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Assessment and Improvement of Energy Utilization in Crude Palm Oil Mill

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Abstract. This paper assessed the energy utilization efficiency and determined the potential of improvement in a selected crude palm oil (CPO) mill in Thailand. Data collections as well as on-site measurement of related parameters were conducted throughout the year 2009. The annual average energy consumption per ton of fresh fruit bunch (FFB) of the CPO process was 0.42 ton of steam and 17 kWh per ton of FFB. The overall energy utilization efficiency of the mill was 54.6%. The largest fraction of energy loss was found to occur at the steam boiler, which has the current efficiency of around 60%. The major energy losses at the boiler were 17.5% through the hot flue gas and 14% through moisture in flue gas (half of which was the fuel moisture). The proposed energy efficiency improvement by the recovery of flue gas to reduce moisture in boiler fuels showed that the average moisture in the fuels could be reduced from 35.5% to 17.5%, which was expected to consequently increase the thermal efficiency of the boiler by about 7% or equivalent to 2,776 tons/year of fuel saving. Based on the current selling price of fuels, the additional income by selling the surplus fuels would be 3,506,593 baht/year, which gave a payback period of 1.51 years.

Keywords: Crude palm oil mill, Energy utilization, Efficiency, Biomass

1. Introduction

Palm oil industry is one of the major agro-industries of Thailand and Southeast Asian region. This is owing to the optimum climate for oil palm plantation. In Thailand, most of palm oil factories are located in the southern part, producing more than 1.4 million tons a year of crude palm oil to be used for cooking oil manufacture, biodiesel production and the rest exported [1]. At present, the area of oil palm plantation in Thailand is 3.6 million rais (or 576,000 hectares in equivalence), producing 9.26 million tons of fresh fruit bunch (FFB) annually at the productivity of 3.22 tons/rai [1]. There are in total crude palm oil factories in Thailand, most of which are located in the southern part of Thailand [2].

Apart from the feedstocks price, the efficiency of the production process is the other important factor that strongly affects the cost of crude palm oil produced. Therefore, the improved overall production efficiency can lower the production cost to be more competitive to the world and increase the business profitability. Efficiency improvement of process units and waste minimization are examples of the means to improve overall efficiency. Utilizing wastes generated from the oil production process not only replaces the use of more costly and price vulnerable fossil fuels, but also reduce the impact to global warming.

The currently used technologies and the energy utilisation patterns for crude palm oil production in Thailand were adopted and continued for more than three decades. To improve energy utilization of crude palm oil mill, an assessment of the current practice is necessary in order to compare with the utilisation best practice. Several previous studies have reported the average and best practice values for energy consumption in palm oil factories. Vijaya et al. [3] conducted a life cycle inventory analysis of crude palm oil production from 12 palm oil mill case studies in Malaysia and found that the average consumption of electricity per ton

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of fresh fruit bunch (FFB) was 20 kWh and the steam consumption for the sterilizer (cooking of the fruits) was 0.5 ton. Chavalparit [4] conducted a survey of palm oil factories in Thailand and Malaysia with aim to find a representative of the best practice in clean technology of the crude palm oil industry. In term of production efficiency, the best practice of electricity and steam consumption for the CPO process was 17.87 kWh and 0.35 ton of steam per ton of fresh fruit bunch (FFB).

This study carried out an assessment of energy utilization efficiency of a selected crude palm oil mill in Thailand with an aim to determine the potential energy improvement and the possible energy cost saving. The findings from this study may be taken as a general guideline for energy auditing and utilization improvement in palm oil industry.

2. Methodology

A palm oil mill located in the southern part of Thailand was selected as a case study. The selected mill processes around 260,000 tons of fresh fruit bunch (FFB) annually and produces various kinds of palm oil products such as crude palm oil, crude palm kernel oil, palm olein, palm stearin, palm fatty acid distillate, etc.

The energy utilization efficiency was assessed based on the principle of mass and energy balance of each process within the constructed system boundary presented in Fig. 1. These processes include crude palm oil (CPO) production, refinery, fractionation, kernel oil (KO) production, tank farm, packing, water treatment, boiler and turbine. The energy utilized in the mill was in form of either or both electricity and steam depending on the process. Almost all electricity and steam were from the in-house boilers firing the process generated wastes including fruit fiber (FB), shell and empty fruit bunch (EFB), with a small proportion of electricity imported from the national grid. The inputs for the assessment were obtained from the available plant historical data and from the field measurement conducted onsite throughout the year 2009. The specific energy consumption, which is defined as the amount of energy consumed per unit of the processed raw material that is the fresh fruit bunch (FFB), was estimated and used as an indicator of energy efficiency for each process of the plant. The overall energy utilization efficiency of the palm oil mill was determined as the proportion of extracted energy from fuels in forms of useful thermal energy and electricity, and the energy losses were estimated by energy balance of the system.

