Updated atmospheric emissions inventory of gaseous and particulate from power generation in Thailand using GAINS-Asia

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Abstract: *To support the fast growing economic development, Thailand's energy consumption has rapidly increased during the last two decades, which led to 198 million tonnes of carbon dioxide (CO_2), representing about 70% of the total national greenhouse gas emissions in 2011. Among all energy related emission sources of CO_2, power generation constitutes the top emitter with more than 40% of the total. However, a national detailed emission inventory in this sector, which appropriately supports air quality management and planning, is still very scarce. In this study, we developed a bottom-up inventory of emissions from power generation in Thailand in 2010. Pollutants of interest include NO_x, SO_2, CO, NMVOC, NH_3, PM_{10}, and $PM_{2.5}$, CH_4 N_2O, and CO_2, Activity data were collected from official statistics and reports. Energy conversion and emission control technologies in use data were gathered by plant survey in order to appropriately select emission factors. The preliminary overall results showed that in 2010 the power generation in Thailand emitted 92.0× 10^3 tonnes of NO_x, 57.5 × 10^3 tonnes of SO_2 , 20.9 × 10^3 tonnes of CO, 6.3 × 10^3 tonnes of NMVOC, 1.1 × 10^3 tonnes of NH_3, 30.3 × 10^3 tonnes of PM_{10}, and 18.7 × 10^3 tonnes of $PM_{2.5}$, 50.2 × 10^3 tonnes of CH_4, 0.8 × 10^3 tonnes of N_2O, and 87.6 × 10^3 tonnes of CO_2. Emissions were then analyzed vs. fuel consumption, energy conversion technology, and emission control technology. For all investigated pollutants, the results are displayed in the form of 10 km x 10 km gridded map, to enable a visualization of spatial distribution of the emissions, and a direct use for air quality modeling. Finally, a comparison to regional and global inventories such as REAS and IIASA_GAINS is presented and discussed.*

Keywords: *Bottom-up inventory; air pollutant emissions; power generation; Thailand; GAINS Model.*

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1. Introduction

Thailand's electricity demand has continuously increased. In 2010, the electricity consumption in Thailand totaled 149,320 Gwh, an increase of 10.4% from the previous year, in accordance with the expanding of Thai economy of 7.8% due to the world economic recovery. The total installed capacity was 31,485 MW, which thermal power plants accounted for 88.8 %. With such an ever-increased electricity demand, there has been a need to expand the total generation capacity of thermal power plants in Thailand.

Combustion of fossil fuels and biomass in thermal power plants produces various emissions in both gaseous and particulate (i.e., aerosol) phases. These include nitrogen oxides (NO_X), sulfur dioxide (SO_2), carbon monoxide (CO), non-methane volatile organic compounds (NMVOC), ammonia (NH_3), particulate matter lesser than 10 μm in aerodynamic diameter (PM_{10}), particulate matter less than 2.5 μm in aerodynamic diameter ($PM_{2.5}$), methane (CH_4), nitrous oxide (N_2O), and carbon dioxide (CO_2). Many of these emissions are involved in acid rain, ozone formation, secondary particulate formation, and global warming.

To achieve effective and proper regional air quality management, a good information system is a must-have, including updated and representative emission inventories. However, for Thailand, such an information system is neither well-established nor regularly updated, leading to the motivation of this study.

The objective of this study is to update the gridded national emission inventory of thermal power plants of those species mentioned above, as an interim finding from the ongoing work on an emission inventory development for power plant in current year and projection in Thailand.

2. Material and methods

The methodology to estimate air emissions can be described by the following Equation:

$$E_{i,p} = \sum_{k}\sum_{m} A_{i,k} ef_{i,k,m,p} X_{i,k,m,p} \qquad \text{(Eq.1)}$$

Where,

i, k, m, p: Country i, activity type k, abatement measure m, pollutant p

$Ei_{,p}$: Emissions of pollutant p in country i

$A_{i,k}$: Activity level of type k in country i

$ef_{i,k,m,p}$: Emission factor of pollutant p for activity level of type k in country i after application of control measure m

$X_{i,k,m,p}$: Share of total activity of type k in country i to which a control measure m for pollutant p is applied

Table 1. Information Used for Emission Estimation

Information	Description	Sources
Activity Data	Fuel Consumption for Whole Country	(DEDE, 2011)
	Plant's Characteristic (Commission Year, Capacity, Fuel Type, Control Technology, and Province)	(EPPO, 2011)
	Boiler Type & Control Technology	EIA Database (ONEP, 2012)
Emission Factor	Uncontrolled EFs	JULY2013 (IIASA, 2013)
	Control Efficiency	JULY2013 (IIASA, 2013)

Fuels used in thermal power plants in Thailand include brown coal (i.e., lignite), hard coal (i.e., sub-bituminous), biomass, fuel oil, and natural gas. Among regions, power plants located in the Central region possess the largest share in fuel consumption, followed by the Northern region. Regarding fuel type, the use of natural gas is dominant in Thailand, followed by brown coal and hard coal.

