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A decade of solar PV deployment in ASEAN: Policy landscape and recommendations

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Abstract

South East Asian countries are blessed with abundant solar energy potential. Yet, the solar photovoltaic potential remains underutilized. There are certain roadblocks in the progress of solar PV deployment in ASEAN. This paper aims to investigate the solar PV policies in the ASEAN region over the past decade. Also, an attempt was made to provide policy recommendations. In spite of solar irradiation advantage and plummeting solar system cost, it was understood that solar PV growth is greatly dependent on regulatory policies and mechanisms. The tremendous growth in solar PV is observed in Vietnam through the successful implementation of the Feed-in-Tariff (FiT) scheme. In addition, the FiT demonstrated to be a suitable scheme to initiate solar PV growth. Over the past decade, the policy landscape in Thailand and Malaysia evolved from FiT scheme to P2P energy trading. This strategy is critical for developing a solid, self-sustaining PV market. Uncertainty and delay affected the success of solar policies in some ASEAN member states. Adoption of the FiT scheme for early-stage PV development and the Renewable Portfolio Standard (RPS) for advanced-stage PV development are the main policy recommendations. This study will serve as a reference to policymakers and energy professionals in the region. The insights of the study will be beneficial in adopting appropriate solar policy instruments.

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Keywords: Energy policy; ASEAN; Solar PV; Sustainability; Carbon footprint

1. Introduction

Energy is viewed as the key driver for a country's socio-economic development. To meet the energy demand, most of the global economies have been relying on fossil fuels. In spite of the COVID-19 impact, International

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Energy Agency (IEA) predicted a rise in demand for all fossil fuels [1]. The combustion of fossil fuels leads to the emission of Green House Gases (GHG). Higher concentration of GHG in the atmosphere is causing inter-related issues such as climate change, sea-level rise, global warming.

South East Asian (SEA) countries are prone to adverse effects of global warming and climate change. During the past decade, extreme weather events such as droughts, floods, and cyclones have become more prevalent in this region. As per the study carried out by Asian Development Bank (ADB), a substantial rise in sea level (around 70 cm) is projected in Indonesia, the Philippines, Thailand, and Vietnam by 2100 [2]. This scenario could result in several socio-economic problems in the SEA region, especially major coastal cities such as Jakarta, Bangkok, and Manila. Tapping renewable energy (RE) sources is a widely accepted solution to mitigate these life-threatening events. United Nations' Sustainable Development Goal (SDG) 7 (Clean Energy) and SDG 13 (Climate Change) also stresses this concept [3]. In this regard, the Association of South East Asia Nations (ASEAN) has set an ambitious target of a 23% share of RE in total primary energy supply (TPES) by 2025 [4,5]. Since the solar irradiation pattern is geographically favorable in the SEA region, the development of solar PV technology is important to achieve its RE targets [6]. Further, there is a global trend of energy transition from a carbon-based to a greener energy system. Hence, ASEAN countries look forward to decentralized and decarbonized power generation through solar energy

Governmental intervention has played a big role in the development of renewable energy in different countries. According to Gorjian et al. the policies of the 6th development plan were detrimental to the solar PV deployment of Iran [7]. Similarly, the solar PV uptake in the Philippines is attributed to abundant solar irradiation and supportive policies [8]. Based on the study of different policies, Raina and Sinha reported that Jawaharlal Nehru National Solar Mission (JNNSM) has significantly contributed to the growth of solar PV capacity in India [9]. The authors in Pathak and Shah examined the photovoltaic development in Colombia and highlighted the favorable opportunities offered by law 1715 for the development of utility-scale projects as well as small-scale projects [10]. Erdiwansyah et al. examined the existing RE policies and development barriers in five major economies, namely Brazil, Russia, India, China, South Africa (BRICS) [11]. They highlighted the need to restructure energy policies with due consideration to social, ecological, geographical, and economic factors. According to Duraskovic et al. a robust legal framework and support policies are needed for renewable energy development in Western Balkan countries [12].

