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ENERGY TECHNOLOGIES AND POLICIES TO REDUCE GLOBAL CLIMATE CHANGE: THE THAI PERSPECTIVE

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Abstract

The power sector now accounts for nearly 33% of Thailand's total carbon dioxide emissions. During the next decade, the power sector will surpass transportation as the major source of CO_2 emissions in Thailand. By the year 2011, the sector will account for 43% of Thailand's CO_2 emissions.

To keep up with the rapidly rising demand for electricity, the Electricity Generating Authority of Thailand (EGAT) is planning to more than double its capacity over the next decade, from 9,000 to 19,000 megawatts (MW). Most of the new plants being built will burn lignite and coal. This trend will lead to greatly increased emissions of carbon dioxide and other greenhouse gases.

This paper focusses on the potential for reducing carbon emissions in the power sector, since this is one of the most rapidly growing sources of such emissions in Thailand. It examines several CO_2 reduction strategies: these include end-use energy efficiency, fuel switching, the utilization of waste heat (cogeneration) and biomass-based (dendrothermal) power systems.

The Thai electric utilities are about to embark on a demand-side management effort that could reduce projected electricity growth by 20% over the next decade. By deferring or eliminating the need to build fossil-fuel fired power plants, the DSM effort could reduce CO2 emissions from the power sector by 13% annually by the year 2006.

The fuel-switching options involve reducing the use of domestic lignite and imported coal and oil. These options include increased reliance on imported natural gas, hydroelectricity, and the construction of nuclear power plants. Together, these fuel-switching strategies have the potential to reduce growth of CO_2 emissions from the power sector by more than 50% anually by the year 2006.

It appears that waste heat utilization and dendrothermal power systems have a significant potential to reduce CO_2 emissions from the power sector.

The most cost-effective of these CO_2 reduction strategies is energy efficiency, which can provide saved energy ("Negawatts") at less than half the cost of building new fossil-fuelled generating capacity. Nuclear power, an oft-discussed option for addressing the problem of global warming, would cost nearly twice EGAT's current long-run marginal cost of production. In addition, no nation has yet developed an acceptable plan for long-range storage of nuclear waste.

Introduction

The composition of the earth's atmosphere has changed rapidly during the past two centuries. The major effects of these changes are increases in the atmospheric temperature, thinning of the ozone layer, and acid deposition. The causes of these global problems are interrelated and include burning of fossil fuels to produce energy and provide transportation, deforestation to provide land and fuel wood, and the widespread use of chemicals (chlorofluorocarbons) that destroy the protective ozone layer above the earth.

Even if the predictions of temperature rise are overstated, the economic impacts of continued high-rate of growth in energy use will be untenable. The World Bank estimates that developing countries will require $1 trillion for capital expenses in their power sectors alone,and $4 trillion over the next three decades. Yet only $10-12 billion per year is expected to be available from multilateral and bilateral agencies, the main funders of electricity supply projects. (IIEC 1991A) Thus the shift to cleaner, cheaper fuels and improved energy efficiency will have additional societal benefits. Likewise, continued deforestation and the unabated use of chlorofluorocarbons will have devastating effects for the every individual on the planet.

Thailand is not currently a major contributor to global warming, in terms of emissions of carbon dioxide and other greenhouse gases. One source has ranked Thailand 18th worldwide in CO_2 emissions, with a contribution of 1.1 percent, but the reliability of this ranking has been questioned. Nonetheless, in the near future, as Thailand's economy expands, and its burning of fossil fuels grows, Thailand will begin to share a larger responsibility for the problem.

Overview of Thailand's Energy Picture

Thailand's primary energy use grew at an average annual rate of 13.4% between 1985 and 1990. The rapid, sustained growth is due to the overall pace of growth of the economy and expansion of industrial, construction, and transport activities. The Seventh Economic Plan projects an economic growth rate of 8.2% from 1992 to 1996. It is expected that energy demand will grow at an even faster rate, for example 10.3% in the power sector (NEPO 1991B).

Transportation accounts for the largest share of primary energy demand at about 30% (NEA 1990). The next largest shares are consumed by the power and industrial sectors (see Table 1).

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During the next decade, the power sector will surpass transportation as the major source of CO_2 emissions in Thailand. By the year 2011, the sector will account for 43% of Thailand's CO_2 emissions. Figure 1 shows the increase in generating capacity and the change in fuel mix. The trend is toward reduced reliance on oil and increase reliance on domestic lignite and imported coal.

This paper focusses on the potential for reducing carbon emissions in the power sector, since this is one of the most rapidly growing sources of such emissions in Thailand. It first summarizes Thailand's current energy balance and energy-related policies. It then examines two strategies that can be used to mitigate rapidly rising CO_2 emissions from the power sector: end-use energy efficiency and fuel switching.

Thailand's Energy Policy

Thailand's energy policy emphasizes the use of domestic energy resources in order to reduce the burden on the country's balance of payments. Domestic energy resources comprise gas, lignite, biomass (including fuel wood) and hydropower. The use of fuel wood and hydropower is unlikely to grow significantly, due to the government's efforts to encourage reforestation and to growing public opposition to the building of dams.

Figure 2 shows that the use of lignite and coal will increase greatly over the next 15 years. In the power sector, where most of the lignite and coal is used, consumption will rise more than fivefold -- from 10.5 million tonnes in 1991 to 56 million tonnes annually in 2006. (EGAT 1990). Table 2 shows the breakdown of CO^2 emissions by sector, forecast through the year 2006.

Energy policy has moved towards greater reliance on market forces. This applies particularly to the modern energy sector, where oil prices are mostly deregulated. In the electricity sector, where the government still has the leading role, a policy of privatization is being explored, though the details remain to be clarified. However, there is agreement in principle for the sale of privately generated electricity to the national grid, and conditions for doing so have been announced.

The major energy sectors are gas and oil, and electricity.

Gas and Oil: The emphasis in this sector is on exploration for new oil and gas reserves, while increasing in production from known reserves continues. The country's refinery capacity is expanding, as the government has granted permits to major oil companies to build at least two new refineries to meet the growing demand for refined products.

Electricity: A major expansion plan for the electricity sector is under way to meet the rapid increase in demand. Capacity is being increased mainly through new installations at existing power plants. In view of the fluctuation in the world oil market following the Gulf crisis, renewed emphasis is placed on the use of lignite, natural gas and imported coal.

Biomass: Policy is particularly weak in this area. The government has paid little attention to the issue of reforestation to provide an alternative supply of wood for energy consumption. However, the private sector has responded to the opportunities created by the closure of the forests to logging in 1988, by planting fast growing trees on privately-owned farm land and by producing charcoal for urban areas.

Energy Conservation: There are considerable constraints on public-sector investment financing for energy conservation. There is little government initiative for energy efficiency outside the electricity sector. However, the Thai utilities proposed a demand-side management program to the National Energy Policy Committee in October 1991. Through the proposed program, significant amounts of utility expenditures will be used as investment capital to promote electricity efficiency. This is in addition to activities already under way in the NEA's Saving Plan.

In sum, macro and sectoral policies have been concerned mainly with the commercial energy supply sector and less with energy conservation and renewable energy sources. However, there is now a more receptive policy environment for energy efficiency in particular.