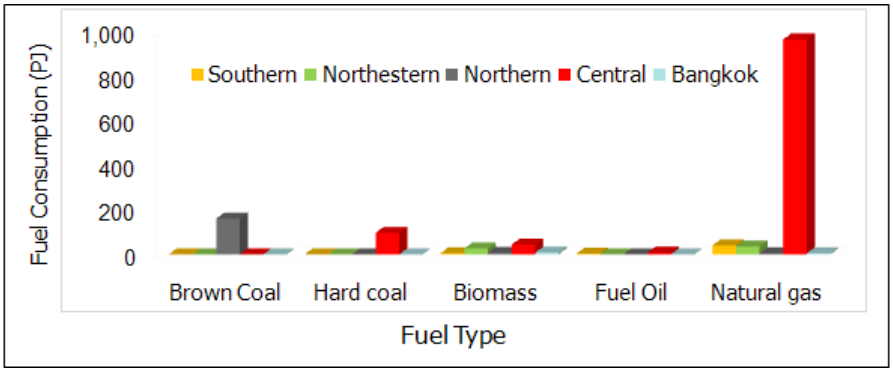


Fig. 1 Fuel Consumption of Thermal Power Plants in 2010 in Thailand

3. Results and Discussion

In 2010, thermal power plants in Thailand emitted 92.0 × 10^3 tonnes of NO_X, 57.5 × 10^3 tonnes of SO_2, 20.9 × 10^3 tonnes of CO, 6.3 × 10^3 tonnes of NMVOC, 1.1 × 10^3 tonnes of NH_3, 30.3 × 10^3 tonnes of PM_{10}, and 18.7 × 10^3 tonnes of $PM_{2.5}$, 50.2 × 10^3 tonnes of CH_4, 0.8 × 10^3 tonnes of N_2O, and 87.6 × 10^3 tonnes of CO_2 (Figure 2). For CO, CH_4 and CO_2, the Central region had the largest share of the total emissions while for SO_2, NO_X, PM_TSP, PM_{10} and $PM_{2.5}$, the Northern region constituted the top contributor.

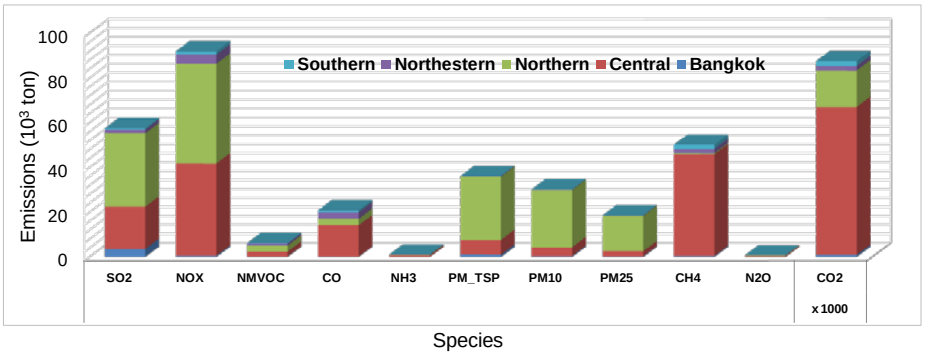
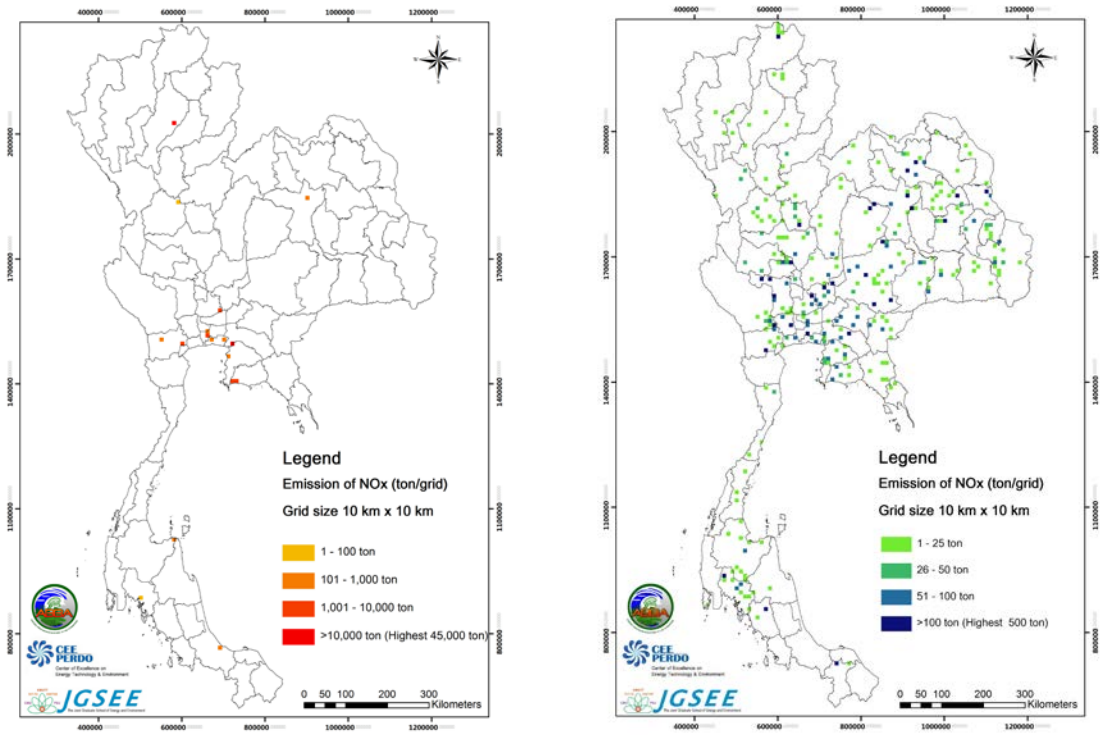


