An analysis of a suitable model for community power plant development: A case study of the Northeast region of Thailand

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Abstract - This paper aims to analyse a suitable model for developing a community power plant in the northeast region of Thailand. In this study, six provinces including Nakhon Ratchasima, Ubon Ratchathani, Chaiyaphum, Buriram, Sisaket, and Udon Thani were selected based on quantity potential and biomass diversity. The results showed that Nakhon Ratchasima appeared to be highest potential in electricity generation from residual biomass (about 83 MW - representing a total of 13community power plants). The capacity is capable of generating electricity from residual biomass up to 3,278 million units per year and representing an estimated revenue from electricity sales of 14,026 million Baht per year. The capacity for community based electricity generation in the other provinces would be between 29 and 51 MW which represents about 5-8 community power plants per province with the capacity to generate electricity from residual biomass approximately 1,145-2,006 million units per year. The revenue from electricity sales would be about 4,899-8,583 million Baht per year. In order to develop a community power plant in a sustainable way, this paper also recommends the addition of other alternative fuels for power generation as well as the promotion of energy crops to be used for community power plants. This would provide several benefits including gain an extra income from the sales of electricity and energy crops, increase in employment in the community and the agricultural sector, and providing job opportunities for young workers whose normally relocate themselves to work in the industrial sector in the metropolitan area. Such benefits would help strengthen the family and hence enhance the community sustainability.

Keywords: BCG model, community renewable energy, biomass and electricity.

1. Introduction

Nowadays, electricity is one of the essential factors driving the development of the agricultural sector, industrial sector, and business sector. According to Thailand's energy balance report, electricity consumption has increased steadily, from 148,700 million kWh in 2011, to 201,106 million kWh in 2021 (DEDE, 2022). However, due to limited energy resources, energy imports accounted for 63% of total primary energy supply in 2021 (DEDE, 2022). This resulted in lessening of the security of the energy supply for power production. Biomass appears to be an alternative energy for Thailand - an agricultural-based country which has high potential in agricultural products for producing electricity. The electricity production from residual biomass in the community through the community power plant project would be one mechanism for driving the Bio-Circular-Green (BCG) economy. The community power plant project appears to be one of the key energy policies for driving the economy. This project aims to help the community generate extra income from selling agricultural residuals and help create more jobs in the community. However, the areas for establishing power plant are required to have high potential for agricultural residual and importantly, are accessible to a distribution system. In November 2020, the National Energy Policy Council (NEPC) has approved the guidelines for establishing a community power plant (EPPO, 2020). Under the guideline, the power plants require the community to take part in holding shares of at least 10% to open spaces for the private sector to offer maximum benefit to the community. The revenue sharing has to be agreed upon between the private sector and the community and the power plant are required to guarantee buying energy crops from farmers through the process of contract farming. This process would ensure farmers to gain extra income from supplying energy crops to the power plants (EPPO, 2020). Against the above background, this paper, therefore, aims to analyse a suitable model for developing a community power plant and to recommend pathway for promoting the use of alternative fuels and developing management planning of community power plant project. This would help increase the value of agricultural products, gain extra income from selling agricultural crops, reduce fuel imports and provide environmental benefits from using alternative fuels derived from biomass energy.

2. Materials and methods

2.1 Research methodology

With a view to obtain the suitable model and recommendation for developing community power plant projects. The research was carried out in the following steps:

1. To study types of biomass with high potential in the northeastern region of Thailand.

2. To review electricity generation technologies that popular for biomass.

3. To collect information for assessing the biomass potential of community power plant projects, for example, agricultural outputs, biomass to yield ratio, biomass heat and moisture value, residual amount of biomass from agricultural products, heat energy potential.

4. To assess the electricity capacity of high potential biomass in different areas.

5. To analyse the suitable types of biomass for community power plant projects in 6 provinces including Nakhon Ratchasima, Ubon Ratchathani, Chaiyaphum, Sisaket, Buriram, and Udon Thani.