ASEAN member states have introduced several policies and programs for renewable energy development. Each AMS has put forward its own national targets on renewable energy. Kan et al. investigated the growth of renewable energy in ASEAN along with an analysis of government schemes and policies [13]. Pranadi et al.. analyzed the RE policies in the South East Asia region based on selected reports and emphasized the need to focus on non-power utilization of renewables [5]. Erdiwansyah et al. reported an overview of solar PV development and policy framework in South East Asian countries [14]. Government policies and schemes are prone to termination/modification. Since policies keep changing with economic and political scenarios, an updated overview of solar policies in ASEAN is always needed. While few literatures reported solar policy in the context of ASEAN, the present study is intended to provide new knowledge in two main ways. To the best knowledge, it is the first attempt to analyze the solar policies implemented between 2019 and 2021. Secondly, this work involves a comparative analysis of solar policies covering all the ten ASEAN member states. Further, there will be bridging of knowledge gap due to the unavailability of IEA's Photovoltaic Power Systems Programme (PVPS) reports in the ASEAN context. In this regard, the present study aims to investigate policies and support mechanisms for the solar PV development in ASEAN member states.

2. Solar PV development in ASEAN

ASEAN countries receive abundant solar energy throughout the year. Global Horizontal Irradiation (GHI) value varies between 1400 kWh/m^2/year and 1900 kWh/m^2/year [15]. Over the past decade, remarkable growth in solar PV installations has been observed in the South East Asia region. Based on the IRENA report, the cumulative installed solar capacity is 22.85 GW [16]. However, this growth is uneven among ASEAN member countries. Between 2011 and 2014, the majority of solar capacity is accounted from Thailand, Malaysia, and Indonesia. By 2016, solar PV capacity addition in the Philippines outpaced Malaysia and Indonesia and secured the second position among ASEAN member states. Most of the member states showed an increase in the share of solar energy in their energy mix. Till 2017, solar PV uptake is almost stagnant in Vietnam. Within three years, the world witnessed mind-blowing solar PV growth in Vietnam, touching 17 GW in 2020. In spite of land limitations, the solar PV capacity in Singapore crossed 250 MW in 2019. Over the past decade, slow growth was observed in some ASEAN

countries such as Brunei, Cambodia, Lao PDR, Myanmar. The variation of installed capacity of Solar PV in ASEAN member states is shown in Table 1. It is interesting to observe the variation in solar PV development in the ASEAN region. Considering the similarities in climatic conditions, these variations can be attributed to the electricity market and support mechanisms prevailing in each country.

Table 1. Variation of installed capacity (MW) of Solar PV in ASEAN countries.
Source: IRENA (2021) [16].

Country	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Brunei	1	1	1	1	1	1	1	1	1	1
Cambodia	4	5	6	9	12	18	29	29	99	208
Indonesia	17	26	38	42	79	88	98	69	155	172
Lao PDR	0	0	0	3	3	4	22	22	22	22
Malaysia	1	25	97	166	229	279	370	536	882	1493
Myanmar	1	3	4	6	21	32	44	48	88	84
Philippines	2	2	3	28	173	784	908	914	973	1048
Singapore	5	8	12	25	46	97	116	160	272	329
Thailand	79	382	829	1304	1425	2451	2702	2967	2988	2988
Vietnam	5	5	5	5	5	5	8	105	4898	16504

3. Solar PV support mechanisms in ASEAN

Many economies have been dependent on fossil fuels for meeting their energy requirements. Therefore, governmental intervention and support are needed to initiate and scale renewable energy projects. Typical support mechanisms for solar PV development implemented across the globe are shown in Fig. 1. The South East Asia region is an emerging photovoltaic market at its early-stage growth. ASEAN countries are expected to have substantial growth in solar PV deployment. The PV market in the ASEAN region has not evolved into a solid, self-sustaining PV market. Hence there is a necessity for policies and support mechanisms in ASEAN countries.

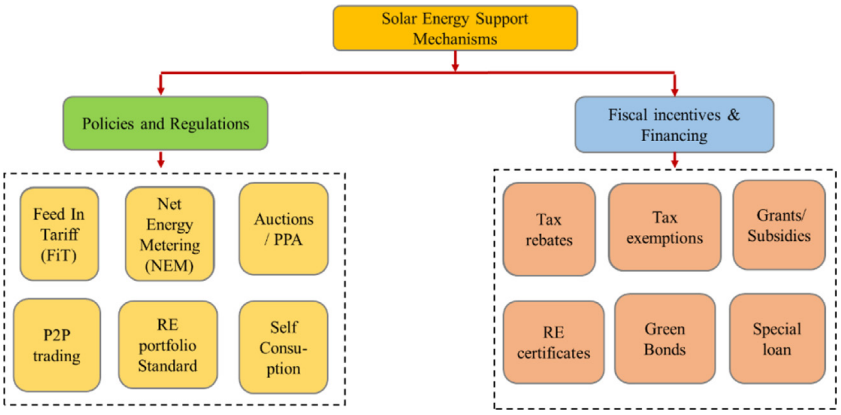

Fig. 1. Different types of support mechanisms for solar PV development.