Sources of Energy

Thailand's current fuel mix in the power sector is diverse, although it is primarily dependent on oil and gas. During the next decade, the mix will change dramatically, and by the year 2006, 64% of Thailand's energy will be generated by coal and lignite. (EGAT 1990)

There is no quick fix to the problem of global warming. Any proposed policies to reduce CO_2 emissions from the power sector should encourage the development of a diverse fuel mix and not rely on a single panacea. End-use energy efficiency should be a primary objective in any policy, since this can reduce the amount of resources required to generate power from all sources of energy.

Below is a review of the current status and potential for Thailand's various energy resources.

The Potential for End-Use Energy Efficiency

Thailand is an inefficient user of energy compared to other countries. The ratio of energy consumption to GNP is 1.5 kg carbon/US$, compared to 0.2 for the U.S., 0.3 for Korea and Singapore, and 0.9 for Malaysia. Efficiency improvements across all sectors can reduce Thailand's energy consumption by at least 30%.

Although the Sixth National Plan (1987-1991) placed a priority on energy conservation, little has actually been accomplished to reduce the rate of growth in energy demand. There are currently two main policy efforts to improve the efficiency of electricity use.

Utility Demand-Side Management. The electric utilities have submitted a five-year plan for demand side management in the power sector. The plan calls for the establishment of a Demand Side Management Office to operate energy conservation programs. The office would be operated jointly by the three electric utilities and would provide financial incentives for the purchase of energy-efficient equipment in the commercial, industrial, and residential sectors. Thailand will be the first country in the Asia region to begin implementation of such energy efficiency programs.

Energy Conservation Law. The Ministry of Science, Technology and Energy has drafted an Energy Conservation Law which was scheduled to be considered by the National Legislative Assembly before the end of 1991. The draft law would require factories to appoint an energy manager and report on their efforts to conserve energy. Because of concerns from industry about the reporting requirements and the intrusive nature of the law, it was sent back to committee in September to be redrafted. The draft law also refers to an energy code for new buildings, developed by the National Energy Administration. When fully implemented, the building code, which would establish minimum requirements for building materials and energy use, would lower the energy use of new buildings by 33% compared to current construction.

Thailand's electricity conservation potential has been well studied. At least 2,000 MW of power plants can be displaced over the next ten years by providing incentives to purchase efficient equipment (see Figure 3). (IIEC 1991B) This is 20% of EGAT's expected capacity growth during the same period. The cost of these saved megawatts is estimated at 0.43 baht/kWh, compared to the electric utility's long-term avoided cost of electricity production of 1.08 baht/kWh.

As a power resource, energy efficiency is cheaper than building new power plants. It also has several other advantages: it comes in small packages with a short lead time, so that its effects are felt immediately; it does not require a reserve margin, as do power plants; it does not suffer from losses during transmission and distribution (14% for electric power); and it does not emit pollutants.

The Potential for Waste Heat Utilization

At present, no large energy generation projects have been established to demonstrate cogeneration. Cogeneration systems have an average efficiency of 55-80%, which is higher than combined cycle plants, which operate at about 46%. (Wibulswas 1991)

King Mongkut's Institute of Technology Thonburi (KMITT) has studied the potential for cogeneration systems in nine different industries: chemical, petrochemical, food, refineries, pulp and paper, textiles, sugar, rice mills, palm oil. (KMITT 1991) The study shows that those industries can generate more than 850 MW, or about 10% of EGAT's installed generating capacity. Overall, the industrial sector could sell about 2,000 MW to the national grids. In the long term, the industrial sector has potential to expand its cogeneration capacity up to 2,800 MW.

In Thailand, the generation and distribution of electricity is government controlled. Until now, only government enterprises have been allowed to produce and sell electricity. However, there are recent policy developments that offer opportunities for the utilization of various agricultural residues for electricity generation. The government is developing draft regulations that will allow private producers to sell electricity, both to the grid and to other users.

Selling to other users: A private producer of electricity can produce and sell electricity to others without government intervention if the transaction does not involve the use of the public transmission facilities.

Selling to the grid: A private producer operating a co-generation facility to produce steam and electricity can sell surplus electricity to EGAT. Conditions are being set for EGAT to buy electricity from such producers. At the time of writing, the purchase price for longer term firm energy contracts is expected to be around B1.08/kWh. The purchase price for a five-year, non-firm energy contract has been proposed at B0.88/kWh. Prices for capacity have not yet been determined.

The Potential for Renewable Energy Sources

Non-fossil energy resources such as hydroelectricity, biomass, solar energy, wind, and photovoltaics have high potential for utilization. The potential of hydropower from domestic and international rivers is quite large. Biomass, especially fuel wood and agricultural residues, will remain the major source of primary energy in rural areas of Thailand for the next two decades. Plantations of fast growing trees can provide an alternative source of energy and help decrease deforestation problems. Solar thermal energy, wind power and photovoltaics are viable technologies that have been identified, developed and implemented.

Hydro Electricity

The total hydro potential of domestic rivers is estimated at about 10,050 MW. (Wibulswas 1991) The current generating capacity of hydro electricity at 2,300 MW represents about 30% of the total generating capacity of the country. Hydro potential of domestic rivers still exists and can be further utilized if and when the significant environmental issues surrounding the building of dams can be resolved in the future.

Large hydropower potential exists on two international rivers. Seven proposed projects on the Mekong River on Thailand's eastern border have the potential to generate 9,600 MW; four projects proposed for the Salween River on the western border could generate 8,200 MW. Hydro-power projects on the international rivers may only be realized, however, once political constraints are removed and environmental considerations satisfied.

As a part of the rural electrification program to bring electricity to 90% of all villages in Thailand by 1990, 29 small hydropower sites have been initially identified as suitable for more accurate cost estimates and detailed engineering work. Thorough feasibility studies of small hydropower projects have shown that the cost of electricity generated from a suitable site can be more economical than electricity generated from a diesel- electric generator or a photovoltaic plant. One step to further reduce the first cost of a small hydropower plant is to run a commercially available pump as the turbine.

Biomass

During the last five years, about 100,000 acres of eucalyptus have been planted. Large plantations of fast-growing trees have been planned by both the public and private sectors.

In 1987, the National Energy Administration performed a feasibility study of dendro-thermal (biomass-based) power systems with a total generating capacity of 1,200 MW. The proposed project would employ over 200,000 families to plant and manage 1.5 million acres of fast growing trees for the power systems. However, the implementation depends on the first investment cost which will be affected by escalating land prices and the first five years of idle time before the planted trees can be fully utilized.

Several agricultural residues have been used as fuels in agro-industries. Seventy percent of the bagasse waste in the sugar industry, estimated at about 7.5 million tons per year, is used as boiler fuel in sugar mills. The supply of rice husks was estimated to be more than 5 million tons in 1987. Roughly 40% of this supply is used as boiler fuel in rice mills. More than 3 million tons is still available as an energy resource for rural industries or electric generation whose potential is estimated to be at least 88 gigawatt hours (GWh) per year. Palm oil wastes consisting of fiber and shells are also used as boiler fuel in about thirty palm oil mills in Thailand.

Other agricultural residues such as straw, maize stalks, cassava stalks, corn cobs, coconut shells and husk also have potential as energy resources for rural areas with their total supply of more than 35 million tonnes per year. Viable utilization technologies are being identified or developed.

Solar and Wind Energy

Thailand is fairly well endowed with solar radiation, which averages 17 MJ/m^2 day on average. About 50% of the radiation appears as diffuse radiation, however, which limits its usefulness. Equipment that relies on direct solar radiation currently has low economic feasibility.