Fig. 2 Emissions from Thermal Power Plants in 2010 in Thailand by Region



(a) EGAT and IPP Power Plants (b) SPP and VSPP Power Plants

Fig. 3 Spatial Distribution of NO_X Emissions from Thermal Power Plants

Fig. 3 presents NO_x emissions from thermal power plants belonged to Electricity Generating Authority of Thailand (EGAT), Independent Power Producers (IPP) (Fig. 3a), the Small Power Producers and Very Small Power Producers (VSPP) (Fig. 3b). It was observed that the high NO_x emissions from thermal power plants are found in the Central and Northern regions resulted from the high number of SPP and VSPP. Despite the presence of only one large plant using brown coal and pulverized firing technology in the North of the country, the contribution of this region to the total NO_x emission is the highest (Fig. 2 vs. Fig. 3). It was found that for SO_2, NO_X, CO, PM_TSP and PM_{10},

our estimates are much lower than those provided by the International Institute for Applied System Analysis, IIASA (Amann et al, 2008) and Regional emission inventory in Asia version 2, REAS (Kurokawa et al, 2013). This can be explained by the difference in the efficiency of control technology accounted in IIASA and REAS compared to the country-specific data obtained from plant surveys on control technology. The efficiency of control technology currently in use in Thailand is higher than what is assumed in IIASA and REAS.

Table 2 Comparison of Emissions from This Study with Other Emissions Databases

	Emissions (10^3 tonnes**)**			**Ratio**		
	REAS (2008)	**IIASA (2010)**	**This study (2010)**	**IIASA /This study**	**REAS /This study**	**REAS/ IIASA**
SO_2	345.7	247.8	57.5	4.31	6.01	1.40
NO_X	199.9	125.5	92.0	1.36	2.17	1.59
NMVOC	66.3	5.0	6.3	0.79	10.52	13.26
CO	369.8	44.4	20.9	2.12	17.69	8.33
NH_3	5.9	0.5	1.1	0.45	5.36	11.80
PM_TSP	-	98.8	36.2	2.73	-	-
PM_{10}	213.7	46.5	30.3	1.53	7.05	4.60
$PM_{2.5}$	63.0	18.8	18.7	1.01	3.37	3.35
CH_4	17.2	50.2	50.2	1.00	0.34	0.34
N_2O	1.7	1.1	0.8	1.38	2.13	1.55
CO_2 (×1000)	87.0	90.7	87.6	1.04	0.99	0.96

4. Conclusion

This study presents a bottom-up inventory of air pollutants emissions from electricity generation in Thailand. The use of country-specific data of activity and control technology enabled to improve the accuracy of the estimate up to 50% comparatively to those provided in global or regional emission inventories. These latter captured well the emissions of compounds involved in air quality studies, but not well the efficiency of emission control technology actually in use in Thailand. Fuel type and control technology playing an important role on the composition and intensity of the emissions, it is recommended for future study to document in details the type of fuel used in small and very small power plants, as well as the efficiency of the control technology applied to these groups of thermal power plants, especially those related to the use of biomass as fuel since it represents the major resource of the country.

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