

Technical Changes in Developing Countries

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**Technical Changes in Developing Countries :
TECHNOLOGIES FOR CARBON DIOXIDE MITIGATION IN
EAST ASIA AND THAILAND**

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ABSTRACT

In 1990, carbon dioxide emissions per capita of most developing countries including Thailand were below the world average value, and were much lower than those of developed countries. In the future, with limited indigenous resources, Thailand has to increasingly depend upon imported fossil fuels. With the increasing import of fossil fuels, greenhouse-gas emission in Thailand has increased so rapidly that its emission per capita in 1995 exceeded the world average figure in 1990. However, the Thai emission per Purchasing-Power-Parity GDP in 1995 was lower than that of USA in 1990.

Most of the energy consumption in the South East Asian Region occurs in the transportation, manufacturing, residential and commercial sectors. Energy conservation seems to be the most effective method to mitigate greenhouse gases. Energy conservation measures such as demand side management have been attempted at national and regional levels. However transfer of better energy conservation technologies and development of technical manpower are still needed in developing countries, for more efficient energy conservation and for further mitigation of greenhouse gas emission.

Utilization of natural gas for power generation, by combined-cycle plants, generates the least carbon dioxide in comparison to other fossil fuels. Lignite, which generally contains a high sulphur content, has already caused detrimental health and environmental impacts. As natural gas reserves in the region are quite large, low-grade lignite for the proposed power stations in Thailand will be substituted by natural gas, until clean coal technologies are better developed and become economical.

Biomass energy sources, whose utilization generates a very small amount of net greenhouse-gas emission, account for large proportions of the total energy supply in developing countries. In several developing countries like Thailand, large amounts of agricultural wastes still remain to be utilized. Hydro-energy resources in Asia are very much under-utilized. Environmental and political problems should be clarified to utilize the remaining hydro-energy resources. Solar energy has been increasingly used for water heating, drying of crops and electricity generation. The potential of solar energy as a clean energy source is expected to be better exploited in the long-term.

Finally, nuclear power may be a good option in several developing countries including Thailand, for energy security and mitigation of greenhouse gas emission from power generation, until renewable energy technologies will be sufficiently and economically developed. However, public acceptance will be needed before implementation.

CARBON DIOXIDE EMISSION

Comparison of Carbon Dioxide Emissions in 1990

Carbon dioxide, the main greenhouse gas, is mainly generated by utilization of fossil fuels. In 1990, net carbon dioxide emissions from fossil fuels in USA, Japan and Thailand amounted to 1,400, 263 and 85 million tons respectively (OECD 1991, Akihiro, 1992, TDRI 1993). USA generated the highest carbon dioxide emission per capita at 7.64 tons, while the value for Thailand was only 1.51 tons. However, if carbon dioxide emission per nominal GDP in the same year is considered, the highest value of 1.2 belonged to Thailand (Khummongkol, 1993) and Japan had the lowest value of 0.16.

It should be noted that, in 1990, the global average value of carbon dioxide emission was 1.60 tons/capita and the average value of European Community in the same year was 2.4 tons/capita. The emission per capita for Thailand was then lower than the world and EC average values.

Carbon Dioxide Emission in Thailand

Thailand is discussed as a case study for a typical developing country in East Asia. During 1995 to 2000, the economic growth of Thailand is forecasted at 7.5 % and, as a result, the consumption of fossil fuels is expected to increase from 40.0 to 65.9 M t.o.e during the same period (NEA, 1991). Carbon dioxide emission from fossil fuels is predicted to grow from the estimated value of 135 Mtons in 1993 to 172 and 277 Mtons in the year 1995 and 2000 respectively (Vinitnantrat et al., 1994).

Table 1 : Growth of Carbon Dioxide Emission from Fossil Fuels in Thailand

	1990	1993	1995	2000
Fossil Fuel Consumption, Mtons.o.e	29.2	40.0	51.0	82.1
Carbon Dioxide Emission, Mtons	85	135	172	277
Emission/Capita, Tons/Person	1.51	2.31	2.90	4.32
Emission/nom. GDP, Tons/k USD	1.28	1.21	1.11	1.24
Emission/PPP GDP, Tons/k USD	-	0.41	0.39	0.48

Carbon dioxide emissions per capita, in 1993 and 1995 (as shown in Table 1), exceeded the world and EC average values in 1990 respectively. By the year 2000, carbon dioxide emission per nominal GDP in Thailand will still be higher than that of USA in 1990. However, it is now generally accepted that the Purchasing-Power-Parity GDP reflects the value of personal income better than the nominal GDP. If the emission is based upon PPP GDP, the emission index for Thailand in the year 1993 would be reduced by a factor of about 2.8 and become lower than that of USA in 1990. The emission per PPP GDP seems to be fairer to developing countries than the emission per nominal GDP.

