Symposium on Environment and Culture
Siam Society & ONEB, Chiangmai, February 1992

ENERGY AND ENVIRONMENTAL IMPLICATIONS WITH EMPHASIS ON URBAN ISSUES

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ABSTRACT

Combustion of imported and indigenous fuels in Thailand is now causing serious air pollution problems. Without a compulsory emission standard, a rapid growth in lignite utilization in the country will increase sulphur dioxide emission from about 0.27 M tons in 1987 to 1.52 M tons in the year 2000. High percentages of sulphur in Thai fuel oil and diesel oil contributed about 0.24 M tons of the sulphur dioxide emission in 1987 and 0.39 M tons in 1990.

The content of tetra ethyl lead in Thai gasoline is about 0.40 g/litre which is quite high in comparison to 0.15 g/litre in Singapore and Malaysia. According to measurement taken in 1988-89, lead contents in the air at several locations in Bangkok reached alarming levels close to 7 µg/cu.m of air.

Combustion of petroleum products and natural gas in Thailand produced 43.8 M tons of carbon dioxide in 1987 and will generate about 201 M tons in the year 2000. Contribution from lignite combustion will increase the amount of carbon dioxide emission from 7.5 M tons in 1987 to about 42 M tons in the year 2000. The amount of carbon dioxide emission from the combustion of biomass which accounted for 35% of the total energy consumption in 1987 was approximated at about 54.9 M tons and slightly decreased to 54.2 M tons in 1990. Combustion of non-commercial biomass has not been included.

To abate the gaseous pollutants from fuels, the Thai government will soon issue improved fuel standards in which the lead content in gasoline will be limited to 0.15 g/litre and the maximum allowable content of sulphur in diesel oil and fuel oil are limited to 0.5% and 2% respectively. The state power company is directed to fit new lignite-fired power stations with flue gas desulphurization units.

As pollution from gasoline engines becomes a threat to public health in urban areas, the Thai government recently issued a regulation requiring installation of catalytic converters on all new gasoline cars registered after 1992. However, technical and economic constraints of the catalytic converter have not been clearly discussed. Alternative solutions should also be considered.

As domestic lignite is rather cheap in comparison to fuel oil, it has potential to be used as a substitute in industrial boilers in urban and sub-urban areas. Promotion of cogeneration in industry will accelerate installation of lignite-fired boilers. Unless a compulsory standard for emission at source is urgently implemented, unabated amount of sulphur dioxide emission from lignite-fired industrial boilers could amount to 0.35 Mtons annually.

INTRODUCTION

Since the last few years, Thailand has achieved one of the highest economic growth in the region. As an example, the growth in 1990 was about 10%. As energy is a necessary input to economic development of a country, the amounts of energy consumption in most economic sectors of Thailand [National Energy Administration, 1990] have increased rapidly as shown below :

	1985	1987	1989	1990
Agriculture	7.2	6.8	6.2	6.2
Construction & Mining	1.1	0.7	0.6	0.7
Manufacturing	27.6	26.6	29.0	29.6
Transportation	32.0	35.3	38.3	39.3
Residential and Commercial	32.1	30.6	25.9	24.2
Total, M t.o.e	18.9	21.1	26.6	28.9

Primary energy supply for Thailand is available from both domestic and foreign sources. Profiles of the past [NEA,1990] and projected primary energy supply for Thailand can be summarized as follows :

	1985	1987	1990	1995	Estimated Annual Growth
Petroleum & Products	38.2	40.2	47.8	43.5	4
Natural Gas	11.8	14.4	13.7	18.3	9
Hydro Electricity	3.2	3.1	2.8	4.1	3
Lignite & Coal	5.7	6.9	9.1	7.9	15
Traditional Energy	40.1	35.4	26.6	25.2	1
	100.0	100.0	100.0	100.0	
Total, M t.o.e	27.4	30.5	41.3	53.2	5
Energy/Capita, kg.o.e	530	570	730		
Energy/GDP, kg/USD	1.74	1.69	1.63		

Traditional energy in the above table includes firewood, charcoal, bagasse and rice husk. Assessment of non-commercial use of firewood and charcoal is very approximate. Non-commercial uses of solar and wind energy in salt production, drying of agricultural products, etc. are not included. From the above table, the average growth of energy consumption from 1985 to 1990 was about 12% per annum and the consumption of traditional energy dropped in percentage but increased slightly in quantity.