3.1. Feed-in Tariff (FiT)

FiT is regarded as the widely practiced solar energy support mechanism globally. Based on this mechanism, ASEAN member states such as Malaysia, the Philippines, Vietnam, and Thailand reaped progress in solar PV installations [5].

Thailand was the first country to adopt the FiT framework in the South East Asia region [17]. Introduced in 2007, this framework was known as the Adder scheme in Thailand. Under the Adder scheme, the power producer is entitled to get 0.22 USD/kWh over the regular electricity tariff for ten years. In 2009, the adder rate was reduced

to 0.18 USD/kWh [6]. Irrespective of system size, the Adder rate remained the same for solar projects. Hence, this scheme was unable to accommodate the high capital expenditure for small-scale energy projects. In 2013, the Adder scheme was replaced with a new FiT approach in which due consideration was given to the system size. Initial FiT rates were between 0.16 USD/kWh and 0.19 USD/kWh for 25 years [18]. Among different system sizes, residential-scale PV had the highest FiT rate. Further, an additional FiT rate (0.01 USD/kWh) was provided for solar projects implemented in four provinces of south Thailand [19]. The 100 MW quota for commercial and industrial rooftop locations was over-subscribed. At the same time, it was not attractive for the residential scale rooftop PV sector and hence under-subscribed. In 2014, FiT rates were revised to a lower value for both rooftop and ground-mounted solar projects [19].

The FiT quota was fully allocated by 2015 and thereafter discontinued for residential, commercial, and industrial sectors [20]. In 2015, Solar Incentive Program for Government Building and Agricultural Cooperatives was initiated by Energy Regulatory Committee. The FiT rate for phase 1 and phase 2 of this program was 0.16 USD/kWh and 0.10 USD/kWh, respectively [6].

In Malaysia, the FiT mechanism was implemented in 2011. It was a key driver for solar PV development in Malaysia [21]. The solar PV capacity rose from 1 MW in 2011 to 279 MW in 2016. However, the quota under the FiT scheme was no longer available by 2017. The financial implication of the FiT scheme was covered with a RE Fund (KWTBB) in Malaysia [22]. Initially, 1% contribution from the electricity bills of consumers was to raise this fund. Later, the contribution was increased to 1.6%.

In 2011, the FiT mechanism was implemented in Indonesia. Unlike Malaysia, the addition of solar PV capacity in Indonesia showed slow progress. A new FiT framework named as Biaya Pokok Penyediaan (BPP) was introduced in 2017 [5]. Under the BPP scheme, the tariff is determined on the basis of the average cost of electricity generation at national and regional levels [23]. As highlighted in work by Pragt [23], the benchmarking of solar tariff with heavily subsidized fossil fuel-based power plants is unfair. In other words, solar PV projects are not able to penetrate regions (such as West Java) where electrification is dominated by low-cost coal. Hence, the carbon footprint of these regions cannot be reduced.

In Vietnam, the FiT mechanism for solar projects was introduced in 2017 with a tariff of 0.091 USD/kWh [24]. This rate was applicable for solar PV projects that were commissioned on 30th June 2019. Later, the FiT rate was revised under the Prime Minister Decision 13. The FiT 2 rates are 0.077 USD/kWh for floating solar projects, 0.071 USD/kWh for ground-mounted solar plants, and 0.085 USD/kWh for rooftop solar systems [25]. More than 5000 rooftop solar projects availed this rate [26]. According to a renowned news magazine, the Vietnam government has plans to extend the FiT scheme in 2021 at lower rates between 0.052 USD/kWh and 0.058 USD/kWh [27].

The Philippines government introduced FiT Scheme in 2012. This scheme was awarded on a first-come-first-serve basis for 100 kW or above solar capacity [8]. The installation target and FiT tariff for Phase 1 were 50 MW and 0.18 USD/kWh, respectively. In 2015, phase 2 was put in place with a reduced FiT tariff (0.16 USD/kWh) and 500 MW quota allocation [14]. Unlike the usual FiT mechanism, a 6% annual degradation in FiT rate is applied for new installations. This FiT program expired in 2017.

