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A Comparative Study of Microgrid Policies for Rural Electricity Transition between Bangladesh and Thailand

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Abstract *– This paper is an exploratory study on the Bangladesh and Thailand rural electricity transition. This study compares the Bangladesh microgrid policies with that of Thailand microgrid policies. The comparative study in several areas considers electricity security, electricity access, environmental sustainability, economic development and growth of the countries. Public data related to microgrid policies in Bangladesh and Thailand had been collected, analyzed and discussed. The comparative case brings out the significant differences while also exploring the range of possible synergies across different dimensions and sectors. Concisely, the transition of rural electricity, driven by microgrid policy in both countries can be achieved by adopting new electricity market structure and regulation. The private sector would play a key role in electricity generation.*

Keywords *– Bangladesh microgrid, microgrid policy, renewable energy, rural electricity transition, Thailand microgrid.*

1. INTRODUCTION

Driving the goal of affordable and clean electricity is a global challenge to fulfill an ambition to achieve a better and more sustainable future. Renewable distributed energy resources have the potential to bring about affordable and clean electricity. It is a significant constituent of the microgrid in an electricity transition. The microgrid presents a way to provide electricity supply in remote areas and a way to use clean and renewable energy [1]. Under some circumstances, the microgrid may be the best way to supply electricity [2].

A pathway toward the electricity sector transformation from fossil-based to less-CO_2 is known as the electricity transition. The microgrid enables the electricity transition because of its predominant part, renewable energy source [3]. Renewable energy potentially provides a large proportion of CO_2 reduction in the electricity sector [4].

Electricity transition in rural areas provides direct and indirect social and economic benefits, from poverty alleviation to better health and education facilities [5]. Several studies have examined the transition of rural electricity access in different countries and regions. Dagnachew *et al.* identified the barriers to electricity access and relevant actors to provide policy recommendations in Sub-Saharan Africa [6]. Yadav *et al.* studied the lessons of a transition to decentralized rural electrification in India [7]. Derks and Romijn explored the challenges of rural microgrids policy in Indonesia, in which the problem was to understand key determinants of microgrid un/sustainability [8]. While there is available literature analyzing rural electrification at individual national and regional levels, there is no recent comparative study on the difference in electricity transition, based on microgrid policies, between two countries. One is with full electricity access, and another is with a different level of electricity access.

Two countries in Asia, Bangladesh and Thailand, are in a transition period of the transformation of affordable and clean electricity. These two countries share some similarities and have some distinctions of rural electricity transition. Exploring these two countries is expected to reveal insights about the national electricity transition in an economically-developing country context. The objective of this study is to investigate the rural electricity transition of Bangladesh and Thailand. Policies related to rural microgrids of two countries are explored. The emerging roles of the microgrid in energy policy in a period of electricity transition are studied. The comparative case study methodology has been applied to conduct this study. Publicly available data of Bangladesh and Thailand rural microgrids from reliable databases, *e.g.*, World Bank, United Nation, World Energy Council, World Economic Forum, have been retrieved, collected, analyzed, discussed, and concluded. This exploratory study will reveal the understanding of the rural electricity transition in two selected economically-developing countries.

2. LITERATURE REVIEW

2.1 Rural Electricity Transition

The World Economic Forum declared that in the economically-developing countries, accelerating access to sustainable energy was essential to the energy transition [11]. Because of dramatic cost declines in solar photovoltaics and energy storage, renewable energy isolated microgrids provided electricity to 150

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million people in the past decade [11]. The Energy Transition Index (ETI), a part of the Fostering Effective Energy Transition initiative of the World Economic Forum, was a fact-based framework to foster a greater understanding of the state and readiness of energy systems for this transition. The ETI framework consisted of two parts: (i) system performance imperatives or Energy Triangle, and (ii) transition readiness enabling dimensions or Enabling Dimensions in short [12]. The Energy Triangle consisted of (i) energy access and security, (ii) environmental sustainability, and (iii) economic development and growth. The Enabling Dimensions consisted of (i) energy system structure, (ii) capital and investment, (iii) regulations and political commitment, (iv) institutions and governance, (v) infrastructure and innovative business environment, and (vi) human capital and consumer participation.

