Impact of Crude Palm Oil Co-firing on Electricity Generation Cost in Krabi Power Plant

Apinya Puapattanakul and Athikom Bangviwat

***Abstract*—Thailand has been the third largest crude palm oil producer of the world after Indonesia and Malaysia. Both countries have a combined output of 85% of global production and play a significant role in dominating the world palm oil market in supply and price. As a result, it is not a convenient channel for Thailand to export its excess in supply of crude palm oil to the world market. An alternative to the export of crude palm oil is to increase in the domestic consumption. As supported by the Alternative Energy Development Plan for 2015-2036 (AEDP2015) which targets the renewable energy consumption at 30% of total energy consumption or accounted about 39,300 ktoe by the year 2036, the Electricity Generating Authority of Thailand (EGAT) modified Krabi power plant to cope with crude palm oil and fuel oil co-firing. The impact of the higher cost of crude palm oil than fuel oil on the production cost of electricity generation was investigated. The sensitivities of the changes in the amount and price of crude palm oil on the electricity generation cost were also included in the study.**

***Index Terms*—Crude palm oil, electricity generation cost, Krabi power plant, policy.**

I. Introduction

Palm oil is the largest agricultural material used to produce vegetable oil. Most of the world palm oil producers take place almost entirely in Asia. Indonesia and Malaysia are the largest palm oil producers with 85% of the global production. Thailand ranks in the third place producer, representing only 3% of the world output [1]. Fig. 1 depicts supplies of crude palm oil from major producers in the world in the year 2013.

Oil palm production in Thailand has been continuously increased during 2014-2016 [1]. Further in 2017, oil palm plantation area and production in Thailand increased by 3% and 36.8% from 2016, respectively, due to the government promotion policy [2]. Most of the oil palm plantation areas in Thailand are located in the southern area as shown in Fig. 2 [1].

However, the major producers, Malaysia and Indonesia have played significant role in dominating the world palm oil market in supply and price due to their higher production yields and plantation areas. Therefore, palm oil products from Thailand are difficult to compete in the world market. As shown in Fig. 3, the prices of crude palm oil supplied by Thailand during January to July 2015 were much higher than those of crude palm oil supplied by Malaysia.

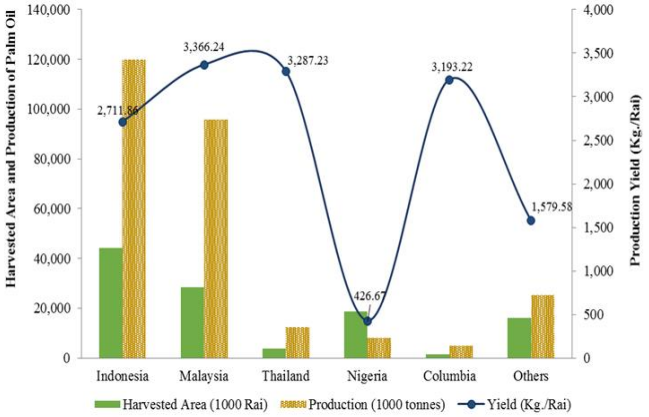

Fig. 1. Supplies of crude palm oil from major producers in the world in the year 2013.

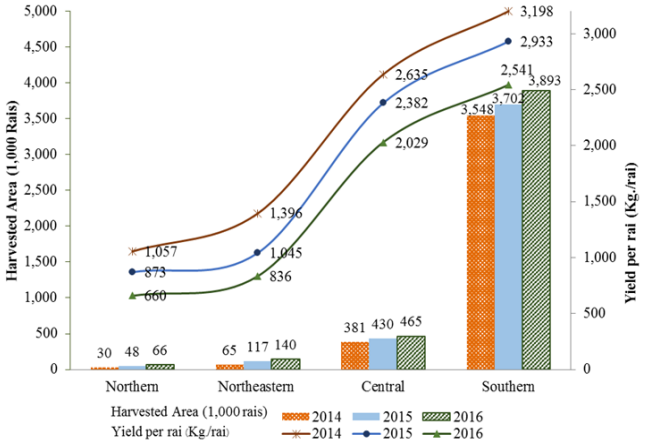

Fig. 2. Thailand's harvested area, production and yield per rai by region of oil palm.

