

AN ASSESSMENT OF RICE HUSK UTILIZATION IN THAI INDUSTRIAL SECTOR: IMPLICATION OF ITS POTENTIAL AND PRICE

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Abstract

Nowadays rice husk has been used as fuel in small power producers (SPPs) to generate electricity and to substitute lignite in large cement plants in Thailand. However, utilization of rice husk occurs in some regions; therefore, the recent problem is how to control rice husk price where its demand is high and vice versa. This study aims at investigating the reasonable price of rice husk and energy saving as well as CO₂ emission reduction by using rice husk in SPPs and cement plants from 2001 to 2030. To achieve the above objectives, rice husk supply and demand for each region are assessed. Then the capacity potential of SPPs and the use of rice husk in place of lignite are obtained. The reasonable price is calculated based on the price when the marginal cost is equal to the marginal revenue. The results show that the reasonable price of rice husk for SPPs is 450 baht per tonne and 402 baht per tonne for cement plants. In 2001 the potential of SPPs from rice husk was 218.9 MW and is projected to go up to 298.9 MW in 2030. Benefits include cumulative saving in fuel oil of 25.08 million tonnes of oil equivalent (toe), lignite of 9.6 million toe, and CO₂ emission reduction of 81 million tonnes during the study period.

Keywords: Rice husk, small power producers, cement plant, Thai industrial sector, and CO₂ emission

Introduction

In Thailand, rice husk has been used for a long time for many purposes such as (i) as fuel for cooking in household in rural areas, brick production, and electricity generation in rice mills, and (ii) as raw material in fertilizer and animal feed industries. Under the present situation of economic uncertainty in Thailand and worldwide, awareness of the climate change caused from the use of fossil fuel, many renewable energy technologies are studied and

implemented as substitutes for the use of fossil fuel. The Thai government has been trying to introduce and implement such projects; for example, the improved cooking stove project and the biogas digester project, in order to reduce greenhouse gas (GHG) emission and decrease dependency on imported fossil fuel. As a result, rice husk has been recently used as fuel to generate electricity in small power producers (SPPs) which then sell the electricity back to the

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grid. There are currently six SPPs using rice husk as fuel with a total installed capacity of 70.9 MW and four SPPs with the total installed capacity of 88 MW are waiting for approval (EGAT, 2003). In addition, rice husk has been used as fuel in place of lignite in the clinker process in the large cement plants located in Saraburi province (The Siam Cement Group, 2003; TPI Polene Public Co., Ltd., 2003). Thus, rice husk demand is on the increase, particularly, in the central and the north-eastern regions where large rice mills, SPPs, and cement plants are located. Consequently, rice husk price has increased in these areas. Hence, nowadays the problem of the use of rice husk which the industrial sector of Thailand is facing how to control the price where its demand is high and how to increase the use of rice husk where its demand is low. As a result, the investigation of the rice husk supply and demand by region is considered in this study. In addition, paddy production gradually increased from 19.1 million tonnes in 1987 to 25.84 million tonnes in 2001 (OAE, 1986/1987; OAE, 2000/2001). Paddy production from the northern, the north-eastern, the central, and the southern regions is around 27.65%, 37.47%, 30.56%, and 4.32% in total, respectively, whereas paddy production per rai increased around 2% per year. The average annual increase of paddy fields over the period 1987-2001 was 0.47%. This paper also aims at assessing fossil fuel savings and corresponding emission reductions from the use of rice husk in SPPs and cement plants. The reasonable price of rice husk is also presented.

