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Sustainable Energy Development Strategies for Thailand

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Abstract : During the last decade, Thailand's average annual energy demand increased by about 4.3%. Fossil fuels represented 81.4% of the total energy supply in 2001. Indigenous natural gas accounted for 33.7% of the supply. Biomass resources including fuel wood, paddy husk and bagasse, whose utilization generates a very small amount of net greenhouse-gas emissions accounts for about 16.6% of the total energy supply of the country.

In 2001, 37.6 % of the total energy demand in Thailand was used in transportation. Diesel oil accounts for more than 50% of the petroleum products consumed in transportation. As a result, particulate matter from diesel engines is the most serious air pollutant in Bangkok. The 24-hr average value for small particulate matter is more than twice the limit in Thai air quality standard. Since 1990, transportation has contributed about one third of carbon dioxide emission from fossil fuel utilization. To

further reduce the traffic congestion and air pollution in Bangkok, existing electric mass transit systems should be extended to the outskirts of Bangkok as soon as possible.

Since Thailand has increasingly depended upon imported fossil fuels, greenhouse gas emission in Thailand has increased so rapidly that its emission per capita before the year 2010 may exceed the world average emission in the base year 1990. Electricity generation has had the largest share of carbon dioxide emission. The present methods for the assessment of carbon dioxide and methane emissions from deforestation and agriculture grossly exaggerate the emissions in developing countries including Thailand.

Energy conservation seems to be the most effective method to mitigate both air pollutants and greenhouse gases. Energy conservation measures such as demand side management have been attempted at national level. However, management development, transfer of better energy conservation technologies are still needed for further control of energy consumption and emissions.

Fast-growing trees, ethanol and plant oils, still have potential for providing larger shares of the total energy supply. Thailand has sufficient surplus of cassava and molasses for gasohol with 15% ethanol content. Hydro-energy resources in Thailand and its neighbours are very much under-utilized and should be further harnessed preferably by small and run-off river hydro-power plants without large reservoirs. Nuclear power should still be kept as the last option.

General Energy Situation

1. Energy Supply

In the year 2001, fossil fuels accounted for 81.3% and indigenous energy sources including natural gas, lignite, hydro-energy and biomass shared about 52.9% of the total energy supply for Thailand. [DEDP, 2002], see Table 1. Non-commercial supplies of solar and wind energy were not officially reported. The share of renewable energy sources decreased to only 18.2% in the same year.

Table 1. Energy Supply by Sources, in %.

Source	**1995**	**2000**	**2001**
Fossil Fuels:	**76.5**	**79.6**	**81.8**
Petroleum and Products	51.1	44.7	42.6
Natural Gas	14.8	24.9	28.2
Lignite and Coal	10.6	10.0	11.0
Hydro-energy	**2.3**	**2.0**	**2.0**
Biomass :	**21.2**	**18.4**	**16.2**
Fuel Wood	14.8	12.3	12.0
Paddy Husk	1.9	2.3	1.5
Bagasse	4.5	3.8	2.7
Total, Mtoe	**66.5**	**78.1**	**80.3**
Energy Supply/Capita, t.o.e/person	**1.11**	**1.26**	

In 2001, the supply of indigenous fuel wood amounted to 12.0% which represented the largest source of the renewable energy supply to Thailand. In the future, fuel wood will remain as a major source of renewable energy supply of the country, but its share may further decrease owing to limited areas for tree plantation.

In the same year, natural gas, mainly from the Gulf of Thailand satisfied 24.9% of the total energy supply for the country. Electricity generation consumed more than 90% of the natural gas supply in 2001 [DEDP, 2002]. Natural gas reserves in the country amount to about 700×10^9 cu.m. Imports of natural gas from large reserves in Myanmar, Malaysia, Cambodia and Vietnam will satisfy the country's demand for at least the next fifteen years [PTT, 2002].

