Chapter 15

Small and very small rice husk power plant transportation network planning in Northeastern Thailand

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A network linear programming model is built to investigate the key issues for the sustainable development of electrical power generation using rice husk in Northeastern Thailand. The first objective of this study is to evaluate how to reduce the rice husk transportation costs for power plants based on actual operational constraints. Second objective is study how effecting to Roi-Et province electric market when the new power generation come in. Three different programming cases with alternative sets of power plants, depending on their contracts with the Electricity Generating Authority of Thailand (EGAT), were conducted in this study. The results show that production areas with relatively higher supply quantity play the key roles in regional rice husk power generation development. Total transportation costs and average rice husk input costs will be higher as new rice husk power plants are allowed to enter the market mainly because of the increasing competition to contract with low-cost rice husk suppliers. As new plants been built in the Northeastern Thailand region, the rice husk electricity market will become more competitive and hence the government can gradually lower their subsidy rates in the future. In terms of transportation the cost-effective distance should be less than 60, 80, and 100 km from the power plant to the rice husk suppliers' district center in cases 3, 6, and 7 power plants respectively.

1. Introduction

Among all current operating rice husk power plants in Thailand, Roi-Et Province is the one province that has initiate and more rice husk power plants than another province; therefore, our empirical study is based on the regional rice husk demand and supply network in Roi-Et Province and six neighbor provinces (Kalasin, Maha Sarakham, Surin, Si Sa Ket, Yasothon, Mukdahan). Roi-Et Province is located in the center of the Northeast of Thailand, with the area of 8,300 km^2. It consists of plateau and a small mountain in the Northeast and plain in the South of the province, where people grow one of the most famous and highest rice quality in the world named "Jasmine Rice". There are three seasons in a year, summer is from February to April, rain season is from May to September and winter is from October to January, and the average temperature is around 27 ° C all year round [1] We should note that if we considering only rice production in Northeastern compare with whole country, it was about 32% or one-third from total rice production in whole country. In additional, we calculated potential of rice husk northeast of country which was about 5,214.89 GWh; if we use this number compare with 13,129 Gwh of northeast electricity demand in 2009, it was about 40% of northeast electricity demand. It's not any surprise that the percentage is very high because almost of this area is rural area, so agricultural products is the main revenue in this area; moreover, rural area is less electricity utilization compare with urban area. The significant percent of rice husk electricity potential to northeast electricity demand is the one reason that northeast of Thailand now is the center of biomass electricity generation.

An area that growth rice in Northeast is concentrate in Roi-Et and six neighbor provinces and total rice production in these seven provinces in 2009 was about 4,544,000 tons or one-fifth of total rice production in whole country. Roi-Et Province's rice production in 2010 was about 984,400 tons and from this number can be calculated energy potential from rice husk to be about 77.9 ktoe or about 900 GWh. Therefore, this area has high potential for building rice husk power plants. Moreover three rice husk power plants have already been built in this province, three power plants will operate near future and one power plant is on feasibility study. Therefore, this led Roi-Et to be the center of biomass power generation and improved energy security in this area and the nearby areas as well[2].

Despite of the economic incentives provided by the government, the current production subsidies is very likely to decrease gradually in the future. As a result, production cost reduction becomes very critical for the future development of rice husk power generation. According to the documents and data provided by the government officials and power plant managers, there has been lack of studies on rice husk transportation network planning. Most of biomass studies were considering only about the potential of general biomass such as Jerasorn and Prasertsan[3-4] which find biomass potential about 5489-10,083 ktoe and still has about 3,339 ktoe of energy surplus, and Very few studies have concentrated on one specific kind of biomass electricity potential for example Suramaythangkoor [5-6] which find cost rice straw can compete among biomass at 0.35-0.53 Baht/MJ(e). However, we could not find a rice husk transportation network that applied to study rice husk power plants based on practical implementation data in developing countries. Our study is the first attempt to evaluate the transportation for rice husk power plants; moreover, in this study we added rice husk heat depreciation in to calculation method to make the result more reality. Therefore, we studied rice husk transportation network that can be used to plan how to reduce rice husk transportation cost and find the best length of distance in difference situations for high efficient utilization of rice husk.

