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ACCOUNT OF THE ENVIRONMENT THROUGHOUT THE LIFE CYCLE OF THE PRODUCTION OF ELECTRICITY FROM BIOMASS

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ABSTRACT

The main objectives of study were the accounting list of the carbon mass and greenhouse gases. They were CO_2 and CH_4. The GHGs were released from the production of electrical energy of biomass power plant. Life cycle inventory was used to assess the costs and environmental impacts of the use of biomasses in the production of electrical energy. The study found that the average of carbon dioxide and methane were released during 2007 to 2011 were 55,043.46 ton.CO_2 and 46,620.14 ton.CH_4, respectively. The environmental impact costs of CO_2 gas was 5.63 baht/ton.CO_2 and CH_4 gas was 6.65 baht/ton.CH_4 in 2007 to 2011. This research also studied to evaluate the production of electricity from mixed biomasses. The results showed that the electrical energy production with mixed biomasses, which they were mixed from rice husk and wood chips at a rate of 4 to 1, was the lowest of direct costs and the costs of environmental impact.

Keywords: biomass, electricity, environment, life cycle inventory.

INTRODUCTION

Energy is very important in today's society. Electrical energy is the infrastructure energy in order to develop the country to progress both the economy and society. Industry factories are necessary to use a large quantity of electrical energy for production. Electricity production requires natural resources. These natural resources are limited quantities such as crude oil, natural gas, coal, and forest. Proportion of raw materials for energy production in Thailand rely on the fossil fuels were 90 percent that they were imported from international as shown in Figure-1 and Figure-2. It made energy security of the country that was declining and impact to environments.

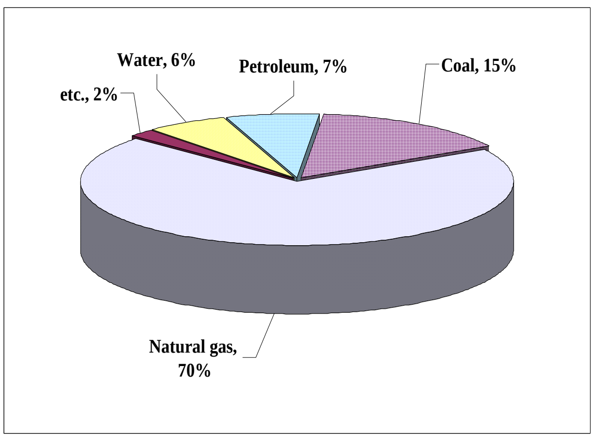

Figure-1. Fuel in electricity production of Thailand. (Prayong Keeratiurai *et al.*, 2012).

Table-1 shows that between the years 2007 to 2011, various sectors emitted greenhouse gas (GHGs) in the form of carbon dioxide equivalents (CO_2 eq.). It shows the potential to cause global warming.

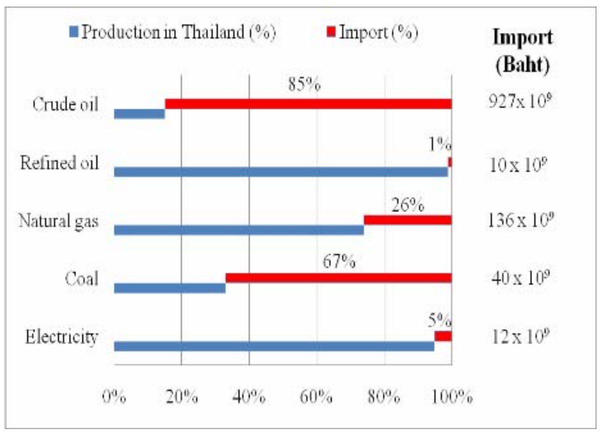

Figure-2. Proportional to the energy of 2011. (Source: www.efe.or.th/datacenter/ckupload/files/aedp25.pdf).

