhgaliyeva & Mishra, 2022; Do *et al.*, 2021; Junlakarn *et al.*, 2021; Le *et al.*, 2022).

#### 3.2.3. Malaysia

FIT was introduced in Malaysia in 2011 under the coordination of the Sustainable Energy Development Authority (SEDA). This regulation has begun to make the local and foreign investors interested to invest in RE in Malaysia (Firdaus Muhammad-Sukki *et al.*, 2014). Since 2012, SEDA set the FIT regulation for biomass and biogas. In general, the cost of FIT is lower along the capacity increases in consequence of optimized factor of the plant. In Malaysia, application of FIT for renewable energy is built upon the quota that available which is regulate by the government each year (Lim *et al.*, 2015; Wong, 2015). FIT Malaysia applies annual payment FIT for every renewable energy (not applicable for small hydroelectric power plant). It is started in every new calendar year from 2013 until now. If the start date has passed, incentives will not be paid again. Since 2016, due to the target of SEDA already reached, application of solar PV feed-in tariff quota is closed. Solar PV through LSS (Large-Scale Solar) and NEM (Net Energy Metering) are chosen by the government for self-consumption schemes. Malaysia has introduced a Net Energy Metering (NEM) policy since 2016 to promote the deployment of solar power. NEM has received several updates in 2019 and 2021. NEM 2021 will consist of NEM Rakyat (domestic customers) and NEM Gomen (government ministries & entities) (Govindarajan *et al.*, 2023).

#### 3.2.4. Thailand

FIT in Thailand was classified with two different categories: natural energy (hydro, wind, solar PV) and bioenergy (urban waste, biomass, biogas). Thailand's FIT for natural has two types, namely Fixed FIT, and Premium FIT. These two designs are applied in term of fixed portion of remuneration and feed-in

premium. These strategies are no longer implemented at the present time. In the other way, FIT for solar PV is already stopped since 2018 and the regulation is being hold. In Thailand, the FIT mechanism was sponsored by charges passed on to their electricity consumers with a flat fee for all consumers. Fuel Adjustment Cost (FAC) was applied in the module in determining tariff for electricity. In the country, the special authority called Electricity Generating Authority of Thailand (EGAT) is an institution that have obligatory for providing electricity generated from RE sources and giving FIT incentive that can be paid to renewable energy that capable to generate electricity under SPP (10-90 MW). Whereas, for small power producer (VSPP, less than 10 MW) scheme, the electricity produced from RE is required to be obtained by Metropolitan Electricity Authority (MEA) (Huenteler, 2014; S Tongsoptit, 2013; Sopitsuda Tongsoptit, 2015; Sopitsuda Tongsoptit *et al.*, 2016).

### 3.2.5. Philippines

FIT was introduced in the Philippines from 2010 and several regulatory changes were made in 2012, 2015, 2016 and 2020. This FIT includes RES purchasing mechanisms including biomass, solar, wind, runoff and ocean. This FIT provides guidelines on the mechanics of a contract model with fixed fees and adjustments according to the year of technology. Initial FIT rates for 2020 are 8.53 PHP/kWh for wind, 9.86 for solar and 5.90 PHP/kWh for hydro (Lagac & Lagac, 2020; Energy Regulatory Commission, Resolution-No-06-Series-of-2020, 2020; Energy Regulatory Commission, Resolution No. 16 Series of 2010, 2010; Energy Regulatory Commission, Resolution No. 16 Series of 2012, 2012). In the Philippines, FITs are set as fixed-price energy tariffs for every type of renewable energy. All electricity users will be charged to fund FIT in the Philippines, and this scheme is called FIT Allowance (FIT-All) (Bakhtyar *et al.*, 2013). FIT-All is a uniform charge in Php/kWh that is calculated each year to be paid by all electricity utility consumers. This FIT scheme has been proved to work and succeeded in growing the installed capacity of renewable energy plants by almost 8 times from 2013 to 2017. The FIT scheme implemented in the Philippines shows some good input on regulation design, such as a long-term structure, consistent, and advance incentives to support the tariffs. The funding model that is charged to consumers rather than the government has also proven to be more attractive to investors because the income is more guaranteed (Guild, 2019).

The different modes of the potential energy based on the renewable source are one of the key points for many countries in ASEAN region especially for photovoltaic, Hydro power, and wind. In this point of view, we analyzed and summarized the

power generated in the region based on these sources in the following description.

### 3.3. Renewable energy potential

#### 3.3.1 Solar Photovoltaic

The climate of Southeast Asia is tropical which allow the countries to receive relatively high amount of daily sunlight, leading to big potential of solar energy utilization. However, as for today, most of this potential has not been converted into useful form of energy (Lidula *et al.*, 2007). Table 3. below summarize the solar PV potentials in ASEAN countries, measured as daily average of practical potential in kilowatt hours per installed kilowatt peak of system capacity (kWh/kWp). The solar PV practical potential is affected by the quantity of solar radiation received, land availability, as well as some technical constraints such as system configuration, air temperature affecting system performance, shading and soiling. The results are ranging from 3.55 to 4.06 kWh/kWp, with Thailand holds the highest amount of solar PV potential among other countries. Vietnam receives the smallest amount of solar potential, which is expected as it is located near the boundary of tropical and subtropical zone.

