CHAPTER 6
GREENHOUSE GASES EMISSIONS FROM RESIDUE FOR ENERGY PRODUCTION

6.1 Introduction

Rice residue is a biomass that has a high potential for energy production [EFE, 2006]. Rice residue energy production is a way to reduce GHG emissions from open burning [Suramaythangkoor, T. and Gheewala, SH., 2010].

Rice residue can be converted to energy form as power/heat, transportation fuel by a conversion process, for example, thermal-chemical process and biological process [McKendry, P., 2002].

Combustion is one of thermal-chemical processes that transforms chemical energy in the rice residue into heat or power through the equipment as stove, furnaces, boiler, and so on. This method is suitable for dried residue (moisture content lower than 50%) [McKendry, P., 2002].

This part aims at to study the potential of unused rice residue for energy production and also estimate the GHG emission mitigation from unused rice residue for heat or power production by using thermal combustion technology.

6.2 Methodology

6.2.1 Potential of rice residue for heat or power production

The potential of rice residue is analysis on demand and supply of unused residue for heat or power production. The unused residue considered for heat or power production is only unused straw. Demand estimates from the installed capacity of the very small biomass power plant (VSPP). The location and installed capacity of biomass power plant is shown in Figure 6.1.

Provincial Electricity Authority (PEA) reports 110 very small biomass power plants in 41 provinces with total 1,183 MW of installed capacity (record on March 2009). The biomass very small power plant includes 102 biomass thermal combustion power plants in 39 provinces with total installed capacity 1,125 MW and 8 biomass gas engine power plants in 7 provinces with total installed capacity 57 MW. The fuel used in the plant is bagasse, husk, palm residue, cob corn, waster wood, and so on.

1 MW of thermal combustion power plant uses 6,138-10,080 tons of straw (based on 14%-26% of power plant efficiency, 5,600-6,500 hr/yr of operating hour) [Gadde, B., 2009]. The total straw demand for serving 1,125 MW of installed capacity is about 6.9-11.34 Mt.

1 MW of gas engine power plant uses 12,090-21,996 tons of straw (based on 9%-17% of power plant efficiency, 7,800 hr/yr of operating hour) [Gadde, B., 2009]. The total straw demand for serving 57 MW of installed capacity is about 0.69-1.25 Mt.