It should also be noted that the projected primary supply in 1995 is based upon an annual growth rate of about 5%. However, the actual growth of total energy consumption in 1990 was about 11% owing mainly to the rapid expansion of the industry, buildings, and transport sectors in the country. Development of domestic energy sources such as natural gas, oil, lignite, biomass, etc., has already been accelerated. However, utilization of domestic sources of energy such as firewood, hydropower, lignite, etc. has also led to serious environmental problems like the imported sources.

SULPHUR DIOXIDE EMISSION

Sulphur dioxide is one of the most serious problems caused by combustion of fuels. In 1985, China emitted 12.5 M tons of sulphur dioxide and appeared at the top of the list of the Asian offenders [Bhatti, et al, 1990]. During the same year, Thailand emitted about 0.43 M tons of sulphur dioxide from combustion of lignite, diesel oil and fuel oil, see Tables 1 and 2, and ranked as the fifth offender in Asia.

Combustion of indigenous lignite is the main contributor of sulphur dioxide emission in Thailand. The consumption of lignite for electricity generation and industries in the country has increased from 5.1 M tons in 1985 to 12.4 M tons in 1990 [National Energy Administration, 1990]. It is estimated that at an average growth rate of about 30% per annum, the consumption of lignite in Thailand will reach 38.1 M tons in the year 2000 [World Bank, 1989].

Assuming the average sulphur content in Thai lignite of 2%, the amount of sulphur dioxide emission will increase from 0.50 to 1.5 M tons between 1990 and the year 2000. Lignite fired power station owned by the Electricity Generating Authority of Thailand (EGAT) will be responsible for over 60% of the sulphur dioxide emission in the country [Chongpirapien, et al, 1990]. Distributions of lignite consumption and sulphur dioxide emission in electricity generation and industries are shown in Table 1 for the base cases.

Fuel oil which is locally refined and has a high sulphur content also significantly contributes to sulphur dioxide emission. The consumption of fuel oil has grown from 2.15 M tons in 1985 to 2.99 M tons in 1990 [National Energy Administration, 1990]. With the average sulphur content of 3%, the amount of sulphur dioxide emission has increased from 0.13 to 0.25 M tons between 1985 and 1990.

The last contributor to sulphur dioxide emission in Thailand is diesel oil. Its consumption has grown from 4.47 M tons in 1985 to 7.42 M tons in 1990. The maximum allowable sulphur content in the Thai diesel oil is quite high at 1 % in comparison to 0.34 and 0.38 % in Hong Kong and Japan respectively. Assuming the average sulphur content in Thai diesel oil of 0.9 %, the amount of sulphur dioxide emission has increased from 0.086 to 0.134 M tons between 1985 and 1990. Table 2 summarizes the distributions of consumptions and sulphur dioxide emissions from the fuel oil and diesel oil.

At present, the emission standard for sulphur dioxide in Thailand is hardly effective since it is a voluntary standard. Measurements of sulphur dioxide emission from a lignite-fired fluidized-bed boiler on the outskirt of Bangkok exhibited the average value of 700 mg/cu.m [Wibulswas et al, 1990]. Sulphur dioxide emission from the largest lignite-fired power complex in Thailand was occasionally detected at 3000 mg/cu.m [World Bank, 1990]. By the year 2000, the unabated sulphur dioxide emission from the same power complex will be over 1 M tons which are about the same as the total amount emitted in West Germany.

Without a compulsory emission standard, it is estimated that sulphur dioxide emission from the combustion of the three fuels will rapidly increase to 2.2 M tons in the year 2000 in comparison to 0.43 M tons emitted by the combustion of the three fuels in 1985, see Table 1. Realizing the detrimental effect of sulphur dioxide emission from the fuels, the Thai government has issued several policy statements, for example, reduction of sulphur contents in diesel oil to 0.5% and in fuel oil to 2% during the Seventh Economic and Social Development Plan [NESDB, 1991], installation of desulphurization units in new lignite-fired power stations owned by EGAT, etc.. Estimated amounts of sulphur dioxide emission from the three fuels with the above pollution abatement measures, shown in Table 1, decrease to about 0.94 and 1.18 M tons in 1995 and 2000. The amount of sulphur dioxide emission from existing lignite-fired power stations could also be reduced by retrofitting with sorbent injection units [Nordic Power Invest, 1990].