Limitations and Assumptions

1. The study period started in 2001 and will end in 2030. The base year was 2001.
2. Both primary and secondary data are used. They are available from government and private agencies such as Energy Policy and Planning Office (EPPO), Bio-Mass Power Co., Ltd., and Siam Cement (Kaeng Khoi) Co., Ltd.
3. The study from (EPPO, 2000) showed that the internal rate of return (IRR) of the rice husk power plant in the size of 9-10 MW, 3-7 MW, and less than 1 MW were 25-33%, 7-15%, and 0.5% respectively. Therefore, only the plant size of 10 MW was used in the analysis.
4. Most rice mills are located throughout the country. They are small in size and there are 215 rice mills with capacities ranging from 100 to 2,000 tonnes of paddy per day (EPPO, 2000). Furthermore, data from (Mitsubishi Securities Clean Energy Finance Committee, 2003) showed that A.T. Biopower, one of the SPPs using rice husk, can collect rice husk from small rice mills nearby to generate electricity in the size of 22 MW. Hence, it is believed that new SPPs could follow A.T. Biopower. As a result, the study assumes that the rice husk from the rice mills with capacities ranging from 100 to 2,000 tonnes of paddy per day in the central and the north-eastern regions is used in cement plants after it is used in rice mills and other purposes while rice husk balance from small rice mills is used by new SPPs since it is too difficult for cement plants to collect rice husk from small rice mills. Concerning the northern and the southern regions, it is assumed that all rice husk is used by new SPPs after being used in rice mills and other purposes.
5. Nowadays cement plants buy rice husk within 200 km from their plants (The Siam Cement Group, 2003). Therefore, the study assumes that SPPs buy rice husk within 200 km from the plants, the same as cement plants. In addition, rice husk price in 2003 at 200 baht per tonne (The Siam Cement Group, 2003; PRG granary Co., Ltd., 2003; Bio-Mass power Co., Ltd., 2003) at a rice mill and transportation cost in 2003 at 1.5 baht per kilometre (The Siam Cement Group, 2003) were used in this study. Concerning the above prices, they stated that the cost of rice husk used in the plant depends on the transportation cost. Therefore, to calculate for the cost of rice husk used in the plants it is assumed that one tonne of rice husk is divided into 4 portions which are bought from 4 areas; A_1 , A_2 , A_3 , and A_4 (Figure 1). A_1 is the area within 50 km from the plants to rice mills, A_2 ranging from 51 km to 100 km, A_3 ranging from 101 km to 150 km, and A_4 is within the range from 151 km to 200 km from the plants to rice mills.

A_1 is calculated by using equation

$A_1 = \pi R_1^2$, where R_1 is equal to 50 km.

Concerning A_2 , A_3 , and A_4 , the corresponding areas are calculated by using equation 1.

$$A_i = \pi R_i^2 - \sum A_{i-1} \quad (1)$$

where; $i = 2, 3$, and 4

The total area, A_L , is the sum of A_1 or $A_L = A_1 + A_2 + A_3 + A_4$. Therefore, 6.25%, 18.75%, 31.25%, and 43.25% of 1 tonne of rice husk are bought from rice mills within distances of 50 km, 100 km, 150 km, and 200 km, respectively.

Rice husk price that SPPs and cement plants gain the net profit around 10% of the total cost is considered as the reasonable price of rice husk in this study. It also assumes that 30% of the gross profit is spent on the operating cost in SPPs, whereas the operating cost in cement plants is assumed to be zero because rice husk is used to substitute lignite. The corresponding emission is CO_2 .

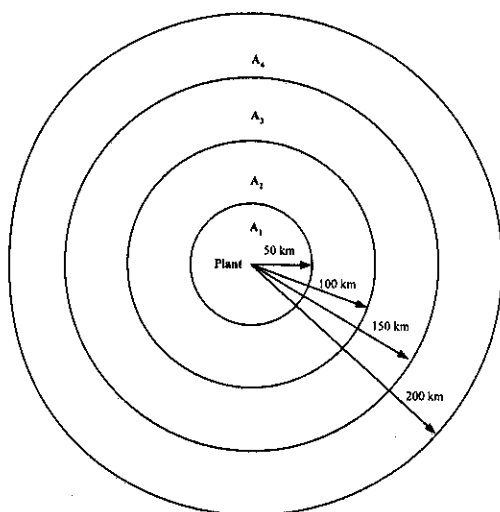


Figure 1. Rice husk supply areas.

Data Analysis and Results

Rice Husk Supply

1. Historical data of paddy plantations were collected.

2. The paddy plantation has been forecasted by using equation 2.

$$PPY = PA \times PPR \quad (2)$$

where PPY = paddy production per year,
 PA = plantation area, and
 PPR = paddy production per rai with an increasing rate of 2% per year.

In addition, to project the paddy production per year the following data were used.

- 2.1 Plantation area of 65,640,000 rai in 2001 was used throughout the study period related to (OAE, 1986/1987; OAE, 2000/2001) as discussed in the introduction section.
- 2.2 Paddy production per rai in the base year was 393.72 kg (OAE, 1986/1987; OAE, 2000/2001).
3. Paddy used in rice mill is calculated by using the data from input-output table (NESDB, 2002). Then rice husk is calculated by using equation 3.

$$RH = PRM \times PRR \quad (3)$$

where RH = rice husk per year,
 PRM = paddy used in rice mills per year, and
 PRR = the ratio of paddy to rice husk which is equal to 0.23 (DEDE, 2000).

