Subsidy for Clean Power Generation and CO_2 Mitigation in Thailand: The AIM/Enduse Modeling

Artite Pattanapongchai, Bundit Limmeechokchai, Yuzuru Matsuoka, Mikiko Kainuma, Junichi Fujino, Osamu Akashi, and Yuko Motoki

Abstract— *The power sector in Thailand is heavily dependent on natural gas and coal more than 92.73%. Thailand has a large target of achievement of 20.4% alternative energy share in total energy consumption by 2022 and CO_2 mitigation. The obvious answer to this challenge is to take advantage of Thailand as an agricultural-based country especially in the domestic renewable energy and clean power generation. In this study, Thailand's Renewable Energy Development Plan (REDP) strategy is considered in case of increasing share of electricity generation from renewable energy up to 2.40% in 2022 forward with total subsidy of US$ 180 million during 2010-2025. This renewable electricity generation is compared to the role of future fossil-based power plant in the long term energy planning. This study uses AIM/Enduse bottom-up model with detailed technology selection framework associated with technology data-base energy system as an analytical tool. The aim of this study is to identify the REDP scenario featuring minimum CO_2 emission and least-cost for long term energy planning in the power sector. Results from AIM/Enduse modeling are presented of total supply system cost, environmental effect of the energy and given adder case, total system cost, revenue from subsidy and co-benefits of alternative energy for clean power generation.*

Keywords— **AIM/Enduse, alternative energy, bottom-up model, co-benefits.**

1. INTRODUCTION

Thailand's primary energy supply in 2009 comprised 72.72% natural gas, 20.01% coal, 3.77% hydro, 1.48% renewable and 0.36% oil shares respectively [1]. However, Thailand has proposed a renewable energy development plan (REDP) by a form of subsidy aiming to promote renewable energy at a share of 20.4% of total primary energy supply in 2022 forward [2]. The subsidy is a form of financial incentive paid on top of system production costs to small renewable power producers by the Thai government in order to make renewable power generation completitive to the conventional power production. Consequently, the carbon dioxide (CO_2) emission and others will also be reduced. Thailand also promotes and supports utilization of renewable energy and the improvement of the energy efficiency in the power sector because of the role of power sector as a major CO_2 emitter. Despite its role in economic development, the power sector in Thailand emitted 83.3 million tons of CO_2 in 2008 and up to 83.41 million tons of CO_2 in 2009. The CO_2 emission from the power sector increased from 38.92% of total CO_2 emission in Thailand in 2002 to 43% and 42.22% in 2008 and 2009 respectively. It is equivalent to an Average Growth Rate (AGR) of 31.28% and 31.44% of total CO_2 emission from the power sector during 2002-2008 and 2002-2009 respectively while the transport sector had an AGR of 7.86% in the same time period. Per capita electricity consumption in Thailand also increased from 122 kWh/capita in 2002 to 161 kWh/capita in 2007, which is equivalent to AGR of 20.66% [2-8]. To mitigate CO_2 emissions from the power sector, supply-side technologies can be substituted and managed to reduce electricity generation and CO_2 emissions [9]. Different growth paths for economy, population, energy efficiency and renewable energy technology would effect associated greenhouse gas and local air pollutant emissions in Thailand [10]. Thailand is the first country in Southeast Asia having an official policy to encourage electricity generation from renewable energy under small power producer (SPP) and very small power producer (VSPP) policies [11-12]. The financial incentive is remarkable in both the promotion of bio-fuels and electricity generation from renewable energy.

The objective of this study is to optimize the long-term energy supply and demand in Thailand with REDP as CO_2 mitigation options. This paper is divided into six sections. Section 2, the explanation of REDP in Thailand is presented. Explainsion of methodology approach for modeling the present and future power plant technologies in Thailand are described in section 3. The long-term energy planning in this study were evaluated by using AIM/Enduse model. The scenarios are described in the Section 4. Finally, findings from the base case and alternative cases are presented and discussed in section 5. The reference energy system which includes primary energy supply, energy process and transformation, useful energy, and demand technologies are analyzed in the AIM/Enduse modeling. Results of co-benefits, total system cost, and environmental effects of energy and

Artite Pattanapongchai is with Energy Technology Field of Study, Sirindhorn International Institute of Technology, Thammasat University, Klongluang, Pathumtani 12120, Thailand.

