technologies for mitigation of greenhouse gas emissions: barriers and promotional approaches

thailand

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INTRODUCTION 01

Global climate change due to the growing concentration of greenhouse gases (GHG) in the Earth's atmosphere presents a major challenge to humankind in the 21st century. Emissions of GHGs are increasing with rising fossil fuel consumption. The growth rate of GHG emissions in developing countries is significantly higher than that in industrialised countries due to the rapid growth of the economies and associated energy demands, especially fossil fuels. It has been projected that developing countries as a group will overtake Organisation for Economic Cooperation and Development (OECD) countries in terms of GHG emissions within the next two decades. Therefore mitigation of GHG emissions and stabilising atmospheric GHG concentrations require efforts from both the developing and industrialised nations of the world.

The Asian Regional Research Programme in Energy, Environment and Climate (ARRPEEC) funded by Swedish International Development Cooperation Agency (Sida) and coordinated by Asian Institute of Technology (AIT), was initiated in 1995. Its broad aim was to enhance capacity and preparedness on identification and assessment of energy related GHG mitigation options in the major sectors in selected Asian developing countries: China, India, Indonesia, Philippines, Sri Lanka, Thailand, and Vietnam.

This booklet presents the synthesis of the study carried out in Thailand in the third phase of ARRPEEC (2002-2005). The study addressed the promotion of climate friendly biomass technologies (Chapter 2) as well as GHG mitigation technologies and options in the power (Chapter 3) sector in Thailand. A summary of key findings of the study is presented at the end of each chapter.

BIOMASS ENERGY IN THAILAND: ASSESSMENT AND STRATEGY FORMULATION

02

Introduction

Biomass fuels are a major source of energy in Thailand, particularly in the residential and industrial sectors. While biomass is traditionally used in inefficient, polluting, end-use devices, modern biomass energy technologies (BETs) have the potential to meet growing energy demand through efficient use of biomass fuels, including those that can be sustainably produced in degraded or marginal land.

The present study was carried out within the framework of the Biomass Project of the Asian Regional Research Programme in Energy, Environment and Climate, Phase III. The objectives of the study were to:

- Characterise and assess selected BETs
- Identify barriers to their introduction and strategies for overcoming them
- Identify and analyse issues affecting transfer of BETs

Characterisation and Assessment of Selected BETS

There are many barriers to deployment of modern BETs. One such barrier is the lack of information on characteristics of these technologies. It is therefore important to generate and disseminate information on their characteristics. If the potential of biomass energy is to be harnessed to the maximum possible extent, it is necessary to carefully assess these technologies.

In the present study three BETs were selected for detailed characterisation based on numerous factors including: diffusion potential, cost effectiveness, conformity to national development goals, and feasibility of local manufacturing.

For the Thailand study, the selected technologies were:

- Biomass-based Combined Heat and Power (CHP) system
- Improved biomass cooking stove
- Biomass gasification for process heat

Biomass-based combined heat and power (CHP)

The CHP system considered for this study was a back-pressure steam turbine-boiler system which is fired by rice husk in a travelling-grate type of furnace.

The study determined that the net present value of the CHP plant is US$ 6.17 million with a 37% internal rate of return; the payback period would be about 2.36 years with a levelised electricity cost of US$ 0.1142/kWh.

The levelised electricity cost of a CHP plant is higher than a comparable fossil fuel-fired plant, but generation of both steam and power results in a higher overall efficiency. The high investment cost makes the CHP's levelised electricity cost sensitive to changes in capital cost.

Benefits

The primary socio-economic benefit of CHP plants is employment generation. Employment benefits could be seen in numerous sectors, especially in the agricultural sector where the collection and processing of fuel would occur. Employment opportunities would also be seen in the manufacturing, assembly, and installation of CHP systems and in their ongoing operation and maintenance.

However, the development and construction of a CHP plant requires a high level of technical knowledge and experience, as well as a high level of capital investment.

CHP plants also provide some environmental benefits, most notably a mitigation of the CO_2 emissions normally associated with power generation.

CO_2 mitigation and emissions

A CHP plant can substantially mitigate CO_2 emissions since the rice-husk fuel is CO_2 neutral. The estimated potential CO_2 mitigation is as

high as 0.842 kg/kWh when compared to electricity generated from diesel-based gas turbines, and 0.826 kg/kWh when compared to coal-thermal generation. Potential CO_2 mitigation was estimated to be 0.682 kg/kWh when compared to fuel oil thermal generation and 0.395 kg/kWh when compared to natural gas combined cycle power plants.