Results show that paddy production per rai in 2030 will be equal to 699.99 kilograms, still lower than the production per rai in 2000 in Indonesia, China, and Japan (OAE, 2003) (Table 1). As a result, the annual increase rate of 2% of paddy production per rai is reasonable. Table 1 also shows that rice husk is projected to increase from 5.12 million tonnes in the base year to 9.11 million tonnes in 2030.

Rice Husk Demand

1. Rice husk demand for electricity generation used in the rice milling process is calculated based on 35.17 kWh per 1 tonne of paddy for the rice milling process (The EC-ASEAN COGEN Programme Bangkok, Thailand,

Table 1. Paddy production and rice husk during the study period.

Year	Paddy production		Rice husk
	(kg/rai)	(million tonnes/year)	(million tonnes/year)
2001	393.72	25.84	5.12
2005	426.25	27.98	5.55
2010	470.70	30.90	6.12
2015	519.79	34.12	6.76
2020	574.01	37.68	7.47
2025	633.88	41.61	8.25
2030	699.99	45.95	9.11

1998) and the conversion factor of 0.62 MWh per tonne (PRG Granary Co., Ltd., 2003; Bio-Mass Power Co., Ltd., 2003; The EC-ASEAN COGEN Programme Bangkok, Thailand, 1998; EPPO, 2003).

2. Historical data of the use of rice husk for other purposes were collected.
3. Rice husk demand for new SPPs, and cement plants was calculated by subtracting the rice husk supply from the rice husk demand for other purposes.

The results in Table 2 show that rice husk supply for rice husk demand for new SPPs in the central and north-eastern regions, hereafter called "C&NE regions", is projected to increase from 0.19 million tonnes in the base year to 0.38 million tonnes in 2030. The rice husk for cement plants is projected to increase from 0.41 million tonnes in the base year to 1.58 million tonnes in 2030. Rice husk surplus, the rice husk supply subtracted by the rice husk demand, in this region is ranging from 0.08% to 2.79% of total rice husk supply. Concerning the northern and southern regions, hereafter called "N&S regions", rice husk supply for rice husk demand for new SPPs is projected to increase from 0.38 million tonnes in the base year to 0.96 million tonnes in 2030 as shown in Table 3. Rice husk surplus in this region is ranging from 0.08% to 6.3% of total rice husk supply.

Fossil Fuel Savings and CO₂ Emission Reduction

1. According to rice husk demand for SPPs, the installed capacity of rice husk power generation is determined by using equation

4. Plant capacity factor of 0.8 (PRG Granary Co., Ltd., 2003; Bio-Mass Power Co., Ltd., 2003) and running hours per year of 7,446 (EPPO, 2000) were used in the study.

Installed Capacity (MW) =

$$\frac{\text{MWh output per year}}{(\text{Plant Capacity factor}) \times (\text{Running hours per year})} \quad (4)$$

2. Fuel oil and lignite savings were calculated. The conversion factor is that 1 tonne of rice husk is equal to 362.11 litres of fuel oil or 0.78 tonnes of lignite (DEDE, 2001).
3. The CO₂ emission reduction is calculated by multiplying the emission factor by the quantity of fuel oil and lignite savings.
 - CO₂ emission from fuel oil-fired steam power plant is 734.07 kg/MWh (Egon Failer, 2003; Kaewboonsong *et al.*, 2003).
 - CO₂ emission from cement plant is 0.37 tonnes per 1 tonne of clinker (The Siam Cement Group., 2003; Carney, 2003; McCaffrey, 2001).

The potential of electricity generation from rice husk was estimated to be 218.9 MW in the base year, and 298.9 MW in 2030 (Table 4). Consequently, Thailand can reduce imported fuel oil by 759.12 million litres in the base year and further reduce to 1,036.55 million litres in 2030 as shown in Table 5. The saving is 5,055.74 million baht in the base year and could increase to 6,903.42 million baht in 2030 at imported fuel oil price of 6.66 baht per litre (EGAT, 2001). Hence, imported fuel oil can be reduced by 26,640.2 million litres and the saving would

be 177,423.72 million baht over the study period. The lignite savings is projected to increase from 0.32 million tonnes in the base year to 1.23 million tonnes in 2030. The corresponding cumulative saving is estimated to be 21.99 million tonnes during the study period, whereas CO₂ emission could be reduced by 1.65 million tonnes in the base year and further to 3.99 million tonnes in 2030. The cumulative CO₂ emission has been estimated to be 81.44 million tonnes during the study period.