Solar energy has been non-commercially used in Thailand for centuries. Solar energy used to produce salt from sea water has been estimated to be as much as 20 million barrels of oil equivalent. Sun drying of about 15 million tons of paddy rice each year uses solar energy that is equivalent to half a million barrels.

A small solar water heating industry has been established in Thailand for almost a decade. Solar collectors have been installed for water heating in hospitals, hotels and a small number of private houses. Current domestic production of solar collectors exceeds 10,000 m^2 per year. Development of solar dryers has been very active in the country, and a few designs of free convection dryers have been commercialized with some success. Several designs of solar stills have been developed, including the vertical surface type. Installation of large solar stills for demonstration is being planned.

Generation of electricity by photovoltaic cells has been rapidly developed in Thailand. A large number of demonstration projects for telecommunication, lighting and water pumping, etc., have been set up in the country with a combined peak output of about 400 kW. Semiconductor laboratories in two academic institutes conduct research and development on solar cell materials and fabrication. Photovoltaic modules are locally produced in two factories.

In general, the potential for wind energy in Thailand does not seem very promising, as the average wind speed in the country is only about 2 m/s. (Such a low wind speed makes the economics unfavorable). However, high wind speeds exist in some coastal areas, and wind mills have been used for water pumping in salt farms and rice fields along the eastern coast. It has been recently shown that traditional sail-type wind mills used for water pumping in salt farms are more economical than diesel-driven water pumps. Demonstration of wind electric power systems has also been conducted.

Strategies to Reduce CO_2 Emissions

There are several viable ways to reduce CO_2 emissions from the power sector. These include end-use efficiency, fuel switching (reducing use of lignite and coal), and increased reliance on a diverse mixture of renewable energy sources.

Table 3 shows estimates of annual CO_2 reductions for several different strategies. The potential for reductions from dendrothermal power and waste heat recovery need further refinement. In the following sections, the effectiveness of end-use energy efficiency and fuel switching are analyzed.

End-Use Energy Efficiency

Demand Side Management Program: In late October, the Energy Policy Formulation Subcommittee of the National Energy Policy Committee approved in principle a utility-managed demand side management program. The initial budget proposed for the plan was 770 million baht over three years, but this amount has not been finalized. The plan calls for the creation of a Demand Side Management (DSM) Office which will be jointly run by the three utilities.

The DSM Office will use a set of tools to influence the amount and timing of customer electricity use. These tools include energy conservation, time-of-day tariffs, and load management.

The three state-owned utilities -- the Electricity Generating Authority of Thailand (EGAT), the Provincial Electricity Authority (PEA) and the Metropolitan Electricity Authority (MEA) -- will offer financial incentives to for projects nationwide to promote the construction of energy-efficiency buildings and the use of energy-efficiency equipment and appliances.

Table 4 lists the technologies proposed for the DSM programs. On average a kilowatt hour provided by end-use efficiency costs less than half the cost of adding one kWh of generating capacity. (A kilowatt hour of electricity saved is the equivalent to one produced, since that unit of electricity is freed up for use somewhere else.)

A serious effort at demand side management (DSM) efforts can save at least 2,000 MW of capacity by the year 2001 (Monenco 1991B, IIEC 1991B). To estimate the amount of CO_2 reduction, we used a conservative estimate of the potential for gigawatt-hour savings by 2001 and assumed the savings would remain constant from 2001 to 2006. (Monenco 1991B) The saved kWh were distributed evenly across baseload and peaking plants. A spreadsheet was used to estimate the amount of CO_2 due to different fuel types, employing conversion factors from the U.S. (ERG 1991)

Table 5 and Figure 4 show the estimated reductions in CO_2 emissions through the year 2006. The potential reductions are due to the deferral or elimination of the need to build thermal plants that burn coal, lignite, oil, or gas. The reduction by 2006 amounts to 14.7 million tonnes CO_2, or 13% of annual emissions.

Fuel Switching

In this scenario, it was assumed that there were switches from lignite, imported coal and fuel oil to natural gas, hydro, and nuclear power plant. The assumptions are described below:

Natural gas from Burma. A quantity of 150 million cubic feet per day would be purchased in 1997; this amount would be increased in steps to 500 million cubic feet per day by 2006. The Burmese gas would be used in the central region of Thailand. It would be used mainly in the new combined-cycle power plants, and the output would replace the Ao Phai coal-fired Unit 3 in 1998 and Lampang lignite-fired Units 1-4 in 1999 and 2000 with a total capacity of 1,900 MW. The balance of gas would be used in the existing oil/gas-fired power plants.

Natural gas from Malaysia. A quantity of 250 million cubic feet per day would be purchased beginning in 1998. The Malaysian gas would be used in the Southern part of Thailand. It would be used in the new combined-cycle power plants, and the output would replace the Saba Yoi lignite-fired Units 1-3 in 2000 and 2002 with a total capacity of 900 MW. The balance of gas would be used in the existing Khanom oil/gas-fired and committed Khanom combined-cycle power plants.

Hydroelectric from Laos. Several hydroelectric projects are in the planning process: Nam Theun 2, Nam Ngum 2 and Nam Ngieb. They would be carried out under the condition that Thailand and Laos jointly invest and sell most of power to EGAT. There have also been discussions regarding the Pa Mong dam project on the Mekong River. It was assumed for the purposes of this study that EGAT would purchase power from these projects; the output would replace the Lampang lignite-fired Units 5-6 and Ao Phai coal-fired Unit 4 with a total capacity of 1,600 MW in 2001.

Nuclear power. From the year of 2002 to 2006, all imported coal would be replaced by six 1000-megawatt nuclear power plants a combined capacity of 6,000 MW. Figure 5 shows that the proposed nuclear plants would represent 26% of EGAT's capacity in the year 2006.

CO_2 emissions are estimated based on the following conversion factors: 0.295 CO_2 g/kcal for petroleum and petroleum products, 0.211 CO_2 g/kcal for natural gas, 0.366 CO_2 g/kcal for lignite and coal. (ERG 1991)

Table 6 shows a list of EGAT's power supply projects and alternative fuel substitution projects. Table 7 summarizes the benefits in terms of reduced CO2 emissions due to the fuel-switching.

The savings from the combination of these projects is dramatic: the combined effect is to reduce projected C02 emissions from the Thai power sector by over 50% in the year 2006 (see Figure 6).

Economic Considerations

To reduce greenhouse gas emissions caused by energy consumption requires new implementation programs. These programs will involve a large, up-front financial investment. For developing countries, the costs of technology transfer and development are substantial, and without financial and technical assistance from the developed countries, the programs are unlikely be implemented successfully.

Table 8 ranks electricity sources in terms of their cost effectiveness. The economics of electric efficiency are the most favorable: the efficiency measures being proposed by the Thai utilities will provide saved energy ("Negawatts") at less than half the cost of building new generating capacity. EGAT's long-term marginal cost of generating electricity is B1.08/kWh. The cost of saved energy for the utilities' proposed DSM program is just 0.50 baht/kWh.

Natural gas and hydroelectric power provide power at a cost that is less than the cost of lignite and coal plants with scrubbers. With regard to gas, however, there is the possibility of future price increases due to pipeline construction and the uncertainty of supply from neighboring countries.

Rice-based cogeneration and dendrothermal power can provide electricity for a price near to EGAT's long-term marginal cost -- in a range of 0.7 to 1.4 baht/kWh.