Adapted from the World Economic Forum definition of energy transition [12], the electricity transition is a transition towards a more inclusive, sustainable, affordable, and secure electricity system that provided solutions to electricity-related challenges, while creating value for business and society, without compromising the balance of three goals – (i) electricity access and security, (ii) environmental sustainability, and (iii) economic development and growth.

The rural electricity transition could be accomplished by using microgrids. The microgrids were proposed to provide sufficient electricity for productive uses, generating incomes, in rural areas because of the technical feasibility to build them in most parts of economically-developing countries [13]. The expansion from one experimental-model microgrid to a larger scale was a challenge because of the technical difficulties and the additional socio-economic and regulatory barriers. A regulatory approach for the integration of microgrids and their generation capacities into the national grid was suggested to be a part of the policy framework. In rural areas, microgrid customers had a low ability to pay, thus a low payment rate. The increase in non-paying customers could affect the financial sustainability of the microgrid business. The loss of financial sustainability could interrupt the microgrid continuity, a loss of the electricity service for a rural community.

2.2 Microgrid

In 1882, Thomas Edison’s first Manhattan Pearl Street electrical power plant, direct current distribution power lines, battery energy storages, and a set of basic electrical control equipment were the first recorded microgrid [14].

A microgrid is a “collection of controllable and physically proximate distributed generator and load resources, incorporating multiple sources of AC power, at least one of which is based on a renewable energy source” [3]. It is worth noting that in this study, the microgrid deals with electricity, rather than other forms of energy. The microgrid constituents are: (i) distributed generation units, (ii) electricity distribution systems, (iii) protection and control units, and (iv) electrical loads [15], [16].

The distributed generation units can be: (i) the conversion of primary fossil fuel to electricity by, for example, reciprocating engine generators, gas turbines, or microturbines; or (ii) renewable energy resources, such as solar, wind, biomass, biogas, and mini-hydro. The latter speed up the progress of the electricity transition. The electricity distribution system of the microgrid can be a medium voltage system and a low voltage system. It mainly includes, for example, poles, wires, cables, and electrical insulators. The protection and control units make the microgrid more reliable and optimal. Information and communication technologies play significant roles in all microgrid constituents, especially in the protection and control units. The microgrid protection and controller make the microgrid smarter. The electrical loads consume electricity. The increasing digital loads require high power quality and reliability of electricity. It is important noting that electricity consumers have an additional role in producing electricity, rather than only electricity consumption. They become prosumers. In addition, electric vehicles, specifically the battery energy storage inside the electric vehicles, have the new unique characteristics of both electricity consumption and electricity supply. The battery energy storage connected to the grid can also perform the same behavior.

Rural microgrids could incorporate renewable energy resources, often as an addition to diesel/gas generator-based units, and sometimes battery energy storage and mobile payment platforms [2]. The rural microgrids allowed economically-developing countries to potentially leapfrog to a world of smart electricity supply, in a similar way that mobile communications provided them to connect to others both in and outside their community.

2.3 Microgrid Policy

Public policy refers to (i) the announcements of principles, wishes, requirements, ideas, actions, interventions, and plans; and (ii) putting the announced statements into action [17]. The survey in three large economic zones, *i.e.*, the European Union, the USA, and China, showed few microgrid studies on effective policies, incentives, and barriers to microgrid promotion and deployment [2], [18]. A finding of the survey showed the key policy drivers that changed the role of microgrids from a secondary energy supply to a primary one.

In the European Union, microgrids and their affiliations, *i.e.*, renewable energy sources and distributed generation, were the solution to European electrical system problems. Three challenging 2030 targets consisted of (i) greenhouse gas reduction of environmental sustainability; (ii) renewable energy penetration; and (iii) energy efficiency. However, there were no specific policies and regulations for distributed generation and microgrid systems in the European Union.