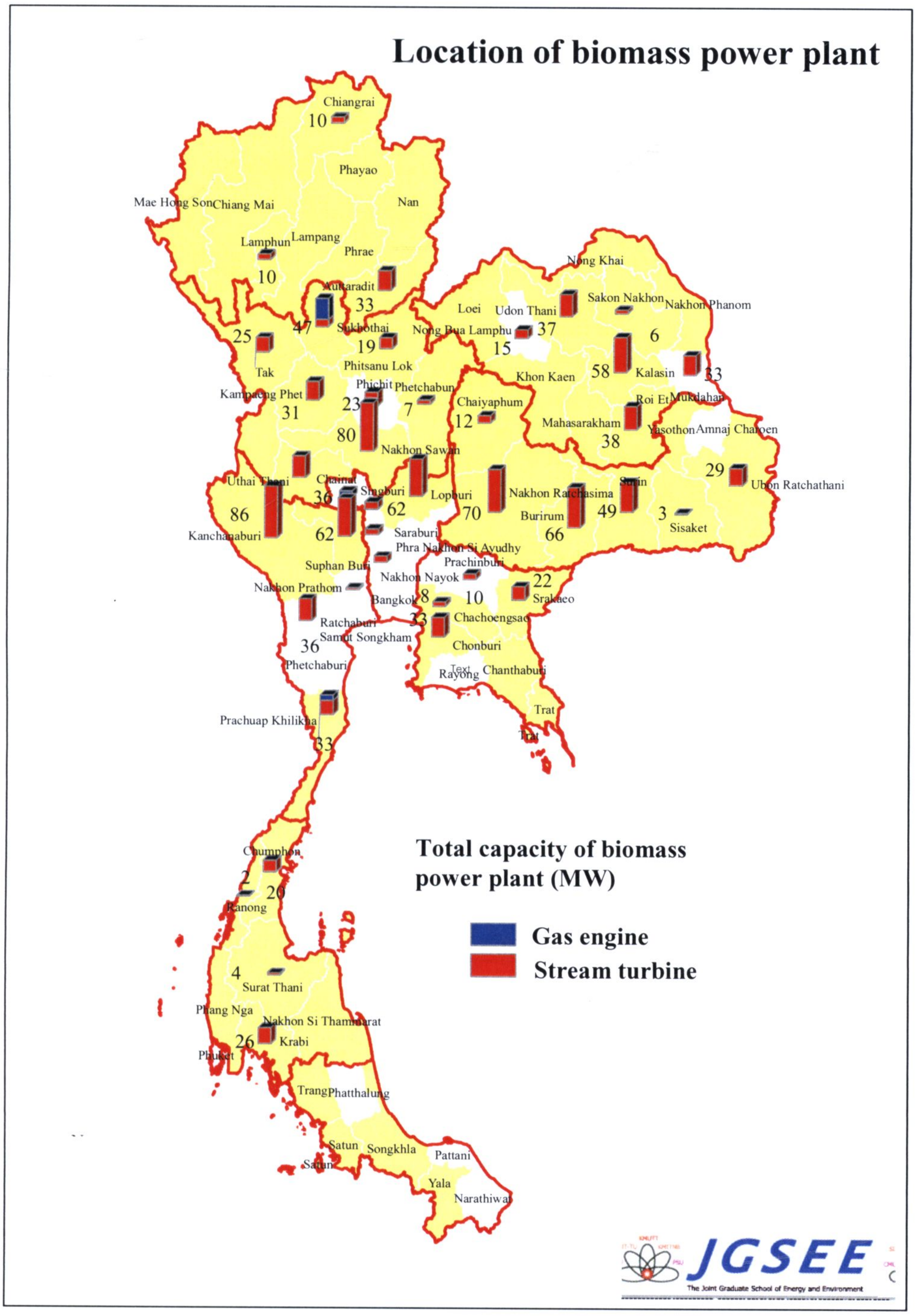

Figure 6.1 Location of biomass very small biomass power plant (VSPP)

Supply estimates from the amount of unused straw. The total amount of unused straw is about 30.8±7.47 Mt. The information of unused straw is shown in Chapter 4.

6.2.2 Estimation of emission from rice residue heat or power production

This study estimates emission from rice residue for heat or power production compared with the emission from coal/lignite for heat or power production. Based on 2006 IPCC guideline, the emission from heat or power production is estimates by using Equation 6.1.

$$Emissions_{GHG,fuel} = Fuel\ consumption_{fuel} \times Emission\ factor_{GHG,fuel} \quad \text{--- (Equation 6.1)}$$

Where:

Emission $_{GHG,\ fuel}$ = emissions of a given GHG by type of fuel (kg GHG)

Fuel consumption $_{fuel}$ = amount of fuel combusted (TJ)

Emission factor GHG, fuel = default emission factor of a given GHG by type of fuel (kg gas/ TJ)

Emission from rice residue for heat or power production

The system boundaries for heat and power production (Figure 6.2) included 3 phases; collecting phase, transport phase, and heat and power production phase.