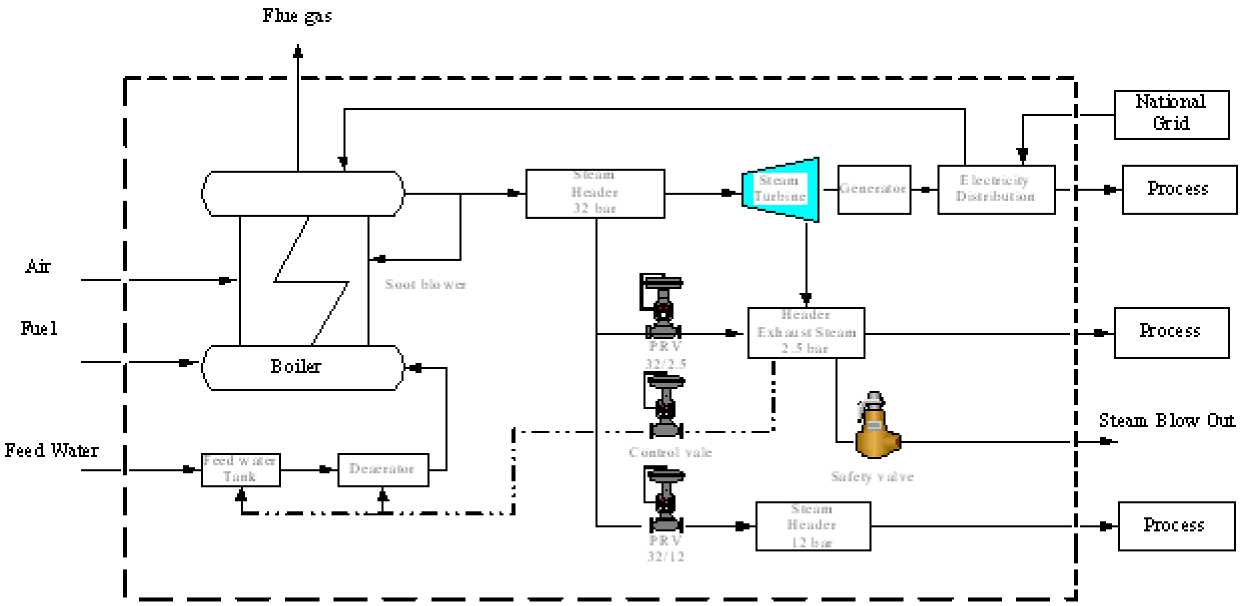

Fig. 1: System boundary for the analysis of the selected palm oil mill

The energy use under the current practice was taken as the energy utilisation baseline for this crude palm oil mill and then compared with the energy uses in other crude palm oil mills reported in various literatures especially the best practices. To identify the potential for energy efficiency improvement in each process, the energy efficiency improvements and estimated cost saving were considered. In general practice, the energy efficiency improvement is implemented via either or both process control and energy management to reduce the energy consumption, while maintaining the quality of products.

3. Results and Discussion

3.1 Characteristics of the raw material and energy consumption for the selected palm oil mill

In this study, the energy consumed is in form of electricity and steam at 2.5, 12 and 32 bars. The average electricity and steam consumption per unit of raw material were calculated for the six production processes including the CPO and KO production processes, two refinery and two fractionation processes and are presented in Table 1. All the high pressure steam (32 bars) was used to drive the steam turbine. The medium pressure steam was used for KO production and the two refinery plants; while the low pressure steam was used at various processes, especially at the CPO production process. The major consumption of electricity and steam was at the CPO process. The CPO process had the specific energy consumption of 17 kWh of electricity and 0.42 ton of low pressure steam per ton of FFB. Compared to the energy consumption values regarded as the best practice of the crude palm oil industry in Thailand reported in [4], this studied CPO process consumed lower for electricity but slightly higher for steam. The average electricity consumption of the kernel oil (KO) plant was 55 kWh per ton of kernel (KN) or 110 kWh per 10^3 liter of KO. This was higher than the average high-range value for KO factories in Nigeria, i.e. 97.22 kWh per 10^3 liter of KO [5]. This was due to additional electricity consumed by the pneumatic conveyor system equipped in the KO process of the selected plant for this study, apart from the solvent extraction system which was the energy consuming process common for both cases. The Refinery 1 process was better than the other in term of average electricity consumption. The latter used the ammonia chiller as the condensing system to separate the free fatty acids from crude palm oil instead of a vacuum system as being used in the former and therefore consumed more electricity. The newer Fractionation 2 process consumed more electricity for the crystallization tank; while the Fractionation 1 process utilized cooling from absorption chiller and therefore consumed more steam.