Bundit Limmeechokchai (corresponding author) is with Sirindhorn International Institute of Technology, Thammasat University, Klongluang, Pathumtani 12120, Thailand. E-mail: bundit@siit.tu.ac.th.

Yuzuru Matsuoka is with Graduate School of Engineering, Kyoto University, Katsura, Nishikyo-ku, Kyoto 615-8510, Japan.

Mikiko Kainuma, Junichi Fujino, and Osamu Akashi are with National Institute for Environmental Studies (NIES), 16-2 Onogawa, Tsukuba, Ibaraki 305-8506, Japan.

Yuko Motoki is with Mizuho Information & Research Institute, 2-3 Kanda-nishikicho, Chiyoda-ku, Tokyo 101-8443, Japan.

subsidy case are compared to the BAU scenario. Finding from AIM/Enduse modeling shows that clean power generation is competitive with other electricity generation technologies.

2. CLEAN POWER GENERATION PLAN

Thailand is an import dependent and fossil fuels intensive country. Crude oil is the primary energy source. Diversification of energy types and sources of supply is therefore a key concern in the country. Ministry of Energy has set six key objectives; *(i)* efficient management of energy sector and establishment of regulatory framework, *(ii)* self energy sufficiency and enhanced energy supply, *(iii)* promotion of energy saving and energy efficiency, *(iv)* promotion of renewable energy and alternative energy, *(v)* reduction of imported energy and diversification of fuel types and sources, and *(vi)* market-based pricing structure.

This plan is called Renewable Energy Development Plan or REDP which promote forward within 15 years. The targets of renewable energy are 0.76%, 1.84% and 2.26% in 2008, 2011, and 2016 of total electricity generation, respectively, and grow up to 2.4% of the total energy consumption in 2022. To achieve the targets, the present feed-in-tariffs for the renewable electricity production is proposed to promote alternative energy policy (see adder cost in Table 1). In the OECD/IEA (2007) [13] studies on renewable energy technology, learning rates of some energy-related technologies such as solar photovoltaic (PV) has undergone significant improvement. During 2006-2010, the technology has been growing at an average decreasing rate of 17.5%. The rapidly growing business has recently received the interest of several project and research activities have been intensified. In the next twenty years the learning rate would decrease to 15% (2011-2020), and 10% (2021-2030) respectively. Biomass energy including biogas, CHP and incineration, and geothermal will be reduced about 5% per period during 2006-2010, 2011-2020, and 2021-2030 while hydro power will be reduced around 1% per period. Costs of wind technology have not been changed during 2006-2010; but in the future, costs will be reduced about 6.5% during 2011-2020, and 5% during 2021-2030.

Table 1. Adder Cost for Electricity Generation

Fuel/Technology	Adder (Bath/kWh)	Years
Biomass	0.3	15
Biogas	0.3	15
Small-hydro (0-200 kW)	0.4	15
Municipal Wastes	2.50	15
Wind	3.5	15
Solar	8	15

3. METHODOLOGY APPROACH

The Asia-pacific Integrated model (AIM) has been developed by National Inatitute for Environmental Studies (NIES) of Japan as a first and only integreted assessment model focusing on Asia which was used to evaluate policy options on sustainable development particularly in the Asia Pacific region AIM/Enduse is a bottom-up optimization model with detailed technology selection framework within a country‘s energy-economy-environment system. It can analyze CO_2 mitigation scenarios by using both AIM/Enduse model. Fig.1 shows the structure of the AIM/Enduse model [14]. Energy technology refers to a device that provides a useful energy service by consuming energy. Energy service refers to a measurable need within a sector that must be satisfied by supplying an output from a device [15]. It can be defined in either tangible or abstract terms, thus service demand refers to the quantified demand created by a service; *i.e.* service outputs from devices satisfy service demands. Fig.2 describes the structure of AIM/Enduse for electricity generation in Thailand for this study. From EGAT (2010) [12], the retirement plan for thermal power plant has arranged with a total capacity of 15,577.20 MW during 2010-2030 (see Fig. 3)