Rice husk combustion does generate certain other pollutants, specifically carbon monoxide (CO) and particulate emissions (classed as Total Suspended Particles or TSP). The high TSP emission is due to the high ash content of rice husk.

At the plant examined by this study, only CO emissions exceeded local standards, though high TSP emissions can be a cause of local concern.

Improved biomass cooking stove

The Improved Cooking Stoves considered for this study were an Improved Charcoal Bucket Stove, and an Improved Fuel-Wood Bucket Stove.

The Improved Charcoal Bucket Stove has already been disseminated, and is in use in some households. The maximum efficiency of this stove is about 34%.

The Improved Fuel-wood Bucket Stove was designed to reduce the reliance on inefficient three-stone open fire stoves and Traditional Bucket Stoves (TBS).

Easy and convenient to use, the TBS is cheaply and widely available. They are portable and can be fired with a variety of biomass fuels including wood, charcoal, and agricultural residue. They remain popular despite their shortcomings which include low efficiency, fragile grates, and a short life cycle.

Benefits

Widespread dissemination of modern, more efficient cooking stoves would result in the reduction of fuel use and attendant costs. This should offset the Improved Bucket Stoves' typically higher initial cost.

Biomass gasification for process heat

The Biomass Gasification system considered for this study was an atmospheric circulating fluidised bed (CFB) gasifier.

The system uses biomass to produce a gas which can be burned to provide “process heat.” The system has a capacity of about 500 kW, and an efficiency of about 59%. At full capacity, it consumes approximately 163 kg of wood chips per hour.

Benefits

Use of Biomass Gasification can reduce dependence on fossil fuel consumption. This can reduce national reliance on imported fuel as biomass is generated and collected locally. This carries additional social benefits in the form of local employment and skills development, as well as rural development.

CO_2 mitigation and emissions

A CFB Gasification plant with a thermal capacity of 500 kW operating at 80% load factor could conserve 0.46 Ml of Liquid Petroleum Gas (LPG), with a corresponding CO_2 emission mitigation of 787.6 tonnes per year.

Emissions of SO_2 are also reduced by using producer gas from the gasification of biomass, as it has a much lower sulphur content than fossil fuels. Acidification of soil and water are also reduced as a result.

Adverse effects

Use of producer gas from biomass gasification does have some adverse effects. Issues of land use and attendant environmental impacts can arise, and there may be occupational and public health concerns as well.

Some adverse effects can be mitigated through properly designed management systems.

Barriers to Selected Biomass Energy Technologies (BETS)

There are many barriers to expanding the use of modern BETs. In order to analyse and address these barriers, they were ranked using Analytical Hierarchy Process (AHP) methodology based on the following criteria:

- Impact of removal
- Ease of removal

In addition to the researchers themselves, responses of manufacturers, policy personnel, and users were also considered in ranking the barriers.

Barriers to biomass-based combined heat and power (CHP)

The study determined that the three issues considered the most significant barriers to the adoption of CHP Plants were:

1. Lack of techno-economic information for decision making
2. Lack of information disseminating institutes
3. Lack of successful references

Despite the relatively high initial capital investment required, the financial barrier was only ranked seventh of the twelve barriers considered.

Barriers to improved biomass cooking stoves

The study determined that the three issues considered the most significant barriers to the adoption of improved biomass cooking stoves were:

1. Lack of high performance devices locally
2. Lack of product standards or performance assurance
3. High initial cost

Barriers to biomass gasification for process heat

The study determined that the three issues considered the most significant barriers to the adoption of Biomass Gasification for Process Heat were:

1. Negative perception regarding biomass energy technologies
2. Risk of being the first to fail
3. Failure of past projects

As in the case of CHP Plants, financial issues are not perceived to be significant barriers; the lack of investment incentives was ranked fifth of the five barriers considered.

Removing barriers to biomass-based combined heat and power (CHP)

Lack of techno-economic information for decision making

Demonstration projects are needed to help reduce apprehension about Rice Husk-based CHP technology which is quite recent and not yet proven substantially in the field. The Energy Conservation fund under the Voluntary Program can be used to promote research and development of energy technologies and energy-efficiency programmes by supporting co-operation between the private sector and government agencies. Supporting mechanisms are also needed, including mandatory programmes for designated factories and feasibility studies at rice mills.