In the USA, state governments formulated and adopted different microgrid policies, *e.g.*, the 2005 Energy Policy Act, Renewable Portfolio Standard, Renewable Energy Standard, and Energy Efficiency Resource Standard. This measure is: (i) to diversify the energy mix with a high percentage of renewable energy and distributed energy resources, (ii) to reduce the carbon intensity of the electricity sector, and to increase the use of distributed energy resources and more localized distributed generation units.

In China, more than 70 microgrid policies involved research and development, promotion, utilization, incentives, and prevention of environmental issues on all the renewable energy technologies, including solar PV, wind, mini-hydro, thermal, biogas, geothermal, and bioenergy. The renewable energy and distributed generation policies aimed to promote the microgrid concept and microgrid facilities. These microgrid policies were, for example, in the 2005 Renewable Energy Law, the Medium and Long-Term Development Plan for Renewable Energy, and the 12th Five-Year Plan for Renewable Energy.

In sum, the microgrid policies of renewable energy resource and distributed generation adoption and promotion in three large economic zones aimed: (i) to increase energy security, (ii) to raise environmental sustainability, and (iii) to promote economic development and growth.

Some typical microgrid policies are (i) financial incentives, *e.g.*, the exemption of transmission use of system charges and transmission loss charges, and the exemption of climate change tax for renewable energy, (ii) legal renewable energy obligation, (iii) interconnection regulation, (iv) power quality and reliability issues and standards, (v) economic benefits of a whole society, (vi) open participation in an electricity market, and (vii) less CO_2 emission [19].

3. CASES:

3.1 Bangladesh Cases

In Bangladesh, information on microgrids in government documents, *i.e.*, the Renewable Energy Policy of Bangladesh, the Revisiting Power System Master Plan (PSMP) 2016, and the Power and Energy Sector Strategy Paper reflected the 7th of Sustainable Development Goal (SDG7) – " clean energy for everyone: secure access to affordable, reliable, sustainable and modern energy for everyone," renewable energy, institutional arrangement, resource, technology, incentive, tariff, penalty, and regulatory setting [20], [21], [22]. In addition to the three mentioned government documents, data from related documents and databases have been collected.

Bangladesh declared the electricity transition as an ambition to achieve the SDG7. Renewable energy sources play significant roles in the process of electricity transition by diversifying energy sources. The integration of renewable energy in electricity generation into the main grid was planned. In doing so, regulations and standards related to grid-connected renewable energy sources were required. The proportion of renewable energy to the total electricity generation was 3.5% in the baseline year of 2015 and 10% in the targeted year of 2020 [22]. Besides, the renewable energy-based capacity would be 2,800 MW by 2021 and 9,400 MW by 2041 to reach the 10% target [21]. The energy efficiency measure was aimed at increasing system reliability and reducing the dependency on foreign energy sources. In Bangladesh, it was demand-side management. The study on the demand side management recommended energy-saving behavior, as a strategy, to potentially reduce energy consumption in a range of 0.5–21.9% [23]. The distribution systems and components, *e.g.*, lines, substations, monitor and, control units, were planned to be upgraded and modernized. They were recommended to become a smart grid.

The microgrid development in Bangladesh was both grid-connected and isolated microgrids. They might be called on-grid and off-grid microgrids, respectively. In 2018, the installed capacity of isolated renewable electricity supply was 289.8 MW, whereas the installed capacity of grid-connected supply was 40.0 MW. The isolated renewable electricity supply had an installed capacity, about 7 times, higher than the grid-connected supply. It was noticed that parts of microgrid, mainly renewable distributed generation units, were developed, studied, and reported. The complete isolated microgrid might be in an early stage of development. The grid-connected microgrids, typically developed by electric utilities, had their planned cumulative capacity of 2,833.0 MW by 2041 [21]. This total capacity consisted of 2,322.0 MW of solar electricity, 510 MW of wind electricity, and 1 MW of biomass-based electricity. The major renewable distributed generation was based on solar, a solar home system in particular [5]. It was worth noting that the 230 MW hydropower plant and the 413.51 MW cumulative solar electricity sources shared portions of the total 647.44 MW renewable electricity installed capacity [24].