Forecasts of the cost of nuclear power are difficult to make. The cost of producing electricity from nuclear plants in the U.S. is at least 2 baht/kW, which is nearly twice EGAT's long-run marginal cost of production. (Delene 1988) During the late 1970s in the U.S. nuclear costs were rising by 16% per year, exclusive of inflation. (Keepin 1988) In addition, no nation has yet developed an acceptable plan for long-range storage of nuclear waste.

Compared to end-use efficiency, the cost of displacing carbon by constructing nuclear plants is quite high. Figure 7 shows that, based on data from the U.S., a dollar invested in efficiency displaces nearly seven times more carbon than a dollar invested in nuclear power.

Conclusions

Within the next decade, the power sector will become the major source of CO_2 emissions in Thailand. Besides the use of renewable energy source (which is not examined in detail here), there are several viable alternatives for mitigating the large expected increases in CO_2 emissions.

The Thai electric utilities are about to embark on a demand-side management effort that could reduce projected electricity growth by 20% over the next decade. By deferring or eliminating the need to build fossil-fuel fired power plants, the DSM effort could reduce CO_2 emissions from the power sector by 13% over the next 15 years.

Another set of options involves fuel substitution to reduce reliance on fuels with higher emissions, such as lignite and coal. This paper analyzed the effects of increasing reliance on imported natural gas, hydroelectricity, and the construction of nuclear power plants. Together, these fuel-switching strategies have the potential to reduce growth of CO_2 emissions from the power sector by more than 50% over the next 15 years.

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Figure 2. Forecast of Primary Energy Demand by Source. (Unit: KTOE) (Sources: TDRI, NEA, NEPO, EGAT)

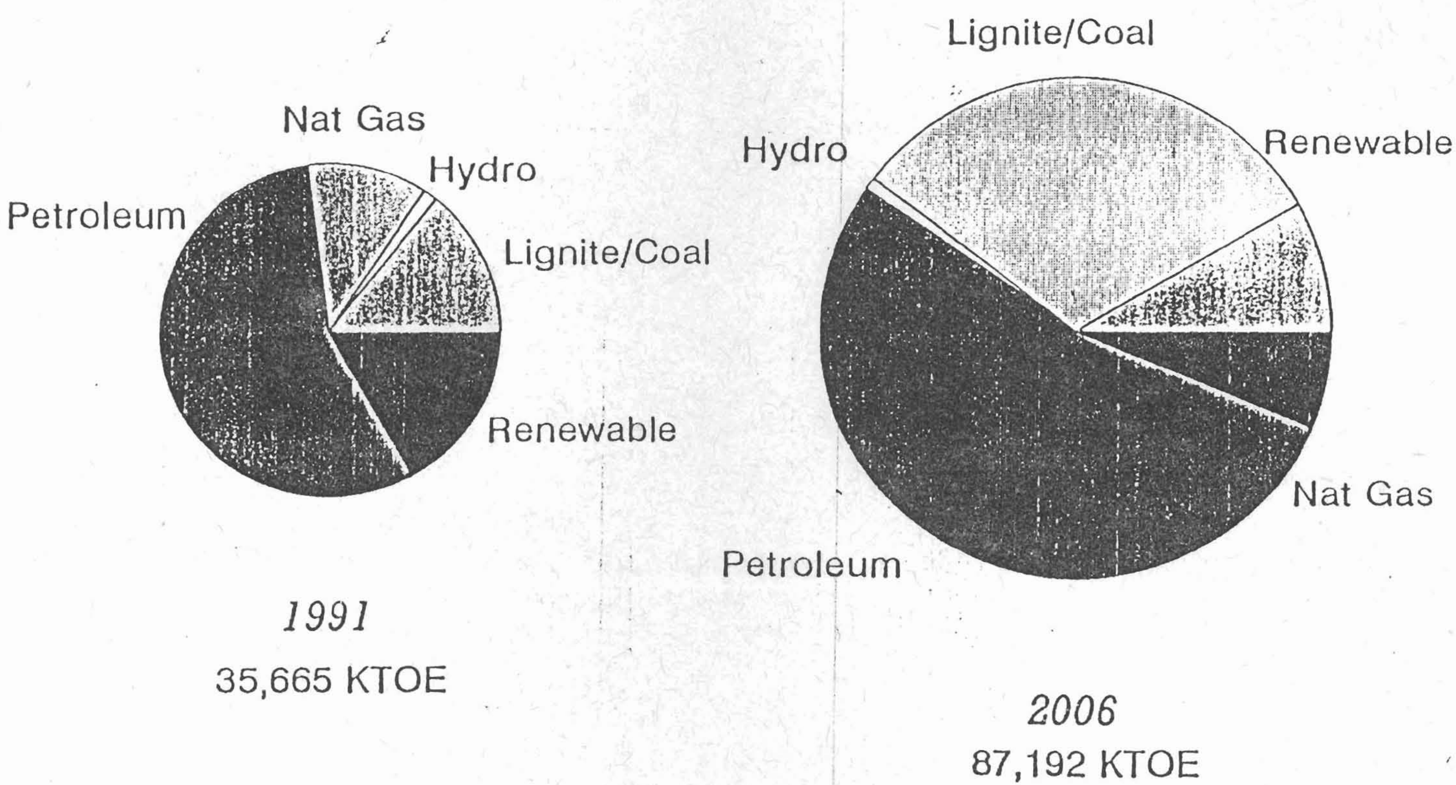


Figure 5. Proposed Energy Generation from Nuclear Power (Source: EGAT)