Indigenous lignite, with total proven reserves of about 2,200 Mtons, generally contains very high sulphur and moisture contents. Lignite consumption which amounted to 19.6 Mtons in the year 2001 has been mainly used for electricity generation at Mae Moh power station. Flue-gas desulphurisation devices increase the cost of electricity by about 20%. Additional utilization of lignite for electricity generation should be postponed until clean coal technologies become more economical.

2. Energy Demand

In the year 2001, three economic sectors namely manufacturing industries, residential and commercial buildings and transportation accounted for 93.8% of the total energy demand [DEDP, 2002], see Table 2. Energy consumption in transportation was the highest at 37.6% of the total energy demand.

As a result of inefficient energy management, the annual energy demand, which increased by 4.3%, was higher than the average economic growth of the country.

Table 2. Energy Demand, in %.

Sectors	1995	2000	2001
Manufacturing	34.4	34.6	34.2
Residential and Commercial Buildings	20.5	21.8	22.0
Transportation	41.0	38.6	37.6
Agriculture & Others	4.1	5.0	6.2
Total, M toe	**45.7**	**48.3**	**49.5**
Energy Demand/Capita, t.o.e/person	**0.76**	**0.78**	

3. Emission from Fossil Fuels and Mitigation Measures

3.1 Transportation

During the last decade, more than 60% of the total petroleum products were consumed in Thai transport sector. Consumption of petroleum products in transportation slightly decreased during the last five years as a result of an economic slowdown in the country [DEDP, 2002]. In 2001, diesel oil accounted for 51.2% of the petroleum products for transportation [DEDP, 2001], see Table 3. Consumption of gasoline increased from 13.8% in 1995 to 16.3% in 2001.

Table 3. Fuel Consumption in Transportation, in %.

Type of Fuel/Year	1995	2000	2001
LPG	0.8	1.0	1.6
Gasoline	24.4	26.6	27.1
Diesel Oil	56.8	53.4	51.2
Fuel Oil	4.2	3.7	3.8
Aviation Fuel	13.8	15.3	16.3
Total, t.o.e	**18.75**	**18.02**	**18.63**
% of Total Petroleum	**69.7**	**67.5**	**68.2**

Particulate matters are the most serious air pollutants. In 2000, the maximum 24hr average value of small particulate matters, PM 10, in Bangkok reached 305 $\mu g/m^3$ of the air and the value was more than twice the limits in the Thai Air Quality Standard. 8-hr average value of carbon monoxide was 13.5 mg/m^3 [DPC, 2000] and was slightly above the limit in the Thai Air Quality Standard. Since January 1993, catalytic converters have been mandated for all new cars but their cost-effectiveness on carbon monoxide reduction in Bangkok seems to be doubtful in comparison to other available mitigation technologies and advances in engine design.

Main sources of suspended particulate matter are diesel engines in buses and trucks. An experimental fleet of 82 natural-gas buses was assessed and the positive result indicated that further expansion of the CNG fleet should be implemented. Heavy trucks and trailers cause both traffic congestion and particulate-matter emission. They have been banned from streets in Bangkok during the daytime. It is hoped that they will also be banned from the streets in central Bangkok at night in the future.

With electric trains, the Bangkok Mass Transit System of 14.5 km in length, now helps improve the quality of life in central Bangkok. The Metropolitan Rapid Transit Underground System of 20 km is financed by the public sector and the service will be available in the year 2004. Electric mass transit systems should be urgently extended to the outskirts of Bangkok and implemented in other large cities.

3.2 Carbon Dioxide Emission

CO_2 emissions are estimated from the energy demand side and classified into power, industry, transportation, commercial and residential buildings. In 1990, Thai emissions were much smaller than those of developed countries. The estimation shows that the power sector in 1994 released the largest quantity of CO_2, at 36% followed by transportation at 32%, and industry, see Table 4.

Table 4. Carbon Dioxide Emissions from Fossil Fuels, in %.

Source	1990	1994
Electricity Generation and Other Energy Transformations	37	36
Transportation	36	32
Industry, Mining and Construction	17	25
Small Combustion	10	7
Total, M tons	**76.7**	**125.5**

[MOSTE, 2000] Regarding strategies to reduce CO_2, power and transport sectors should be given priority.