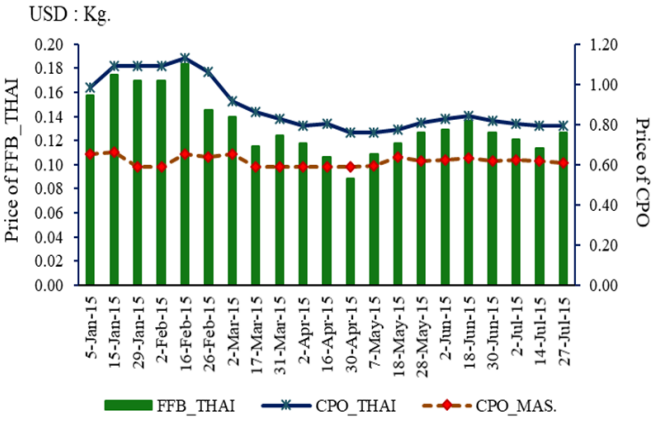

Fig. 3. Supplies of crude palm oil from Thailand and Malaysia and their prices [3], where FFB_THAI is fresh oil palm price of Thailand, CPO_THAI is Thailand crude palm oil price, and CPO_MAS is Malaysia crude palm oil price.

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In the past, Thailand faced a downturn in palm oil price and the Government had to divert significant money from the budget to subsidize palm oil prices. This problem has continued in recent years because of the uncertainty and inconsistency of supply to the domestic market and/or the world market. For this reason, the Thai Government proposed the policy to allow the Electricity Generating Authority of Thailand (EGAT) for using crude palm oil as a fuel to generate electricity in Krabi power plant, that would increase demand for crude palm oil (CPO) and crude palm oil prices. Krabi power plant is a thermal power plant located in Nuea Khlong District, Krabi Province, the south of Thailand and designed with a capacity of 315 MW and fired by using fuel oil. During 2013-2015, 10,000 tons per year of crude palm oil were fired in the power plant and then increased to 15,000 tons per year after 2015. This policy is in line with the Alternative Energy Development Plan for 2015-2036 (AEDP2015) which targets the renewable energy consumption at 30% of total energy consumption or accounted about 39,300 ktoe by the year 2036 [4]. Fig. 4. presents Krabi power plant housing a thermal 315 MW generating unit which was designed to use both of CPO and bunker oil as fuel.

Fig. 4. Krabi power plant.

Likewise Indonesia who the world's biggest palm oil producer, Indonesia's government target to reduce fuel oil consumption by replacing with renewable energy source to achieve the target of greenhouse gas emission reduction. Petr Procházka and Vladimír Hönig [5] present the results of economic analysis of diesel-fuel replacement by crude palm oil in Indonesian power plants. The results show that use of CPO instead of diesel can be prospective in Indonesia with lower price of CPO and decreasing of diesel subsidies by the government. Base on the data of 0.75 MW power plant, economy of a CPO power plant in Indonesia presents approximately 4 years payback period and return on investment at 23.2%.

EGAT invested US$1.44 million in the modification of Krabi power plant to facilitate the use of crude palm oil in the fueling process. The facility comprises 1.5 million liter crude palm oil tank, CPO main pump, CPO pipeline tired-in with fuel oil (FO), and CPO heater for preheating as shown in Fig 5 [6].

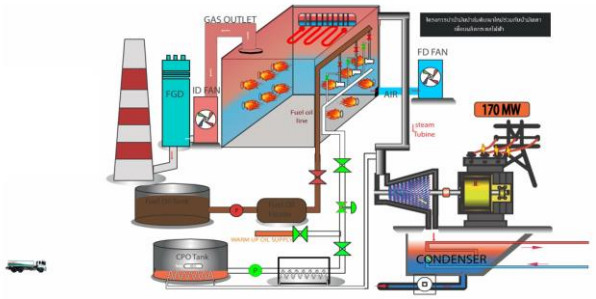

Fig. 5. Facility for co-firing with crude palm oil.