Table 1: The annual average electricity and steam consumption per unit of raw material (as of 2009)

Process	Electricity consumption	Steam consumption	
		Low pressure (2.5 bar)	Medium pressure (12 bar)
	kWh/raw material	Tons/raw material	Tons/raw material
CPO production	17.00	0.42	-
KO production	55.00	-	0.38
Refinery 1	23.30	-	0.29
Refinery 2	34.00	0.11	0.10
Fractionation 1	15.30	0.33	-
Fractionation 2	20.00	0.18	-

3.2 System analysis based on mass and energy balance

The details of mass and energy balance of all major processes within the constructed system boundary (presented in Fig. 1) can be found in Sommart [6]. In this paper, only the overall energy balance and selected analyses including the mass distribution of steam utilization and energy balance of the boiler are reported.

The mass balance focusing on the distribution of steam is shown in Fig. 2. The boiler produced 217,617 tons per year of high pressure steam at 32 bars, and around 80% of which was supplied to the steam turbine for power generation. The exhaust low pressure steam from the turbine rear was distributed to other processes, most of which was used by sterilizers in the CPO production process. For the rest of the high pressure steam from the boiler, the pressure reducing valve, PRV 32/12 and PRV 32/2.5 reduced the steam pressure from 32 bars to 12 and 2.5 bars, respectively, for use in other processes. The steam blow out from the system accounts for 0.37% steam loss.

The energy balance of the boiler is shown in Fig. 3. The efficiency of the boiler was about 60% (on the GCV basis), which is considered rather low compared to the typical efficiency of new biomass boilers. The value was also lower than the average boiler efficiencies for seven selected palm oil mills in Malaysia [7]. The major energy losses were found to be via flue gas 17.45%, evaporation of inherent moisture in boiler fuel 7.28% and evaporation of fuel hydrogen derived moisture 6.79%. The rest was attributed to fouling and sintering of burned fuels, incomplete combustion, etc. Recovery of these energy losses can therefore improve the boiler efficiency, and an option proposed here was a recycle of the hot combustion flue gas to dry the fuels before feeding into the boiler.