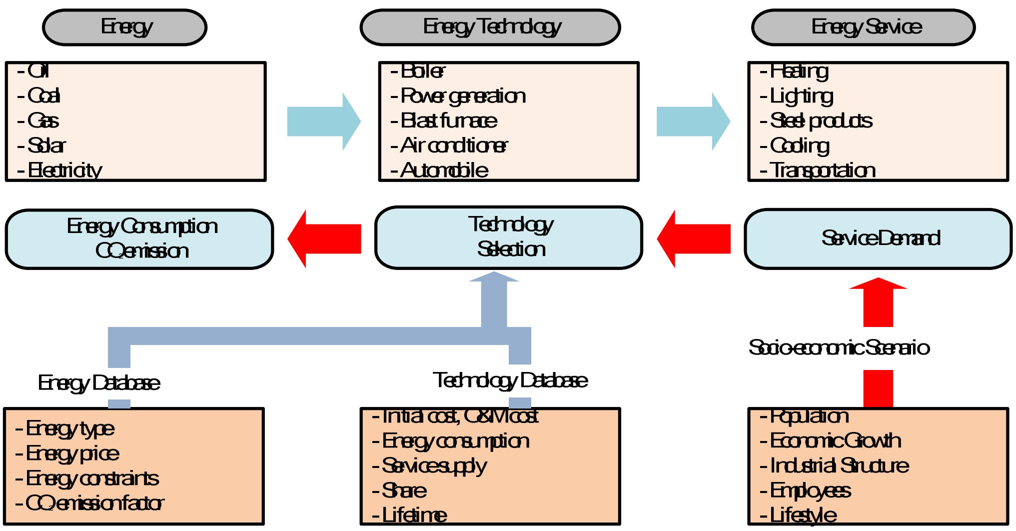

Fig.1. Structure of AIM/Enduse Model.