6. To estimate income from electricity sales.

7. To recommend pathway to develop management planning of community power plant project.

2.2 Data considerations

In this research, data collection is an important process in order to achieve its objectives. This research required a broad range of data including agricultural products information, biomass calendar, biomass potentials data, biomass to yield ratio, heat value and moisture value of biomass, amount of used biomass and residual biomass, data on fuel utilization rate for electricity generation by each type of biomass, information on technologies for electricity generation from biomass, and the purchase rate of electricity from very small power producers. The information on agricultural products was collected from the Office of Agricultural Economics (OAE, 2021). The biomass calendar was taken from the Energy for the Environment Foundation (EFE, 2020). The biomass information such as potential of different types of biomass in the country, ratio of biomass to yield, amount of used and residual biomass for agriculture was collected from the Department of Alternative Energy Development and Efficiency (DEDE, 2013). The data on heat and moisture values of biomass, rate of fuel consumption for electricity generation from various types of biomass, types of technologies for electricity generation from biomass was available from the Department of Alternative Energy Development and Efficiency (DEDE, 2020). And, the information on the purchase rate of electricity from very small producers was taken from the Energy Regulatory Commission (ERC, 2022).

3. Concept for estimation of biomass potential for electricity generation

In order to assess the power generation potential by each type of biomass, the assessment required procedures and information as follows:

1. Estimation of the amount of biomass by using the amount of agricultural products and the biomass-to-yield ratio.

2. Calculation of the amount of residual biomass by subtracting the amount of biomass (tons per year) with the amount of utilized biomass.

3. Assessment of the electricity production potential of biomass by using the amount of residual biomass and the heating value of each type of biomass.

4. Assessment of the electricity production potential of biomass under the condition that the community power plants specified in this paper operate 24 hours a day, 330 days a year, and the community power plant's electricity generation efficiency is 20%.

4. Biomass potential in the Northeastern region in Thailand

Biomass is the material or substance derived from nature or living organisms (excluding fossil fuels). Thailand is an agricultural country with a wide range of agricultural products such as rice, sugar, cassava, rubber, and oil palm. In the past, most of the biomass was left behind as organic fertilizer in the cultivation area or was burn to get rid of it which resulted in an increase of PM 2.5 emissions. A rise of PM 2.5 emissions could affect the respiratory system - a contemporary health concerns. A high potential biomass is mostly from agricultural products that are industrial crops in Thailand, for example, rice, maize, oil palm, cassava, sugarcane, and rubber. Biomass derived from agricultural products includes rice straw, rice husk, rhizomes, cassava stems and leaves, corn cobs, corn stalks, palm fibres, palm bunches, and palm shells. In the case of sugarcane, it was not taken into account as biomass for community power plants because of the fact that most of the biomass from sugarcane is used for electricity generation by the sugar mills that have already purchased sugarcane. According to the biomass survey in the northeastern region of Thailand in 2020 by the Office of Agricultural Economics (OAE, 2021), biomass in the region consisted of rice, maize, cassava, and oil palm. In order to estimate the amount of biomass, this paper estimated from the ratio of biomass to yield which was obtained from the Office of Agricultural Economics (OAE, 2021). And the amount of biomass employed to assess the potential of electricity generation considered the residual biomass. From Table 1, the residual biomass in the Northeastern region in 2020 was calculated the amount of biomass generated minus the amount of utilized biomass.

Table 1. Amount of residual biomass from utilization in the Northeast of Thailand in 2020 (unit: tons)

Province	Rice Husk	Rice Straw	Corn Cob	Corn Stover	Cassava Rhizome
Kalasin	3,046	202,572	3	105	205,517
Khon Kaen	3,234	215,061	74.688	2,863	170,513
Chaiyaphum	2,908	193,383	1,809	52,011	493,019
Nakhon Phanom	2,307	274,836	0.067	26	13,750
Nakhon Ratchasima	5,846	388,786	11,51	441,338	1,071,718
Buriram	4,133	274,836	9	34	271,432
Bueng Kan	669	44,412	-	-	4,004
Maha Sarakham	668	234,848	-	-	107,817
Mukdahan	782	52,012	-	-	89,823
Yasothon	2,187	145,459	0.600	23	70,406
Roi Et	4,695	312,211	-	-	48,673
Loei	4,517	300,394	556	21,295	137,151
Si Sa Ket	3,305	219,788	1	53	12,818
Sakon Nakhon	3,046	202,572	3	105	205,517
Surin	4,710	313,213	1	51	106,937
Nong Khai	1,139	75,710	3	130	12,818
Nong Bua Lamphu	1,097	72,939	441	16,911	62,106
Udon Thani	3,193	212,335	47	1,783	288,958
Ubon Ratchathani	6,359	422,845	1,395	53,458	342,429
Amnat Charoen	1,569	104,309	6	222	84,119