Reasonable Price of Rice Husk

As mentioned above, most large rice mills, SPPs, and large cement plants are located in the C&NE regions. Therefore, rice husk demand in these regions is high so the price of rice husk always increases and vice versa in the N&S regions. Results in Table 2 and 3 also show that at present additional SPPs in the C&NE regions should not be built for a capacity over 20 MW in order to prevent high price of rice husk due to the competition between SPPs and cement

Table 2. Rice husk supply and demand in C&NE regions.

Year	Rice husk supply (million tonne)	Rice husk demand (million tonne)						Rice husk surplus (million tonne)
		Milled rice production	Household ¹	SPPs ^a	Others ²	New SPPs	Cement plant	
2001	3.49	0.86	0.062	1.1	0.82	0.19	0.41	0.049
2005	3.77	0.93	0.067	1.1	0.89	0.19	0.53	0.068
2010	4.17	1.02	0.074	1.1	0.98	0.28	0.70	0.009
2015	4.60	1.13	0.082	1.1	1.08	0.29	0.89	0.030
2020	5.08	1.25	0.090	1.1	1.20	0.29	1.10	0.063
2025	5.61	1.38	0.099	1.1	1.32	0.38	1.33	0.003
2030	6.20	1.52	0.110	1.1	1.46	0.38	1.58	0.044

Source: ^a [EGAT, 2003]

Note: ¹ Rice husk used by household in the base year was 2.35% of total rice husk with an average annual decreasing rate of 0.0018% (DEDE, 2000).

² "Others" refers brick, livestock feed, fertilizer manufactures and others, which equal to 31.2% of total rice husk supply (The Siam Cement Group, 2003).

Table 3. Rice husk supply and demand in N&S regions.

Year	Rice husk supply (million tonne)	Rice husk demand (million tonne)					Rice husk surplus (million tonne)
		Milled rice production	Household ¹	SPPs ^a	Others ²	New SPPs	
2001	1.64	0.40	0.029	0.42	0.39	0.38	0.016
2005	1.77	0.44	0.031	0.42	0.42	0.38	0.084
2010	1.96	0.48	0.035	0.42	0.46	0.48	0.081
2015	2.16	0.53	0.038	0.42	0.51	0.66	0.001
2020	2.39	0.59	0.042	0.42	0.56	0.77	0.009
2025	2.64	0.65	0.047	0.42	0.62	0.86	0.038
2030	2.91	0.72	0.052	0.42	0.69	0.96	0.080

plants. On the other hand, new SPPs in the N&S regions should be engaged because these regions recently have had a potential of 84 MW of the total installed capacity (Table 4). In addition, the

cement plants in the northern region do not use rice husk because the lignite price is very low when compared with rice husk price (Table 6).

Table 4. The potential of rice husk power plant.

Year	Rice husk power plant or SPPs (MW)				Total
	C&NE regions		N&S regions		
	Recently	New	Recently	New	
2001	114.9	20	44	40	218.9
2005	-	20	-	40	218.9
2010	-	29	-	50	237.9
2015	-	30	-	69	257.9
2020	-	30	-	80	268.9
2025	-	40	-	90	288.9
2030	-	40	-	100	298.9

Table 5. Fossil fuel saving and CO₂ emission reduction by using rice husk in SPPs cement plants.

Year	Fossil fuel saving (million)		CO ₂ reduction (million tonne)		
	Fuel oil (litre)	Lignite (tonne)	SPPs	Cement plants	Total
2001	759.12	0.32	0.96	0.69	1.65
2005	759.12	0.42	0.96	0.90	1.86
2010	825.01	0.55	1.04	1.19	2.23
2015	894.37	0.69	1.13	1.51	2.64
2020	932.51	0.86	1.18	1.86	3.04
2025	1,001.87	1.04	1.26	2.25	3.52
2030	1,036.55	1.23	1.31	2.68	3.99

Table 6. Cost of lignite and rice husk in the northern region in 2003.