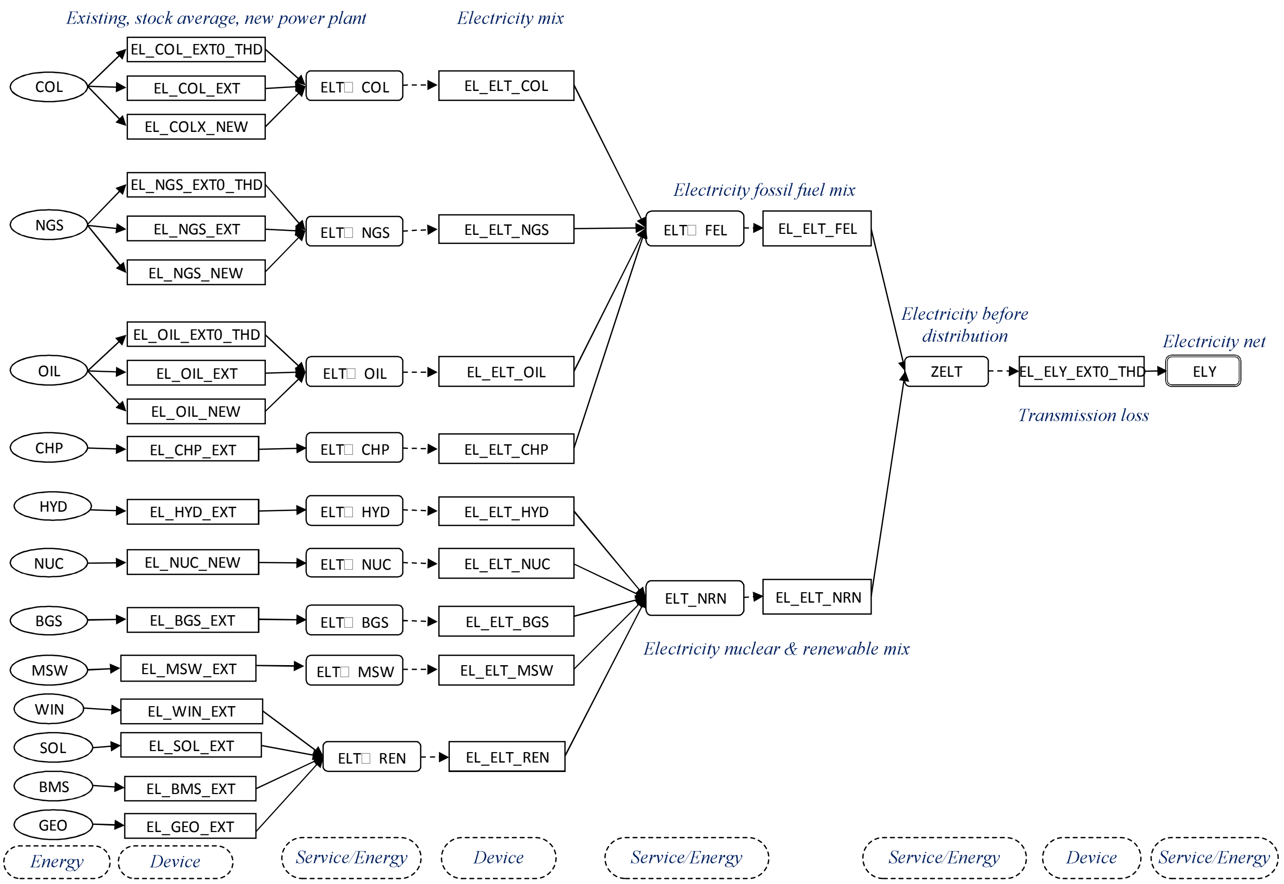

Fig.2. AIM/Enduse for Electricity Generation in Thailand.

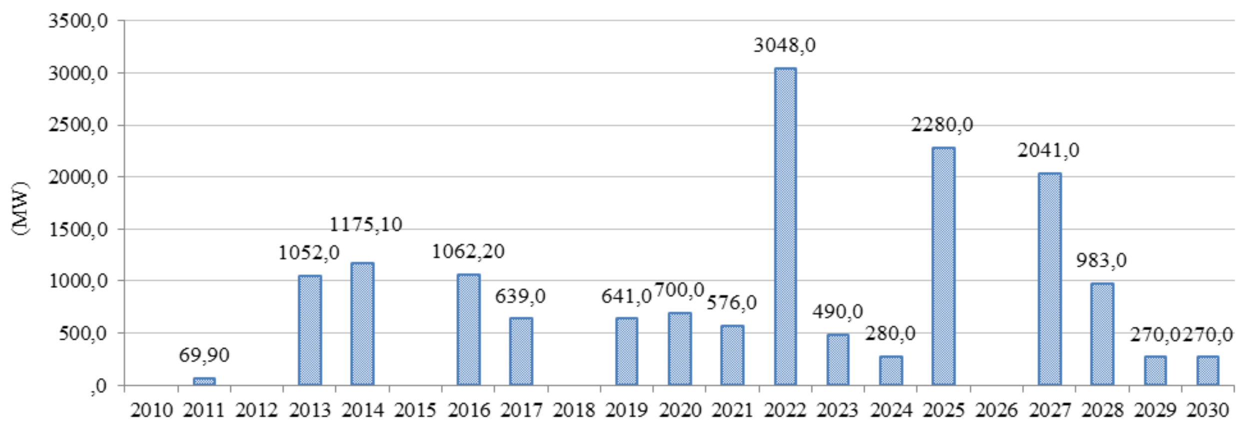

Fig.3. Power Plant Retirement Plan in Thailand during 2010-2030.

4. DESCRIPTION OF SCENARIOS

In this study two scenarios are analyzed in the long term planning; the business-as-usual (BAU) scenario and the subsidy (ADD) scenario. The characterization of each scenarios and selected technology are expressed as following:

BAU Scenario

This scenario investigates existing Thailand's energy system trend, and projects future demands. The AIM/Enduse for electricity generation in Thailand is used as a tool in analysis with PDP2007 [11] and PDP 2010 [12] for development of an optimum plan in the next 25 years. In the BAU scenario, the economies of each sector are projected to undergo a moderate economic development and market-oriented transformation during 2005-2030. The maximum available stocks of non-renewable energy resource, e.g., coal, lignite, oil and natural gas, were estimated by the sum of three quantities: proven reserve, 50% of probable reserve, and 25% of possible reserve [16]. The international prices of imported oil, gas and coal are estimated to increase during 2005-2030. A discounted rate of 7% per year is used in this study [17]. All cost figures discussed in this paper are expressed in 2005 constant prices. Basic assumptions driving the energy systems such as future energy demands, domestic resources availabilities, conversion technologies and their appliances stocks in the starting year and energy prices are collected from several sources, where as emission factors used to quantify the pollutants and emissions are based on the previous data from EGAT's Environment Division from 1970 to 2008 (see APPENDIX). The planning period of the study is 2005-2030.

ADD Scenario

In the ADD scenario, the maximum level of electricity generation from renewable energy was extended to 2.4% of total electricity generation as required in the REDP during 2022-2030. This study assumed that financial incentive for renewable electricity generation is given in the form called "*adder*" at the rates of 2010 adder during 2010-2025 with the total subsidy of 180 million US$. All other things are kept the same as in the BAU scenario.