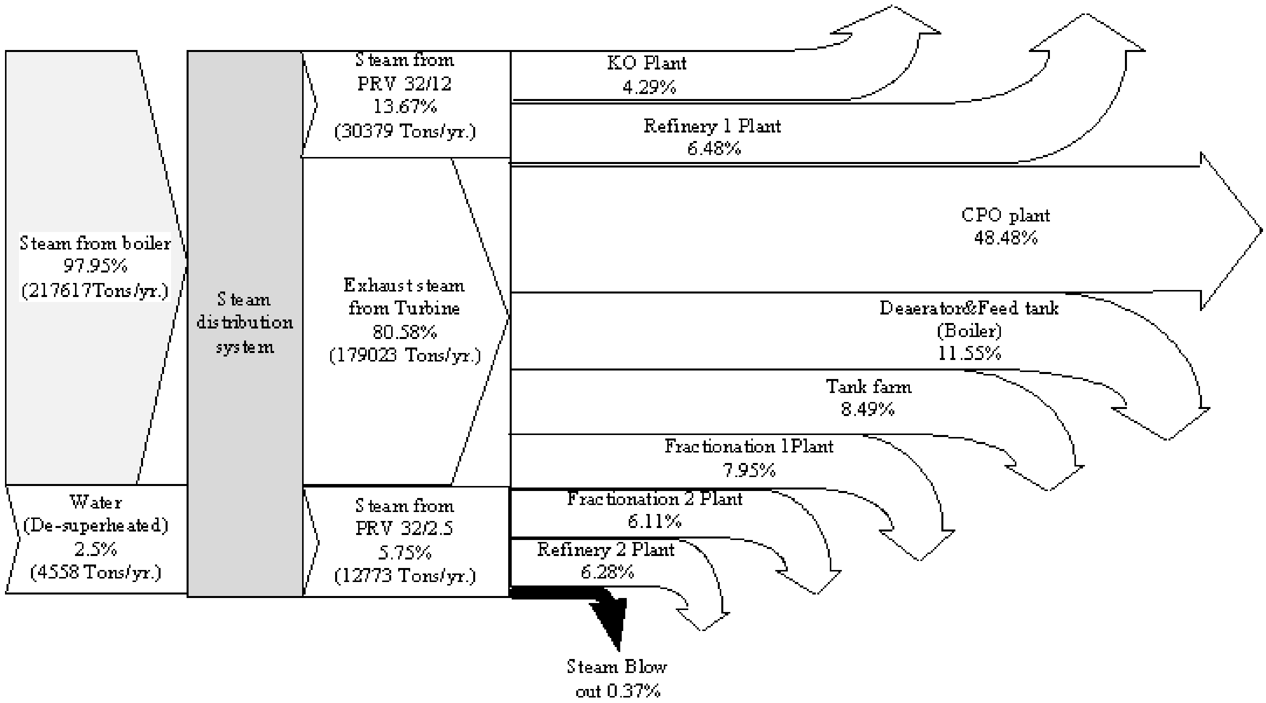

Fig. 2: Shanky diagram of the balance of steam system

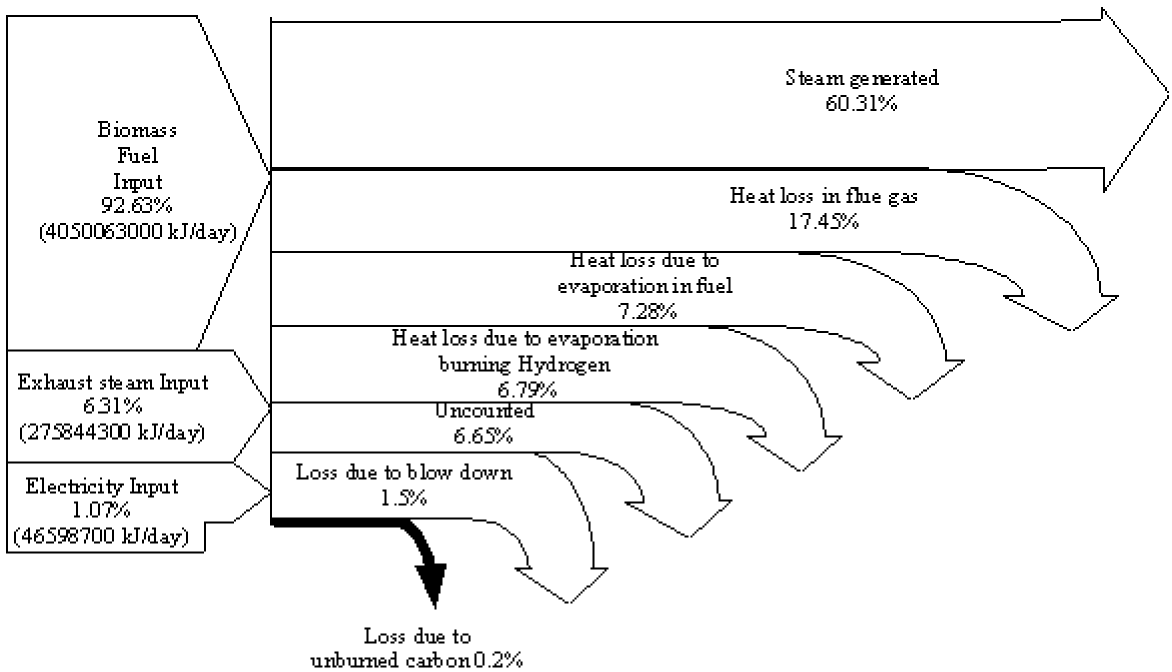

Fig. 3: Shanky diagram of the energy balance of the boiler system

The overall energy balance of the mill is summarized in Fig. 4. As mentioned earlier, almost all the total energy consumption or around 1 million GJ/year was produced from the plant generating wastes and only 0.3% in form of electricity was purchased from national grid. The highest energy consuming process was the CPO production or about 29.10% of the total energy input to the system. The largest energy loss occurred in the boiler process, accounting for 42.6% of the total energy input. This is due to the low efficiency of the boiler, i.e. only about 60%. Increasing the boiler efficiency, therefore, has a high potential for the energy efficiency improvement of the mill.