2. Number of Small Power Plants (SPP) and Very Small Power Plants (VSPP)

Considering seven power plants which be used on this study are Roi-Et Green (REP), Buasommai project 1 (B1P), Buasommai project 2 (B2P), Buasommai project 5 (B5P), Srisangdow (SDP), Advance Clean Power (ACP), and Green Power (GP). REP, B1P and B5P are located in Nuean Mueang sub district, Mueang district, Roi-Et Province and these three power plants are very close to each other; thus we assume these three power plants are located in the same location. The other two power plants are SDP and B2P, they are located in Sraku sub district, Suwannaphum district, Roi-Et province, and their addresses are very close to each other; so we assume these two power plants are located in the same location as well. ACP that will be operated near future is located in Pondtong district Roi-Et province; GP that in Kaset-Wisai district Roi-Et province is in feasibility study.

Considering rice husk power plants in Roi Et electricity market, from Table1, we can separate in tree processing of power plants. Firstly, REP, B1P and B2P, these three power plants are initial rice husk power of Thailand especially REP that generate electric from 2003 until present. Second processing of power plant is B5P, SDP and ACP; theses power plants will operate in near future because they have signed contract with EGAT already. GP, last processing of power plant, is still in studying process and need to evaluate in both of financial feasibility and environmental impact.

3. Data source

A summary of data types and sources applied in this study is presented in Table 2. Rice production in crop year 2010-11 data was collected from official documents of Agricultural Statistics of Thailand from the Office of Agricultural Economic (OAE)[7]. Rice husk was calculated from rice production by using conversional factors from the Department of Alternative Energy Development and Efficiency study (DEDE)[3] and the Energy for Environment Foundation studies (E for E)[8]. Rice mills data were accessed from the Department of Internal Trade (DIT), Ministry of Commerce's web site [9]. The transportation distance from each supplier (in the center of district where the rice mills are located) to each power plant was collected using Google Map. If rice husk transportation has more than one route, we assume that the driver will choose the shortest time route from supplier to power plant because the shortest time road is more convenient, wider and transportation cost is calculated in length of distance (see in Table 4).

TABLE 1. List of VSPP and SPP in Roi-Et province that use rice husk as raw material

	Power plant name	Location	Capacity	Purchasing electricity	Processing
1	Roi Et Green[1] (REP)	Mueang district Roi-Et province	9.9	8.8	Operating
2	Buasommai project1 (B1P)	Mueang district Roi-Et province	6	5	Operating
3	Buasommai project2 (B2P)	Suwannapum district Roi-Et province	9.9	7.5	Operating
4	Buasommai project5 (B5P)	Mueang district Roi-Et province	9	8	Signed contract and will operate in the near future
5	Srisangdow Biopower (SDP)	Suwannapum district Roi-Et province	9	8	Signed contract and will operate in the near future
6	Advance Clean Power[2] (ACP)	Pondtong district Roi-Et province	9.9	8	Signed contract and will operate in the near future
7	Green Power (GP)	Kaset-Wisai district Roi-Et province	9.5	8	Studying

Moreover, most of shortest distance are narrow and not safety if the driver use at night. Transportation cost were taken from interview data from power plant managers or engineers, and some data was taken from E for E researches. In this study, we face lack of labor cost data; therefore, we use reference wage rate from Ministry of Labor and newspapers. On the other hand, demand of rice husk was calculated based on REP and Buasommai power plants data, and we used the Rule of Three in Arithmetic to calculate possible rice husk demand of future power plants.

[1] By contract, RoiEt Green is SPP otherwise are VSPP but RoiEt Green capacity size likes VSPP, so in this study we assume RoiEt Green is VSPP.
[2] Biomass power plant that mean rice husk is one of raw material that the power plant used

TABLE 2. Data source

Type of data	Source
Rice production (crop year 2010-2011)	Office of Agricultural Economics (OAE) [7]
Quantity of rice husk supply	Department of Alternative Energy Development and Efficiency (DEDE) [3], Energy for Environment Foundation (E for E)[8],
Rice mills	Department of Internal Trade (DIT) [9]
Power plants	Energy Planning and Policy Office (EPPO) [10]
Distance	Google map
Rice husk transportation cost	Interview data from power plants and rice mills managers, engineers or officers, and Energy for Environment Foundation (EforE)[8, 11]
Ordering cost	
Holding cost	