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Table-1. The amount of CO_2 eq. emission in 2007-2011

Sources of CO_2 release	**CO_2 eq. emission** (Megatons per year)				
	2007	**2008**	**2009**	**2010**	**2011**
Power sector	82.09	83.37	81.80	82.52	82.03
Transport sector	54.55	52.38	55.34	54.02	53.68
Industrial sector	42.32	45.02	42.79	44.11	43.97
Etc.	16.89	17.37	17.73	17.42	17.84
Total	195.85	198.15	197.66	198.06	197.51

Source: www.dede.go.th (2011)

Government set the power development plan of Thailand in 2010-2030. It was made to resolve the energy demand, which is likely higher and achieved energy security, social and economic. It was a support to purchase electricity from renewable energy production. As mentioned above, we had to find resources that could be used in the production of electrical energy with minimal environmental impact such as wood chips, cassava stalks, rice husks, bagasse, and cobs. These raw materials and waste were residues from agricultural products, also called biomass. Thailand had much agricultural wastes. The possibility will produce electrical energy from biomass in commercially. Surin Province is located in the northeast of Thailand. It has an area of 8124.056 square kilometers or 5, 077, 535 rais and has an area of approximately 3, 106, 432 rai for rice cultivation on season. Surin Province has much the rice cultivation so there is a lot of rice husk. The survey found that Surin province has enough rice husks that they were the main raw material for the production of electricity with small biomass power plants. Small power producer with biomass (SPP) was created which used rice husks and wood chips as raw materials in the production of electrical energy. Small biomass power plant had been classified in thermal power plant used the condensing Steam Turbine. It had the production capacity 9.9 megawatts (MW) and the boiler size 55T/h. Life cycle assessment (LCA) and the accounting of environment were tools that help in managing the environment. They were evaluating on the impacts related with the products and the production system. They were checked the life cycle of the product since the preparation of main raw materials, production processes, assembly, transportation, deployment, and disposal or recycle. Life cycle assessment enhanced our understanding of the relationship between human activity and the impact on the environment (Prayong Keeratiurai and Nathawut Thanee, 2013).

Electricity production from biomass could be done with the direct combustion and thermo chemical conversion. The rice husks were biomass from rice mills. One ton of paddy were rice husk about 220 kg. These main objectives of study were the accounting list of the carbon mass and greenhouse gases (GHGs). They were released from the production of electrical energy of biomass power plant. Life cycle inventory was used to assess the costs and environmental impacts of the use of biomasses in the production of electrical energy.

METHODOLOGY

The carbon emission evaluated from the production of electrical energy of biomass power plant. The small biomass power plant has a capacity of 9.9 megawatts (MW). The study would collect data and analyze the resources used to produce electrical power from 1 January 2007 to 31 December 2011. This study used secondary data of small biomass power plant in Surin province as a case study. The mass of carbon in the biomass that used in the production of electrical energy were analyzed.

The power generation evaluated environmental impacts with life cycle inventory. This study analyzed the use of several types of biomass, including rice husks alone, biomass mixed of rice husks with pieces of chopped wood in the ratio of 4 to 1 and 5 to 1. This study evaluated the accounting of GHGs as CO_2 and CH_4 from the production of electrical energy. This study analyzed the production of electrical energy since the biomass transport process into the burning process until it had power and ash.

This study also analyzed the direct and indirect costs of the small biomass power plant. The direct costs were the fixed costs and variable costs of the electrical energy production such as personnel, biomasses, transportation, and disposal ashes. The indirect costs were the environmental impact of the electrical energy production. Carbon emission from fuel combustion into the atmosphere was based on fuel consumption and the carbon content of the fuel elements (Phukij Phankasem *et al*., 2012). Evaluated CO_2 and CH_4 gases that were released could be calculated from the global warming potential with the form of the equivalent of CO_2 as Model 1 and Model 2 (IPCC, 1995 and 2001; Prayong Keeratiurai *et al*., 2012 and 2013).