#### 3.3.2. Hydro

Hydropower is generated from available energy stored in moving water. Thus, the potential amount of this renewable resource is determined based on the annual rain levels and the number of rivers flowing in the area. In Southeast Asia, one of major source of hydropower is Mekong River that is estimated has 250 Giga Watt of hydropower capacity, shared to four ASEAN countries it passes through (Vidinopoulos *et al.*, 2020). Table 3. shows the technical hydro energy potential in Terra Watt hours (TWh) of ASEAN countries. Indonesia owns the highest amount of hydro energy potential of 402 TWh which is expected from the largest country to have the most amount of rain and rivers as sources of hydropower. Malaysia, which has about one sixth of area compared to Indonesia, has a very large hydropower potential of 210 TWh. Next, followed by Vietnam that owns 96 TWh of hydropower potential which around 60 percent of it has been utilized to generate electricity. At least until the end of 2016, hydropower is a dominant source of electricity in Vietnam that contributed to 37.6% of their electricity generation (Nguyen *et al.*, 2019). Lastly, Philippines and Thailand have the least amount of hydropower potential of 24 and 55 TWh respectively.

#### 3.3.3. Wind

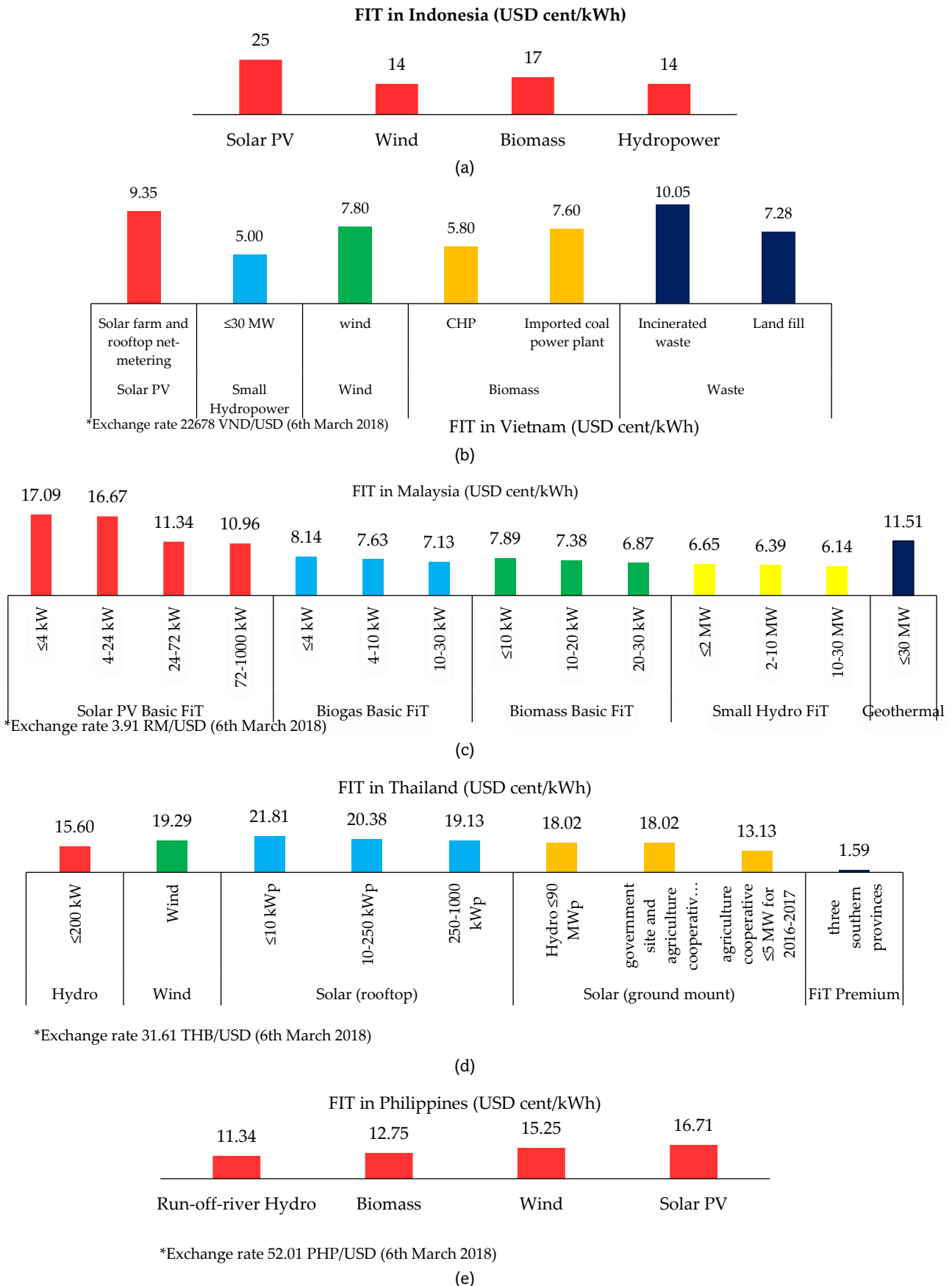
Wind contains kinetic energy that can be harvested as an alternative source of electricity power. The amount of wind