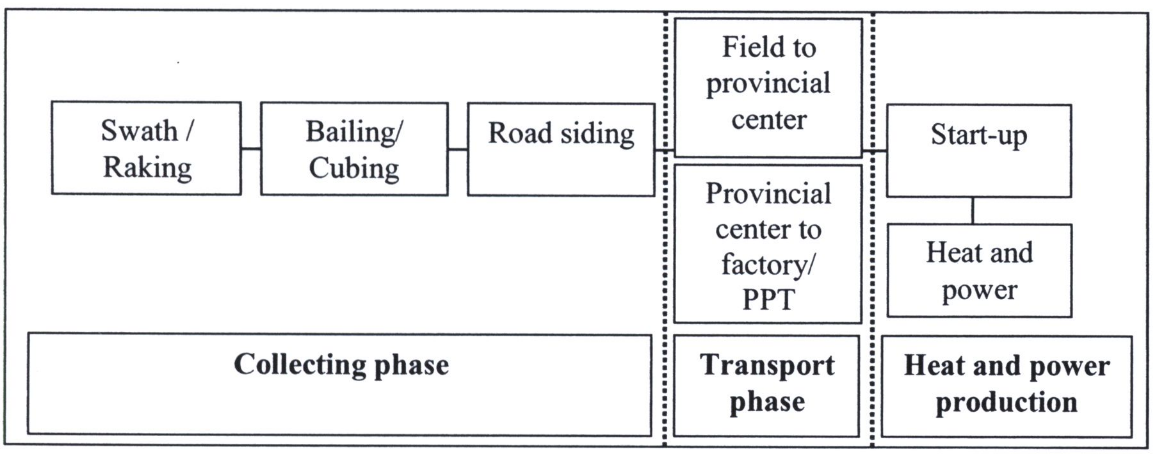

Figure 6.2 Process of heat and power production by straw

Collecting phase:

Collecting phase is the process of collecting rice residue. Rice residue in the field is baled by baler. The bale size is about 0.35×0.47×1.00 (m) weight 15-18 kg. The baler uses diesel as a fuel. The amount of diesel consumption varies on paddy area (irrigated area/

rain fed area). The rate of diesel consumption is about 13.75 L/ha for rain fed area and 22.19 L/ha for irrigated area [Chamsing, A. et al., 2005].

Transport phase:

Transport phase is the process of transport rice residue from the field to the source of heat or power production. Transport has 2 sub-processes: (1) transport from field to center of province (within province) and (2) transport from province center to heat or power production. The residue is transported by truck vehicle, 320 hp which consumption rate 4.7 km/l [Dongbang, W. and Sirisenapan, S., 2007]. It is the most feasible option in the residue collection system [K. Kadam et al., 2000].

This study studies on regional scale. The concept of the organized transport process is to transport a large amount of goods within a short period of time over a long distance [Gebreselassie M., et al.]. Based on transportation concept, this study assume each province has a storage center used to collect rice residue from each field and rice residue is sent to the destination (user) from the storage center.

The flow chart of transportation concept is shown in Figure 6.3. The distance from field to storage center and distance from storage center to heat/power producer is measured by apply 1 km×1 km grid cell. Grid cell is overlaid with province, then measuring the distance between center of province and each side of boundary (see Figure 6.4). The average distance is analyzed and used as a distance of transportation. The average distance used in this study is summarized as shown in Appendix G.

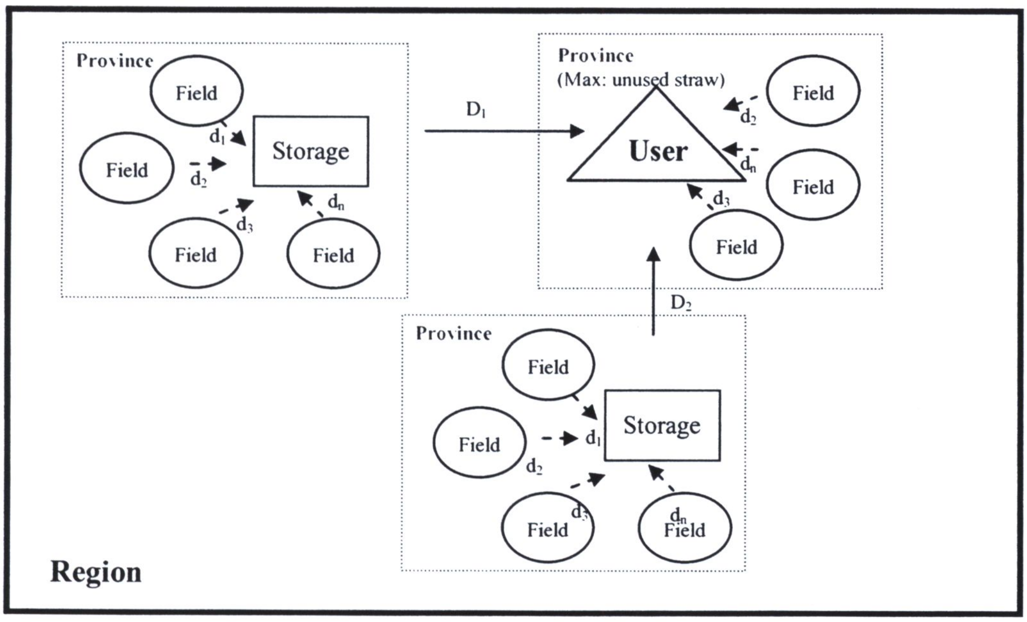

Figure 6.3 Concept of transportation in regional scale

The amount of residue available for heat/power production is only about 95% of overall amount of residue because of 5% loss from transportation.