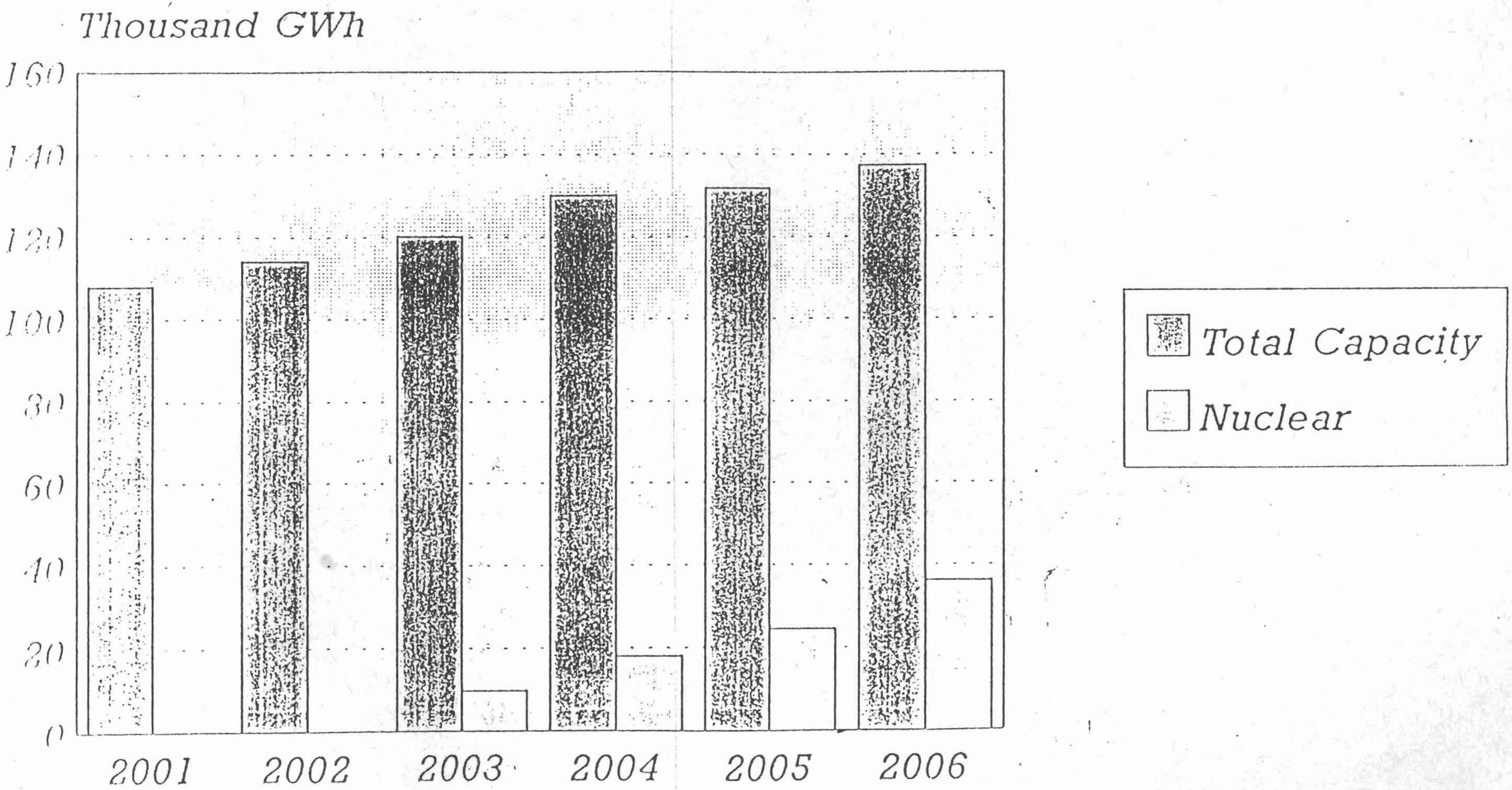


Figure 6. CO^2 Emissions Reductions from the Power Sector Due to Fuel Switching.

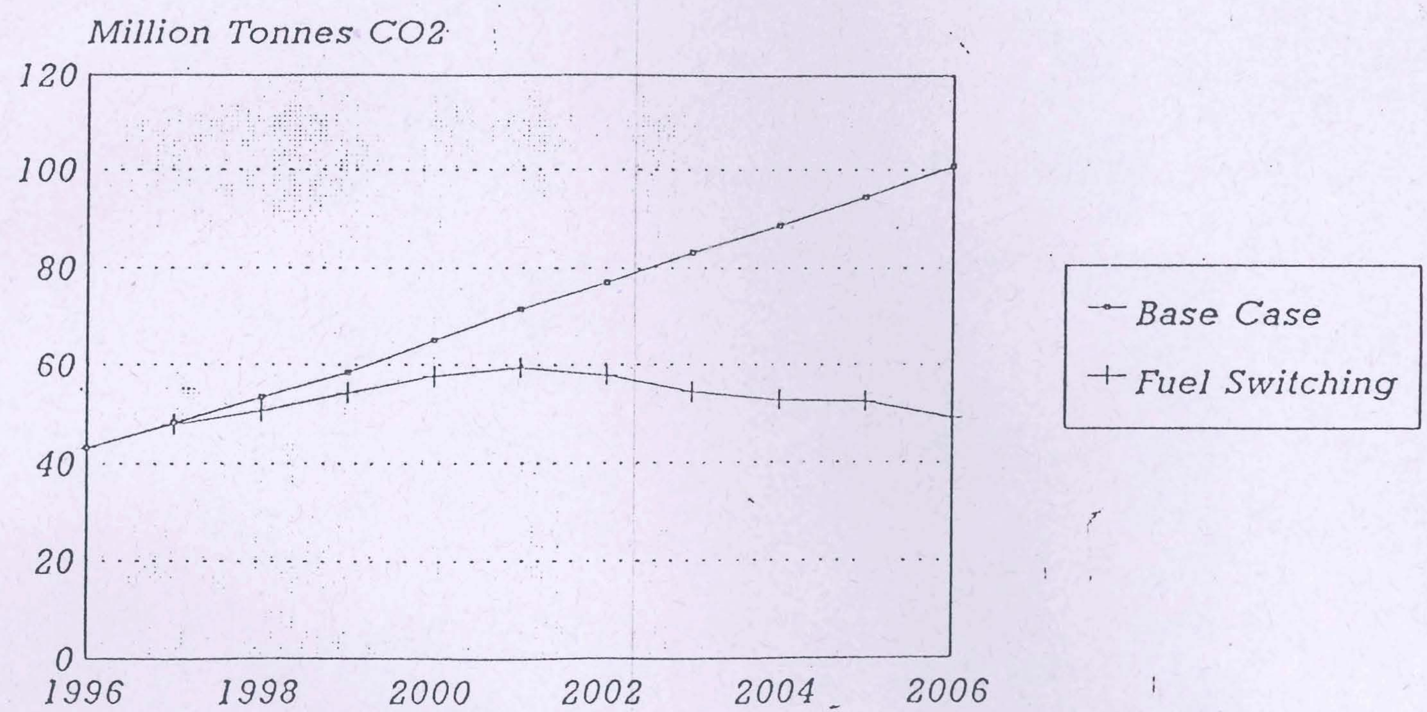
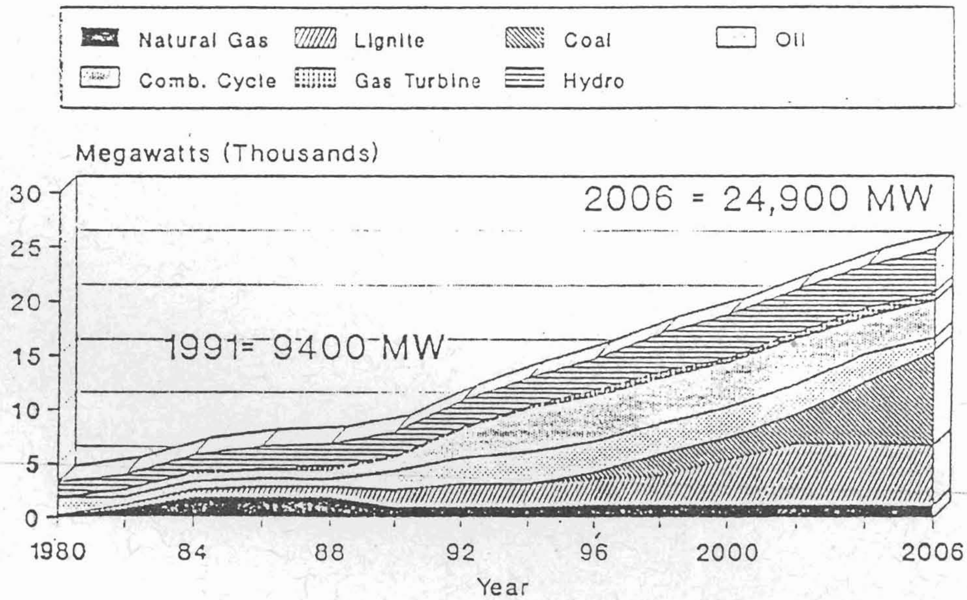


Figure 1. Thailand Generating Capacity: 1991 Forescast by Plant Type.