In the UN Framework Convention for Climate Change and Kyoto Protocol in 1997, European Union, Japan and USA agreed to reduce GHG emissions to levels below 1990 by the year 2010. Later, USA demanded that some developing countries would also have to reduce GHG emissions. The demand is unreasonable as developed counties like USA have emitted GHG since the industrial revolution.

One of the issues for the mitigation of GHG is the choice of a suitable index for GHG emission control. The emission per capita has been used by most countries. However, developed countries propose the emission per GDP as an alternative index for their advantage. However, the emission per purchasing-power-parity (PPP) GDP reflects the value of personal income better than the nominal GDP and seems to be a fairer index for developing countries like Thailand.

Fuel wood from forests is one of the main sources of energy supply in most developing countries. The present method for the assessment of carbon dioxide emission from deforestation grossly exaggerates the emissions in developing countries. Wood is not only used as fuel but also in construction, furniture industry, etc. A better method of carbon dioxide assessment from deforestation should be developed.

With increasing demand on fossil fuels for Thailand as shown Table 5, CO_2 emissions per capita before the year 2010 will exceed the world average value of the base year 1990 [Prida, 2000]. By the year 2000, CO_2 emission per nominal GDP of Thailand would still be higher than that of the US in 1990.

Efficient energy conservation and development of non-fossil-fuel options should therefore be urgently implemented.

Table 5. Growth of Carbon Dioxide Emission from Fossil Fuels in Thailand.

	1995	**1999**	**2005***
Fossil Fuel Consumption	50.9	59.8	80.2
Carbon Dioxide Emission	143	168	225
Emission/Capita	2.40	2.72	3.53

* *Predicted values*

4. Energy Conservation

To accelerate energy conservation efforts in the country, the Thai government has already implemented several energy conservation measures. Import duties on energy conservation equipment and materials have been sharply reduced. Natural gas has been increasingly used to generate electricity by the highly efficient combined cycle and cogeneration. Private co-generators of heat and power can sell their surplus electricity to the national grid with reasonable buy-back rates. Several energy technologies such as energy cascading techniques have been well recognized for their energy efficiencies, they should be more strongly promoted. Demand-side management has been fairly successful in the conservation of electricity and in the reduction of growth on power generating capacity [Chullabodhi, 2000].

Energy efficiency indicators in Table 6 confirm that energy conservation efforts have had little success, with increasing percentage of conversion loss between energy supply and demand. As efficient energy conservation helps save foreign exchange for imported fuels and reduce emission from combustion of fuels, the energy conservation fund should be better managed to reduce the growth of energy consumption to a level below the economic growth of the country [Chullabhodi, 2000]. France and Japan have implemented very successful energy conservation measures and should serve as good examples.

Table 6. Energy Efficiency Indicators.

Indicator	1995	2000	2001
Energy Supply / GDP kg.oe / 1000 Baht	22.6	26.2	NA
Energy Loss between Supply and Demand, %	31.2	38.1	38.4

5. Biomass Energy

5.1 Fuel-Wood

Consumption of fuel wood in 2001 amounted to 9.65 Mtoe, which represents a slight increase of 0.2% over the previous year [DEDP, 2002]. Fuel wood or charcoal still remains the main source of renewable energy supply in Thailand, especially for cook-stoves in rural areas. Continuous improvement of the Thai bucket stove has helped reduce consumption of charcoal and consequently fuel-wood in the country. Promotion of plantation of fast-growing trees will ensure a continuous supply of fuel-wood.