**Table 3**  
Practical solar PV, hydro, wind, & geothermal potential in ASEAN countries

Country	Solar: average: practical potential (kWh/kWp/day)	Hydropower: technical potential (TWh)	Wind energy: mean power density (kWh/m <sup>2</sup> )	Geothermal: resources (MW)
Indonesia	3.77	402	44.57	23,357
Vietnam	3.55	96	175.03	-
Malaysia	3.74	210	32.62	-
Thailand	4.06	55	122.91	-
Philippines	3.93	24	185.47	4,064

Source: (Alhusni *et al.*, 2023; Fronda *et al.*, 2021; MEMR of Republic of Indonesia, 2023; Vidinopoulos *et al.*, 2020; World Bank, 2019, 2020)





**Fig 4.** FIT for different model of RE electricity in ASEAN Countries; (a) Indonesia, (b) Vietnam, (c) Malaysia, (d) Thailand, (e) the Philippines (Source: ACE & CREEI, 2018).

power potential in one area is dependent on its wind climate and topography. Some possible ways to measure this potential is by assessing the wind speed or wind power density. Table 4.

gives estimation of the average wind power density in ASEAN countries, up to 100m height above the ground (onshore) or sea (offshore). From the Table 3, it is shown that the Philippines



holds the most wind power potential with the wind power density averaging on 185.47 kWh/m<sup>2</sup>. Vietnam has slightly lower wind power density of 175.03 kWh/m<sup>2</sup>. From the past study, it has been found that southern and coastal area of Vietnam, and north and northeast areas of Philippines are having good to excellent wind potential which can be a factor to their high wind power density (Lidula et al., 2007). While, Malaysia and Indonesia have considerably very low wind power density compared to other ASEAN countries, with only 32.62 and 44.57 kWh/m<sup>2</sup> respectively.

### 3.3.4. Geothermal

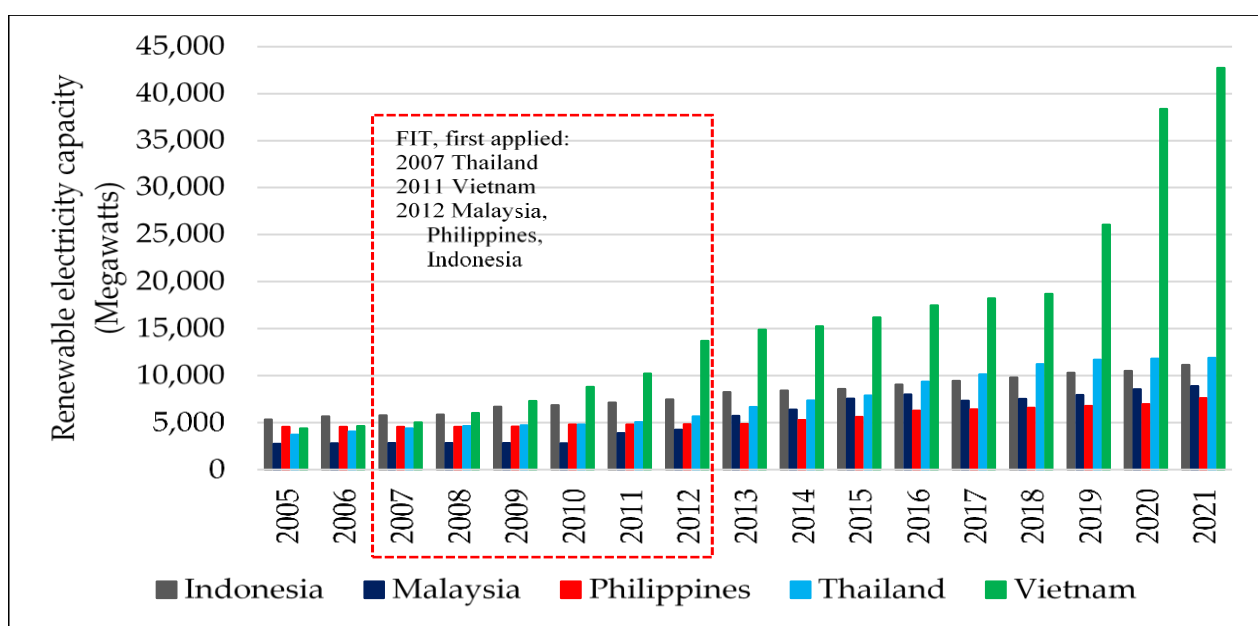
According a geothermal resources at Table 3, Indonesia has 23,357 MW and the Philippines has 4,064 MW. The installed capacity of geothermal power plants in Indonesia will reach 2,343 MW in 2022, and 1,935 MW in the Philippines in 2022 (Alhusni et al., 2023; Fronda et al., 2021; Richter, 2023). Geothermal power plants in the Philippines contribute around 10% of electricity (Frondda et al., 2021; IEA, 2023b). Geothermal development in Indonesia faces several challenges, such as uneconomical due to high exploration risks due to the lack of heat sources in wells, reduction in the steam capacity of production wells, and operational problems due to corrosive environmental conditions & Condensable gas generated. Geothermal sites in remote areas away from the power load center present additional challenges and are relatively expensive with high capital costs of approximately \$4,000 to \$5,000 per kW. Problems with forest functions and land regulations are also resistors (Alhusni et al., 2023; Purwanto et al., 2019; Setiawan, 2016).