However, utilization of CPO as mixing fuels in power plant may have an impact on palm oil demand and supply and electricity generation cost. Thus, this paper aims to evaluate the impact of crude palm oil co-firing on electricity generation cost in Krabi power plant. Moreover, the sensitivity of the changes in the amount and price of crude palm oil on the electricity generation cost are also included in the study.

II. Objectives

1. To determine palm oil demand and supply functions, and
2. To investigate the impact on electricity generation cost in Krabi power plant when co-firing with crude palm oil.

III. Methodology

This study utilized secondary information from public and private agencies. The relevant data included plantation area, productivity, demand, and supply of crude palm oil, etc. The impacts of related factors on palm oil demand and supply were analyzed by using quantitative analysis. The 20 years (1997 to 2016) data was collected and input in the work, as provided in Table I.

This study was focused on using the regression technique to examine the factors affecting the palm oil productivity, price behavior, and domestic consumption by apply from the report of Demand and Supply model for crude palm oil in Thailand [7] as follows:

A. Harvested Area of Oil Palm in the Year (A_t)

The desired oil palm plantation area in year t is related to the last 2 years of the real domestic price of palm oil and the actual plantation area in the previous year. The equation can be proposed as follows:

$$A_t = a_0 + a_1 A_{t-1} + a_2 [PCPO/CPI]_{t-2} + a_3 TIME_t \quad (1)$$

B. The Uield of Palm Oil Product (Y_t)

Palm oil product per area is a function of time, price of palm oil, and consumer price index. In order to identify the significant factor affecting crude palm oil production, the equation is developed as follows:

$$Y_t = b_0 + b_1 [PCPO/CPI]_{t-1} + b_2 TIME_t + b_3 [PCPO/CPI]_t \quad (2)$$

TABLE I: PLANTATION AREA, PRICES OF CRUDE PALM OIL, PRODUCTIVITY, DEMAND OF CRUDE PALM OIL, CONSUMER PRICE INDEX (CPI), AND MANUFACTURE PRICE INDEX (MPI) DURING 1997 TO 2016

Year	*Plantation Area*	*Y-COP*	*QCOP*	*DCPO*	*PCPO*	*PCPO*	*MPI*	*CPI*
	(1,000 Rai)	(Kg. per rai)	(1,000 tones)	(1,000 tones)	(Baht/Kg.)	(USD/Kg.)		(2015=100)
1997	1,109.32	432.88	480.20	440.49	16.60	0.50	91.95	66.10
1998	1,284.31	274.17	352.12	379.57	26.47	0.80	83.40	69.00
1999	1,345.13	526.31	707.95	536.11	18.99	0.58	93.69	69.40
2000	1,437.83	403.08	579.56	582.51	12.92	0.39	100.00	70.50
2001	1,517.83	514.15	780.39	668.08	10.86	0.33	100.00	70.90
2002	1,643.86	390.31	641.61	640.75	17.29	0.52	109.80	72.10
2003	1,799.39	480.07	863.84	725.00	18.26	0.55	123.90	73.40
2004	1,935.09	424.19	820.84	770.50	20.17	0.61	137.60	75.50
2005	2,026.20	433.07	877.48	816.00	16.89	0.51	149.90	79.90
2006	2,374.20	491.59	1,167.13	861.50	15.77	0.48	159.50	82.80
2007	2,663.25	418.88	1,115.58	907.00	24.45	0.74	172.40	85.30
2008	2,884.72	535.15	1,543.76	1,265.00	28.96	0.88	179.10	85.70
2009	3,188.83	421.86	1,345.25	1,290.70	24.33	0.74	166.30	88.70
2010	3,385.00	380.36	1,287.51	1,394.00	29.10	0.88	190.30	91.40
2011	3,565.00	513.93	1,832.15	1,273.21	34.12	1.03	172.90	94.70
2012	3,700.51	511.36	1,892.30	1,558.64	30.86	0.94	181.60	98.10
2013	3,773.12	565.91	2,135.25	1,679.24	25.24	0.76	175.70	99.70
2014	4,023.82	497.17	2,000.52	1,781.77	28.57	0.87	167.70	100.30
2015	4,297.39	481.38	2,068.66	1,797.68	27.33	0.83	188.20	100.00
2016	4,563.90	473.57	2,161.34	1,810.00	31.95	0.97	191.20	100.60