In December 1994, the Government of Thailand ratified the UN Framework Convention on Global Climate Change. The analysis in Table 1 implies that Thailand has to be more serious on the mitigation of greenhouse gases from national and international points of view, especially with respect to carbon dioxide.

Some Issues on Carbon Dioxide Emission

Estimation of carbon dioxide emission from deforestation should be based on the fact that only a part of carbon in wood is converted to carbon dioxide emission, mainly by combustion. It is not correct to convert all carbon in the wood into carbon dioxide. As wood is also exported, carbon dioxide emissions from wood should belong to the importing countries.

As forests absorb carbon dioxide from the atmosphere, carbon dioxide per forest area should be used as an index for auditing green-house gas emission. The index will give an incentive to reforestation at the national level and give more benefit to developing countries.

ENERGY CONSERVATION

Conservation of Fossil Fuels

Oil, natural gas and coal have been the main sources of energy for Thailand and the East Asian region. Power generation has also relied heavily on these fossil fuels as primary energy sources. Table 2 compares contributions, in %, of the fossil fuels to total energy supplies and to power generating capacities in Korea (Sook, 1993), Philippines (Labanan-Garcia, 1994), Taiwan (Young et al., 1993), and Thailand (DEDP, 1993; EGAT, 1993) in 1992.

It has been generally agreed that energy conservation is at present the best measure for carbon dioxide mitigation as it also helps reduce the energy cost of the nation. In 1992, Thailand enacted Energy Conservation Promotion Law and consequently an annual fund of about 60 M.USD was initiated by the government in 1993 to promote energy conservation. For many countries, as well as those in Table 2, another benefit of energy conservation is the savings of foreign exchange for imported fossil fuels.

Table 2 : Contributions, in %, of Fossil Fuels to Total Energy Supply and to Power Generating Capacity, in 1992

	Total Energy Supply	Power Generating Capacity
Korea	86	58
Philippines	-	59
Taiwan	83	33
Thailand	67	73

Demand Side Management, DSM

For electricity conservation and carbon dioxide mitigation, DSM is a very effective measure. Several countries in the region have already developed ambitious DSM plans. From Table 3, fossil fuels contributed more to the power generating capacity in Thailand than those in other countries. The total installed power generating capacity in 1995 is about 17,500 MWe (DEPD, 1995). Since 1991, the Electricity Generating Authority of Thailand has been implementing a DSM plan, with an initial fund of 190 M.USD, to reduce its power generating capacity and electrical energy (EGAT, 1995), as shown in Table 3. If the DSM plan reaches its target in the year 2006, the total growth in the power generating capacity during the next decade would be reduced by about 6,000 MWe and the annual growth in the total generating capacity on the average should be reduced from 1800 MWe to about 1,200 MWe.

Table 3 : DSM Plans for Thailand and Indonesia

Types of Reduction	1995	1997	2000	2001	2006
Thailand:					
Power Generating Capacity, MWe		1,400		1,641	3,526
Electrical Energy, GWh		3,400		3,846	9,670
Indonesia, Java-Bali System:					
Power Generating Capacity, MWe	103	161	408		
Electrical Energy, GWh	613	949	2,476		

A DSM plan in the residential sector of Indonesia (Marbun, 1994), as shown in Table 3, is rather impressive. By the year 2000, 408 MWe of generating capacity or 2,476 GWh of electrical energy would be saved in Java-Bali system alone. The amounts of carbon dioxide mitigation by DSM can be quite substantial. A study shows that a DSM plan proposed for Korea (Kim, 1993) would reduce carbon dioxide emissions by 121 and 158 M tons in the years 2000 and 2010 respectively.

Energy Cascading

The efficiency of energy conversion can be considerably improved by cascading energy from very high to very low temperatures. Two main types of energy cascading are combined heat and power generation and combined-cycle power generation.

Cogeneration of power at a high temperature and process heat at a lower temperature is a well-known and cost-effective technology (Watson, et al, 1996). However, in tropical countries, buildings normally require more cooling than heating. A technology such as absorption refrigeration should be further developed to economically convert the surplus heat at a low temperature from power generation for space cooling.

The efficiency of combined-cycle power generation by natural gas is now almost double the world-average power generation efficiency of about 30%. Further development of coal gasification technology should make coal gas cost-effective for combined-cycle power generation.