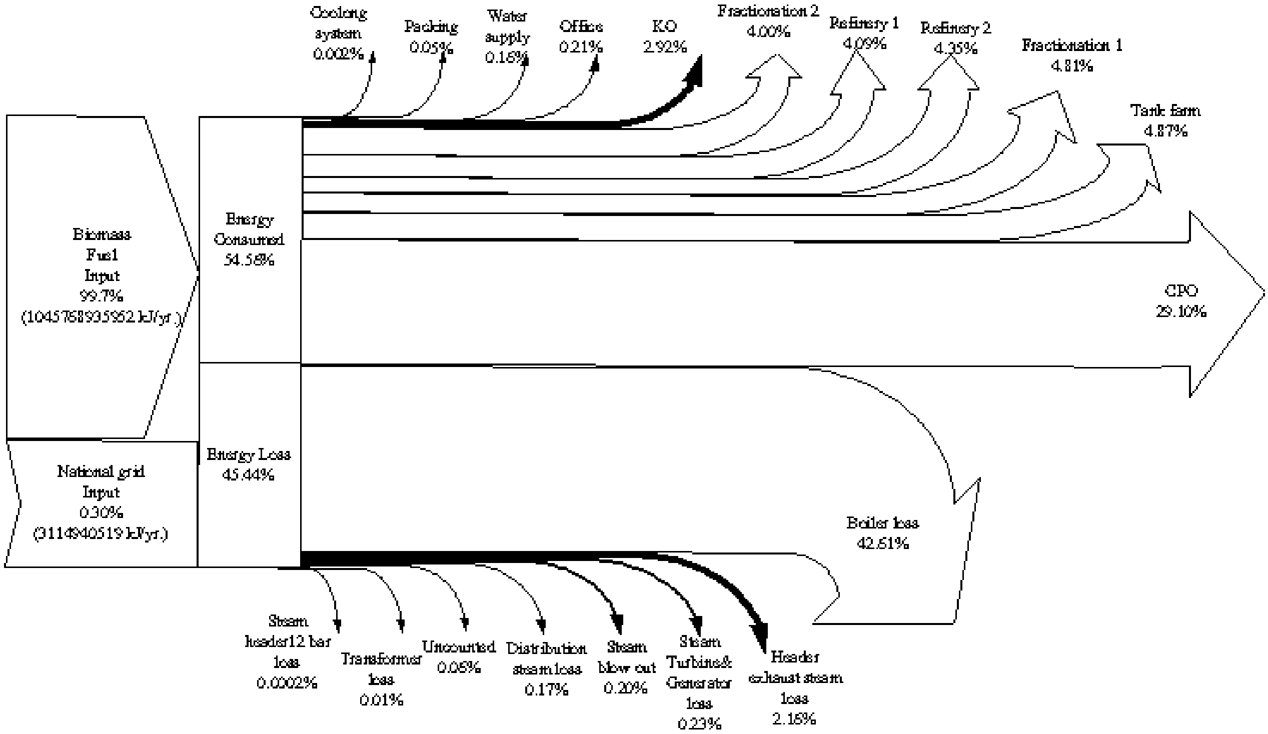

Fig. 4: Shanky diagram of the energy balance of the selected palm oil mill

3.3 Estimation of the Potential Energy Cost Saving from Recovery of Heat Loss from Boiler

From the energy analysis of the system, the potential energy efficiency improvement at the boiler was significant. Here, the recovery of the heat loss through the hot flue gases for drying the boiler fuels was proposed. The potential for energy efficiency improvement and energy cost saving compared to the current practice which was taken as the baseline was then assessed assuming that the quality of products will not be altered.

The energy recovered from hot flue gas was assumed to be used for moisture removal from the two high moisture fuels used for the boiler, that are fruit fiber and empty fruit bunch. The current moisture content of boiler fuels is excessively high, i.e. 35.54%, or 28,271 tons/year based on the annual fuel consumption of 79,547 tons of wet FFB. A huge amount of produced energy (both sensible and latent heat) must be partially used to evaporate the inherent moisture in the fuels. If all the heat loss through the flue gas at 36,389,675MJ/year could be recovered and fully used for pre-drying the wet fuels, the 14,278.3 tons/year of moisture could be removed from the fuels or the reduction of fuel moisture content to about 15% (wet basis). Regarding the energy efficiency improvement, the boiler efficiency was estimated to increase by about 7% and hence a significant fuel cost would be saved.