EGAT PDP 90-03

Figure 3. Thailand DSM Potential in 2001: Various Estimates. (IIEC 1991B)

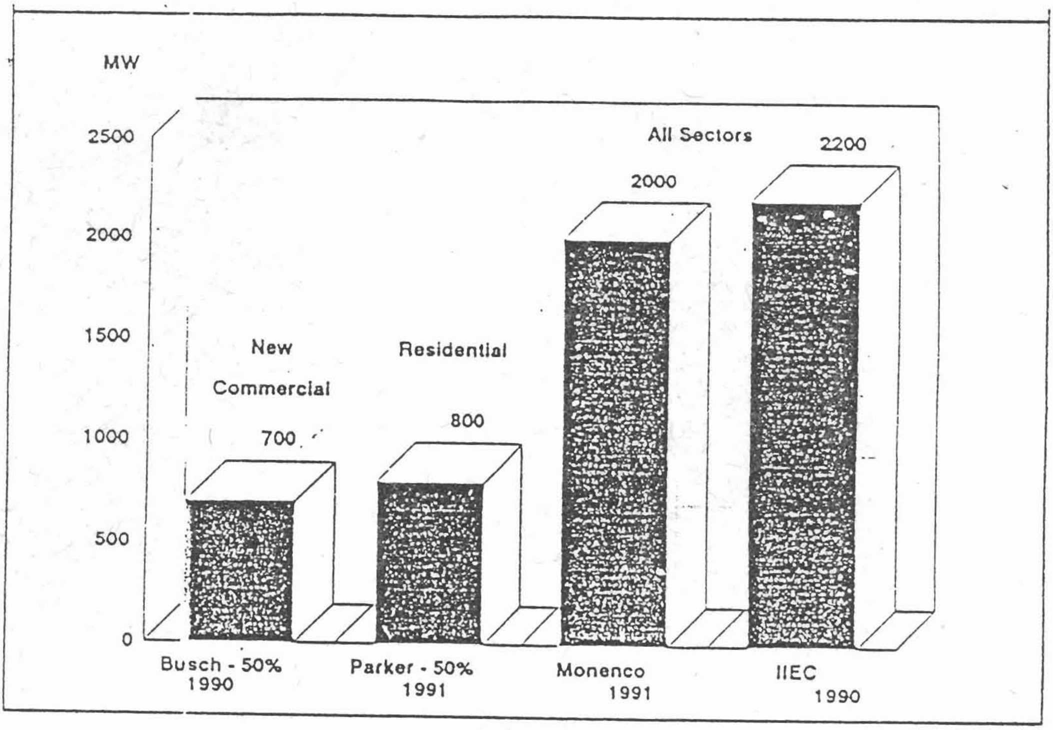


Figure 4. CO_2 Emissions from the Power Sector under Base Case and DSM Scenarios.

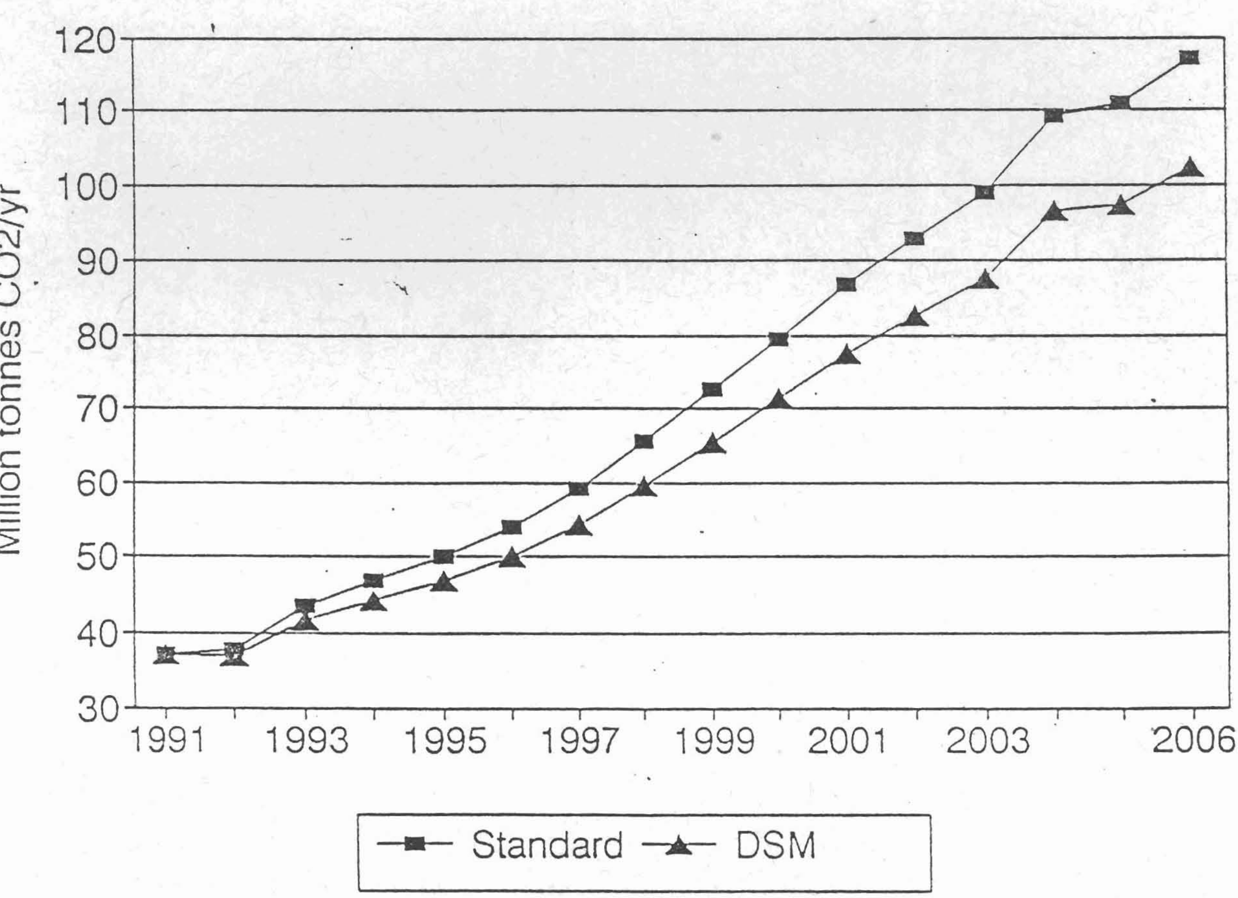


Table 7. Comparison of CO2 Emissions Under Base Case and Fuel-Switching Scenarios