Fuel	Price (baht/tonne)	Heating value ¹ (kcal/tonne)	Fuel cost (baht/kcal)
Lignite price ²	424.14	4,400	0.10
Rice husk price within 50 km	275.00	3,440	0.08
Rice husk price within 100 km	350.00	3,440	0.10
Rice husk price within 150 km	425.00	3,440	0.12
Rice husk price within 200 km	500.00	3,440	0.15
Average price of rice husk	-	-	0.11

Source : ¹ [DEDE, 2001]

² [http://www.egat.co.th/english/report_2001/key.pdf]

Reasonable Price of Rice Husk for the Small Power Producers (SPPs)

In this study, data of SPPs with installed capacity of 10 MW from (EPPO, 2000) was selected to show costs and benefits as an example of rice husk power generation. Details of benefit-cost analysis are presented in Table 7. Normally, the total cost (TC) is expressed as the sum of the total fixed cost (TFC) and the total variable cost (TVC); $TC = TFC + TVC$. In this study, according to the data in Table 7, the TFC is the capital cost which is equal to 0.22 baht per kWh while the TVC is the fuel cost equal to 0.61 baht per kWh. According to (Orrapin, 1996), the maximum price of rice husk can be obtained at the point that the marginal cost (MC) is equal to the marginal revenue (MR). Since, in this study the SPPs make their revenue equal to 1.41 baht per kWh, meaning that $MR = 1.41$ baht per kWh. Therefore, $MC = MR = 1.41$ baht per kWh. To investigate the reasonable price of rice husk, the variable factor in this study is only the price of rice husk at rice mills. Therefore, the maximum price of rice husk at rice mills derived from the above relationship is 559 baht per tonne. However, at the rice husk price at 559 baht per tonne at rice mills, SPPs do not want to produce electricity because they cannot make the profit as shown in Table 8. For this reason, the price is lower than 559 baht per tonne. Related to the assumption of the reasonable price of rice husk, the price of rice husk at the rice mills at 450 baht per tonne is determined as the reasonable price of rice husk for SPPs (Table 9).

Reasonable Price of Rice Husk for Cement Plants

To produce 1 kg of clinker, 742.63 kcal of energy is used in the clinker process in cement plants (The Siam Cement Group, 2003). Therefore, to produce 1 tonne of clinker, 0.17 tonnes of lignite or 0.22 tonne of rice husk is used (DEDE, 2001). To calculate the reasonable price of rice husk for cement plants, the price of lignite in 2003 at 900 baht per tonne for cement plants in the C&NE regions (The Siam Cement Group, 2003; TPI Polene Public Co., Ltd., 2003) was considered in this study. Regarding the assumption of the reasonable price of rice husk,

402 baht per tonne and 473 baht per tonne at rice mills are determined as the reasonable price and the maximum price of rice husk for cement plants, respectively (Table 10).

After an investigation of both SPPs and cement plants, the results show that the reasonable price of rice husk for SPPs is 450 baht per tonne while for cement plants the price is 402 baht per tonne. Moreover, the SPPs have potential to buy rice husk at the price above 450 baht per tonne because they can reduce their operating cost, whereas cement plants have potential to buy rice husk at the maximum price at 473 baht per tonne (Table 10). Since SPPs can offer a higher price of rice husk than cement plants, rice mill owners prefer to sell rice husk to SPPs rather than to cement plants. Under this situation, in the national perspective to reach the maximum benefit from the use of rice husk, the intervention from the government is necessary. For example, at present the government should limit the total installed capacity of additional SPPs in the C&NE regions at 20 MW as suggested. On the other hand, the government should pay more attention to encouraging the SPPs to invest in the N&S regions. Consequently, the severe competition between SPPs and cement plants in the C&NE regions will be less and the equilibrium price of rice husk will stabilize when rice husk demand is equal to rice husk supply as a result from market price mechanism. It is believed that the equilibrium price of rice husk is lower than 450 baht per tonne so both SPPs and cement plants in the C&NE regions gain more profit. Then, the rice husk demand and its price in the N&S regions will increase.