5. Electricity generation technologies for biomass

Nowadays, biomass has widely been used as fuels to produce heat and electricity. The technologies employed for the production of heat and electricity have ranged from small to power plant. To convert biomass into energy, there are 3 main technologies that are commonly used (Wattana, 2021).

1. Direct combustion technology is a system that works with steam turbine technology to generate energy from biomass which is the most commonly used system in the world. With this technology, an important component is the kiln employed as a device for converting biomass into thermal energy. Several types of kilns are widely used such as kilns that use human labour to feed the fuel, Stoker, pulverized, cyclone, and fluidized bed. Kiln is an important component of the heat or electricity generation system that can be used in various industrial plants. The selection of appropriate kiln types depends on the type of biomass used as fuel. For example, stoker kilns are suitable for relatively large pieces of biomass. Fluidized bed kilns or cyclone kilns are suitable for small pieces or seeds of biomass such as sawdust and rice husks. Stoker kilns can be used for a variety of fuel types and sizes. Cyclone kilns requires very dry fuel. Fluidized kiln is a relatively new system. It is adaptable to changes in fuel quality.

2. Gasification technology is the dissociation of hydrocarbon compounds under controlled oxygen content in a proportion lower than the value that causes complete combustion. This process provides gas which main components comprise carbon monoxide, hydrogen, and methane, which are called synthesis gases. In the case of using air as a catalyst, gas would have a low calorific value. Gas would have a higher calorific value if steam is added. If oxygen is used as a catalyst, gas would have even higher calorific value than using air and steam as catalyst. This gas can then be used in the form of fuel to generate energy. This gasification technology is suitable for small power generation - less than 1 MW. The limitation of this technology is that the derived product is gas mixed with bitumen. This limitation, therefore, results in an unpopular utilization of this technology due to purified problems of derived gas. Suitable biomass for this technology includes rice husks, wood chips, palm shells, and bagasse. Biomass used for this technology should be in an appropriate size and the humidity should not be higher than 20%. This is because small size of biomass is unable to allow air to pass through and large size of biomass could result in an incomplete fuel combustion.

3. Pyrolysis technology applies a thermal decomposition process. It is the process of burning biomass without using much oxygen. The products include charcoal, biofuels, and gases, in which the proportion of products obtained depends on the type of biomass and the heating method. The pyrolysis technology can be divided into two main types: slow pyrolysis and fast pyrolysis. The slow pyrolysis process performs with a heating rate of less than 10 degrees Celsius per second and the temperature used is less than 500 degrees Celsius. Most of the products are bitumen and wood charcoal. On the other hand, the fast pyrolysis process gives a heating rate in the range of 10-10,000 degrees Celsius per second and the temperature is between 400 and 1,000 degrees Celsius. The

products are mainly gases and liquids. If the main product is liquid in the form of oil, a fast pyrolysis process is suitable. And, if the main product is charcoal, a slow pyrolysis process with a low heating rate and medium temperature is suitable.

Based on the aforementioned discussion, it appeared that the production of electricity from biomass using direct combustion technology is most suitable for community power plant projects due to the fact that biomass can be directly used to generate electricity. In addition, the patterns of biomass in the Northeast are mainly solid and medium to large size, which is most suitable for direct combustion technology. In the case of the gasification technology, the primary product is gas which need to be passed through another process to obtain electricity. For the pyrolysis technology, the primary products are biofuels that are commonly mixed with gasoline and diesel, and hence the product is not applicable with the community power plant project.

6. Results and discussion

In order to assess the biomass potential for electricity generation in 6 provinces, this paper considers the quantity and diversity of biomass available in each province. Since biomass is a by-product of agricultural products available during seasons, it lacks consistency throughout the year. The biomass diversity help reserving sufficient biomass feedstock for power plants throughout the year. According to Table 1, it appeared that the provinces with the highest amount and diversity of biomass cultivation were Nakhon Ratchasima, Ubon Ratchathani, Chaiyaphum, Sisaket, Buriram, and Udon Thani. As a result, this paper estimated the potential of biomass for electricity generation in the above noted provinces by considering the proportion of biomass types and the quantity of residual biomass (as shown in Figures 1 and 2).