Efficiency in Transport Sector

In most countries in the region, the proportions of fuel consumed by the transport sector are quite large in comparison to other economic sectors. In 1992, the Thai transport sector accounted for 57.4% of the total demand for petroleum products in the country. As a result, the contribution of carbon dioxide emission from the transport sector is highly significant. For example, the transport sectors in Australia and Indonesia contributed 23 and 26% to the energy use carbon dioxide emission in 1990, while the world average contribution was 19% in the same year (BTCE, 1994). Taiwan and Thailand contributed 18% in 1992 (Young, 1993) and 30% in 1991 (Khummongkol, 1993) respectively. In 1995, the transport sector in Korea is predicted to contribute 19% to the total carbon dioxide emission from energy use.

The traffic condition in Bangkok, like in several capitals in Asia, continuously deteriorates. More than 500 M.USD worth of fuels are wasted annually as a result of the traffic congestion in Bangkok in addition to unnecessary carbon dioxide emission. A case study on an electric mass transit project under construction, which will cover a total distance of 20 km in Bangkok, indicates that 78 millions passenger car trips would be avoided in the year 2006 (Wangwacharakul, 1993). This would result in a reduction of carbon dioxide emission by 0.56 Mtons from the one mass transit project alone. Construction of another electrified mass transit system has already commenced.

BIOMASS

In most Asian developing countries, biomass accounts for large proportions of energy supplies. For example, in 1991, shares of biomass in the total energy supplies for Indonesia, Vietnam and Thailand (FAO, 1996) were 39, 50 and 32% respectively. Fuel wood has the largest share among various biomass supplies. Firewood is still the main source of energy for cooking in rural areas.

Table 4 : Renewable Energy Supply by Sources in Thailand, %

Sources	1985	1987	1990	1995
Hydro-energy	3.3	2.9	2.6	2.1
Biomass:				
Fuel wood	31.4	32.2	27.6	22.6
Paddy husk	4.0	2.4	1.4	0.9
Bagasse	4.5	3.9	3.8	4.3
Total, M tons	26.9	31.7	45.1	72.8

In 1995, fuel wood, paddy husk and bagasse accounted for 22.6, 0.9 and 4.3 % of the total energy supply to Thailand (DEDP, 1995). The share of biomass energy has decreased in percentage but still increased in quantity, (see Table 4) and amounted to 20.2 Mtoe. Bagasse, paddy husk and oil palm wastes provide about 961 MW of power for sugar mills, rice mills and palm oil mill in Thailand (Wibulswas, 1996) - see Table 5. The technical potential to generate electricity from the surplus of these wastes is about 575 MW, which can be exported to the national grid system if the buy-back rate of electricity is increased by about 10 %.

Table 5 : Power from Biomass Cogeneration in Thailand, MW

	Installed Capacity	Economic Potential	Technical Potential	Total
Paddy Husk	100	80	160	340
Bagasse	850	80	-	930
Cane Trash	-	-	240	240
Oil Palm Waste	11	15	-	26
Total, MW	961	175	400	1,536

Agricultural wastes in Thailand including sugar-cane trash, straw, cassava and mung-bean stalks, etc. yield about 50 Mtons per annum, and thus have potential for energy production. However, the cost of the waste collection is so high that utilization of the wastes as fuels is hardly cost-effective. Furthermore, these biomass resources contain very high moisture content; better conversion technologies and better buy-back rates of electricity are still required to enhance their utilization.

It should be noted that as these crops will be replanted annually, their net carbon dioxide emissions can be assumed zero.

Dendro-Thermal Power Systems

Plantation of fast-growing trees (such as acacia, eucalyptus) for wood-fired power generation has received a great deal of interest in several countries in the region. The Philippines has installed five dendro-thermal power systems with a total capacity of about 17 Mwe, with acacia chosen for tree plantation (Ner, 1988). The systems have faced with some management and technical difficulties and the dendro-thermal programme in Philippines has at present no expansion plans.

A Thai feasibility study (Wibulswas, 1996) indicated that a 25 MWe dendro-thermal power system fired with *eucalyptus camaldulensis* would generate electricity at a cost of about US\$ 5.1 per kWh. A project proposed by the Department of Energy Development and Promotion recommended 83 dendro-thermal power systems to generate 2,000 MWe (NEA, 1987). The proposed project would involve very large plantation areas for eucalyptus of about 1.5 M acres on marginal lands, and would probably face difficulty in plantation management.