5.2 Wastes from Agro Industries

In 2001, 2.17 Mtoe of bagasse were used in about 50 sugar mills to cogenerate power and heat for sugar processing [DEDP, 2002]. The total installed power generating capacity in the sugar mills is estimated at 850 MWe [Prida, 1999]. With suitable energy conservation measures, baggasse could be saved to generate additional power of more than 100 MWe for export to the national electricity grid. If cane leaves and tops are also used as fuel in the existing sugar mills, the total potential for additional generating capacity could be more than 300 MWe. The amount of paddy husk used as fuel in 2001 was 1.21 Mtoe [DEDP, 2002]. About 300 large-rice mills with milling capacities over 100 tons of paddy per day use paddy husk to generate approximately 100 MW of power for milling. Additional power generation of about 80 MW can technically be generated for export from these large rice mills if the surplus husk is used as fuel [Prida, 1999]. In 1998, about 360,000 tons of palm oil were produced from over 30 palm oil mills in Thailand [Prasertsan, 2000]. Large palm oil mills use spent fibre and kernel shells to cogenerate heat and power for internal consumption. With efficient energy conservation measures, power generation in the large palm oil mills could have a surplus of about 20 MWe for export. Fruit bunches from

560,000 acres of palm oil plantation in the country also has potential to be used as fuel up to 8.92×10^9 MJ/annum [Prasertsan, 2000].

5.3 Ethanol

Ethanol can be blended with gasoline and used in spark-ignition engines. Ethanol has a higher octane than methyl tertiary butyl ether, MTBE, which easily dissolves and causes pollution in water. Ethanol can be produced from several agricultural products such as sugar cane, cassava, corn etc. Ethanol as an alternative to MTBE in gasoline will help reduce green-house gas and imported MTBE and raise incomes of farmers [Prida, 2002].

A recent study confirms that it would be possible to produce gasohol up to 15% ethanol content. Available raw materials are cassava and molasses, which have sufficient qualtities for the production of 3 million litres per annum of anhydrous ethanol [Klanarong et al., 2002].

5.4 Plant Oils

Thailand and neighbouring countries are main producers of palm oil. Tests have been conducted on the use of plant oils including palm oil blended with diesel oil in compression-ignition engines. The tests have confirmed their feasibility as fuels in low-speed engines in agricultural machines and ships with acceptable emission quality if the amount of palm oil is kept below 5% [Wibulswas et al., 2000]. Utilization of plant oils in the engine as a substitute to diesel oil will lead to the reductions of carbon dioxide emission and spending of foreign currencies on imported diesel oil. At present, the amount of available palm oil in Thailand can substitute less than 1% of diesel oil. Joint development of plant oils as fuels will be of mutual benefit for the South East Asian region.

5.5 Other Biomass Resources

In addition to the biomass wastes used in agro-industry, agricultural residues such as straw, soybean stalks, corn stalks, etc., which amount to about 60 Mtons per annum can also be used as fuels. Wastes from rubber trees and rubber wood industry can yield about 125 Mm^3 with an energy content of about 1.20×10^9 MJ/year [Prasertsan, 2000]. However, better technologies have to be developed for better utilization of these residues as fuels.

Fast-growing trees such as eucalyptus, etc. can economically provide fuel wood on a sustainable basis. A feasibility study indicated that dendro-thermal power plants of 30-50 MWe capacities would generate electricity at a cost of about 5.2 USc/kWh. Management of a large tree plantation may however be rather complicated and further study and assessment are still needed, particulary on the possible social effects on small farmers. Municipal wastes also contain enough biomass to be used as fuels for electricity generation. A feasibility study indicated that the cost of electricity generated by the wastes would be about 5.4 USc/kWh [Prida, 1999].

As biomass will still be the main renewable source of energy for the region and its combustion practically generates no net carbon dioxide emission, its development and utilization should be more rigorously promoted in the region.

6. Electricity Supply and Demand

6.1 Sources of Energy for National Grid Generation

In the year 2000, natural gas was the main source of energy supply for national grid generation and accounted for 62.9% of the total amount of 85.8 x 10^{12} kWh generated [DEPP, 2001], see Table 7. Contribution from hydro energy sources in the same year was only 6.3%. During the years 1995 to 2000, the average annual amount of electricity generated for the national grid increased by 1.3% only, as a result of increasing private generation. Natural gas utilization increased sharply by 9.9% per annum during the same period.