From an aspect of rural electricity access, about 80 rural electrification cooperatives under the supervision of the Bangladesh Rural Electrification Board were set up, operated, and maintained rural electricity distribution systems as well as supplied electricity to about 25.2 million customers [25]. However, households, getting connected to the expanded rural electricity grid, remained low as compared to the total number of rural households. Poor households had a lower electrification rate as compared to non-poor households because of the high upfront cost of getting connected to the electricity grid and other constraints, *e.g.*, income/distance of line, revenue collection efficiency, cost of service, and losses [5].

The participation of private investors was in the Revisiting Power System Master Plan 2016 and a record of the Sustainable and Renewable Energy Development Authority [21], [26]. Stakeholders from private sectors extended the national capabilities to design, plan, construct, install, operate, and maintain the development projects. Private participation contributed to the acceleration of the rural electricity transition, *e.g.*, renewable energy development and microgrid development.

3.2 Thailand Cases

In Thailand, a microgrid, a sprout of smart grid, has been in the National Power Development Plan, the Thailand Smart Grid Development Master Plan, and the Thailand 5-year Smart Grid Development Action Plan, for a decade. The microgrid constituent, especially the renewable distributed generation, has been in the Alternative Energy Development Plan. One of the microgrid affiliations, energy efficiency, has been a policy in the Energy Efficiency Plan for about five years. Instruments of energy efficiency policy were, for example, energy efficiency resource standard, soft loan, and tax incentive.

It was observed that there was no explicit SDG7 in all above-mentioned plans [27]-[31]. However, Thailand has been in the process of transition to sustainable, affordable, and clean electricity for all. The renewable electricity sources, including the solar home systems, were in both on-grid and off-grid microgrids. The microgrid development in Thailand had taken place in various places for different purposes. Most of the microgrids were on-grid. Developed at the Chiang Mai Rajabhat University, an exceptional campus off-grid microgrid was a direct current, rather than an alternating current microgrid. The campus microgrids were mainly aimed at creating a body of knowledge about microgrids. The main aim of the utility microgrids of three state-owned enterprises and other government agencies was to learn and demonstrate microgrids and to strengthen the power quality and reliability of the main grid. The business microgrids of private companies were primarily aimed at creating value-added solutions and generating revenue.

The promotion of renewable energy was obviously in the Alternative Energy Development Plan and the existence of renewable energy sources in several locations. The planned target of renewable energy installed capacity was 1,876 MW in total by 2047. Electricity from renewable energy sources increased from 5,960 GWh (4.3%) in 2007 to 17,217 GWh (9.9%) in 2014. In terms of installed capacity, electricity from renewable energy sources in 2017 was 10,949 MW or 23.8%. Electricity from solar shared the largest proportion of the total planned capacity. The most popular renewable energy was solar photovoltaic. A proportional order of the installed capacity was biomass, wind, biogas, and waste, respectively. In 2019, the Ministry of Energy promoted the initiative of the very small biomass community power plant. It was not only the promotion of renewable energy but also the economic growth of the community. This initiative was in the process of effective action.

From an aspect of rural electricity access, Provincial Electricity Authority (PEA), the largest distribution electric utility in Thailand, has constructed, operated, maintained, and expanded the electricity grids to rural areas for about six decades. Households in the protected and environmentally sensitive areas or on remote islands have been challenges of Thailand's rural electrification. All villages in other areas are 100% electrified. The Thailand electricity access rate is high because of the free-of-charge electricity consumption when electricity consumption was not more than 100 kWh in the past or is not more than 50 kWh at present.

There were various roles of the private sector participation in the microgrid development, including renewable distributed generation. With solar rooftop, private individuals and families in areas electrified from the main grid became solar electricity producers in addition to electricity consumers. These cases usually were the on-grid sources. However, some cases in marginalized rural areas were the off-grid sources, the solar home system in particular. In a renewable energy market, the private sector was active in several business activities, *e.g.*, design, installation, and maintenance. Thailand had the national capabilities to do these business activities.

3.3 Case Comparison

Both Bangladesh and Thailand are in Asia. Bangladesh is in South Asia. Thailand is in Southeast Asia. They had some similarities and differences, as shown in Table 1, Figures 1 and 2 [32]-[35].