4. Transportation cost minimization

In this study, a transportation model is formulated for solving problems with the following unique characteristics: 1) rice husk is transported from a number of suppliers to a number of rice husk and mixed biomass power plants at minimum possible cost; and 2) each supplier is able to supply a fixed number of rice husk quantity and each power plant has a fixed rice husk demand. Because the total supply of the studied region is greater than the total demand of the power plants, we apply an unbalanced transportation model in this study. The transportation routes between rice mills and rice husk power plants can be illustrated by a network system. Therefore, network models have been widely used to study various transportation problems especially for a large-scale and complicated transportation network [12]. In this study, we assume that rice husk is gathered at a central rice mill in each district due to the following data constraints: (1) currently there is no rice husk production and capacity data for each individual rice mill in Maha Salakham province; (2) detailed address of some specific rice mills are currently not available. Currently rice husk cost and its transportation cost are combined together as the selling price to each power plants, therefore we assume the rice husk purchasing price is the same with the same transportation distance (see Table 3).

In order to study impact of new power plant and guide for new investors, we provide minimize transportation cost in three cases number of power plants as a following:

(1) first case is three power plants that operating in the present (power plant number 1 to 3 in Table1),

(2) second case is six power plants that operating and will operate in the near future (power plant number 1 to 6 in Table 1),

(3) third case is seven power plants that operating, will operate and on feasibility study (power plants number 1 to 7 in Table 1).

Since the quantity of rice husk in Roi-Et Province was not sufficient to serve all three operating power plants that we was mention in potential of rice husk in Roi-Et province, so we included rice husk supply from six neighbor provinces into this study. To calculate the quantity of rice husk supply in each district, we calculated it based on the rice husk production in the whole province, the capacity or number of rice mills in each district, and δ% of rice husk product was taken to rice husk or mixed biomass power plant in northeast of country as this formula:

$$\begin{aligned} &\textit{Rice husk supply in district } i \\ &\quad = (\textit{total rice husk output in province } \mathrm{P} \times (\frac{\delta}{100})) \\ &\quad \times \frac{\textit{total rice mill capacity in district } i}{\textit{total rice mill capacity in province } \mathrm{P}} \end{aligned}$$

Purchasing rice husk is the one of main cost of power plants that has seasonal effect from rice production. In crop year 2010-11rice husk price was around 900-1,200 baht per ton. We should note that rice husk price that power plants purchase is already include transportation cost and capital cost (track depreciation). To make purchasing rice husk easy to calculate buyer include the transportation and capital cost together and it is calculated according to the distance from the supplier to the power plant. Furthermore, this study assumed the average transportation capacity of each truck was 15 tons with came from rice mill interview data.

One aim of this study is to minimize rice husk transportation cost; therefore, to minimize this cost, we set up transportation network by using the linear equation as the following:

$$\begin{aligned} \mathbf{Min} \sum_{i=1}^{8} \sum_{j=1}^{n} c_{ij} x_{ij}^{1} + \sum_{i=9}^{15} \sum_{j=1}^{n} c_{ij} x_{ij}^{2} + \sum_{i=16}^{24} \sum_{j=1}^{n} c_{ij} x_{ij}^{3} + \sum_{i=25}^{29} \sum_{j=1}^{n} c_{ij} x_{ij}^{4} \\ + \sum_{i=30}^{36} \sum_{j=1}^{n} c_{ij} x_{ij}^{5} + \sum_{i=37}^{42} \sum_{j=1}^{n} c_{ij} x_{ij}^{6} + \sum_{i=43}^{44} \sum_{j=1}^{n} c_{ij} x_{ij}^{7} \end{aligned}$$