### 3.4. Economic Aspects

Several indicators can be used to assess the economic feasibility of a power plant project. One of the most commonly used metrics is the LCOE which indicates the unit cost of electricity over the life of the project. (Aldersey-Williams & Rubert, 2019; Singh & Singh, 2010; Yang, 2010). LCOE is accustomed to assessing the relative profitability of various power plant technologies. Comparing LCOE results are implemented in selection of power generations. For example, the results of

LCOE calculations of a solar PV system with an LCOE of 0.17 €/kWh is compared to a coal fired power plant with an LCOE of 0.21 €/kWh). If the LCOE is lower than the specific cost, then development in such technology is considered profitable, while if it is higher, then it is not (Nissen & Harfst, 2019). The specific cost has the same typical incentive as LCOE but slightly higher. This condition triggered to LCOE can be applied with more profitable. In that case, grid parity is reached, with the specific conditions, where the LCOE the RET is equal to the cost of conventional electricity generated based on the fossil fuel such as coal and natural gas (Branker et al., 2011). The results of LCOE calculations can also be an essential aspect in setting feed-in tariffs (Ouyang, 2014). Therefore, considering policies that affect LCOE calculations can guide policymakers in setting incentives in the future (Aldersey-Williams & Rubert, 2019).

LCOE systems became a fundamental principle for countries such as Malaysia, the Philippines, Thailand, and Vietnam when setting their FIT prices and accommodating premium returns on investment for multivarious technologies. The FITs prices applied to a multi variation of power plants in those countries depend on the power sources that become alternative energy sources for them; the distribution can be seen in Figure 4. FIT are applied in Indonesia with a different incentive scheme in which a FITs price is set as the highest price (ceiling price) by the government, adjusted for local, and national electricity generation. Previously applied FIT policies set the number of solar PV power plant FIT at 25 cents USD/kWh for any level of power plant capacity (based on MEMR Regulation no 17 of 2013). The regulation was implemented for the first ten years, yet for the next ten years, FITs dropped to 13 cents USD/kWh with a chance of extra-incentive if the solar photovoltaic modules used in the solar PV power plants were local brand products with a minimum usage of 40% of the entire module used in the power plants. Other countries such as the Vietnam, Thailand, and Philippines (shown sequentially in Figure 4 sections b, d, and e) sequentially set the FITs price at 16.71 cents USD/kWh, 18.13 to 21.81 cents USD/kWh (based on power plant capacity), and 9.35 cents USD/kWh, which became the lowest FITs price amongst countries that joined ASEAN. In Figure 4, Section b, there is the highest FIT set by Malaysia, which is 17.09 cents USD/kWh,



**Fig 5.** Trends in the capacity of renewable energy power plants during FIT implementation (reprinted from ref. (UNESCAP, 2023b)).

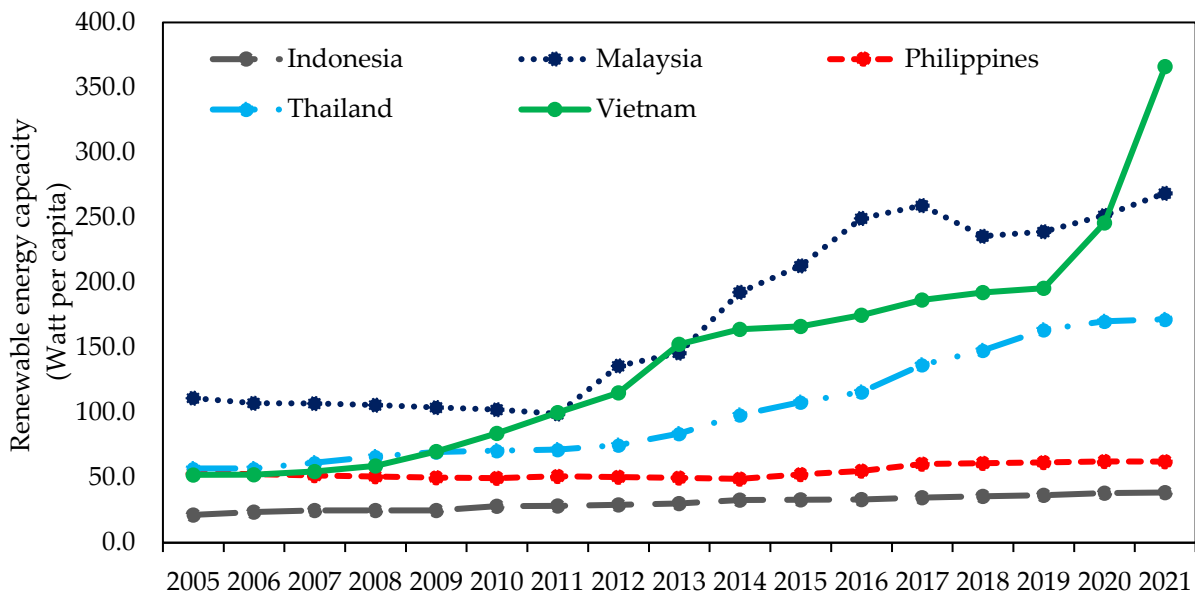


Fig 6. Trend of renewable energy power plant capacity per capita during FIT implementation (reprinted from ref. (UNESCAP, 2023b)).