Lack of information disseminating institutes

Demonstration projects and feasibility studies can also raise awareness of BETs. National government institutes such as the Department of Alternative Energy Development and Efficiency (DEDE) should consider funding studies and demonstration plants.

Experts from all relevant institutions including universities and the Energy Conservation Center of Thailand (ECCT) can help resolve technical problems. Existing renewable energy networks at all levels should also be encouraged to collaborate and pool information for dissemination. The government can encourage and support cooperation

among manufacturers and experts by organising technology development forums.

Lack of successful references

Promotion of simple, reliable, low-maintenance CHP plants at small mills will facilitate demonstration of the technology and dissemination of information.

Removing barriers to improved biomass cooking stoves

Lack of high performance devices locally

Technical training programmes for rural potters should be developed and promoted.

The DEDE has set up a two year plan for the promotion of improved biomass cooking stoves. Year One will see the dissemination of prototypes and Year Two will see promotion at the household level. It is hoped that after two years, the number of improved cooking stoves will be 16 000 units, or 80% of the biomass cooking stoves in use in the targeted region. This success can then be used to promote the improved cooking stoves in other regions in subsequent years.

Lack of product standards or performance assurance

Standards for efficient stoves need to be established.

The DEDE plans to promote demonstration of construction, testing, and performance of improved cooking stoves, and to publicise the potential savings from their use. Target groups will be monitored to help solve problems which may arise.

High initial cost

Financial support for rural pottery training is necessary.

The DEDE plans to work with the public to identify suitable incentives for the widespread adoption of improved biomass cooking stoves. This may include community fund or soft loan investment.

Removing barriers to biomass gasification for process heat

Negative Perception Regarding Biomass Energy Technologies
There is a need for the development of demonstration projects and information dissemination. An improved funding environment is necessary to encourage the development and demonstration of as yet unproven biomass energy technologies.

Risk of being the first to fail

Technology guarantees are needed to build the confidence of users, and suppliers must be encouraged to ensure replacement of failed equipment.

failure of past projects

Research to overcome past technological shortcomings should be promoted. Past failed projects should be analysed, and the reasons for their failure explained to ensure that past mistakes can be avoided in future.

Study of the Transfer of Selected BETS

In order to promote the transfer of Biomass energy technology to local stakeholders several recommendations can be made regarding national policies, institutional structure, and financing mechanisms.

National policy measures should focus on establishing a long term energy plan with clear targets for biomass energy technologies. Such a plan would help to build investor confidence and allow independent and small, power producers (IPPs and SPPs) to sell electricity to the grid on favourable terms. This would in turn create investment opportunities.

At the institutional level, co-operation and co-ordination should be encouraged among government departments. The Energy Planning and Policy Office (EPPO) has proposed a “One-Stop Clearing House” to give advice and information regarding biomass-based power

generation which may help to reduce the length of the planning process and associated transaction costs.

Financial mechanisms can also be implemented to encourage technology transfer and development. Loan guarantees and recognition of BET systems as an asset against loans should be considered to reduce the risks to investors. Fair appraisal of BET projects which accounts for the small size and relatively high initial costs is important.

Grants and soft loans for pilot and demonstration projects should be considered. High risk loans can be provided by development banks, by bilateral and multilateral aid agencies. Micro-financing schemes with local organisations should be employed so that small business and households can get access to credit.

Summary

Use of domestic biomass resources for energy generation can enhance national “energy security” by reducing reliance on imported fossil fuels. Modern BETs can help the country industrialise while limiting harmful emissions. CHP and Biomass Gasification can both help to reduce reliance on fossil fuels while mitigating CO_2 emissions; improved Cooking Stoves can make more efficient use of the biomass fuels already being used.

In order to overcome the perceived barriers to the introduction of BETs, successful demonstration projects are key to building investor and consumer confidence. Dissemination of information about BET options and about successful projects will further enhance their appeal.

Transfer of modern BETs in Thailand is vital for clean and efficient utilisation of its biomass resources. It is important to ensure that transferred technologies meet the country’s needs and priorities. Transfer of such technologies can be facilitated by undertaking a wide rage of measures encompassing national policies, institutional structures and financing mechanisms.

STRATEGIES FOR PROMOTION OF ENERGY EFFICIENT AND CLEANER TECHNOLOGIES IN THE POWER SECTOR IN THAILAND

03

Introduction

The overall objective of the ARRPEEC III project for the power sector is to analyse the technical and policy options for mitigating the environmental emissions produced in the power production process.