Subjected to

$$\sum_{j=1}^{n} x_{ij}^{p} \le S_i; \; i = 1, \ldots, 44, j = 1, \ldots, \mathrm{n}$$

$$\sum_{i=1}^{44} x_{ij}^{p} \leq D_j;\; i = 1,\dots,44, j = 1,\dots,\mathrm{n}$$

$$x_{ij}^{p} \geq 0 \; for\; all\; i\; and\; j$$

Where

i is supplier i, i = 1,…,44,

j is power plant j, j = 1,2,3 for case 1, j = 1,…, 6 for case 2, j = 1,…, 7 for case 3

p is province p,

p = 1 for Roi-Et province,

p = 2 for Surin province,

p = 3 for Si Sa ket province,

p = 4 for Yasothon province,

p = 5 for Kalasin province,

p = 6 for Maha Sarakham province,

p = 7 for Mukdahan province,

n is power plant n in three difference cases, n=3 for case1, n=6 for case2, n=7 for case 3,

S_i is rice husk supply of supplier i, and i = 1,…,44

D_j is rice husk demand of power plant j,

is number of truck that transported from i in province p to j,

is transportation cost per truck from i to j (Baht/truck/trip).

5. Results and discussions

Considering the optimal transportation cost of power plant, almost power plants; costs are increased when the new power plant enter to the market because contracting rice husk suppliers competitiveness. However, for B2P in cases 2 and 3, the total cost is reduced from 20.981 million baht to 20.219 million baht in case 2 and 3 respectively because an exchange of rice husk suppliers among power plants. Therefore, B2P get suppliers that have lower transportation cost from other power plants for adequate rice husk but higher cost to serve their rice husk demand. Because GP is in feasibility study process, we need to provide some information for new venture power plant and stakeholders. From Table 3, the percentage of unit transportation cost increasing of case 2 and 3 was calculated by using an increasing of unit cost (272 and 282 Baht) compare with average purchasing price of rice husk (1,100 baht in 2010). The results show that the percentage of unit transportation cost increasing of rice husk is increased from

24.72% in case2 to 25.63% in case 3; therefore, an increasing of this cost is less than 1% (0.91%) if we build GP in the future. The diversification of power plant was the other one topic that we studied as well. From Table 1 that gives capacity of seven power plants in the market; even though, this market will has six power plants on operating but Buasommai project 1,2 and 5 power plant are the same company. Therefore, if we build new power plant such as GP that has 9.9 MW of capacity, it will reduce market share of Buasommai power plants from 46.37% in case 2 to 39.40% in case3. From this two main results, when new power plant enter to the market the percentage of unit transportation cost increasing is increased less than decreasing of market share of Buasommai power plants; therefore, the market will be more competitive and more beneficial to sellers in finally. Moreover, considering in rice husk supply side, rice husk supply of seven provinces still can cover demand of rice husk of seven power plants that has included Green Power already. In order to decide new power plant should or should not build by using these three reasons (percentage of unit transportation cost increasing, diversification and supply), we suppose that GP should be build in near future.

TABLE 3. Summary cost in each case and unit cost of rice husk transportation

Power plant	Case 1	Case 2	Case 3
Roiet Green (REP)	20,870,000	25,476,000	25,664,000
Buasommai1 (B1P)	9,100,000	12,932,000	14,960,000
Buasommai2 (B2P)	15,975,000	20,981,000	20,219,000
Buasommai5 (B5P)		14,900,000	15,860,000
Srisangdow Biopower (SDP)		17,237,000	20,633,000
Advance Clean (ACP)		4,824,000	4,824,000
Green Power (GP)			18,053,000
Total cost	45,945,000	96,350,000	120,212,000
Total rice husk used	193,830	353,990	426,790
Unit cost of rice husk transportation (baht/ton)	237	272	282
Unit cost of rice husk transportation (baht/truck)	3,556	4,083	4,225
Unit transportation cost increase percentage[3]		24.73	25.64
About 20 -31 % of rice husk purchasing price (900 – 1,200 Baht/ton in 2010) is transportation cost			

In order to find radius of longest distance to minimize transportation cost in different number of power plant, we used transportation cost per trip and transportation and capital cost considering together. As a result, in case 1, highest transportation cost is 4,500 baht per trip; therefore, longest distance that power plants in case 1 should order from suppliers who located less or equal to 60 km. In case 2, highest transportation cost is 5,400 baht; therefore, longest distance that power plants in case 2 should order from suppliers who located less or equal to 80

[3] Unit transportation cost increase as a percentage of average rice husk price, the average rice husk price in 2010 is 1,100 baht/ton

km. In case 3, highest transportation cost is 6,000 baht; therefore, longest distance that power plants in case 3 should order from suppliers who located less or equal to 100 km.