CARBON DIOXIDE EMISSION

According to a report by the US-based World Resources Institute, developing nations now emit 45 % of the world's greenhouse gases, though USA and USSR are at the top of the list of the greenhouse offenders and contribued 17.6 and 12.0 % of the word total emission respectively [Brewster, 1990]. Thailand ranks eighteenth on the list with a contribution of 1.2 %.

One of the main greenhouse gases is carbon dioxide emitted mainly from combustion of fuels containing carbon atoms. In Thailand, petroleum-based fuels including natural gas contribute to the carbon dioxide emission more than biomass fuels.

The consumption of petroleum-based fuels has grown from 10.3 M tons in 1985 to 19.4 M tons in 1990 [NEA,1990]. As a result, the amount of carbon dioxide emission has increased form 30.2 to 46.9 M tons between 1985 and 1990, assuming an average carbon content in the petroleum products of 80%. By the year 2000, the amount of carbon dioxide emission from petroleum products is estimated at 115 M tons.

Thai natural gas contains about 10% of carbon dioxide which is separated at two gas separation plants. The consumption of domestic natural gas has steadily increased from 4.8 Mtons in 1985 to 15.1 M tons in 1990. Carbon dioxide emission from natural gas utilization is estimated at 21.7 M tons.

With the rapid growth of lignite consumption in the country, if it is assumed that the average carbon content in Thai lignite is about 30%, carbon dioxide from lignite combustion will increase from 13.6 M ton in 1990 to 41.9 M tons in the year 2000.

Biomass fuels in Thailand comprise mainly firewood, charcoal, bagasse and rice husk. Accurate determinations of their consumptions are rather difficult, especially the amounts of non-commercial utilization. However, their consumptions in 1987 [NEA, 1987] were approximated at 33.1 M tons from which 54.9 M tons of carbon dioxide were produced by combustion. The total carbon dioxide emission from both petroleum-based and biomass fuels and lignite in 1987 amounted to about 84.4 M tons and increased to 146.5 M tons in 1990, see Tables 1, 2, 3 & 4.

It should be noted that about 40 M tons of agricultural residues such as rice straw, stalks of maize, cassava, mungbean, sorghum, soybean and cotton, etc. are generated annually [Pitakarnnop, 1986]. They are normally burned in the fields to fertilize the soils or to destroy as waste materials.

Table 1. Lignite Consumption [World Bank & NEPO, 1989] and Emissions, M tons

	1985	1987	1990	1995	2000
Consumptions					
Electricity	4.60	5.73	9.65	20.8	34.0
Industry	0.53	1.09	2.77	3.3	4.1
Total	5.13	6.82	12.42	24.1	38.1
Emission, M tons					
Sulphur dioxide	0.21	0.27	0.50	0.96	1.52
				0.59*	0.71*
Carbon dioxide	5.64	7.50	13.65	26.5	41.9

Table 2. Petroleum Products' Consumption [NEA, 1987 & 1990] and Emissions, M tons.

	1985	1987	1990	1995	2000
Diesel Oil:					
Consumption	4.76	5.54	7.42	12.3	18.0
Sulphur dioxide	0.09	0.10	0.13	0.22	0.32
				0.12*	0.18*
Fuel Oil:					
Consumption	2.15	2.21	2.99	5.85	7.35
Sulphur dioxide	0.13	0.14	0.25	0.35	0.44
				0.23*	0.29*
Gasoline:					
Consumption	1.56	1.994	2.58	4.35	6.06
Lead, k tons	0.69	1.16	1.33	2.60	3.61
				0.98*	1.35*
Petroleum products:					
Consumption	10.3	11.8	19.4	29.2	39.3
Carbon dioxide	30.2	34.6	56.9	85.7	115.2

Table 3. Natural Gas Consumption [NEA, 1990] and Carbon Dioxide Emission, M tons

	1985	1987	1990	1995	2000
Comsumpton	4.8	6.4	15.1	46.5	59.7
Carbon Dioxide	6.9	9.2	21.7	66.8	85.8

* Alternative scenarios with pollution abatement measures.