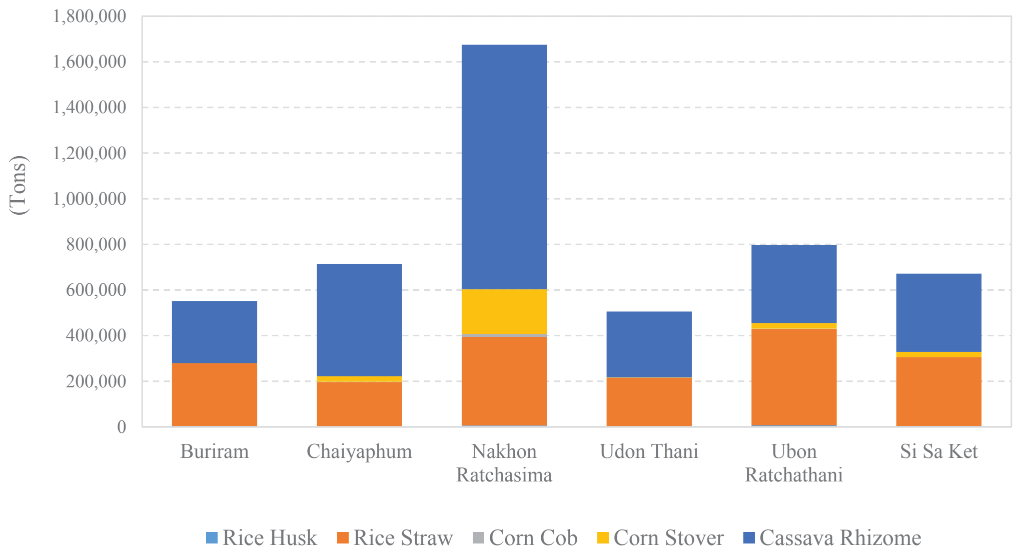

Figure 1. Types and quantity of residual biomass from utilization in the year 2020