For the location of user, this study assumes the location of user is in the province that has the largest amount of rice residue available for heat/power production (unused straw) in the region.

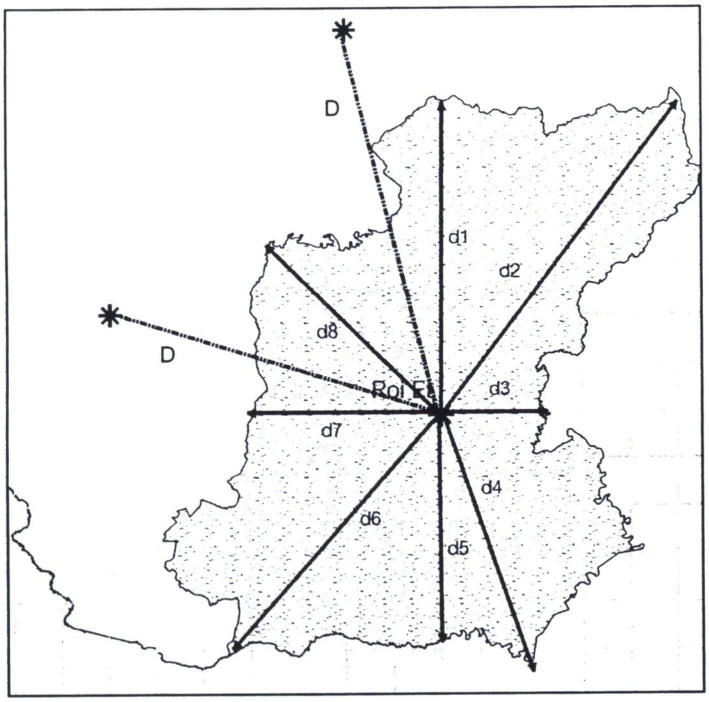

Figure 6.4 Distances measuring

Heat or power production process:

Heat or power production requires 2 sources of fuel: rice residue and diesel for start-up engine [Suramaythangkoor, T., 2009].

For heat production, this study focuses on only direct combustion. The heating value of rice straw is about 13.08 MJ/kg [DEDE, 2009], 75% of boiler efficiency, and 6,000 hr/yr of work period.

For energy production, this study focuses on only direct combustion. Efficiency of power plant is about 20% (Loo and Koppejan suggests, the overall efficiency of biomass power plant is about 20%-28%), and 6,000 hr/yr of work period.

The boundary of heat/power production by straw is represented in Figure 6.5.