Table 4. Biomass Consumption [NEA, 1990] and Carbon Dioxide Emission, M tons.

	Consumption			Av. Carbon	Carbon Dioxide		
	1985	1987	1990	Content,% [KMITT,1992]	1985	1987	1990
Fuel wood	23.3	22.9	21.4	50	42.7	42.0	39.2
Rice husk	3.4	3.3	3.3	60	7.5	7.3	7.3
Bagasse	6.8	6.9	9.6	22	5.5	5.6	7.7
Total	33.5	33.1	34.3		55.5	54.9	54.2

Table 5. Industrial Demand for Lignite, 1985-2000 [World Bank, 1989].

	1985	1987	1989	1995	2000
Cement	0.39	0.74	1.49	2.73	3.47
Tobacco	0.09	0.08	0.14	0.11	0.10
Industrial Boilers	-	0.02	0.48	0.52	0.82
Total	0.48	1.02	2.12	3.36	4.39

Table 6. Sulphur Dioxide Emission from Industrial Boilers [Wibulswas, 1991].

	1987	1989	1995	2000
Base-case	0.008	0.019	0.021	0.033
Lignite substitution	-	-	0.031	0.031
Sub Total	0.008	0.019	0.052	0.064
Cogeneration	-	-	0.144	0.288
Total	0.008	0.019	0.196	0.352

Table 7. Tentative Thai Emission Standard [NEB, 1985].

Pollutant	Source	Limiting Value
Sulphur dioxide	Bangkok	400 ppm
	Others	700 ppm
Nitrogen oxides	Combustion	1000 mg/m^3
Carbon monoxide	All sources	1000 mg/m^3

Amounts of carbon dioxide produced from these agricultural residues are being estimated.

EMISSION OF LEAD COMPOUNDS

Tetra ethyl lead is widely used as an additive to increase the octane number of gasoline as it is much cheaper than alternative additives. Upon combustion in gasoline engines, lead oxide and lead sulphate are produced and over 70 % are emitted into the air.

The maximum allowable amount of lead in Thai gasoline is relatively high at 0.40 g/litre [NEB, 1989] in comparison to 0.21 and 0.15 g/litre in Japan and 0.15 g/litre in both Malaysia and Singapore respectively. The consumption of gasoline in Thailand increased from 1.56 M tons in 1985 to 2.58 M tons in 1990 [NEA, 1990] and as a result, lead emission grew from about 780 tons to 1330 tons respectively, see Table 2.

Measurement of lead contents in the air in Bangkok during 1988-89 indicated that at several locations, alarming levels of the lead contents were reached, for examples, 6.9 and 6.3 µg/cu.m of air at the Great Circle and Din Daeng Toll Gate. It should be mentioned that the air quality standard in Thailand limits the lead content at 10 µg/cu.m of air.

Realizing the danger of lead emission, the Thai government has issued a policy to reduce the maximum allowable lead content in Thai gasoline down to 0.15 g/litre in 1993. As the first step, local production of methyl tertiary butyl ether as a cleaner additive will be granted investment privileges. At the same time, feasibility of production on ethyl alcohol as an alternative additive is being studied as Thailand produces several types of raw materials suitable for ethanol production such as cassava, sugar cane, corn, etc. and their exports now become more difficult.

POLLUTION FROM GASOLINE ENGINES

A research institute in Thailand has recommended that though non-leaded gasoline is now available in Bangkok, it should be available in the whole country by 1993 so that catalytic converters can be installed in all new cars then [Chongpirapien et al, 1990, 235-236]. Subsequently, the Thai government recently issued a regulation requiring the installation of catalytic converters on all gasoline cars produced after 1992. Though the three-way catalytic can effectively control the emission of carbon monoxide, nitric oxides and gaseous hydro-carbons, the environmental impacts of nitrogen oxides and hydro-carbon in the country have not been clearly determined in order to justify the cost of imported catalytic converter sets at about 300 M USD per annum.