Table 7. Sources of Energy for National Grid Generation, %.

Sources	1995	2000
Natural Gas	**42.5**	**62.9**
Lignite and Coal	18.6	18.5
Oil	30.5	11.6
Hydro Energy	8.4	7.0
Total Energy, kWh × 10^{12}	**79.8**	**85.8**

6.2 Power Generating Capacity

During the year 1995 to 2000, the average annual growth of the total generating capacity, including private power for own use and co-generation of heat and power increased by 11.5, 18:4 and 211 % respectively [DEDP, 2001].

In the year 2000, the power generating capacity of the Electricity Generating Authority of Thailand, EGAT, accounted for about 80% of the total installed capacity of 27,647 MW [DEDP, 2000] and the spare capacity of the national grid at the peak demand was about 25%. In the same year, the shares of combined cycle and private generation were 33.6 and 18.3% respectively [DEDP, 2000].

6.3 Electricity Demand

In the year 2000, the industrial sector accounted for 45.7% of the total electricity demand of 87,932 GWh [DEDP 2001]. The demand had an average annual growth of 4.7% during 1995-2000. In provincial areas, the growth of electricity demand decreases while the economic growth increases as a result of effective energy conservation efforts. A forecast for power generating capacity required until the year 2010 is presented in Table 8.

Table 8. Power Generating Capacity Forecast, in MW.

Generating Capacity / Year	2005	2007	2010
Installed	25,000	NA	NA
Peak Demand	20,000	23,000	28,000
With 15% Reserve	**23,000**	**26,450**	**32,200**
With 20% Reserve	24,000	29,000	33,600

6.4 Hydro-Electricity Resources

In spite of criticism of large hydro-power plants, consumption of hydro-electricity in several Asian countries has grown considerably. Hydro-power generated in China and Japan will be larger than the total generating power in Thailand. The growth of hydro electricity in Indonesia which is well endowed with fossil fuels namely petroleum, natural gas and coal, has been remarkably high at about 500% since 1980. In comparison to fossil fuels, utilization of hydro-power does not generate gaseous pollutants such as SO_x, NO_x, carbon dioxide. Moreover, large dams have helped control floods and increased irrigation and aqua-culture areas in several countries.

6.5 Hydro-Electricity Resources in Thailand

In 2000, the installed hydro-power plants in Thailand had a total capacity of about 2,936 MWe and represented only 7.0% of energy sources for EGAT power generation, see Table 7. [DEDP, 2000]. Mini and micro hydropower power plants make a small contribution of less than 1 MW. They however cause very little environmental impact and feasibility of their further expansion should be assessed.

A hydro-power potential of about 10,000 MWe is still available in the country and feasibility studies have been conducted on several hydro-power projects for the generation of about 1,500 MWe. However, to harness this potential, environmental and political problems such as deforestation siltation, competition for irrigation and resettlement of people from the lands required for reservoirs, loss of animals, etc. have to be solved.

Development of run-off-river hydro-power plants without large dams in the country should still be possible and be assessed. It should be noted that Japan has installed more than 22,200 MWe of hydro-power and plans to further install 4,300 MW of small hydro-power plant during the next decade [NEF, 1999].

6.6 Hydro-Electricity from Neighbouring Countries

Large hydro-power potential also exists on the two international rivers on the Thai borders, the Mekhong and Salween. However, deforestation and resettlement of people will again be major environmental impacts to be overcome. A recent study by the Mekhong River Commission shows that run-off-river hydro-power plants with a combined generating capacity of 13,000 MWe would be feasible at nine locations on the Mekhong [Subin, 2000]. Resettlement of population from each of these locations will be limited to less than one thousand people. Most of the electricity generated would be purchased by Thailand. The problem of deforestation and relocation of people have yet to be carefully studied and settled.