3.2. Net metering (NEM)

Net metering mechanism promotes local self-consumption. It is a pathway to make consumers' energy self-sufficient. Further, the stress on the electric grid can be reduced. Few ASEAN countries such as Indonesia, Malaysia, and Thailand have put in place the NEM mechanism. Brunei has initiated a Net metering program which is in the pilot phase [28].

In Malaysia, Net Metering (NEM) scheme has been in place since 2016 [17]. Due to poor financial return, the first phase (NEM 1.0) was not commercially attractive. In 2019, NEM 2.0 was introduced with the true net metering concept. In NEM 2.0, consumers are allowed to export excess energy on a one-on-one basis [21]. The 500 MW quota was fully subscribed with major participation from industrial sector. In line with the positive response from the solar industry and efforts to scale up solar energy, the NEM 3.0 was rolled out with a 500 MW quota for three years (2021–2023) [29]. The three categories under NEM 3.0 quota are namely NEM Rakyat Program (100 MW), NEM GoMEn Program (100 MW), and NOVA Program (300 MW). NEM 3.0 and NEM 2.0 shares the same concept of a one-on-one offset basis. Amid the covid pandemic, this is an example of continuous efforts by the Government of Malaysia towards achieving its sustainability goals.

Indonesia's Net metering policy was enacted in 2013 under Regulation 0733.K/DIR/2013. Excess electricity fed into the utility grid (Perusahaan Listrik Negara (PLN)) is considered a deposit that consumers can utilize in succeeding months [14]. This policy failed to attract consumers due to the lack of monetary benefits and monthly grid connection charges. In 2019, an updated net-metering policy was released. Certain amendments such as reduction in capacity charge, evading of operational license for small-scale systems, and abandoning emergency charge are likely to improve its commercial interest. At the same time, a limit in connection capacity (100% of PLN customer capacity) and ceiling credit for exported tariff (65% of PLN's applicable tariff) was put in place [6].

Foreseeing the vibrant market scenario and falling solar prices, Energy Regulatory Commission (Thailand) initiated a pilot project on self-consumption for rooftop solar projects. In May 2019, the net metering scheme was launched for rooftop solar PV installations (up to 10 kW) in households. Compensation is provided for the excess electricity for ten years [18,30]. Further, a grid connection fee is levied from the investor. Under this scheme, the government looks forward to a 100 MW target addition per year from 2019 to 2027. However, it is challenging due to the low value of compensation which is far less than the current residential tariff of 0.11 USD/kWh [31].

In the Philippines, the net-metering framework was implemented in 2013 [14]. This program aimed to promote small-scale solar PV systems with less than 100 kW capacity. The purchase rate for the excess electricity is 50% of the market rate. The amount earned by the prosumer is deducted from the next month's electricity bill. By 2016, this scheme was able to attract many participants who are mainly driven by falling PV prices and high electricity tariffs [8]. Since 2016, solar energy producers have been allowed to sell electricity to the electric grid [14].

Under the net-metering mechanism in Singapore, solar PV owners can choose from 4 different payment schemes, which are based on installed solar capacity and energy sale willingness. For solar capacity, less than 1 MWac, Simplified Credit Treatment Scheme (SCT) is offered to solar energy producers. The options available for large scale solar systems (more than 1 MWac) are Enhanced Central Intermediary Scheme (ECIS), Register as a Market Participant (Non-Exporting), and Register as a Market Participant [32].

3.3. Auction & Power Purchase Agreement (PPA)

Different countries implemented auction mechanisms with the aim of reduction in Levelized Cost of Electricity (LCOE). It involves a competitive bidding process. Auction of large-scale solar plants has proven to be effective in the ASEAN context.

Till 2016, there were no commercial-scale solar PV installations in Cambodia. With the technical and financial support of the Asian Development Bank (ADB) and Climate Investment Funds (CIF) [33], a 10 MW utility-scale solar power plant was commissioned in October 2017. Based on the tariff bidding scheme, Sunseap Group secured the project at a low tariff of 0.09 USD/kWh [34]. This project's success was phenomenal in boosting the confidence of the Cambodian government on MW scale solar projects. In 2019, the National Solar Park Project of 100 MW was established. Through an international auction, 60 MW capacity (phase 1) was successfully bid at the lowest rate in Southeast Asia (less than 0.04 USD/kWh [35]. The Cambodian solar park model and associated auction scheme became limelight in the South East Asian region.