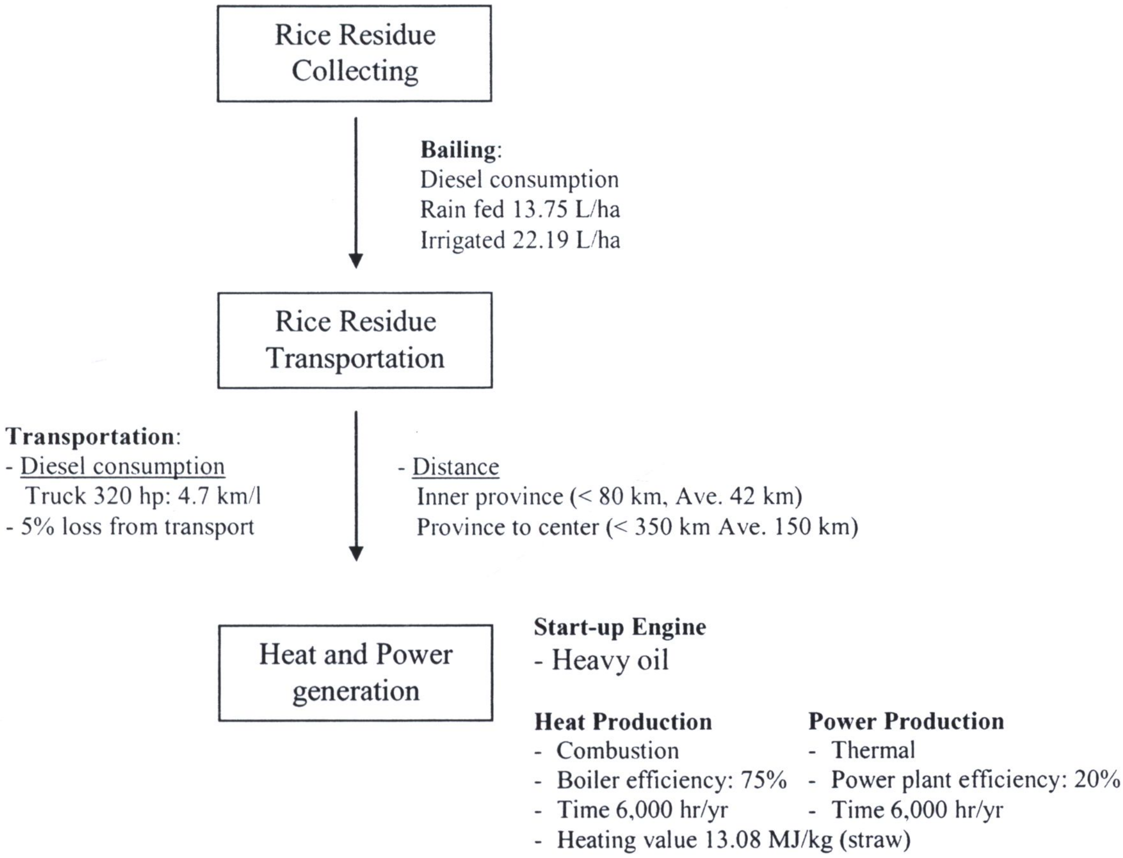

Figure 6.5 Summary of heat and power production

Emissions from heat or power production

Emissions from heat production estimate from the emission factor of lignite heat generation in industry. Emission from power production estimates from the average carbon intensity of thermal power plant-coal/lignite. The average carbon intensity is about 0.914 $kgCO_2/kWh$ [Patumsawad, S., 2010].

6.2.3 Parameter influencing emission from rice residue heat or power production

There are 3 processes for using rice residue to produce heat and power: collecting, transport, and production. Based on Equation 6.1, the amount of emission from production of heat and power by rice residue depends on type of fuel, amount of fuel consumed, heating value of fuel, and emission factor. The value of each factor used in this study is summarized as shown in Table 6.1.

Table 6.1 Type, rate, and heating value of fuel used for heat or power production

	Type of fuel	Rate	Conversion factor (MJ/unit)	EF (kg/TJ)		
				CO_2	CH_4	N_2O
Collecting process						
	Diesel	13.75 l/ha (rain fed) 22.19 l/ha (irrigated)	36.42 MJ/l	74,100[a]	3.90 [a]	3.90 [a]
Transportation process						
	Diesel	4.7 km/l	36.42 MJ/l	74,100[a]	3.90 [a]	3.90 [a]
Heat and Power production process						
Start-up engine	Residual heavy oil		40.4 TJ/Gg [a]	21.1 [a]	3 [a]	0.6 [a]
Heat or power production	Rice straw		13.08 MJ/kg [a]	0.102 [b]	4.7E-07 [b]	1.1E-06 [b]

Remark: ☐ Depends on amount of rice residue used for heat and power production
Source: a IPCC, 2006
b National environmental research institute, 2010

There is 5% loss during transportation and handling [Suramaythangkoor, T., 2009]. So, the actual amount of rice residue for heat and power production is only 95% of available of rice residue. In this study, the amount of residue available for heat and power production is the amount of unused straw. The available and actual amount of unused straw for heat/power production is summarized as shown in Table 6.2.