Hydro-power development inside the Lao PDR and Myanmar for export to Thailand appears to be more realistic. A contract for the purchase of hydro-electricity up to 4,000 MWe from six locations in the Lao PDR has been drafted by the Thai government [NEPO, 1997]. These hydro-power projects have been financed by several countries. A memorandum of understanding for the purchase of 1,500 MWe from six hydro-power projects in Myanmar has already been signed by the two governments [NEPO, 1998]. The feasibility studies for the purchases of 1,200 MWe from a hydro-power project in Yunnan and 3,000 MWe from projects on the Salween, Myanmar have been completed.

7. Other Renewable Sources of Energy

7.1 Solar Thermal Energy

The annual average intensity of daily total solar radiation in Thailand is about 17 MJ/m^2-day, which can be considered as fairly good. Several types of solar thermal equipment and systems have been developed in Thailand. Research and development work on solar thermal energy may be classified into six categories, namely, solar radiation data analysis; low temperature heating processes and medium temperature heating processes, solar collectors and water heaters, solar drying, solar distillation including water distillation and alcohol distillation; other solar thermal processes such as absorption refrigeration, solar water pumps, solar pond for heating and power generation and energy storage [Soponronnarit, 2000] Present applications of solar energy thermal processes in Thailand are limited. Only solar water heaters are commercialized while solar dryers are accepted for fruit drying. However, research, development and demonstration of solar thermal equipment and systems should be supported, as they are applications of a clean and renewable source of energy. Priorities should be solar refrigeration, solar water/alcohol distillation, and energy storage.

7.2 Photovoltaic Systems

More than 5 MW peak of PV modules have been used in Thailand [EGAT, 1999]. Three interest groups: users, local manufacturers/distributors and academic institutions are involved in PV utilization activities. Potential applications of PV utilization can be substantial in the remaining thousands of remote communities at which PV systems will be used economically instead of diesel driven generators or conventional grid.

About eighty percent of the PV modules installed in Thailand are funded by the governmental sector or overseas assistance. Main applications are telecommunications, water pumping, battery charging stations, village electrification, education, health care, navigation and audio visual aids, domestic lighting.

There are three local manufacturers of PV modules in Thailand. They import ready-made solar cells for panel assembly. The annual production capacity is about 3 MW and this should increase with more grid-connected applications, such as solar houses.

7.3 Wind Energy

Wind energy in Thailand is mainly use for water pumping, roof ventilation and generating electricity. The first two have been widely used while the latter has been conducted as demonstration projects. At present, there are three basic types of windmills for water pumping: low-speed sail rotor type, high-speed wooden rotor type and multiblade steel rotor type. More than 600 units are used in the whole country [Tongstit, 1997]. There are also at least 7 electricity-generating systems with a total power of 192 kW with grid-connection facilities. Potential of wind energy for electricity generation is, however, limited to some coastal areas and the central plain of Thailand.

Recommendations for research and development on wind energy include Thailand's wind potential mapping, establishment of a national wind data center, assessment of off-shore potential and hybrid systems for generating electricity. Wind energy for water pumping in rural areas should be better promoted. The average wind speed of about 2 m/s in the country is however too low for economical generation of electricity.

Conclusions and Recommendations

Though energy is an important input to the economic growth of a country, utilization of fossil fuels has caused serious environmental impacts such as air pollution, green-house effect, etc. In addition, fossil fuels have caused energy instability and financial and currency problems to several countries in the region. For sustainable development of the country and better quality of life, the following guidelines are recommended to develop alternative energy resources.

1. Accelerate energy conservation measures including development of technical personnel and energy efficient technologies.
2. Promote research, development and utilization of renewable sources of energy in order to increase their contributions to the total energy supply of the country.
3. Limit pollutants and environmental impacts from energy production and utilization by complying to accepted standards within the region.
4. Negotiate with neighboring countries to share energy resources and to control transboundary emission of gaseous pollutants for mutual benefits.
5. Study the feasibility of nuclear power as the last option for green-house gas mitigation in the future.
6. Negotiate clean development mechanism for mutual benefits between developed and developing countries.

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