Prior to 2013, Indonesia's PLN was directly negotiating to purchase electricity from solar investors [14]. Under MEMR Regulation No 17/2013, the first auction mechanism for 140 MW ground-mounted solar took place in Indonesia. The project developers could sign a 20-year fixed Power Purchase Agreement (PPA) with PLN [6]. However, the program was shut down due to the issues raised by the Supreme court on foreign-partnered investments [36]. Under the MEMR Regulation 12/2017, a pre-qualification process was initiated by PLN for the development of a 168 MW solar power plant in Sumatra, Indonesia [36]. The project developer was offered a 20-year PPA on a Built-Operate-Own-Transfer (BOOT) basis. In spite of a price ceiling at 85% of local generation cost and substantial local content requirement (materials (40.68%) & services (100%)) [6], this proposal was well-received by the developers. However, developers' confidence diminished due to delay occurred in the announcement of qualified developers. In 2020, another pre-qualification procedure occurred for large-scale floating solar plants at different locations. Since floating solar projects are relatively new, the design–build–finance–operate (DBFO) model was proposed in this proposal [6]. In BOOT model, the investor has the right to build, own and operate a project for a specific period of time. While, the investor has the entire responsibility for designing, building, financing, and operating a project in the DBFO model. In both models, the project ownership is retained by the government or government-owned institutions.

Since 2016, Malaysia has been implementing Large-Scale Solar (LSS) programs through a competitive bidding process [21]. As of 2021, four cycles of the competitive bidding process have been implemented. The first three cycles of the LSS scheme involved capacity subscriptions between 370 MW and 500 MW. The latest offer, LSS4 had a 1000 MW solar quota with more preference to local bidders. However, these solar projects are expected to begin its operation by the end of 2023 [37]. LSS program contributed significantly to developing utility-scale solar PV plants in Malaysia [38]. Further, Solar power producers are allowed to fed electricity to the grid without a power purchase agreement (PPA) or a service level agreement (SLA). This addition of the category is based on updated guidelines for New Enhanced Dispatch Arrangement (NEDA) released in May 2019. NEDA scheme is expected to pave way towards a merchant market system in near future [39]

Business in Thailand is provided the option to engage in a Direct power purchase agreement (DPPA) with renewable energy producers for the long term. A pilot DPPA scheme was launched in Vietnam [40]. Also, it was understood that other ASEAN countries are exploring the implementation of auction schemes. Discussion on replication of solar park model is underway in Vietnam, Indonesia, Myanmar, and Timor-Leste [41]. Further, ADB initiated a new program, 'ASSURE', to support South East Asian countries in developing solar parks with private sector participation [33].

In Singapore, an auction program called 'SolarNova' was introduced for government buildings by Singapore Economic Development Board [14]. Between 2015 and 2020, five phases of this auction program were completed. Almost 296 MW of solar capacity was awarded during the five-year duration. Hence, the SolarNova program played a significant role in the solar development of Singapore [42].

3.4. Other support mechanisms

The P2P trading system is entirely different from the conventional electricity market. The exemption of middle party involvement is the main difference. Pilot projects of P2P energy trading took place in Malaysia and Thailand. In August 2018, a pilot program on P2P renewable energy trading happened in Thailand. This program covered 635 kW capacity, which was implemented across the T77 precinct over two years duration [43]. In 2019, Malaysia participated in a worldwide pilot project in P2P energy trading [21]. This 8-month program was conducted in two phases: Alpha run and Beta run [44]. An untraded energy condition was encountered i.e.; the available energy is higher than the traded energy. Such conditions may incur a loss to the prosumers and need to be avoided in the P2P trading platform. A detailed study on economic return and uncertainties in trading is needed before implementation on a commercial scale.

Renewable Portfolio Standard (RPS) is being considered in some ASEAN countries. In RPS, selected energy consumers are entrusted with minimum use of renewable electricity. In Republic Act No. 9513, the Government of the Philippines highlighted the need for an RPS mechanism [6]. It is observed that Indonesia will introduce RPS soon, which in turn creates a market for Renewable Energy Certificates (RECs) [45]. In Vietnam's Renewable Energy Development Strategy (2016–2030), the RPS mechanism is emphasized for selected power generation companies. Those companies with more than 1000 MW capacity are required to have 10% of the total capacity from renewables by 2030 [46].