CO_2 eq. from CH_4 = 21-25 time of kg.CH_4

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Total of CO_2 eq. = CO_2 eq. from (biomass combustion + transportation + using electricity and petroleum + disposal + environmental impact)

RESULTS

These main objectives of study were the accounting list of the carbon mass, CO_2 and CH_4 gases. They were released from the production of electrical energy of the small biomass power plant. Life cycle inventory was used to assess the costs and environmental impacts of the use of biomasses in the production of electrical energy. The results of this study showed electrical energy, carbon mass, GWP of GHGs and GHGs emission from the electrical energy production of the small biomass power plant (9.9 MW) in 2007 to 2011 as shown in Table-2 and Figure-3. While the power generated by the fuels of the Electricity Generating Authority of Thailand (EGAT) between the years of 2007 to 2011 that caused GHGs in CO_2 eq. form as shown in Table-3. The CO_2 eq. per year per unit of electrical energy (kg.CO_2 eq. / yr. / kWh) was compared between EGAT and this small biomass power plant in the year of 2007 to 2011 as shown in Figure-4. The results of comparison of this study showed the small biomass power plant emitted GHG_S less than EGAT for the electrical energy production.

Table-2. The Global warming potential of GHGs emissions of electricity production from the small biomass power plants 9.9 MW.

Years	Electrical energy (MWh)	Carbon mass (ton.C)	GWP of CO_2 (ton of CO_2/yr)	GWP of CH_4 (Megaton of CO_2 eq./yr)
2007	81.72	14,709.23	53,933.86	1.132
2008	79.36	14,284.79	52,377.57	1.099
2009	86.80	15,624.36	57,289.32	1.203
2010	82.28	14,809.50	54,301.50	1.140
2011	86.84	15,631.38	57,315.06	1.203
Average	83.40	15,011.85	55,043.46	1.155
S.D.	3.31	595.84	2,184.76	0.045

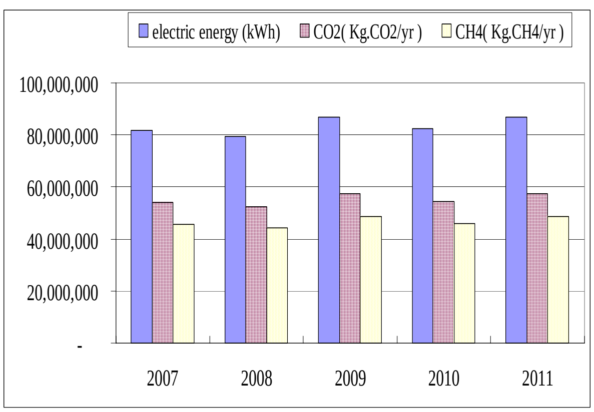

Figure-3. Comparison between GHGs emissions and electrical energy of the small biomass power plants 9.9 MW.

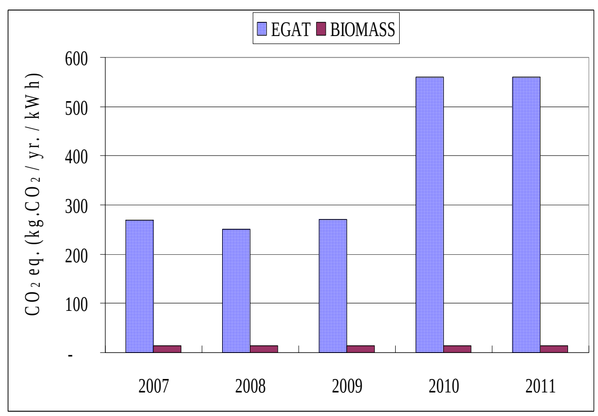

Figure-4. Comparison of CO_2 eq. emission per year per power (kg.CO_2 eq. / yr. / kWh) between EGAT and the small biomass power plant.

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Table-3. Global warming potential and CO_2 eq. emissions of electricity production from EGAT.