Year	CO2 from Lignite		CO2 from Coal		CO2 from Oil		CO2 from NG		CO2 from Hydro	CO2 from Nuclr	Total CO2 BC	Total CO2 PC
	BC	PC	BC	PC	BC	PC	BC	PC				
	MMTon	MMTon	MMTon	MMTon	MMTon	MMTon	MMTon	MMTon	MMTon	MMTon	MMTon	MMTon
1996	12.6	12.6	0.7	0.7	12.6	12.6	17.1	17.1	0.0	0.0	43.0	43.0
1997	15.2	15.2	5.9	5.9	9.3	6.0	17.7	20.6	0.0	0.0	48.1	47.7
1998	15.2	15.2	9.9	7.9	10.8	0.5	17.4	26.9	0.0	0.0	53.3	50.5
1999	16.9	15.2	11.9	7.9	13.5	5.4	16.0	25.6	0.0	0.0	58.3	54.1
2000	21.2	15.2	11.9	7.9	16.6	8.6	15.4	25.9	0.0	0.0	65.1	57.6
2001	28.2	15.2	11.9	7.9	15.9	9.3	15.4	26.9	0.0	0.0	71.4	59.3
2002	31.7	15.2	15.8	7.9	14.1	5.8	15.4	28.8	0.0	0.0	77.0	57.7
2003	32.1	14.6	24.5	7.9	11.1	2.1	15.4	29.7	0.0	0.0	83.1	54.3
2004	32.4	14.9	31.8	7.9	9.0	0.0	15.4	29.7	0.0	0.0	88.6	52.5
2005	32.6	15.2	37.5	7.9	8.6	0.0	15.6	29.2	0.0	0.0	94.3	52.3
2006	32.3	14.8	47.7	7.9	5.0	0.0	15.6	26.2	0.0	0.0	100.6	48.9

BC: Base Case

PC: Proposed Case

Source: Electricity Generating Authority of Thailand (1991).

Table 6. List of Power Supply Projects.

Year	Existing Plan PDP 90-03	Proposed Plan (Reduced GHG)
1997	Existing Oil/Gas-fired	Imported Natural gas
Apr 1998	Ao Phai #3 (700 MW)	R1 CC #1-2 (2x350 MW)
Jan 1999	Lampang #1 (300 MW)	R1 CC #3 (300 MW)
Jul 1999	Lampang #2 (300 MW)	R1 CC #4 (300 MW)
Jan 2000	Lampang #3 (300 MW)	R1 CC #5 (300 MW)
Apr 2000	Saba Yoi #1 (300 MW)	R3 CC #1 (300 MW)
Jul 2000	Lampang #4 (300 MW)	R1 CC #6 (300 MW)
Oct 2000	Saba Yoi #2 (300 MW)	R3 CC #2 (300 MW)
Jan 2001	Lampang #5 (450 MW)	Imported Hydro (450 MW)
Jul 2001	Lampang #6 (450 MW)	Imported Hydro (450 MW)
Oct 2001	Ao Phai #4 (700 MW)	Imported Hydro (700 MW)
Apr 2002	Saba Yoi #3 (300 MW)	R3 CC #3 (300 MW)
Oct 2002	Imported Coal #1 (1000 MW)	Nuclear #1 (1000 MW)
Apr 2003	Imported Coal #2 (1000 MW)	Nuclear #2 (1000 MW)
Jan 2004	Imported Coal #3 (1000 MW)	Nuclear #3 (1000 MW)
Jan 2005	Imported Coal #4 (1000 MW)	Nuclear #4 (1000 MW)
Oct 2005	Imported Coal #5 (1000 MW)	Nuclear #5 (1000 MW)
Apr 2006	Imported Coal #6 (1000 MW)	Nuclear #6 (1000 MW)

NOTES: Ao Phai, Lampang, and Saba Yoi are lignite fired- power plants
R1 and R3 are the Central and Southern Regions of Thailand respectively
CC is Combined cycle using natural gas

Source: Electricity Generating Authority of Thailand (1991)

Table 5. CO2 Emissions from the Power Sector Under Base Case and DSM Scenarios.

	1991		1993		1995		1997		1999		2001		2003			2006
Hydro Plant (GWh)	3,665	5,410	5,410	5,515	5,905	5,905	5,905	5,942	6,603	7,018	7,097	7,097	7,097	7,097	7,097	7,097
Adjusted GWh	3,665	5,298	5,202	5,223	5,520	5,459	5,406	5,398	5,958	6,298	6,342	6,310	6,281	6,281	6,229	6,207
Unadjusted Total Emissions (Mtonnes)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DSM Adjusted Total Emissions (Mtonnes)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Natural Gas (GWh)	20,090	25,552	24,023	28,491	32,429	36,253	37,452	36,960	34,273	33,082	33,064	33,236	33,317	33,321	32,993	32,803
Adjusted GWh	20,090	25,015	23,098	26,981	30,313	33,514	34,288	33,576	30,925	29,690	29,545	29,551	29,488	29,492	28,959	28,687
Unadjusted Total Emissions (Mtonnes)	11.369	14.460	13.595	16.123	18.352	20.516	21.194	20.916	19.395	18.721	18.711	18.809	18.854	18.857	18.671	18.564
DSM Adjusted Total Emissions (Mtonnes)	11.369	14.156	13.071	15.269	17.155	18.966	19.404	19.001	17.500	16.802	16.720	16.723	16.687	16.690	16.388	16.234
Heavy Oil (GWh)	13,207	10,678	16,109	16,932	17,996	18,209	13,482	15,594	19,591	22,226	21,370	18,711	14,341	15,810	10,926	5,740
Adjusted GWh	13,207	10,453	15,489	16,035	16,822	16,833	12,343	14,166	17,677	19,947	19,095	16,636	12,693	13,993	9,590	5,020
Unadjusted Total Emissions (Mtonnes)	13.147	10.629	16.036	16.855	17.914	18.126	13.421	15.523	19.502	22.125	21.273	18.626	14.276	15.738	10.876	5.714
DSM Adjusted Total Emissions (Mtonnes)	13.147	10.406	15.418	15.962	16.745	16.757	12.287	14.102	17.597	19.857	19.009	16.561	12.635	13.929	9.547	4.997
Diesel Oil (GWh)	368	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Adjusted GWh	368	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Unadjusted Total Emissions (Mtonnes)	0.366	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
DSM Adjusted Total Emissions (Mtonnes)	0.366	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Lignite (GWh)	11,950	12,320	13,470	13,470	13,470	14,275	17,230	17,230	19,195	24,120	32,005	35,947	36,360	36,687	36,932	36,602
Adjusted GWh	11,950	12,081	12,951	12,756	12,591	13,197	15,774	15,653	17,320	21,647	28,598	31,962	32,181	32,471	32,417	32,010
Unadjusted Total Emissions (Mtonnes)	12.222	12.600	13.776	13.776	13.776	14.599	17.622	17.622	19.631	24.668	32.732	36.764	37.186	37.521	37.771	37.434
DSM Adjusted Total Emissions (Mtonnes)	12.222	12.335	13.246	13.046	12.877	13.497	16.133	16.008	17.713	22.139	29.248	32.688	32.913	33.209	33.153	32.737
Imported Coal (GWh)	0	0	0	0	0	766	6,900	11,500	13,800	13,800	13,800	18,400	28,255	36,465	43,035	54,535
Adjusted GWh	0	0	0	0	0	708	6,317	10,447	12,452	12,385	12,331	16,360	25,008	32,274	37,774	47,692
Unadjusted Total Emissions (Mtonnes)	0	0	0	0	0	0.779	7.013	11.688	14.026	14.026	14.026	18.701	28.717	37.062	43.739	55.427
DSM Adjusted Total Emissions (Mtonnes)	0	0	0	0	0	0.720	6.420	10.618	12.656	12.588	12.533	16.628	25.417	32.802	38.392	48.473
Purchase (GWh)	740	710	705	705	705	705	705	705	705	705	705	705	705	705	705	705
Total (GWh)	50,020	54,670	59,717	65,113	70,505	76,113	81,674	87,931	94,187	100,951	108,041	114,096	120,075	130,085	131,688	137,482
Adjusted Total	50,020	53,520	57,417	61,663	65,905	70,363	74,774	79,881	84,967	90,601	96,541	101,446	106,275	115,135	115,588	120,232
Unadjusted Total Emissions (Mtonnes)	37.104	37.690	43.407	46.754	50.042	54.020	59.250	65.749	72.554	79.540	86.742	92.900	99.034	109.177	111.058	117.139
DSM Adjusted Total Emissions (Mtonnes)	37.104	36.897	41.735	44.277	46.777	49.939	54.244	59.730	65.466	71.386	77.509	82.600	87.652	96.630	97.480	102.441