Bangladesh had ranked 168th in electricity consumption per capita with the annual per capita consumption of 336.46 billion kWh in 2018, while Thailand had ranked 94th with the number of 2,735.72 billion kWh per capita [36]. The annual electricity consumption per capita of Bangladesh was eight times less than that of Thailand. One of the reasons for this is that Bangladesh had less access to electricity than Thailand (as shown in Table 1), causing the electricity consumption per capita to remain low, despite the higher unmet demand.

The ratio of non-RE and RE electricity capacity, it indicated that Bangladesh had lower electricity from RE than Thailand. More than 90% of electricity generation came from fossil fuel, while less than 2% came from renewable energy, for example, hydro and solar (as shown in Figure 1) [32], [33], [36].

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Table 1. Bangladesh and Thailand data.

Item	Bangladesh	Thailand	References
Region	South Asia	Southeast Asia	[32], [33]
Total area (sq. km)	147,570	513,120	[32], [33]
Population in 2019	163,046,161	69,625,582	[32], [33]
GNI per capita 2019 ($US)	1,940	7,260	[32], [33]
Access to electricity (% of population 2016)	76	100	[34], [35]
Electricity consumption per capita in 2019 (billion kWh/person)	336.46	2,735.52	[36]
Non-RE: RE electricity capacity 2018	98:2	78:22	[34], [35]
CO_2 emissions (metric tons per capita 2014)	0.474	4.62	[34], [35]

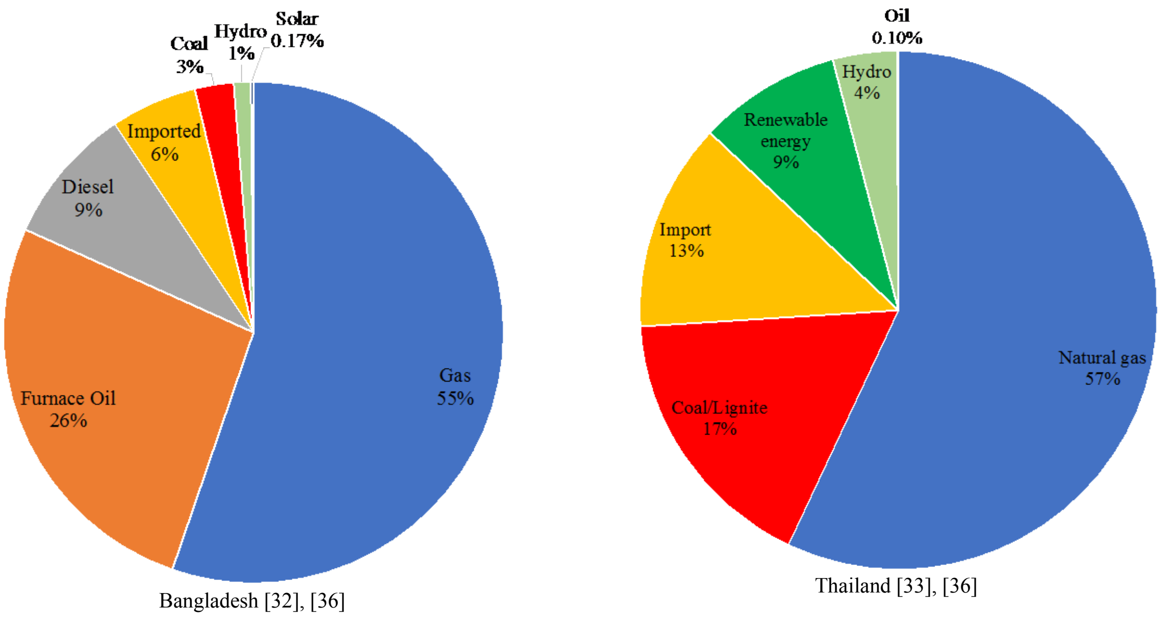


Fig. 1. Electricity generation based on fuel in 2018.