Considering about length of distance in each power plant, an initiate power plants is effected when new power plants enter into the market in different effectiveness. To make it easier, Figure 1 was provided, it shows a changing of radius when new power came to the market in different cases; meanwhile, a different color of circle shows different length of distance (radius) from each power plant to furthest suppliers. The results in each case which three power plants in case1, six power plants in case2, and seven power plants in case3 of power plants shows as a following:

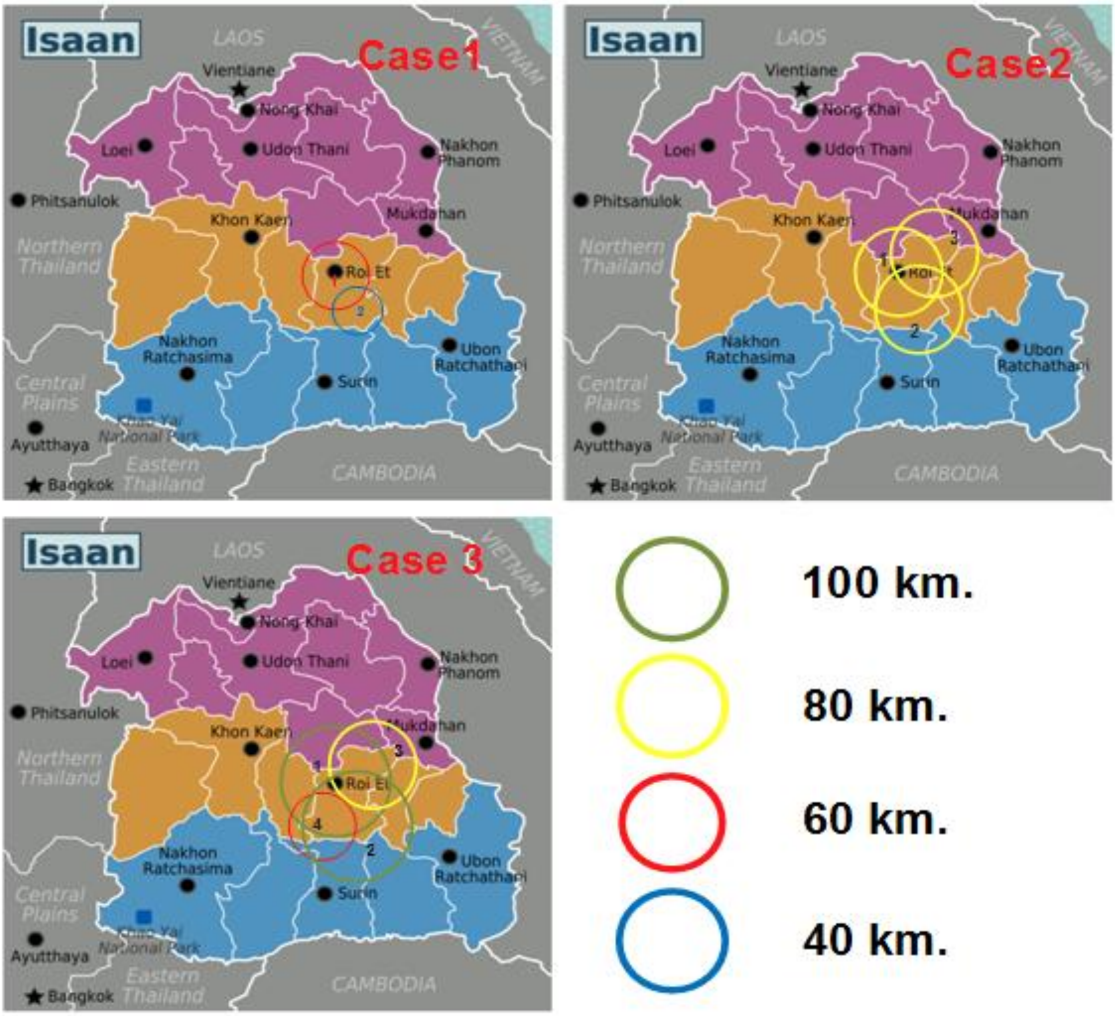

Figure 1. Rice husk power plant radius changing in three different cases

(1) In case 1, because REP and B1P are located close to each other, when B1P gets large amount of Mueang Roi Et rice husk suppliers to serve its demand. This situation effects to REP that needs to find other sources to serve its demand, and the longest length of distance is about 60 km (red cycle). On another hand, B2P which located in Suwannaphun district hasn't competitor, so all of rice husk in Suwannaphum district occupy by B2P (40 km, blue cycle).

(2) In case 2, an entering to the market of B5P affects to initiate power plants in Mueang district, consequently radius of cycle is increased from 60 km. in case 1 to 80 km. in case 2 (yellow cycle number 1). Meanwhile, B2P is mainly effected by an entering of SDP; because of limitation of rice husk and huge rice husk demand of SDP, it makes radius of this area increases from 40 km. to 80 km. (yellow cycle number 2). Future venture like ACP, it begins with 80 km. of radius because that area is located further from supplier sources (yellow cycle number 3).

(3) In case 3, the power plants that are located in both of Mueang and Suwannaphum district are effected by an entering of GP; as a result, the radius of two districts increases from 80 km. in case 2 to 100 km. in this case.

(4) ACP, unlike power plants that located in two districts, isn't effected from new power generation (GP) because the distance of this power plant is further compare with other power plants in this area, so it has freely to choose suppliers than other power plants (green and black line are the same radian at 80 km.) in case 3.

In general case, we can conclude that when the new power enter to market it will effect to initiate power plants in difference effectiveness depend on distance between initiate and new power plant, number of power plant, quantity of raw material in each area, and distance from power plant to suppliers.

6. Conclusions