Self-consumption is complementary to the NEM program. The energy producer is not supposed to export the excess energy to the electric grid. The government of Malaysia introduced a self-consumption (SELCO) scheme in 2017. In this scheme, there is no limit for solar capacity installation [21]. However, a private generating license is to be acquired for any solar system above 72 kW size.

In leasing mechanisms, solar companies could provide zero up-front cost packages to customers. Malaysia implemented a solar leasing policy in January 2019 [21,47]. This mechanism is based on the Supply Agreement with Renewable Energy (SARE). Solar Power Purchase Agreement, Solar Hybrid, and Solar Lease are the three types of the solar solution under SARE. The main difference between these types is the contract term, tariff rate, energy meter specification, and installment [44].

3.5. Fiscal incentives

Various forms of financial and fiscal incentives exist in ASEAN countries such as Malaysia, Thailand. The government of Malaysia implemented Green Investment Tax Allowance (GITA), and Green Income Tax Exemption

(GITE) to support its renewable energy companies [47]. These initiatives supported industries to adopt solar through the NEM scheme. According to Budget 2020, companies involved in solar leasing solutions can apply for a 70% income tax exemption for up to 10 years. Certain RE projects could get 100% investment tax allowance and income tax exemption. Further, Malaysian-owned companies can avail financial support for their RE projects through the Green Technology Financing Scheme (GTFS) [14]. In addition, a 10% exemption in sales tax is granted for locally manufactured solar PV modules.

To provide financial support to energy projects, the Government of Thailand established The Energy Service Company Revolving Fund under the aegis of the Department of Alternative Energy Development and Efficiency. Using this fund, financial support was provided from 2015 to 2018 in terms of interest rate (within 3.5%), installment period (within five years), and credit line (within 50 million THB). Tax exemptions for imported machinery as well as income tax exemptions were provided for a specific duration towards the installation of rooftop solar systems in Industry and SMEs [18]. Further, non-tax supportive measures include permission to bring in expatriates, 100% foreign ownership in solar projects, permission to buy land, and streamlined remittances of foreign currency [48]. The solar market in Thailand has also witnessed investment through green bonds. In 2018, a certified climate bond was issued for the first time in Thailand. This bond was used to finance nine solar projects having a cumulative capacity of around 68 MW [43]. Through RE Act 9513, several tax incentives are offered for renewable energy projects. Further, government banks lend financial support to solar projects that are recognized by the Department of Energy, Philippines [14]. Since 2013, businesses can avail non-taxable cash pay-out equivalent to 60% of the qualifying expenditure (up to S$100,000). In addition, tax deduction is provided to limited R&D expenses on an annual basis [14].

Renewable Energy Certificate (REC) is a carbon offset instrument that is often bought by businesses to achieve sustainability goals [49]. Typically, a REC denoted one MWh of renewable electricity. The sale of RECs is additional revenue for solar developers. On the one hand, REC indirectly promotes the development of solar in a country. While, on the other hand, such mechanisms evade the need to stay away from fossil fuels. As per the report by USAID Vietnam [50], the REC market in Vietnam is backed by international platforms, namely Tradable Instrument for Global Renewables (TIGR) and International REC (I-REC). In Malaysia, Green Electricity Tariff (GET) was launched in December 2021. Under the GET program, customers can subscribe for renewable electricity along with Malaysia Renewable Energy Certificates (mRECs) [51]. An additional charge is levied on GET subscribers. RECs are also offered in Thailand and Indonesia [40]. To improve the credibility and accountability of RECs, a new standard (SS 673: Code of Practice for Renewable Energy Certificates) was announced by the Energy Market Authority, Singapore on October 2021 [52]. A Country-wise comparison of various solar policies and support mechanisms in ASEAN countries is shown in Table 2.

4. Policy recommendations

In general, ASEAN countries receive a good amount of solar irradiation with similar weather seasons. However, solar PV growth varied widely from one country to another. Some countries like Vietnam, Malaysia, Thailand made substantial growth in solar PV capacity. While others are still in the early stage of solar PV growth with an immature

Table 2. Comparison of various solar policies and support schemes in ASEAN member states.