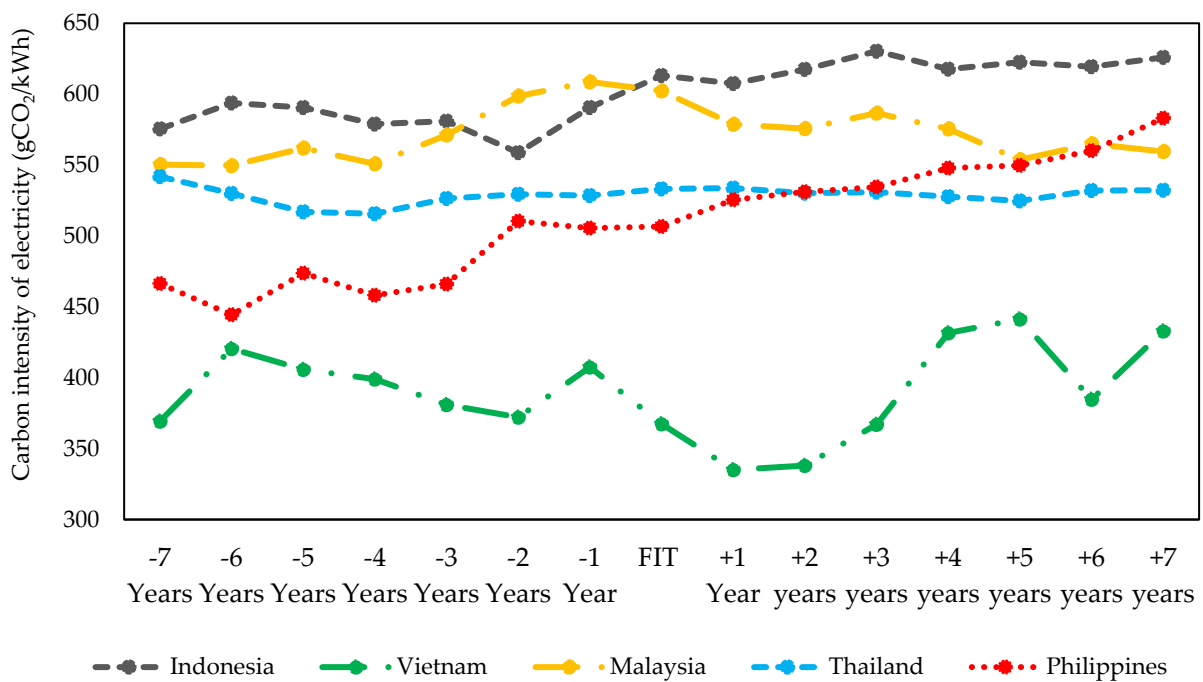
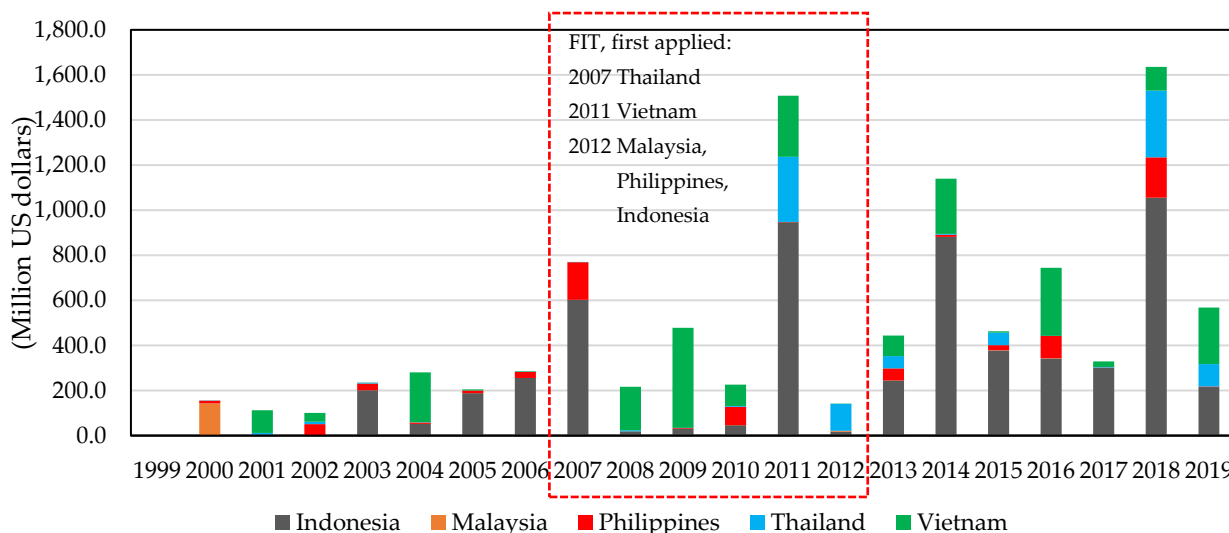


Fig 7. Carbon dioxide (CO<sub>2</sub>) emission intensity from energy production 5 years before and after FIT implementation in ASEAN countries (reprinted from ref. (ourworldindata, 2023)).

with a chance of a bonus which is possible to be applied if it is suitable for the criteria. FITs price applied in Malaysia is adjusted to power plant capacity and generator potential.