Another feasibility study for dendro-thermal power systems in New Zealand was based upon *Pinus radiata* as fuel (Sims, 1994). It was reported that a 10 MWe system would be more cost-effective than a 3 MWe system, and the cost of electricity generation would vary from NZc 4.5-6.5 c/kWh. In the future, improved wood gasification technology should help increase the efficiency of electricity generation by using combined cycle technology and the amount of carbon dioxide emission would be much reduced.

The net carbon dioxide emission from fuel wood utilization in a country is more complicated to assess as trees are partly planted for fuel and other industrial uses, and Thailand still loses more than 0.5 M acres of forests annually.

Municipal Solid Waste

Municipal wastes generally consist of commercial refuse, industrial wastes, institutional wastes, residential wastes and market wastes. On average, municipal wastes comprise 85.3 % combustible, 8.6 % non-combustible and 6.1 % miscellaneous components. The combustible component on average consists of 58.5 % moisture, 13.3 % ash and 28.2 % combustible content and net heating value is about 16.1 MJ/kg, dry basis (Wibulswas and Tia, 1992).

Bangkok municipal area generated about 7,500 M tons of solid wastes per day in 1995. Two compost plants have been set up, and operate with a combined capacity of 1000 tons of municipal wastes per day. More than 6000 tons of the wastes are still available as fuel for electricity generation. A study assumed that six power stations would be set up, each with a capacity of 1000 tonnes of the municipal wastes per day.

The feed rate of the municipal solid waste to each of the proposed plants is 14.7 tons per hour of combustible content, dry basis. With a super-heated boiler, each proposed power plant should be able to generate about 8.33 MWe. The combined generating capacity of the six power plants is therefore 60 MWe. Financial analysis including the cost of the wastes processing shows that the proposed power stations would be able to generate electricity at 1.06 B/kWh (adjusted to 1996). On the other hand, if the total cost of the fuel, including the cost of waste collection is taken into account, the proposed power station would not be economically feasible as the cost of electricity would be about 1.60 Baht/kWh (Wibulswas, 1992).

OTHER OPTIONS FOR GREENHOUSE GAS MITIGATION

Hydro Energy Resources

Contributions of hydro energy resources are rather small for most countries in this region. In Malaysia and Thailand, hydro energy resources contributed only 6.9 % in 1989 (Arif, 1991) and 2.1 % in 1995 (DEDP, 1995) respectively. Development of large hydro energy resources have often faced difficulties against environmental issues and public acceptance. However, as hydro energy resources are clean and renewable, their utilization should still be considered as a good option to mitigate carbon dioxide emission. A recent report (NEF, 1996) confirmed that, among new energy facilities for electricity generation in Japan, small and medium hydro-power plants accounted for 78.7% of the total capacity or 2383 MWe. Run-off-river hydro-power plants may be more acceptable as they do not require large reservoirs which normally involve loss of forests and relocation of people.

Regional co-operation on development of hydro energy resources exists in The South East Asia peninsula. The installed hydro power capacity in Laos is 194 MWe. As her peak load is only 60 MWe, the rest is exported to Thailand (Poshyananda, 1994). Laos government has given mandates to at least six hydro energy projects to private investors from Australia,

Japan, Korea, Sweden, Thailand and USA to generate about 2,807 MWe (NEPO, 1995) most of which will be exported to Thailand. It is also feasible to further develop about 2,000 MWe in Laos for export.

Several hydro energy resources on the border rivers of Thailand have potential to be jointly developed between Thailand and neighbouring countries (Poshyananda, 1994). On the Burmese boarder, Salween has potential of 6,000 MWe. On the Laotian and Cambodian border areas, the Mekong river has potential of at least 5,000 MWe. In addition, the combined hydro-power potential of the Mekong river inside Laos and Cambodia is greater than 10,000 MWe. The Mekong River Commission has been established by Thailand, Cambodia, Laos and Vietnam, to initially develop about 13,000 MW (MRC, 1995). However, more than 50,000 people may have to be relocated from reservoir areas unless run-off-river hydro-power plants are installed.

Natural Gas

In general, no sulphur dioxide is generated from combustion of natural gas. Lignite, which is used for power generation in several countries, normally contains high moisture, ash and sulphur contents. Sulphur dioxide emission has caused detrimental impacts to health and the environment. For example, in October 1992 sulphur dioxide emissions from a large lignite-fired power complex in the north of Thailand caused respiratory illness to more than 500 people in one day (Wibulswas and Towprayoon, 1993). Damages to crops and livestock were also reported. Expansion of the lignite-fired power plant has already been postponed.