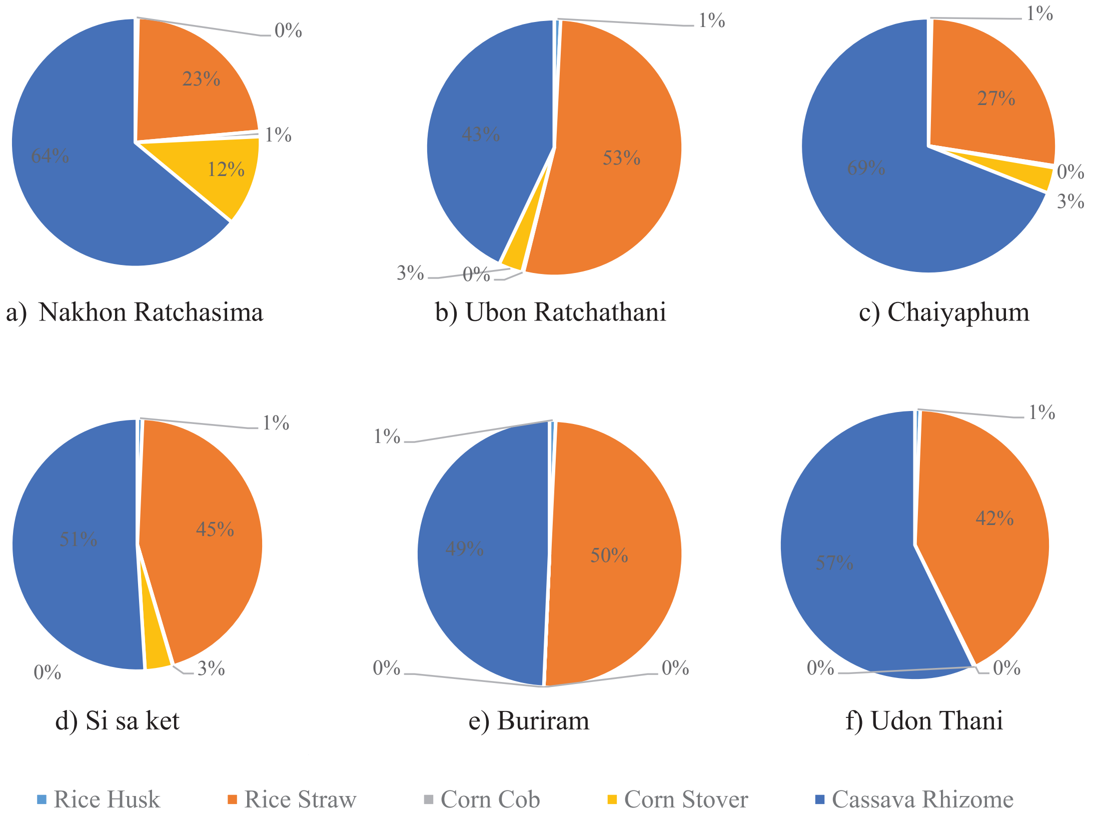

Figure 2. Percentage share of residual biomass for 6 provinces in 2020.

By considering the types and quantity of residual biomass (as shown in Figures 1 and 2), it showed that the amount of cassava rhizome and rice straw left over from utilization was quite high compared to that of rice husks, corn cobs, and corn stover. It further showed that the provinces with the most quantity of residual biomass from utilization were Nakhon Ratchasima, followed by Ubon Ratchathani, Chaiyaphum, Sisaket, Buriram, and Udon Thani respectively. In terms of the diversity of residual biomass, provinces with high biomass diversity include Nakhon Ratchasima, Ubon Ratchathani, Chaiyaphum, and Sisaket respectively. In the case of Nakhon Ratchasima, the proportion of cassava rhizomes, rice straw, corn stover and corn cob in biomass were 64%, 23%, 12%, and 1% respectively. For Ubon Ratchathani, the proportion of rice straw, cassava rhizomes, corn stover and rice husks in biomass were 53%, 43%, 3%, and 1% respectively. In the case of Chaiyaphum, the percentage share of cassava rhizomes, rice straw, corn stover and rice husks in biomass were about 69%, 27%, 3%, and 1% respectively. For Sisaket, the percentage share of cassava rhizomes, rice straw, corn stover and rice husks in biomass were about 51%, 45%, 3%, and 1% respectively. To estimate the potential of electricity production, the amount of residual biomass was employed. Table 2 shows electricity generation potential of residual biomass and estimated number of community power plants for 6 provinces.

Table 2. Electricity generation potential of residual biomass and estimated number of community power plants for 6 provinces

Province	Energy potential of residual biomass (TJ)	Electricity generation potential of residual biomass (MW)	Estimated number of community power plant projects (Project)
Nakhon Ratchasima	11,799	82.8	13
Ubon Ratchathani	7,222	50.7	8
Chaiyaphum	5,102	35.8	5
buri ram	4,810	33.7	5
Sisaket	4,534	31.8	5
Udon Thani	4,121	28.9	4

Note: The estimation of the number of community power plants, in this article, considers the size of the community power plant project for biomass fuel which is specified not to exceed 6 MW according to the regulations of the Energy Regulatory Commission (ERC, 2022)

From Table 2, it appeared that Nakhon Ratchasima has highest potential in electricity generation from residual biomass - about 83 MW. With such a high capacity, the estimated number of community power plants are likely to be built up to 13 projects. Nakhon Ratchasima has high capacity for developing community power plants could be due to the fact that the quantity of residual biomass in Nakhon Ratchasima is higher than other provinces and also biomass types are more diverse than other provinces. The quantity and diversity of biomass should be considered as key factor for assessing the electricity generation potential in community power plants since the agricultural products in the Northeast are different harvest seasons. For example, rice cultivation is usually farm-in-season, the harvest season is from October to December. On the other hand, cassava has a relatively long harvest season from January to July and corn has a harvest season from May to October. The variety of biomass types, therefore, result in the availability of biomass for generating electricity throughout the year The biomass diversity help reserving sufficient biomass feedstock for power plants throughout the year.