CO2 EMISSIONS FACTORS	lbs/kWh	kg/kWh	tonnes/GWh
Hydro	0.000	0.000	0
Natural Gas	1.245	0.566	566
Heavy Oil	2.190	0.995	995
Lignite	2.250	1.023	1,023
Coal	2.238	1.018	1,018

Table 1. Primary Energy Demand by Sector, 1990. (Unit: KTOE)

Sector	Coal	Oil	Nat.Gas	Hydro	Biomass	Total	% Share
Resident & Commercial	0	931	0	0	3,541	4,472	14.1
Industry	796	2,610	266	0	2,760	6,432	20.3
Agriculture.	11	1,796	0	0	0	1,807	5.7
Transportation	0	9,512	0	0	0	9,512	30.2
Power	2,078	2,654	3,986	461	0	9,179	29.0
Mining	0	58	0	0	0	58	0.2
Construction	0	147	0		0	147	0.5
Others	0	0	0	0	0	0	0.0
Total	2,884	17,707	4,252	461	6,301	31,605	100.0
% Share	9.1	56.0	13.5	1.5	19.9	100.0	

Source: National Energy Administration 1990

Table 2. Total CO^2 Emissions By Sector (10^6 tonnes of CO^2), 1998 - 2006. (Source: TDRI)

Sector	1991	2006
Industry	8.9	37.1
Agriculture	2.5	7.7
Residential & Commercial	2.3	10.3
Transportation	27.5	89.9
Power Generation	16.3	110.9
Refineries	1.1	3.1
TOTAL	58.6	255.9

Table 3. Examples of CO^2 Reductions from Various Strategies

Strategy	MW	GWh	CO^2 Reduction (10^6 tonnes)
Efficiency	2,000	17,250	14.7
Fuel Switching	---	---	51.7
Cogeneration	478	2,931	3.0
Dendrothermal	1,200	6,132	6.3

NOTES: The assumptions used to calculate reductions from efficiency and fuel switching are explained in the text and are the annual savings by the year 2006. For cogeneration, we converted MW into GWh (EGAT 1990) and then used conversion factors to estimate CO2 emissions reductions. (ERG 1991) For cogeneration, we used KMITT (1991) to derive the MW estimate of biomass-fuelled cogeneration potential. For dendrothermal we relied on a 1987 feasibility study by the National Energy Administration.

Table 4. Proposed end-use efficiency programs for the Thai Utility DSM Effort.

Commercial	• New building design and construction • Efficient lighting in large commercial buildings and shophouses
Industrial	• Efficient motors in factories
Residential	• Insulation and efficient air conditioners • Increase refrigerator efficiency • Efficient lighting

Figure 7. Relative Effectiveness of Nuclear and Efficiency Investments (at the Margin) for Abating CO_2 Emissions from Coal-Fired Power Plants.

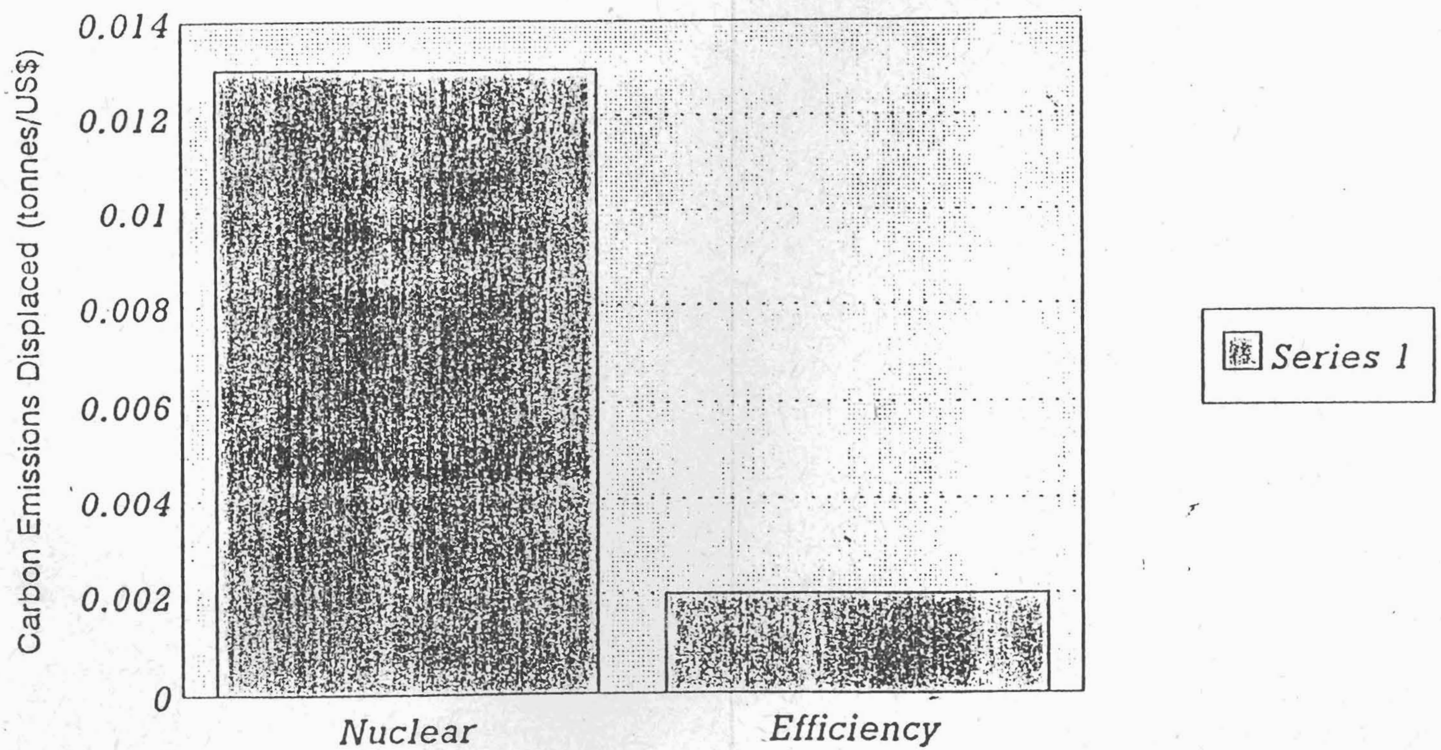


Table 8. The Cost of Different Electricity Resources.

Measure	Cost of Service (baht/kWh)
End-use efficiency	0.5
Cogeneration (rice husks)	0.7-1.1
Dendrothermal (50 MW)	1.2-1.4
Natural gas	1.3
Nuclear	2.0
Solar thermal	2.3
Wind	3.0
Photovoltaics	3.3-4.0

(Sources: Thai data and Akbari 1990)