Discussions and Conclusions

At present, Thailand has rice husk power plants with total installed capacity of 70.9 MW while the potential was 218.9 MW in 2001 and is projected to increase to 298.9 MW in 2030. Many small power producers (SPPs) recently have been interested in rice husk power generation. The cement plants are also interested in replacing lignite by rice husk in the clinker process. These are the results from the promotion of the use of renewable energy by the Thai

Table 7. The costs and benefits of rice husk power generation with installed capacity of 10 MW_a

Item	Unit	Data
Selling back to EGAT	(MW)	8.80
Capital cost	(million baht)	422.68
Subsidy (0.17 Baht/kWh) ^a	(million baht)	12.66
Net capital cost	(million baht)	410.02
Capital cost per year	(million baht/year)	16.40
Rice husk needed to produce electricity	(tonne/year)	119,710.61
Rice husk supply cost	(million baht/year)	45.45
Total cost per year	(million baht/year)	61.85
Total cost per kWh	(baht/kWh)	0.83
Selling back to EGAT ¹	(million baht)	104.18
Saving from electricity used in plant ²	(million baht)	0.71
Total revenue	(million baht/year)	104.90
Payback period	(Year)	3.91
Profit per year	(million baht)	43.05
Profit per kWh	(baht/kWh)	0.58

Source : ^a [http://www.eppo.go.th/encon/encon-spp-renewb2.html]

Note : Operation cost does not include in the total cost.

Life time of rice husk power plant is 25 years. (Mitsubishi Securities Clean Energy Financial Committee, 2003)

Electricity charge rate for large rice mill is 1.67 baht/kWh. (EPPO, 2003)

¹ Electricity price is 1.59 baht/kWh. (EPPO, 2003)

² Saving from electricity used in plant is 0.80 baht/kWh which comes from electricity charge rate (1.67 baht/kWh) subtracted by electricity price (1.59 baht/kWh).

Table 8. The costs, revenues, and profits of rice husk power generation in the base case and in the case of the maximum price of rice husk at rice mill.

Case	TFC (baht/kWh)	TVC (baht/kWh)	TC (baht/kWh)	MC (baht/kWh)	TR (baht/kWh)	MR (baht/kWh)	Profit (baht/kWh)
The base case	0.22	0.61	0.83	0.83	1.41	1.41	0.58
The maximum price	0.22	1.19	1.41	1.41	1.41	1.41	-

Table 9. The costs, revenues, and profits of rice husk power generation at the reasonable price of rice husk at rice mill.

TFC (baht/kWh)	TVC (baht/kWh)	TC (baht/kWh)	TR (baht/kWh)	Gross profit (baht/kWh)	Operating cost (baht/kWh)	Net profit	
						(baht/kWh)	(% of TC)
0.22	1.01	1.23	1.41	0.18	0.05	0.13	10

Table 10. The fuel cost and saving cost of cement plant from using rice husk instead of lignite at rice husk prices of 200, 402, and 473 baht per tonne at rice mill.

Item	Unit	Rice husk price at rice mill (baht/tonne)		
		200	402	473
Lignite price	Baht/0.17 tonnes	153.00	153.00	153.00
Rice husk price	Baht/0.22 tonnes	93.92	137.59	152.95
Saving cost	Baht	59.08	15.41	0.05
	%	38.62	10.07	0.04

government. Nowadays, it reveals that the problem is the high price of rice husk in the C&NE regions because of the high demand. The results of the analysis also suggest a solution that the government should limit the total installed capacity of additional SPPs in the C&NE regions at 20 MW and promote new SPPs investors in the N&S regions. By this strategy, the problem of high price of rice husk in the C&NE regions could be solved. Then the rice husk demand and its price in the N&S regions will increase. Cement plants can also reduce the production cost by using rice husk instead of lignite. However, though the present rice husk is more valuable than in the past, farmers do not get any benefits because the revenue from selling rice husk is obtained by rice mill owners. So this is the challenge for the government to find out how to distribute this benefit back to farmers. The farmer co-operative organization would be an alternative because this organization can collect paddy from farmers and sell to rice mills and then take rice husk back and sell to SPPs or cement plants directly. As a result, local farmers can get the revenue from selling rice husk. In addition, one of the serious problems of power plant construction in Thailand is the local public resistance due to high pollution from the existing fossil-fired power plants. To solve this problem, public awareness of the local people is needed. The participation in the development of an infrastructure project, environmental impact assessment, and social impact assessment from the local people are important. Furthermore, as Thailand has high potential in using renewable energy, it is believed that the power production cost per kWh from renewable energy

technologies in the future will be cheaper than the fossil-based technologies. Therefore, the research and development of renewable energy technologies should be paid more attention to. Finally, the use of renewable energy can also reduce CO₂ emissions.

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