The FIT that set in ASEAN countries except Vietnam is still within the range of LCOE calculations compared to developed countries such as Germany. Meanwhile, when compared to Canada, the LCOE is significantly higher. But it should be noted that because Germany and Canada are in cold climates, the level of sunlight is not as much as in tropical countries. Therefore, it is not surprising that the LCOE calculation results in these two countries are higher than the FIT set in ASEAN countries.

Furthermore, for the comparison of developing countries, the FITs applied in ASEAN countries are not much different from the results of the LCOE calculation in Malaysia (Yun Lau *et al.*, 2014) and are still within the range of 2014 LCOE calculations in China (Ouyang, 2014). But over time, the industry and technology for solar photovoltaic continue to develop. This causes the cost of electricity generation from this energy source to continuously decline. Previous study reported that RE was successfully conducted in China (Tu *et al.*, 2020; M. Zhang & Zhang, 2020). These studies reported that LCOE calculations demonstrated a decrease in 2018. The same trend has happened on a global scale (Yao *et al.*, 2021) The outcome of LCOE is much lower than Vietnam's FIT even though China



**Fig 8.** International financing for renewable energy development (UNESCAP, 2023a).

has a subtropical climate with less sunlight than tropical countries in Southeast Asia. Although the sunlight potential is not the only factor affecting the calculation of LCOE in each country, these results can still be considered. An indication that the FIT set for solar photovoltaic in ASEAN countries needs to be reviewed by considering the rapid development of industry and technology for this type of energy and LCOE calculations from other countries.

**3.5. Impacts of FIT Implementation**

This section evaluates the impacts caused by the FIT implementation in ASEAN countries related to RE capacity growth and the environment.

**3.5.1. Growth of Renewable Energy Electricity-Generating Capacity**

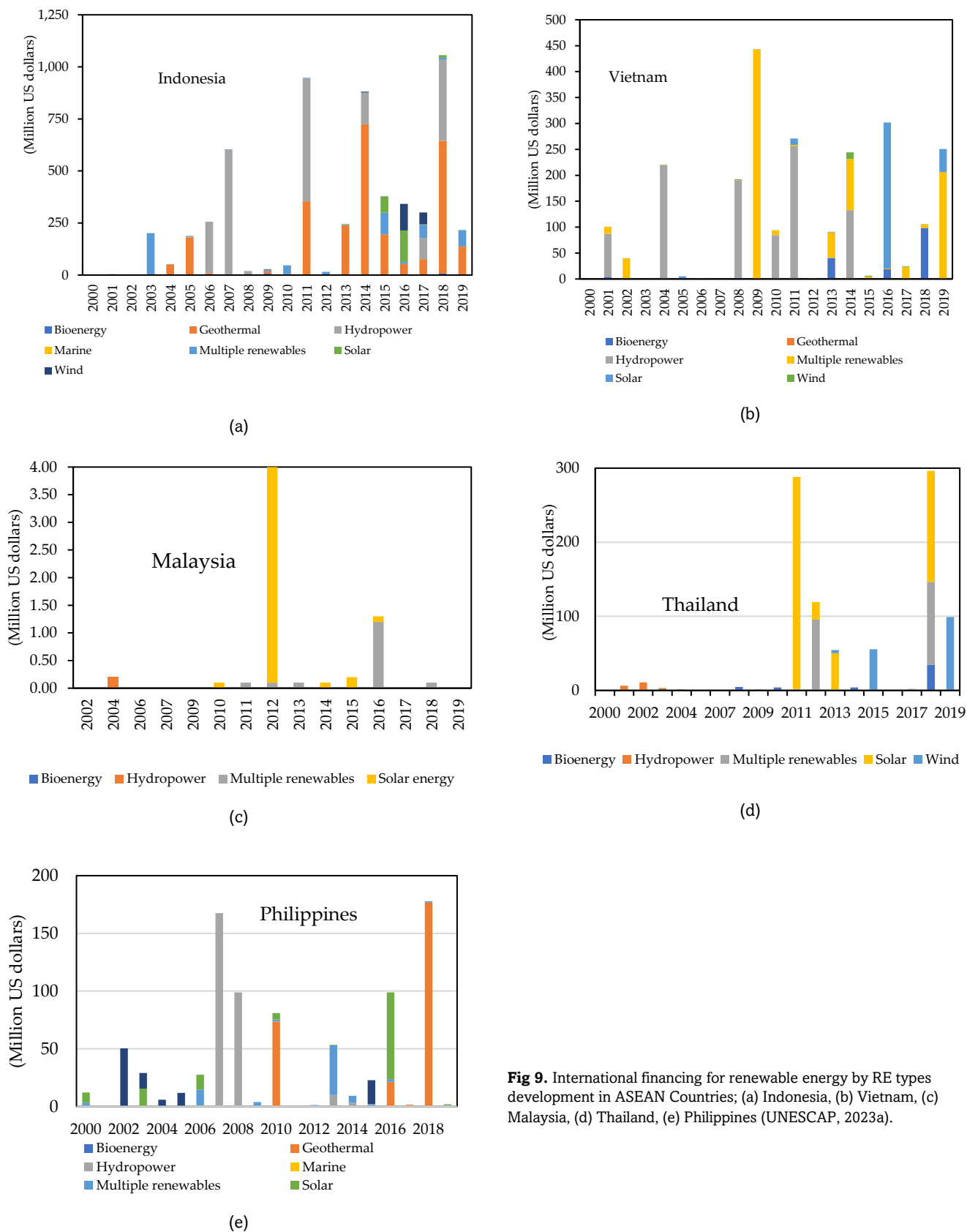
The success of a program that aims to increase renewable energy utilization was capable of being checked from the growth of RE electricity installed capacity after the program is run. Therefore, usually, each country has a specific target related to the amount of installed capacity that must be achieved at a certain time. For example, China targets total installed capacity for hydropower, solar PV, and wind power plant to increase to 350 GW, 100 GW, and 230 GW respectively by 2020 through the twelfth "Five-Year Plan" (Yan et al., 2016). Figure 5 shows the early stages of FIT implementation in ASEAN countries, with Thailand being the pioneer of FIT in the region. According to data analysis, the average annual growth rate of RET capacity in the period before the FIT introduction was 2.16% (2001-2006) in Thailand and 10.28% (2001-2011) in Vietnam. Indonesia, Malaysia, and The Philippines have implemented FIT since 2011. The annual growth rate of renewable energy capacity from 2001 to 2012 was 2.71% in Indonesia, 3.69% in Malaysia, and 5.21% in the Philippines. After the initial implementation of the FIT, each country recorded an average annual increase in RET growth compared to its pre-FIT. The annual growth rate of RET capacity is 7.52% in Thailand (2007-2021), 16.38% in Vietnam (2011-2021), 4.56% in Indonesia (2012-2021), 9.11% in Malaysia (2012-2021), and 5.21% in the Philippines (2012-2021). Vietnam has the highest annual growth rate of renewable energy capacity, while Indonesia has the lowest annual growth rate of renewable energy capacity. Figure 6 shows that the RE per capita going up fastly after the introduction of FIT in Vietnam, Thailand, and