5. RESULTS AND DISCUSSIONS

Primary energy supply

Results indicate that the total primary energy supply used in the BAU scenario increases from 6,350.5 PJ in 2005 to 39,229.1 PJ in 2030, which is equivalent to Average Annual Growth Rate (AAGR) of 7.59%. Total useful energy increases from 2,660.6 PJ to 8,524 PJ by 2030, which is equivalent to 4.85% AAGR. The percentage of total imported fossil fuel increases from 638.1 PJ to 4,026.0 PJ or 7.67% of AAGR. In the all economic sectors, *i.e.* the commercial, industrial, residential, transport, and agricultural sectors, the total fuel consumption increases with AAGR of 8.08%, 5.66%, 1.73%, 3.14%, and 3.72%, respectively. In the non-energy sector, the total fuel consumption has an AAGR of 5.28%. In the future, imported coal and lignite will increase at an AAGR of 9.83 %, from 220.7 PJ in 2006 to 2,338.0 PJ in 2030. This growth rate reflects the least cost energy demand and supply for Thailand in the period of 2005-2030. The reliability of the scenarios is estimated by comparing the results with related researches of NIES studies.

Environmental effects in the BAU and ADD scenarios

This study considered five gas emissions: CO_2, CO, PM, NO_x, and SO_2. CO_2 emission from electricity generation, the transportation, the industrial, the commercial, the residential, and the agricultural sectors would grow at an AAGR of 6.45% during 2005-2030. In the electricity generation sector CO_2 emission would increase from 62,728.63 kt in 2005 to 181,691.34 kt in 2030, and accounted for an AAGR of 4.43%. CO_2 emissions would increase over the planning horizon due to increasing use of coal, lignite, diesel and fuel oil in the power plants. The increasing SO_2 emission would have an AAGR of 5.43% due to increasing lignite and coal consumptions in power generation. The NO_x emission would grow at an AAGR of 1.58% during the planning horizon. By 2030, the power sector would contribute 32.82% share of total CO_2 emission, followed by the industrial (28.41%) and transport (28.06%) sectors, respectively. The cumulative NO_x and SO_2 emissions from the power sector during 2005-2030 are 3,996.26 and 27,912.14 thousand tonnes, respectively. These emissions come from combine cycle gas turbine (CCGT natural gas) and gas turbine (GT diesel), oil-fired (fuel oil), and coal-fired (coal and lignite) power plants.

Total system cost and revenue from feed-in-tariff

Subsidy policy for renewable energy promotion would change the energy supply for power generation. The use of coal and natural gas for coal-fired power plant technologies is found to decrease from 85.72% in the BAU case to 67.14% in the ADD case. In the case of natural gas based gas-fired power plant, the use of gas fuel would decrease from 73.14% in the BAU case to 60.85% in the ADD case. The use of diesel for diesel gas turbine plant technologies is found to increase from 4.46% in the BAU case to 6.15% in the ADD case. The use of renewable energy (such as biomass, biogas, hydro (small), solar PV and wind) would increase from 0.013% in the BAU case to 8.21% in the ADD case. The results also show that role of the adder as financial incentive is very important for CO_2 mitigation in Thailand's power sector.

Co-benefits of alternative energy for clean power generation

Co-benefits are the benefits from policy options implemented for various reasons at the same time. The examples of co-benefits of greenhouse gas mitigation or energy efficiency program are health, emissions, waste, production, operation and maintenance, working environment and others. There are several advantages that can be influent on co-benefits of CO_2 mitigation, and have been studied in Thailand [18] [19]. This paper investigates benefits of GHG mitigation and revenue from Clean Development Mechanism (CDM), increasing potential of renewable energy, and improving public image by using cleaner fuels**.** All co-benefits can be described as followings;

- *GHG emission mitigation and revenue from CDM*: The strategies to meet the increasing share of renewable energy are likely to have effect on total discounted costs, total emission level and energy security of the country. The present study shows that the least cost strategy to achieve renewable and CO_2 mitigation targets will also generate benefits in forms of lower cumulative SO_2 and NO_x emissions during the planning horizon. When more mitigation options are added by utilizing CDM program for REDP project, the cumulative revenue from CDM during 2008-2016 will be about 1,098,685.1 US$ (@ the price of 16.8 US$/t$CO_2$ or 11.34 €/tonne of CO_2). The CO_2 mitigation will be 2,724.91 thousand tonnes of CO_2/annum while the total subsidy for this policy will be around 10,722 million US$ during 2008-2024.
- *Increasing potential of renewable energy*: The REDP project is supporting the strategy of Thailand's renewable energy and its future energy for agro-industry which targets at 2.40% of total nation-wide

energy usage with a sizeable population growth. Its electricity demand continuously increases. Therefore, alternative energy is a promising alternative to fulfill the country's future electrical needs.