Table 6.2 Available and actual amount of unused straw for heat or power production by region

	Available amount of rice residue (unused straw) for heat and power production (Mt)	Actual amount of rice residue for heat and power production [a] (Mt)
Eastern	1.24±0.279	1.18±0.265
Central	4.61±1.098	4.38±1.043
Western	3.09±0.767	2.94±0.729
Lower-Northern	3.52±0.861	3.34±0.818
Upper-Northern	0.93±0.241	0.88±0.229
Lower-Northeastern	0.17±0.041	0.16±0.039
Upper-Northeastern	0.25±0.061	0.24±0.058
Lower-Southern	0.10±0.026	0.10±0.025
Upper-Southern	0.06±0.012	0.06±0.011
Total	**13.97±3.380**	**13.27±3.211**

Remark: [a] 5% loss from transportation and handling [Suramaythangkoor, T., 2009].

6.3 Results and Discussion

6.3.1 Potential of rice residue for operated biomass power plant

Based on the installed capacity of very small biomass power plant, rate of fuel for thermal power plant and gas engine power plant (6,138-10,080 tons for thermal power plant and 12,090-21,996 tons for gas engine power plant) found the total straw demand is about 7.6-12.6 Mt. 6.9-11.3 Mt is used for thermal power plant. 0.7-1.3 is used for gas engine power plant. The installed capacity and demand of straw by regional is shown in Table 6.3.

Table 6.3 Power capacity and demand of fuel (straw) classified by region

Region	Thermal PPT		Gas engine PPT		Total demand (Mt)
	Capacity (MW)	Demand (Mt)	Capacity (MW)	Demand (Mt)	
Eastern	73	0.45-0.73	0	0.00	0.45-0.73
Central	95	0.58-0.95	10	0.12-0.22	0.70-1.18
Western	211	1.29-2.13	9	0.11-0.20	1.41-2.33
Lower-Northern	231	1.42-2.33	36	0.43-0.78	1.85-3.11
Upper-Northern	52	0.32-0.53	0	0.00	0.32-0.53
Lower-Northeastern	226	1.39-2.28	3	0.03-0.06	1.42-2.34
Upper-Northeastern	187	1.15-1.89	0	0.00	1.15-1.89
Lower-Southern	0	0.00	0	0.00	0.00
Upper-Southern	51	0.31-0.51	0	0.00	0.31-0.51
Total	**1,125**	**6.90-11.34**	**58**	**0.70-1.27**	**7.60-12.61**

From regional capacity and demand of straw found the area where need the largest amount of straw is the lower northern region which requires 1.8-3.1 Mt of straw (serving 267 MW). Followed by the lower northeastern and the western regions which requires the similar amount about 1.4-2.3 Mt (serving 220 MW in the lower northeastern and 226 MW in the western).

Comparing between demand and supply (as represented in Table 6.4) in the overall level found unused straw has a potential to produce power (the total supply is about 10.59-17.35). Take consideration on the potential in regional level found the unused straw in the lower northeastern, the upper northeastern and the upper southern regions is not enough for very small biomass power plant. In the upper southern region is able to uses the unused straw from the lower southern. This result demonstrates the unused straw has the potential in term of the whole country but insufficiency in regional scale.

Table 6.4 Demand and supply of unused straw for biomass power plant

Region	Demand (Mt)	Supply (Mt)
Eastern	0.45-0.73	0.91-1.44
Central	0.70-1.18	3.34-5.42
Western	1.41-2.33	2.21-3.66
Lower-Northern	1.85-3.11	2.53-4.16
Upper-Northern	0.32-0.53	0.66-1.11
Lower-Northeastern	1.42-2.34	0.12-0.20
Upper-Northeastern	1.15-1.89	0.18-0.30
Lower-Southern	0.00	0.07-0.12
Upper-Southern	0.31-0.51	0.05-0.07
Total	**7.60-12.61**	**10.06-16.48**

6.3.2 Potential of rice straw for power production

The power production bases on direct combustion, operation hour at least 6,000 hr/yr, and 20% of plant efficiency. 10.06-16.48 Mt of unused rice straw provides a capacity of 1,221-1,998 MW (median value 1,609 MW). The regional capacity of unused straw for power production is shown in Table 6.5.