Malaysia. Renewable energy growth was very slow in Indonesia and the Philippines (UNESCAP, 2023b).

**3.5.2. Environmental impacts**

Today, the power generation account for the largest contribution to the harmful gases emission that damage the environment. Thus, to meet the rapidly growing energy needs, clean energy requires to be utilized so that it does not further damage the environment (Bull, 2001). The use of RE has different effects on the environment, depending on the type and generation model used. However, in general, RET has been proven to minimize the rate of climate change by reducing emissions of hydrocarbon gases, CO, CO<sub>2</sub>, SO<sub>2</sub>, and particulate emissions (Owusu & Asumadu-Sarkodie, 2016; Panwar et al., 2011). The FIT system as a policy aimed at increasing RE utilization is certainly expected to contribute to climate change mitigation efforts.

The quantity of CO<sub>2</sub> emitted per unit of energy generation can be used as the calculation that determine carbon intensity of energy production (kilograms of CO<sub>2</sub> per kilowatt-hour). The data as illustrated in Figure 7 can provide an overview of the percentage of low-carbon energy produced compared to energy produced by using fossil fuel, before and after the FIT scheme is implemented in ASEAN countries (ourworldindata, 2023; Ritchie, 2022; Xia et al., 2022). If the carbon intensity of energy production is increased, it means that conventional fossil energy production has grown faster than RE generation in the country. The purpose of FIT implementation is to increase the RE ratio to gain environmental benefits such as reducing CO<sub>2</sub> emission, the carbon intensity should become lower each year so the FIT implementation can be considered successful. Indonesia is the country with the highest CO<sub>2</sub> emissions, while Vietnam is the lowest CO<sub>2</sub> emitter. Indonesia and the Philippines tend to increase CO<sub>2</sub> emissions, while the remaining 3 countries tend to stagnate. Table 4 shows that the average annually CO<sub>2</sub> emissions before and after the FIT implementation in Vietnam, Malaysia, and Thailand tended to be stable, showing that along with the growth of electricity production, emissions lead to CO<sub>2</sub> emissions tending to be the same. This is supported by the utilization of RET in the energy source composition of their electrical system. Different things happened in Indonesia and in the Philippines, which as an increase in CO<sub>2</sub> emissions after the



**Fig 9.** International financing for renewable energy by RE types development in ASEAN Countries; (a) Indonesia, (b) Vietnam, (c) Malaysia, (d) Thailand, (e) Philippines (UNESCAP, 2023a).

implementation of the FIT. Indonesia has a CO<sub>2</sub> production increase of 6.67%, while the Philippines has a 15.25% increase. The low use of RE in their power system is one of the reasons for the increased CO<sub>2</sub> emissions.