In the case of Udon Thani, the estimated number of community power plants were only 4 projects. This is contributed by a quite low quantity of residual biomass from utilization in Udon Thani. The low biomass diversity further results in such a low capacity, with only cassava rhizomes and rice straw in the province. In order to enhance electricity production potential, increase in fuel types as well as power generation technologies would help provinces with low biomass potential could increase its capacity for developing community power plant projects. The addition of alternative fuels such as biogas from the fermentation of waste and agricultural waste or biogas from fermented animal manure could be one option suitable for farmers in areas that have both animal husbandry and crop farming. Moreover, the cultivation of new energy crops would help reduce the lack of food crops for both humans and animals. The energy crops that are suitable for biomass feedstock should be fast-growing crops and has high calorific value, low humidity, and easy to harvest such as napia grass, acacia, eucalyptus and bamboo. These crops are suitable for using as fuels for electricity generation due to their ability to grow in infertile areas and less demand for fertilizers and pesticides.

Table 3. Electricity generation and revenue from electricity sales by community power plants

Province	**Electricity generation from residual biomass (Million units/year)**	**Revenue from electricity sales by community power plants (Million baht/year)**
Nakhon Ratchasima	3,278	14,026
Ubon Ratchathani	2,006	8,583
Chaiyaphum	1,417	6,063
buri ram	1,336	5,716
Sisaket	1,260	5,391
Udon Thani	1,145	4,899

Note: Revenue from electricity sales is calculated from the feed-in tariff rate for community power plant projects with biomass fuel size more than 3 MW according to regulations of the Energy Regulatory Commission (ERC, 2022)

Regarding the income from the electricity sale, Table 3 showed that the use of residual biomass to produce electricity contribute to an increased income in community. For example, Nakhon Ratchasima has the potential to generate electricity from biomass as high as 3,278 million units per year - representing an estimated income of up to 14,026 million baht per year. In the case of Ubon Ratchathani, Chaiyaphum, Buriram, Sisaket, and Udon Thani, electricity generation potential was estimated to be about 2,006 million units, 1,417 million units, 1,336 million units, 1,260 million units, and 1,145 million units per year, respectively. These helps the communities in each province have extra income from selling electricity worth up to 8,583 million baht, 6,063 million baht, 5,716 million baht, 5,391 million baht, and 4,899 million baht per year, respectively. In addition to the benefits from the sale of electricity, the community power plant projects would also provide economic and social benefits such as income from the sale of biomass derived from agricultural products and increased employment in community and agricultural sector, all of which are beneficial to the people in the community. Furthermore, the power plant projects also provide job opportunities in the community for young workers whose normally relocate themselves to work in the industrial sector in the metropolitan area. Such opportunities would help strengthen the family and hence enhance the community sustainability.

7. Conclusions

This paper analyses a suitable model for developing a community power plant in the northeast region of Thailand. In this paper, six provinces including Nakhon Ratchasima, Ubon Ratchathani, Chaiyaphum, Buriram, Sisaket, and Udon Thani were selected based on quantity potential and biomass diversity. The results showed that The results showed that Nakhon Ratchasima has capacity to generate electricity by about 83 MW - representing a total of 13 community power plants. The capacity is capable of generating electricity from residual biomass up to 3,278 million units per year and representing an estimated revenue from electricity sales of 14,026 million Baht per year. The capacity for community based electricity generation in the other provinces would be between 29 and 51 MW which represents about 5-8 community power plants per province with the capacity to generate electricity from residual biomass approximately 1,145-2,006 million units per year. The revenue from electricity sales would be about 4,899-8,583 million Baht per year. In order to develop a community power plant in a sustainable way, this paper also recommends the addition of other alternative fuels for power generation as well as the promotion of energy crops to be used for community power plants. This would provide benefits in terms of several perspectives. Firstly, the projects would help community to earn more income from electricity sales. Secondly, the projects would also provide economic and social benefits to the people in the community such as income from the sale of biomass derived from agricultural products and increased employment in the community and the agricultural sector, all of which are beneficial to the people in the community. Thirdly, the power plant projects also provide job opportunities in the community for young workers whose normally relocate themselves to work in the industrial sector in the metropolitan area. Such opportunities would help strengthen the family and hence enhance the community sustainability.

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