In comparison to coal-fired or oil-fired power plants, combined-cycle plants which run on natural gas generate electricity with about 50% less carbon dioxide emission. By 1998, production of natural gas in Thailand, at 40 M. cu.m. per day (PTT, 1994), will not be sufficient to satisfy the demand for power generation. Natural gas will be imported from Myanmar, and from a joint-development area with Malaysia, up to 24 M.cu.m. per day by 2002. The imported natural gas will be used mainly for electricity generation of about 5,000 MW by combined-cycle plants. Joint development programmes on natural gas production with Cambodia and Vietnam are being discussed.

Import of liquefied natural gas from the Middle East is also considered. Deep-sea ports may have to be developed for refrigerated tankers, and environmental problems such as loss of beaches or mangrove forests may arise.

Nuclear Power

As the population in Asia grows rapidly, increases in power demand will cause widespread use of fossil fuels, particularly coal and lignite. Impacts on the environment from emission such as SO_x, NO_x and particulate matters, become more serious. Long-term accumulation of carbon dioxide creates concerns about damages arising from global warming. It has been well accepted that nuclear power is very effective for carbon dioxide mitigation (Watson, et al, 1996).

In Asia, Japan and Korea have had long experiences on harnessing nuclear power. Japan operates 51 nuclear power stations and has three power stations under construction (IAEA, 1996). Korea operates nine nuclear power stations and is designing an indigenous nuclear power plant herself. Vietnam considers nuclear power as an option after the year 2015 to ensure security of power supply (Tu, 1995) and plans to co-operate with Korea on nuclear power development. Even with very large reserves of oil, natural gas and coal, Indonesia still has a long-term plan to generate 12,600 MWe by nuclear power in the year 2019 (Ahimsa, 1995). Australia probably has largest uranium reserves in the world.

As the transport sector is responsible for a large contribution of carbon dioxide emissions, implementation of electric cars and an electrified mass transit systems in major cities like Bangkok would considerably reduce carbon dioxide and other air pollutants, if electricity is generated by nuclear energy.

With the expertise and experience on nuclear power generation of several countries and availability of uranium in the region, nuclear power seems to be a sensible option for mitigation of carbon dioxide and other air pollutants for immediate decades ahead, until the technologies of the alternative non-polluting and renewable energy resources have been sufficiently developed and implemented. The main barriers against the implementation of nuclear power are public acceptance and radio-active waste management.

CONCLUSIONS AND RECOMMENDATIONS

As economic and population growth in the East Asian region continues, demand for fossil fuels also increases, and subsequent carbon dioxide mitigation to help control global warming seems inevitable. A mix of suitable indices for greenhouse gas emission such as emission per capita, emission per purchasing-power-parity GDP, emission per forest area etc., should be thoroughly discussed for acceptance by both developed and developing countries.

At present, energy conservation is the most effective and economical measure for greenhouse gas mitigation. Thailand and several countries in the region have already implemented demand-side management to reduce greenhouse gas from electricity generation and to avoid the capital investment on new power stations.

Availability of large natural gas reserves in the region offers a medium-term solution to greenhouse gas mitigation, as combined-cycle power plants fired by natural gas produce much less carbon dioxide emission than those fired by oil or coal. Indigenous natural gas in Thailand has been used mainly for electricity generation by combined-cycle power plants. With increasing electricity demand, Thailand will soon import natural gas from her neighbours to supplement the indigenous resource base.

Better utilization of renewable energy sources such as biomass, solar-energy, etc., should be a good non-fossil-fuels option. Agricultural wastes and fast-growing trees have been increasingly utilized as biomass fuels in ASEAN and Thailand. Fluidized-bed combustion and gasification technologies should enhance biomass utilization. Research, development and commercialization of renewable energy resources should be strongly and continuously promoted at the national and regional levels. This will be furthered if the buy-back rate for electricity generated from renewable energy sources is 10-20 % higher than the rate for electricity.

The large hydro-power potential in the South East Asia peninsula should be further exploited, and may be soon realized through the Mekong River Commission. To avoid deforestation and relocation of people, medium and small hydropower plants such as run-off-river type should be considered as alternatives to large hydro-power systems.

As a long-term policy, nuclear power seems to be a logical non-fossil-fuel option for electricity generation in Thailand (Wibulswas and Chaisompob, 1995). With expertise, experience and uranium resources in developed countries in the region, harnessing of nuclear power in developing countries should be possible and highly effective for greenhouse gas mitigation in the future.

Finally, as the greenhouse effect has not been proven beyond doubt, a GHG mitigation technology will be realized only when it leads to energy efficiency like combined-cycle and/or energy security like nuclear power.

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