**3.5.3. Renewable energy investment**

In general, since the introduction of FIT in Indonesia, Vietnam, Malaysia, Thailand and the Philippines (2007-2012), there has been an increasing trend of international investment or

financing in the RE sector, as shown in Figure 8. Data Analysis of international lending levels in the RE sector shows that investment value in five countries is increasing. Indonesia received a total of US\$ 2,140 million (2004-2011) in funding in the RE sector, increasing to US\$ 3,456 million (2012-2019) when FIT implementation began in 2012. Vietnam also sees an increase in international funding growing from US \$ 998 million (2002-2010) to US\$ 1,297 million (2011-2019). Thailand received grants ranging from US\$ 22.5 million (2000-2006) to US\$ 472 million (2007-2013). Philippines increased funding from US\$ 298 million (2004-2011) to US\$ 367 million (2012-2019). Meanwhile, Malaysia received an increase in funding from US\$ 0.5 million (2004-2011) to US\$ 5.9 million (2012-2019).

The range of international funding allocations for different types of RETs is shown in Figure 9. Indonesia has received numerous international grants in the fields of geothermal and hydropower. Vietnam, Malaysia, and Thailand account for a big share of financing in the generating PV. The Philippines now has more capital in the geothermal sector. In terms of funding, Indonesia has the largest amount of international funding, followed by Vietnam, Thailand, the Philippines, and Malaysia.

#### 4. Discussion

The policy related to tariff incentives in ASEAN countries indicated that the policy could generate an increased number of RE sources in all countries participating in the present study. These trends are also founded in different countries such as Germany (Schnaars, 2022), United States (Hotchkiss *et al.*, 2022; Li & Woo, 2022), EU member countries (Klopčič *et al.*, 2022), and Russia (Korolev, 2022). Moreover, the study related to the improvement and development of tariff regulation based on a previous study (Tolstyakova & Batyrova, 2022) can be used in several scenarios, such as modernizing and improving the systems, transparent and independent regulations, shifted to a digitalization-based model. The evaluation should be based on assessing the company performance, implementing scientific methods, and improving the innovation in tariff incentives. Other research also lists these solutions (Choobineh *et al.*, 2022) where the fundamental problem (infrastructure, scalability, regulation, consensus mechanism, and security) often occurred when digit alization was applied in the systems. The last, FIT implementation was applied in different situations and conditions. The impact that occurred during the implementation of FIT in all developing and developed countries is about the socioeconomic that happen in household and industrial sectors. Since the government implemented and announced the regulation, the price, regulation, and industry performance also need to be considered (Kozhageldi *et al.*, 2022; Shahid *et al.*, 2022).

**Table 4.**

The average annual carbon intensity of energy production in ASEAN countries 7 years before and after the FIT implementation (ourworldindata, 2023; Ritchie, 2022; Xia *et al.*, 2022)

Country	7 Years before FIT (Average gCO <sub>2</sub> /kWh)	7 Years after FIT (Average gCO <sub>2</sub> /kWh)	Change (%)
Indonesia	581.30	620.09	6.67%
Vietnam	393.62	390.11	-0.89%
Malaysia	570.17	570.64	0.08%
Thailand	526.96	530.24	0.62%
Philippines	474.96	547.40	15.25%

#### 5. Conclusions

The most notable results of this study show that the ASEAN members (Indonesia Vietnam, Malaysia, Thailand, and the Philippines) have implemented FIT schemes with different models. The FIT funding model that is charged to electricity users (Philippines and Thailand) has been proven to be better than those that are funded by the government (Indonesia, Malaysia, and Vietnam). From the perspective of investors, the payment from the government is not as reliable as from electricity users which makes it less attractive. Comparison between FIT solar PV prices with LCOE of the same energy source from developing countries indicated that the FIT pricing in ASEAN countries is generous that the solar PV FIT prices ranging from 0.093 to 0.218 USD/kWh, while China solar PV LCOE in 2018 ranging from 0.054 to 0.073 USD/kWh. After the initial implementation of the FIT, each country recorded an average annual increase in RET growth compared to its pre-FIT. The annual growth rate of RET capacity is 7.52% in Thailand (2007-2021), 16.38% in Vietnam (2011-2021), 4.56% in Indonesia (2012-2021), 9.11% in Malaysia (2012-2021), and 5.21% in the Philippines (2012-2021). FIT managed to keep CO<sub>2</sub>/kWh emission production stable in Vietnam, Malaysia, and Thailand while increasing renewable energy production in their power system. Meanwhile, CO<sub>2</sub> emissions in Indonesia increased by an average of 6.67% per year and in the Philippines by an average of 15.25% per year after the implementation of the FIT. FIT has succeeded in increasing the value of international funding investments in the field of RE in Indonesia, Vietnam, Malaysia, Thailand, and the Philippines.

This study is limited to addressing the FIT performance indicators in Indonesia, Vietnam, Malaysia, Thailand, and the Philippines from the perspective of growth in renewable energy use, reduction of CO<sub>2</sub> emissions in the power sector, and international support in financial for renewable energy development in these countries. Other aspects such as political conditions, legal certainty, economic, social changes, and others are not covered in this study. Future studies can discuss in more detail regarding these aspects of FIT success. With the finding that there is a positive correlation between FIT implementation and RET growth, as well as the significant reduction in emissions associated with RET increase in this article, the article contributes to further bringing the FIT pricing policy as the solution to encourage the use of RET and reduce emissions.

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