C. Demand for Palm Oil Product ($DCPO_t$)

Palm oil is widely utilized in food and non-food products, such as cooking oil, shortenings, margarine, and as a feedstock for biofuel. Palm kernel oil is primarily used as a raw ingredient within a wide range of consumer products, including soaps, cosmetics, candles, and detergents. The domestic consumption of palm oil can be specified as a function of previous year consumption, domestic price, consumer price index, and manufacture production index. The equation is shown as follows:

$$DCPO_t = c_0 + c_1\, DCPO_{t\text{-}1} + c_2\, [PCPO/CPI]_t + c_3\, MPI \quad (3)$$

D. Crude Palm Oil Product ($QCPO_t$)

The product of crude palm oil relates to harvest area and yield of palm oil product as shown in (4).

$$QCPO_t = A_t \times Y_t \quad (4)$$

where:

A_t is the desired oil palm area in year t (rai),
Y_t is a yield of palm oil product in year t (kilogram/rai),
$PCPO_t$ is the real domestic price of crude palm oil,
$DCPO_t$ is the domestic demand for crude palm oil,
$QCPO_t$ is the amount of crude palm oil product,
CPI is the consumer price index,
MPI is the manufacturing production index,
a_0, a_1, a_2, a_3 are estimated coefficient of harvested area,
b_0, b_1, b_2, b_3 are estimated coefficient of yield of palm oil,
c_0, c_1, c_2, c_3 are estimated coefficient of palm oil demand.

E. Electricity Generation Cost in Krabi Power Plant

The impacts of using crude palm oil for co-firing in Krabi power plant on the electricity generation cost and the demand of crude palm oil are investigated. The sensitivities of the impacts are also analyzed to demonstrate the effects crude palm oil price and its demand.

IV. RESULTS

A. The Relationship between Palm Oil Product and Demand

With an application of data in Table I, the relationships among the parameters of interest in (1) - (4) can be determined as follows;

$$A_t = 344{,}303 + 0.753\, A_{t\text{-}1} - 188{,}705\, [PCPO/CPI]_{t-2} + 55{,}914.2\text{TIME}$$

$$Y_t = 694.804 - 0.504\, Y_{t-1} + 302.001\, [PCPO/CPI]_{t-1} + 9.479\, TIME - 662.785\, [PCPO/CPI]_t,$$

$$DCPO_t = -130{,}234 + 0.836\, DCPO_{t\text{-}1} - [\text{PCPO/CPI}]_t + 2{,}588.94\, MPI.$$

As a result of the above relationships, the projection of palm oil products and domestic demands in the year 2017 to 2022 can be estimated as shown in Fig 6. The demand for crude palm oil from 2017 to 2022 ranges from 1,873,992 tons to 2,332,490 tons, and the excesses of the supplies over the domestic demands of crude palm oil are between 565,370

tons and 715,687 tons in the same period.

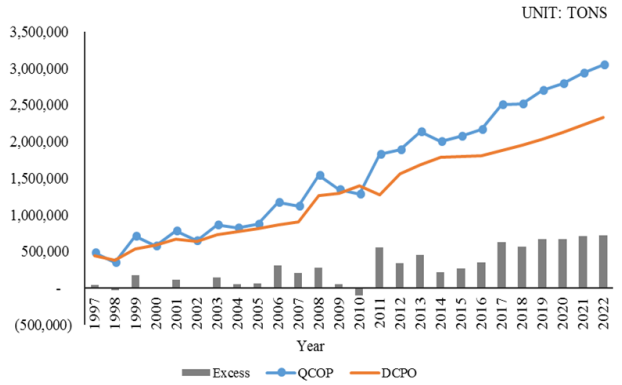

Fig. 6. Relationship between crude palm oil product and demand in the year 1997 – 2022.