- *Cleaner fuel use in the power sector:* As a result of increasing share of renewable energy, the power sector efficiency would be *improved* and the fossil fuels use in the power sector would be decreased as compared with the BAU scenario. The power sector would utilize more renewable energy, which would take place through the relatively smaller diesel and coal-based power generation and increased natural gas, biomass, hydro and biogas-based power generation during 2005-2030. As a result of increasing share of renewable energy like bagasse from sugar mills, paddy husk from rice mills, woodchip from wood factories, and biogas from palm oil mill, power generation from biomass, biogas, small hydro, wind, geothermal solar, and wastes would also gradually increase during 2005-2030. Moreover co-benefits give the good image to the power plants as being of the environmentally conservative. Furthermore, the promotion of renewable power generation by adders or financial incentive would be necessary.

6. CONCLUDING AND REMARKS

This study developed the Thailand-AIM/Enduse model for the power sector in Thailand under two scenarios during 2005-2030. The purpose of this model is to investigate CO_2 mitigation cost under subsidy for renewable energy scenario. In this study, the current adder cost was introduced in the power sector from 2008-2024. The renewable energy for electricity generation is introduced for CO_2 mitigation in the ADD scenario. The results show that current adder has a very important role to mitigate CO_2 emission when considered with incremental emission reduction cost. Coal and natural gas consumption decreases in the ADD scenario resulting in reduction of CO_2 emission around 7,276.06 kt CO_2/year and 2,972.63 kt CO_2/year respectively. The ADD scenario results in more CO_2 emission and higher total system cost when compared to the BAU scenario. In the case of neglecting incremental emission reduction cost, renewable energy can be economically beneficial if it operates at high capacity. During 2008-2030, the increasing shares of the renewable electricity production at 2.40% of the total electricity production can reduces CO_2 emission around 4.18% when compared with the BAU case.

The target of 2.4% of electricity from renewable energy will meet the country's target. It is recommended that costs of carbon credit for renewable energy should be reviewed and studied because the present prices of CERs are not effective for promoting renewable energy in Thailand. Finally, promotion of alternative energy for clean power generation must have financial incentives and mechanism. Subject to the large uncertainties in energy prices in the long-term future, it indicates that clean energy scenarios could possibly be cost-effective compared with fossil fuels, with economic savings from efficient energy use paying for the subsidy of renewable energy. This suggests that the main barriers to a sustainable energy future are not depend on new or advanced technologies, but also on national policy and financial mechanism such as incentives on renewable energy in developing country. The continuous policies and mechanism strategies are required to encourage the most clean power generation, energy efficiency improvement and renewable energy promotion. A regulatory framework such as liability, licensing, and royalties is needed for private investment and public acceptance. Governments should also establish long-term policies to stimulate private investment and emission mitigation mechanisms.

Moreover, Thailand is an agriculture based country. Currently, nuclear power is the sensitive issue in Thailand, and nuclear power plant cannot be considered as solution for alternative sources without public aceptance. It is also not acceptable from several groups of Thai people. However, increasing public awareness of energy-environment issues would result in acceptance of such alternative technology in the near future.

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APPENDIX

Emission Factors of Various Fuels and Technologies in Thailand

Fuels and technologies	Average emission factors				
	kt CO_2/PJ	kt SO_2/PJ	kt NO_x/PJ	kt CO/PJ	kt PM/PJ
Coal and lignite	108.217	0.137	0.374	0.009	0.004
Natural gas	63.269	0.038	0.06	0.016	0.004
Fuel oil	76.75	0.146	0.128	0.044	0.022
Gas turbine	53.575	0.00028	0.0760	0.160	0.00347
Diesel-engine	73.113	0.007	0.0006	0.017	0.0417
Diesel-gas turbine	74.361	0.0074	0.178	0.015	0.0085

Source: EGAT (2009) [20]