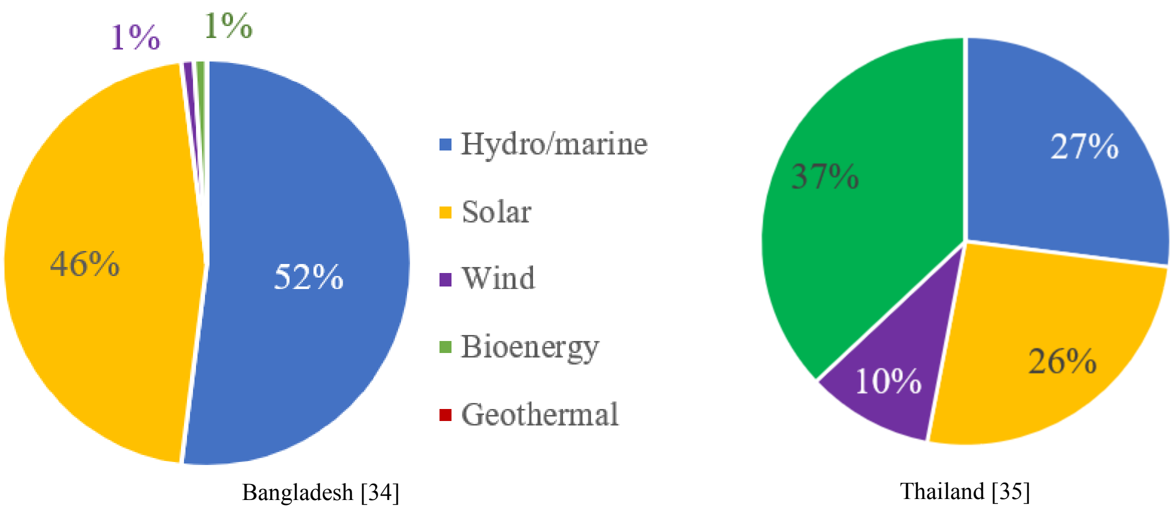


Fig. 2. Renewable capacity in 2018.

Both countries were dependent on gas for the majority of the electricity generation. However, Thailand seemed to have more energy diversity, especially renewable energy. About 98% of the total renewable capacity in Bangladesh was solar and hydropower, while Thailand had a more diverse range of renewable energy sources from bioenergy, solar, hydro, and wind (as shown in Figure 2). To enhance Bangladesh energy security, a diverse range of renewable energy should be promoted.

4. DISCUSSION

Collected evidence showed that both Bangladesh and Thailand were in an electricity transition process. It was clear that both countries aimed to make their electricity supply more secure. Several measures, including microgrids, were applied to increase the electrified areas and to upgrade and expand the electricity grid. The grid had better power quality and reliability.

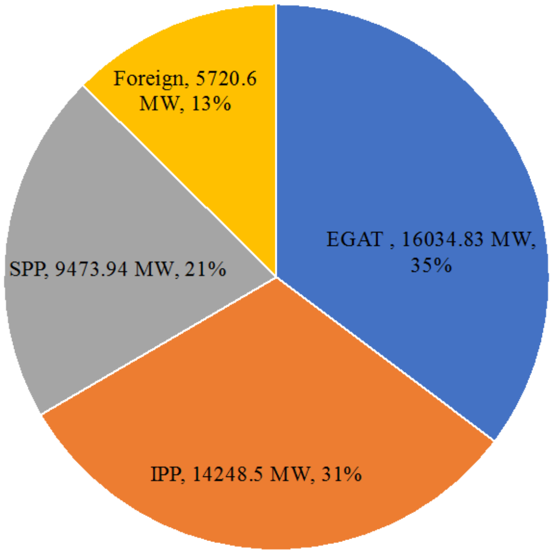
Bangladesh had more challenges than Thailand to achieve (i) a higher rate of electricity access and (ii) more clean electricity, renewable energy in particular. However, the CO_2 emission of Bangladesh was much less and better than that of Thailand. In other words, Bangladesh was more environmentally-friendly than Thailand. The future of Bangladesh's CO_2 emission will depend on how the country supplies the increasing consumption of electricity. It can be expected to be higher with rising gross national income (GNI) per capita.