Years	**Electric energy** (MWh)	**Carbon mass** (Megaton of C)	**CO_2** (Megaton CO_2/yr)	**GWP of CO_2** (Megaton CO_2/yr)
2007	146.88	26.44	39.63	39.63
2008	148.20	26.68	37.02	37.02
2009	141.66	25.50	38.25	38.25
2010	74.33	13.38	41.57	41.57
2011	73.15	13.17	40.92	40.92
Average	116.84	21.03	39.48	39.48
S.D.	39.43	7.10	1.87	1.87

The results also showed mass of carbon that was released from the production of electricity with biomass varies according to the amount of biomass, fuel, diesel and electrical power. If they were used in large quantities, the mass of carbon would be emitted lot of in the form of GHGs and ashes. Production of electricity from biomass had air pollutants and most impacted on the environment was the fuel handling system. This process emitted CO_2 and CH_4 gases per year were 130,978.85 ton of CO_2/kWh/L/year and 497.82 ton of CH_4/kWh/L/year, respectively. This process also made the global warming potential from CO_2 and CH_4 per unit per year was 130, 978, 846 kg.CO_2/kWh/L/year and 2, 750, 555, 761 kg.CO_2 eq./kWh/L/year, respectively. The process cooling tower system emitted CO_2 and CH_4 less than the process of fuel handling system. This process emitted CO_2 and CH_4 gases per year were 3, 058.12 ton of CO_2/kWh/L/year and 2, 775.48 ton of CH_4/kWh/L/year. This process also made the global warming potential from CO_2 and CH_4 per unit per year was 3, 058, 121.088 kg.CO_2/kWh/L/year and 64, 220, 542.85 kg.CO_2 eq./kWh/L/year, respectively. The production of electricity from biomass process impacted less on environment was the process of plant system and water system. This process emitted CO_2 and CH_4 gases per unit per year were 22.21 ton of CO_2/kWh/L/year and 20.16 ton of CH_4/kWh/L/year. This process also made the global warming potential from CO_2 and CH_4 per unit per year was 22, 207.68 kg.CO_2/kWh/L/year and 466, 361 kg.CO_2 eq./kWh/L/year, respectively.

This research also studied total costs for the production of electricity from biomass. The results of this study showed the costs of personnel, fuel, environmental impact (indirect costs). The average personnel cost was 15, 892, 473.30 Baht per year. The average fuel cost was 100, 288, 139.08 Baht per year. The average of indirect costs from environmental impact was 2, 596, 582.070 Baht per year. The total costs were 118, 777, 194.45 Baht per year. The result also showed the costs of environment per unit of CO_2 and CH_4 emission were 0.00563 Baht per kg.CO_2 and 0.00665 Baht per kg.CH_4, respectively. Ashes caused from the biomass combustion of the small biomass power plant for electricity production. The average cost of ashes storage was 550, 279.242 Baht per year. The average cost of ashes to environmental impact was 1,247,929.24 Baht per year or 0.0957 Baht per kilogram of biomass. Revenue from ash sales was 387, 670.00 Baht per year.

The results showed assessment of the cost of using biomass in any types that they produced electrical energy. Production of electricity from rice husk alone emitted CO_2 gases were 113, 479.30 ton of CO_2 and CH_4 gases were 41, 124.65 ton of CH_4. The average costs of rice husk alone to environmental impact were 0.00273 Baht per kg.CO_2 and 0.00753 Baht per kg.CH_4. Production of electricity from biomass mixing with the ratio of 4 rice husks: 1 wood chips emitted CO_2 gases were 111, 320.81 ton of CO_2 and CH_4 gases were 40, 342.42 ton of CH_4. The average costs of biomass mixing with the ratio of 4 rice husks: 1 wood chips to environmental impact were 0.00278 Baht per kg.CO_2 and 0.00768 Baht per kg.CH_4. The results also showed the small biomass power plant produced electricity that was 83, 399, 184.00 kWh, total costs were 118, 777, 194.45 Baht, and cost per unit was 1.412 Baht per kWh in the year 2007 to 2011.

CONCLUSIONS

The mass of carbon that was released from the production of electricity with biomass varies according to the amount of biomass, fuel, diesel and electrical power. If they were used in large quantities, the mass of carbon would be emitted lot of in the form of GHGs and ashes. Production of electricity from biomass had air pollutants and impacted on the environment were the process of fuel handling system, the process of cooling tower system, and the process of plant system and the water system, respectively.

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