B. *Electricity Generation Cost in Krabi Power Plant*

During 2013-2015, 10,000 tons per year of crude palm oil were fired in the power plant and then increased to 15,000 tons per year after 2015. As reported by EGAT [8], at 100 megawatts (MW) of electricity production, the electricity cost was increased from 3.45 Baht/kWh to 4.44 Baht/kWh or 0.15%, when 10,000 tons of crude palm oil was used to co-fire in the electricity production process. At the time the prices of crude palm oil and fuel oil were 23.95 Baht/liter and 13.86 Baht/liter respectively. It can be calculated that if all the excesses in the supplies of crude palm oil in 2018-2020 are used in the Krabi power plant with full load at 315 MW and 233 days per year, the costs of electricity generated will equal 8.65, 10.01, and 10.04 Baht/kWh in 2018, 2019, 2020 respectively, assuming the prices of crude palm oil and fuel oil are unchanged.

However, the sensitivity of the cost of electricity generated from Krabi power plant due to the changes in the amount of crude palm oil use for the substitution of fuel oil and the price of crude palm oil, can be analyzed as shown in Fig. 7.

There are two variables for this analysis including crude palm oil price and the amount of crude palm oil to estimate the production cost. Fig 7 shows the relationship between the amount of CPO and price effect on electricity production cost.

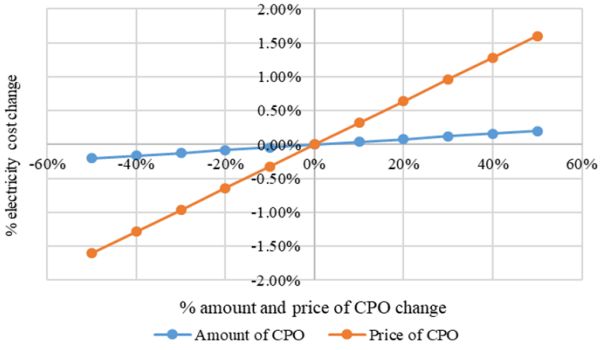

Fig. 7. Sensitivity analysis on electricity generation cost.

The results show that increase 50% of the amount of CPO in Krabi power plant from 10,000 tons per year to 15,000 tons per year affects the production cost of electricity up to 0.2%. If the CPO price is increased by 50%, then the production cost rise up to 1.6%.

V. Conclutions and Recommendations

1. Instead of a continuous increase in oil palm plantation area over the year, the productivity should be increased in order to lower the production cost of crude palm oil for competing in the world market.

2. The amount of crude palm oil used to generate electricity remains small, thus using palm oil as co-firing fuel can temporary absorb palm oil excess in supply, but does not significantly affect palm oil price in the market.

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References

[1] OAE yearbook, "Agricultural statistics of Thailand 2016," *Office of Agricultural Economics (OAE), Ministry of Agriculture and Cooperatives*, pp. 34-35, March 2017.

[2] S. Preechajarn, "Thailand oilseeds and products annual 2018," *Gain Report Number: TH8047, USDA Foreign Agricultural Service*, March 21, 2018.

[3] Prices situation of palm oil (FFB). Thai crude palm oil (CPO_THAI), and Malaysia crude palm oil (CPO_MAS). *Office of Agricultural Economics (OAE). Ministry of Agriculture and Cooperatives*. [Online] Available: http://www.oae.go.th/download/hotpalm/CPO_T-CPO_M.pdf

[4] K. Chatinun, *Crude Palm Oil – Fuel Oil Mixed Firing Project at Krabi Power Plant Helping Palm Oil Farmers in Krabi Province.*

[5] P. Procházka and V. Hönig, "Economic analysis of diesel-fuel replacement by crude palm oil in Indonesian power plants," *MDPI Journals. Energies 2018*, February 27, 2018.

[6] Krabi Power Plant. Corporate Communications Division. Electricity Generating Authority of Thailand (EGAT). [Online]. Available: http://www.egat.co.th

[7] S. Prasethanon and S. Techasripracert, "Demand and supply model for crude palm oil in Thailand," *Agricultural Development Policy and Planning Division, Office of Agricultural Economics (OAE), Ministry of Agriculture and Cooperatives*, April 2005.

[8] Krabi Power Plant, *Group Interview*, 17 May, 2018.

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