The power sector is the largest contributor of CO_2 emissions in most of the developing countries in Asia. In Thailand the power sector contributed 33% of the total CO_2 emissions in the year 2000. Low power plant efficiency is also a chronic problem with the thermal efficiency of power plants in some countries in Asia being up to 10% less than the average for all OECD countries.

Total emissions from greenhouse gases (GHG) including CO_2 from the power sector are expected to rise in future unless corrective measures are undertaken. There is thus an urgent need to conduct research on the various options, determine the strategies for the promotion of clean and energy efficient technologies (CEETs), and to analyse the barriers that impede their adoption.

In this phase of the ARRPEEC project research has been conducted to:

- Analyse the implications of carbon and energy taxes as instruments to reduce GHG emission reduction
- Identify the barriers to the adoption of selected CEETs and identify the measures to overcome the barriers

Overview

Demand for electricity in Thailand has grown at an annual rate of 8% over the decade starting in 1992 reaching 100,173 GWh in 2002, while

generation capacity over the same period expanded from 11,732 MW to 24,157 MW.

In 2002, electricity generation in Thailand consumed 35% of the total primary energy supply comprising coal, natural gas, and petroleum products and it produced 63,458 million tonnes of CO_2 representing 33% of the total CO_2 emissions (Department of Alternative Energy Development and Efficiency [DEDE] 2002).

Fossil fuel fired plant capacity accounted for 79.85% of the total installed capacity in 2002 and the proportion of electricity generated from fossil fuels is forecast to increase corresponding to electricity demand.

Small Power Producers (SPP) in the private sector use agricultural wastes such as bagasse, rice husk, and wood waste in their power plants. The Royal Thai Government policy allows SPPs to sell electricity to the state owned power utility, the Electricity Generating Authority of Thailand (EGAT), at a buy-back tariff set by EGAT. In April 2000, 11.4% of the 1580 MW actual sales by SPPs were generated by renewable energy.

As a result of the Royal Thai Government's Energy Conservation programme, which supports grid-connected power schemes using non-conventional energy, waste, or renewable energy co-generation, power purchases from SPPs in 2004 increased to 300.5 MW from 180 MW in the year 2000. The Ministry of Energy has set a goal to increase the share of renewable energy from 0.5% to 8% of total energy supplies over the next decade. Photovoltaic (PV) technology generates about 5 MW mostly in remote areas. Applications include pumping water for village water supply, but surplus energy is not connected to the national grid.

Energy produced from CEETs represents a small fraction of energy products and the Royal Thai Government's policy on CEET has been focussed on fuel-switching and increasing the use of cleaner fossil energy sources such as natural gas or low sulphur content coal rather than technology-switching to energy efficient coal technologies like Integrated Gasification Combined Cycle (IGCC). EGAT has conducted studies on clean coal technology and although IGCC plant efficiency

is higher than conventional coal-fired plant the technical and economic perspectives currently make IGCC less attractive.

Implications of Introducing Carbon and Energy Taxes

Implications of carbon tax

Introducing a carbon tax has implications for utility planning, the mix of technologies and fuels used for power generation, generator efficiency, and expansion. The electricity price would increase and changes in demand for electricity would impact on the total capacity and generation requirements during the planning period, 2006 to 2025.

The conventional coal fired power plant additions would reduce from 69,000 MW at base case to 15,000 MW at US$ 200/tC carbon tax mainly due to the high tax imposed on conventional coal technology compared to other cleaner technologies. At US$ 200/tC tax plant capacity additions would include biomass, Supercritical-coal, IGCC-coal (Integrated Gasification Combined Cycle), BIGCC (Biogas Integrated Gasification Combined Cycle) and combined cycle gas turbine.

Table 1. Generation mix at different carbon tax rates by fuel type, (%)

Carbon tax rate (US$/tC)	Fuel type				
	Hydro	Oil	Coal	Gas	Biomass
0	2.30	5.90	70.90	17.90	3.00
5	2.33	5.40	71.45	17.80	3.02
100	2.90	3.51	23.98	64.60	5.00
200	3.13	3.82	16.24	67.81	8.99

The percentage share of the total generation with each fuel type is shown in Table 1. The most significant changes are that the share of coal based generation would decrease to 16.24% while the gas

generation share would increase to 67.81% and the Biomass share would increase to 8.99%.