Three different programming cases with alternative sets of power plants, depending on their contracts with EGAT, were conducted in this study. The results show that production areas with relatively higher supply quantity play the key roles in regional rice husk power generation development. Total transportation costs and average rice husk input costs will be higher as new rice husk power plants are allowed to enter the RoiEt electricity market mainly because of the increasing competition to contract with low-cost rice husk suppliers. The total transportation cost of three power plants in Case 1 is about 45.9 million Baht and it increases to 96.4 million Baht in Case 2 with six power plants and 120.2 million Baht in Case 3 with seven power plants, respectively. The cost depends mainly on the distance from the rice husk supplier to the power plant, shipping quantity, and the number of transportation trips in each year. The strategy that the power plant operators could employ to reduce cost compared to their current transportation management is to purchase rice husk from the nearest supplier or going directly to the supplier with large quantities. And then purchase rice husk from farther suppliers with lower transportation costs.

According to the recommended transportation strategy above, we found that REP and B1P power plants in Case 1 should buy rice husks from suppliers located within the distance of 60 km. The suppliers located within the radius of 60 km from the power plant have sufficient quantities to meet the demand with the lowest cost. For the same reason, B2P power plants should buy rice husks from suppliers located within the distance of 40 km. In Case 2, REP, B1P, and B5P power plants should buy rice husks from suppliers located within the distance of 80 km. B2P and SDP should buy rice husks from suppliers located within the distance of 80 km. ACP should buy rice husk from suppliers located within the distance of 80 km. In Case 3, REP, B1P, and B5P power plants should buy rice husks from suppliers located within the distance of 100 km. B2P and SDP should buy rice husks from suppliers located within the distance of 100 km. ACP should buy rice husks from suppliers located within the distance of 80 km. GP should buy rice husks from suppliers located within the distance of 60 km. As a general rule, the results suggest that the rice husk transportation radius for each power plant should not be farther than 100 km. In addition to the seven power plants included in Case 3, we found that future new power plants should be built in Mueang District Surin Province and Mueang District Sisaket Province where the rice husk production is sufficient enough to meet the demand. As new plants been built in the Northeastern Thailand region, the rice husk electricity market will become more competitive and hence the government can gradually lower their subsidy rates in the future.

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