Table 6.5 Capacity of unused straw for power production by region

Region	Unused straw available for power production (Mt)	Capacity (MW)
Eastern	0.91-1.44	110-175
Central	3.34-5.42	405-657
Western	2.21-3.66	268-444
Lower-Northern	2.53-4.16	307-504
Upper-Northern	0.66-1.11	80-135
Lower-Northeastern	0.12-0.20	15-24
Upper-Northeastern	0.18-0.30	22-36
Lower-Southern	0.07-0.12	8-15
Upper-Southern	0.05-0.07	6-8
Total	**10.06-16.48**	**1,221-1,998**

Remark: calculate based on: 13.08 MJ/kg of straw LHV, 20% of power plant efficiency

Consideration on the regional scale found there is different power potential among region. The central region has the highest capacity for unused straw power production (405-657 MW), followed by the lower northern (307-504 MW), and the western regions (268-444 MW).

Table 6.5 reports the potential of unused straw for power production. The potential of unused straw is quiet wide range due to the cumulative of the uncertainty of regional unused straw estimation.

6.3.3 Emission from unused rice straw for power production

Rice straw power production includes 3 main processes: bailing process, transportation process, and energy production process. About 0.030 tCO_{2eq} of GHG is contributed from 1 MWh of rice straw power production (exclude neutral CO_2 from rice straw power production) which included 0.0025 tCO_{2eq} from bailing process, 0.013 tCO_{2eq} from transportation process, and 0.015 tCO_{2eq} from power production.

In terms of emissions from unused straw power production, 10.06-16.48 Mt of unused rice straw provides a capacity of 1,221-1,998 MW that contributes about 0.22-0.36 $MtCO_{2eq}$. About 6.47-10.59 $MtCO_{2eq}$ will be avoided from coal power production. The information of emission from power production by unused rice straw and coal/lignite is shown in Table 6.6.

Table 6.6 Emission from power production

Power production	**Emission (tCO_{2eq})**			**Carbon intensity ($kgCO_{2eq}/kWh$)**
	CO_2	**CH_4**	**N_2O**	
Straw power production		292,607		0.030
- Bailing process	23,729	25	372	
- Transportation process	122,442	134	1,984	
- Power production process (from start up engine)	11,395	1,218	3,871	
- Power production process (from straw-power production)	14,987	32,283	95,050	
Thermal PPT		8,826,498		0.914

Remark: estimated from the median value between 1,221-1,998 MW power productions

Based on literature review on carbon intensity of power production found the average carbon intensity of coal-thermal power plant is about 0.91-0.98 $kgCO_{2eq}/kWh$ [EGAT 2008; Patumsawad, S., 2010]. In this study, the carbon intensity of rice residue-power is about 0.03 $kgCO_{2eq}$/ kWh.

6.4 Conclusions

This part studied the potential of unused rice residue for heat or power production and also effects of GHG emissions from unused rice residue for heat or power production using thermal combustion technology based on 2006 IPCC guidelines. The potential of unused rice residue considered from the fuel demand for serving installed capacity of very small biomass power plant (VSPP). The effects of GHG emissions from unused rice residue for heat or power production considered on the emission mitigation from using residue heat or power production instead lignite heat or power production. The rice residue that can be used for heat of power production was only unused straw. The cycle of unused straw for heat or power production included bailing process, transport from field to provincial storage process, transport for provincial storage to heat or power producer process, and heat or power production process.

Regarding to the study on the potential of unused straw for power production found Thailand had 102 biomass thermal combustion power plants in 39 provinces which total installed capacity 1,125 MW and 8 biomass gas engine power plants in 7 provinces which total installed capacity 57 MW. The total installed capacity (1,183 MW) required the unused straw 7.60-12.61 Mt (Based on 1 MW of thermal combustion power plant required 6,138-10,080 tons of unused straw, 1 MW of gas engine power plant required 12,090-21,996 tons). The total supply of unused straw was about 10.06-16.48 Mt. This information demonstrated unused straw has a high potential in country level for serving biomass very small power plant which has installed capacity 1,183 MW (recorded March 2009).

According to the unused straw power production based on direct combustion, operation hour at least 6,000 hr/yr, and 20% of plant efficiency; 10.06-16.48 Mt of unused straw provided a capacity of 1,221-1,998 MW. 1 MW of electricity in thermal combustion system would require about 9,010 tons of unused straw per year that contributed 0.03 tCO_{2eq} (excluding neutral CO_2) and 0.884 $kgCO_{2eq}$ is avoided from 1 kWh coal power production.