Support mechanism	FiT	NEM	Auction	RPS	Selco	P2P	Fiscal incentives
Brunei	–	PP	–	–	–	–	–
Cambodia	–	–	OG	–	–	–	–
Indonesia	OG	OG	–	–	–	–	–
Lao PDR	–	–	–	–	–	–	–
Malaysia	EP	OG	OG	–	OG	PP	OG
Myanmar	–	–	–	–	–	–	–
Philippines	EP	OG	–	–	–	–	OG
Singapore	–	OG	EP	–	–	–	OG
Thailand	EP	OG	–	–	–	PP	OG
Vietnam	OG	–	–	–	–	–	–

EP—Expired, OG—Ongoing, PP—Pilot Phase.

PV market. This scenario is greatly influenced by the solar energy policy adopted in each country. Based on the level of solar policy, countries could be categorized into three stages: Entry stage, Developing stage, and Advanced stage. In the ASEAN context, the entry-stage countries can be Brunei, Lao PDR, and Myanmar. These nations have a low level of PV growth with no specific regulatory policy. Cambodia, Indonesia and Vietnam can be categorized as countries in the developing stage of PV growth. These countries have made decent progress in solar PV through the application of at least one solar policy. Within geographical limitations, Singapore made remarkable growth and has implemented policies such as net-metering, auction, tax rebates etc. Malaysia, the Philippines, and Thailand made remarkable growth with the self-sustaining solar market. However, these countries are lagging behind at the world level where China is leading the show. There is scope for improvement at each stage. For example, none of the advanced-stage countries have implemented Renewable Portfolio Standard (RPS), which supports energy transition and diversification. The policy recommendation is shown in Fig. 2.

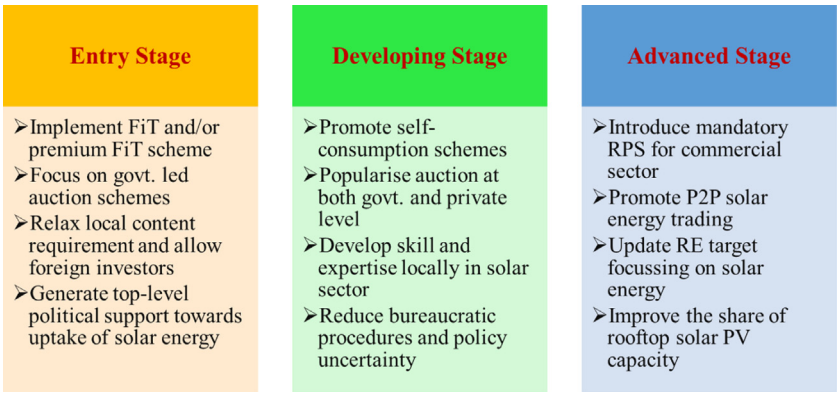

Fig. 2. Policy recommendation for different stages of policy level.

5. Conclusion

In this paper, solar policy and support mechanisms in ASEAN countries are investigated. In general, solar PV development in the past decade has been remarkable. Based on the available data, Vietnam has the highest installed capacity (16.5 GW) in 2020, followed by Thailand and Malaysia. The following conclusions are inferred from this study.

- It is understood that the solar PV growth in a country is greatly dependent on regulatory policy and support mechanisms. Along with solar irradiation and falling prices, the FiT mechanism played a significant role in Vietnam's huge leap in solar PV capacity addition.
- It is concluded that FiT is the most important scheme to initiate solar PV growth. This is visible from the solar PV development in Indonesia, Malaysia, the Philippines, and Thailand.
- The transition from one policy to another plays a big role in the sustainable development of solar PV. Over the past decade, the policy landscape in Thailand and Malaysia evolved from FiT mechanism to P2P energy trading. This approach is much needed to establish a robust PV market that sustains on its own.
- The policy landscape influences the share of rooftop and ground-mounted solar projects. On the one hand, most of the solar PV installations in Thailand are ground-mounted projects. While on the other hand, the majority of solar PV projects in Vietnam are installed on the rooftop. This disparity can be evaded by developing policy framework appropriately.
- Policy uncertainty and delay in its execution have diminished the confidence of investors. This has affected the solar development in some ASEAN member states. Effective communication with stakeholders of solar industry is important for the success of solar policies. Further, a country-specific approach is more suitable than a generalized solar policy framework.
- A detailed study on policy aspects and status of energy storage technologies in the context of ASEAN can be future work. Foreseeing the massive RE growth and adoption of electric vehicles, a robust policy framework for energy storage facilities is anticipated in the near future.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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