At the current fuel mixed proportion of empty fruit bunch, fruit fiber and shells fed to the boiler at 34:45:21, the potential heat recovery of 36,389,675 MJ/year would be equivalent to a fuel saving of 2,776.4 tons/year. Since the supply of fuels in this mill is always in excess, the fuel saving would mean an additional income. Assuming the selling prices of surplus fuels at 2,500 baht/ton of shell, 450 baht/ton of EFB and 1,300 baht/ton of fruit fiber, the price of fuel mixture was 1,263 baht/ton or the annual fuel cost saving of 3,506,593 baht/year. For the fuel drying system installation, most of the expenses would be investment and operation of a rotary dryer. The simple payback period was then calculated based on the following assumptions [8]:

1. An investment of a rotary dryer with a capacity of 12 tons of fuel/hour = 4,000,000 baht
2. Operating and maintenance cost (excluding electricity) = 400,000 baht/year
3. Electricity cost (22 kW x 7008 h x 3 baht) = 462,528 baht/year

The calculated payback period was 1.51 year, which is generally considered attractive for further implementation. The payback period has a tendency to decrease even more due to the continuous increase in fuel selling prices.

4. Conclusions

This study carried out an assessment of energy utilization efficiency of a selected crude palm oil mill in Thailand with an aim to determine the potential energy improvement and the possible energy cost saving. All technical data were collected throughout the year 2009 for the analysis. From the analysis, several conclusions can be made and summarized as following.

- Among the processes in the mill, the major consumption of electricity and steam was at the CPO production process. The specific energy consumption of the CPO process was 17 kWh of electricity and 0.42 ton of low pressure steam per ton of FFB. Compared to the energy consumption values regarded as the best practice in Thailand, this studied CPO process consumed lower electricity but slightly higher steam. The average electricity consumption of the kernel oil (KO) plant was 110 kWh per 10^3 liter of KO, which was higher than the average high-range value for KO factories in Nigeria.
- Almost all the energy consumed in this mill was derived from the process generating wastes with only 0.3% in form of electricity purchased from national grid.
- The overall energy utilization efficiency of the mill was 54.56%. The largest fraction of energy loss, i.e. 42.61%, occurred in the boiler system. This is due to the rather low efficiency of the boiler, i.e. about 60%, compared to the typical values found for other palm oil mills. The major energy losses of the boiler system were 17.45% through the hot flue gas and 14.07% through moisture in flue gas (half of which came from the fuel).
- The proposed energy efficiency improvement by the recovery of flue gas to reduce moisture in boiler fuels showed that the average moisture in the fuels could be reduced from 35.5% to 17.5%, which was expected to consequently increase the thermal efficiency of the boiler by about 7% or equivalent to 2,776 tons/year of fuel saving. Based on the current selling price of fuels, the additional income by selling the surplus fuels would be 3,506,593 baht/year, which gave a payback period of 1.51 years.

5. References

[1] Office of Agricultural Economics (OAE). Available at: http://www2.oae.go.th, 2009.

[2] Department of Industrial Works (DIW). Available at: http://www.diw.go.th, 2009.

[3] S. Vijaya, A.N. Ma, Y.M Choo, N.S. Nik Meriam. Life cycle inventory of the production of crude palm oil - A gate to gate case study of 12 palm oil mills. *Oil palm research*. 2008, 20: 484-494.

[4] O. Chavalparit. Clean Technology for the Crude Palm oil Industry in Thailand, *Ph.D. Thesis*, Wageningen University, The Netherlands, 2006.

[5] S.O. Jekayinfa, A.I. Bamgboye, M.Z. Abdullah. Energy use analysis of selected palm-kernel oil mills in south western Nigeria. *Energy*. 2008, 33: 81-90.

[6] K. Sommart. Assessment and Improvement of Energy Utilization in Crude Palm Oil Mill. *MEng Thesis*. The Joint Graduate School of Energy and Environment, King Mongkut's University of Technology Thonburi, Thailand, 2010.

[7] Z. Husain, Z.A. Zainal, M.Z. Abdullah. Analysis of biomass residue based cogeneration system in palm oil mills. *Biomass and Bioenergy*. 2003, 24: 117-124.

[8] Prachongkij Karnchang Co., Ltd., Available at: http://www.pck-Chainconveyor.com, 2009.