Installation of the three-ways catalytic converters on all new gasoline cars in Thailand is a controversial issue since technical and economic constraints have not been thouroughly discussed [Wibulswas, 1992]. For example, the converter works efficiently within a narrow range of the air-fuel ratio and therefore has to be installed in conjunction with a microprocessor-based electronic ignition control unit [Ferguson, 1986]. The cost of an imported set of the converter and control unit will be very high, probably around USD 1500. In 1993, over 200,000 gasoline cars are expected to be registered in the country and hence, the total cost of the converter sets would be about Million USD 300. As the useful life of the converter set is under five years, therefore in 1998 new converter sets have to be installed on both new and old gasoline cars, the total cost for the country could then reach Million USD 600.

Instead of installing catalytic converters on all new cars, several alternatives seem to be more suitable and should be fully assessed. First, mass transit systems should be urgently constructed in major cities such as Bangkok. Second, emission standard for gasoline cars should be enforced without specifying equipment for the emission abatement. Third, if it becomes clearly necessary, catalytic converters should be made compulsory only for large gasoline cars registered in major cities.

LIGNITE-FIRE INDUSTRIAL BOILERS

Since the last few years, domestic lignite has been promoted as a cheap alternative to fuel oil. As domestic lignite contains about 4% sulphur, dry and ash-free basis, lignite is environmentally worse than fuel oil which will be allowed to have a maximum sulphur content of only 2% in the near future.

In industry, lignite-fired boilers are used mainly in pulp and paper, food and textile factories. In a base-case, the lignite consumption in industrial boilers is estimated to increase from 0.20 M tons in 1987 to 0.82 M tons in the year 2000 [World Bank, 1989]. However, recent studies indicate that lignite as a substitute for fuel oil in industrial boilers can amount to 0.77 M tons per annum [Chullabodhi, et al, 1990]. In addition, potential for lignite consumption in industrial cogeneration systems could reach 7.2 M tons by the year 2000 and sulphur dioxide emission from the boilers could amount to 0.28 Mtons [Wibulswas, 1991].

As most of the lignite-fired industrial boilers are in urban or sub urban areas and domestic lignite contains high sulphur content, sulphur dioxide emission from the boilers poses direct threat to public health. Studies on sulphur dioxide emission from lignite-fired boilers [Wibulswas, 1991] revealed that the sulphur dioxide contents in the flue gas greatly exceed the limit set by the recommended emission standard [NEB, 1985]. Emission abatement measures have to be seriously enforced.

CONCLUSIONS AND RECOMMENDATIONS

The recommended Thai emission standard on sulphur dioxide emission is quite mild in comparison to the compulsory standards in West European countries [Altdorfer, 1987]. The standard should be made mandatary as soon as possible. Otherwise, by the year 2000, the total amount of sulphur dioxide emitted in Thailand will exceed those in Korea, Japan, Italy, etc. Neighbouring countries may be affected by acid rain then.

As a result of the rapid growth of fuel consumption, Thailand position will not be low on the list of greenhouse offenders after the year 2000, and fossil fuels will account for more than 80 % of the carbon dioxide emission in the country. As the biomass will remain one of the main sources of energy in Thailand for at least two decades, accelerated reforestation programme can help reduce the amount of carbon dioxide emission in the country.

Though the Thai government's policy is to reduce the lead content in gasoline down to 0.15 g/litre by 1993, non-leaded gasoline has already been available in Thailand. Technical specifications for non-leaded gasoline should be improved to ensure uniform quality of the gasoline throughout the country. Emission controls for internal combustion engines should be based upon mandatory emission standards without specifying control devices. Comparative merits between methyl tertiary butyl ether and ethyl alcohol as additives should also be thoroughly studied.

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APPENDIX

Sulphur Dioxide Estimation:

Combustion Equation, $S + O_2 \longrightarrow SO_2$
Mass, 32 64

If s = mass fraction of sulphur in a fuel,
M = mass of the fuel,

Amount of sulphur dioxide emission = 64 sM/32
= 2 sM.

Carbon Dioxide Estimation:

Combustion Equation, $C + O_2 \longrightarrow CO_2$
Mass, 12 44

If c = mass fraction of carbon in a fuel,
M = mass of the fuel,

Amount of carbon dioxide emission = 44 cM/12
= 3.67 cM