In Bangladesh, an electricity access rate was low, to some extent, because of the low ability to pay customers in rural areas. In Thailand, two state-owned distribution electric utilities provided free-of-charge electricity to customers who consume a little electricity. In rural areas, Bangladesh developed the off-grid electricity supply more than Thailand. This might result from the low coverage of the grid in Bangladesh, compared to Thailand.

In Bangladesh and Thailand, both solar energy and hydro energy played a significant role in the renewable electricity supply, the clean energy supply. Bioenergy, *i.e.*, biomass and biogas, had the highest proportion to Thailand's renewable electricity capacity, whereas hydro is the highest in proportion in Bangladesh's renewable electricity capacity. Wind energy had a 1% share of Bangladesh's renewable electricity capacity, whereas it had a 10% share of the Thailand's renewable electricity capacity.

Microgrids in Thailand revealed more constituents than those in Bangladesh. It seemed that Thailand had more opportunity than Bangladesh to diversify the renewable electricity supply. Microgrids already were set as an electricity policy in the Thailand Power Development Plan and the Thailand Smart Grid Development Master Plan. Microgrids are recommended for Bangladesh to make renewable electricity supply better and accelerate a process of rural electricity transition. Based on the collected data, Bangladesh had more unelectrified areas than Thailand. Bangladesh was likely to have more opportunities to make an investment in microgrids than Thailand. If the appropriate microgrid technologies, well-designed microgrids, and well-planned microgrid projects are implemented cost of initial investment, operation of microgrids, and the microgrid sustainability can be enhanced. Bangladesh might accomplish the rural electricity transition, especially in a sense of environmental sustainability, faster than Thailand.

From an investment perspective, investors tend to acquire and deploy new technologies when such technologies lead to lower costs and/or higher profits, the short payback period. In the case of rural electrification, most people in rural areas still had low income and low ability to pay for electricity. This might delay the innovation of microgrid technologies. In both Bangladesh and Thailand, microgrids can take place together with new actors, including private investors. This might demand a new electricity market structure and regulation. In a new circumstance, even the government agencies themselves have to adapt to the new structure if the microgrids are widespread.



[Adapted from [37]]

Fig. 3. Thailand electricity generation capacity.

In Thailand, private power producers could be divided into three categories: Independent Power Producer, Small Power Producers, and Very Small Power Producer (VSPP) as shown in Figure 3. It was expected that the private sector would play a key role in electricity generation (especially VSPP or Distributed Generation) when microgrid started. The private sector in Bangladesh played a role as the electrical equipment supplier in electrical power systems (including microgrids). Other roles of the private sector as power producer, distribution, supervision, and control of the electrical power systems in Bangladesh were in the early stages. The electricity market structure, rules, and regulations should be newly introduced and/or adjusted in Bangladesh to sufficiently incentivize the private sector.

Private participation in Bangladesh and Thailand enhanced the national capabilities to deal with microgrids and their affiliations. The private sector of the electricity industry could accelerate the electricity transition towards more inclusive, sustainable, affordable, and secure electrical power systems.

World Energy Council [9] and the World Economic Forum [11], suggest in cases of Bangladesh and

Thailand, the rural electricity transition should take the country context, including economic development and growth, into consideration, in addition to (i) electricity access and security, and (ii) environmental sustainability. Several cases of the microgrid in the European Union, the USA, China, India, and Indonesia gave a direction of electricity transition. In short, microgrids were necessary for the electricity transition, especially in rural areas.

5. CONCLUSION

This study investigates rural electricity transition in Bangladesh and Thailand from the perspective of microgrid policies by using public data. The comparative case study, the methodology of the study, revealed similarities and differences between the electricity transition in rural areas of two cases. The findings show, in a period of the electricity transition, (i) the necessity of renewable distributed electricity generation, and (ii) the emerging roles of the microgrid and the private participation in the energy policy. The electricity transition ensures a way towards a more affordable, clean, secure, and sustainable electricity system. Private participation, electricity market structure, and regulations are the study areas of both practitioners and scholars in the field of energy policy.

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