The increasing carbon tax would lead to the selection of cleaner and more efficient technologies in the generation plan. Advanced coal fired technologies like ICGG and supercritical-coal, which have higher thermal efficiency that is have lower fuel consumption rates, to some extent counter the influence of cost increases due to the carbon tax and contribute to an increase in the weighted average thermal generation efficiency to 43.84% compared to 36.18% in the base case.

The total cost increases significantly as shown in Table 2. The total cost at US$ 200/tC increases by 37.8% compared to base rate. This is due to the increased operating cost resulting from the increase in fuel cost with carbon tax, while the reduction in capital cost is due to the reduction in capacity additions.

Table 2. Cost composition with carbon tax over 2006-2025

Carbon tax rate (US$/tC)	Operating cost ($ millions)	Capital cost ($ millions)	Total cost ($ millions)
0	34,152	10,038	44,190
5	34,454	9,804	44,258
25	37,404	7,938	45,342
100	45,721	6,432	52,153
200	54,405	6,483	60,888

The average incremental cost of generation would increase the electricity price. Although the total cost compared to base case would increase by 37.8%, the average incremental cost of generation would increase by 98% at the US$ 200/tC carbon tax rate to US cents 6.12/kWh due to lowered demand with an own price elasticity of demand of -0.48. The electricity price would also increase by the same amount.

There would be a large reduction of CO_2, SO_2 and NOx emissions from the power sector when the carbon tax is introduced as shown in Table 3. At carbon tax rates up to US$ 25/tC the CO_2 emission reduction is

mainly from the electricity demand effect however at carbon tax rates above US$ 25/tC the supply side effect would become the dominant factor. In the case of SO_2 and NOx the trend is more apparent with the reduction in emissions being 80.69% and 63.01% respectively.

Table 3. Power sector impact on emissions over 2006-2025 with carbon tax

	Carbon Tax (US$/tC)					
	5	10	25	50	100	200
CO_2 mitigation due to supply side effect[1] (ΔE_{SSE})	0	26	42	692	1,391	1,626
CO_2 mitigation due to demand-side effect[2] (ΔE_{DSE})	82	158	324	684	1,147	1,377
Total CO_2 mitigation (ΔE_{total})	82	184	366	1,376	2,538	3,003
% CO_2 mitigation	1.60	3.59	7.15	26.87	49.56	58.64
SO_2 mitigation (10^3 tons)	359	1,258	2,301	12,204	25,124	27,595
% SO2 mitigation	1.05	3.68	6.73	35.68	73.46	80.69
NO_x mitigation (10^3 tons)	292	541	1,149	4,455	8,662	9,955
% NO_x mitigation	1.85	3.42	7.27	28.20	54.82	63.01

1 SSE-supply side effect; change in emissions due to changes in supply technologies and fuels with the imposition of carbon tax

2 DSE-demand side effect; change in emissions due to the change in electricity demand with the imposition of carbon tax

Implications of energy tax

The introduction of an energy tax levied on all thermal plants, including biomass fired plants, would affect utility generation plans, technology mix, generation mix and the demand for electricity. The large hydro plants would also be taxed based on average efficiency of thermal plants.

The electricity price would increase and changes in demand for electricity would impact on the total capacity and generation requirements during the planning period.

The energy tax would impact on biogas power plants since they would not be selected. The capacity share of coal fired power plants would

reduce while oil fired power plants and the generation from new technologies would increase.

The generation mix by fuel type during the planning period at different energy tax rates is shown in Table 4.

Table 4. Generation mix over 2006 - 2025 at different energy tax rates by fuel type, (%)

Carbon tax rate (US$/MBtu)	Fuel type				
	Hydro	Oil	Coal	Gas	Biomass
0	2.30	5.90	70.90	17.90	3.00
0.5	2.43	5.24	72.38	19.00	0.94
1.0	2.57	5.37	75.70	20.00	0.06
2.0	2.83	3.26	75.70	18.15	0.06
5.0	3.41	4.10	44.29	48.20	0.00

The overall thermal generation efficiency would increase significantly from 36.18% in the base case to 43.43% at the US$ 10/MBtu energy tax rate. The improvement in efficiency is due to the substitution of conventional coal fired steam power plants by efficient gas fired combined cycle power plants.

The total cost would increase by 101% to US$ 88.983 billions at the US$ 10/MBtu energy tax rate as shown in Table 5, mainly as a result of increases in operating cost due to the large increment in fuel and variable cost due to tax imposed on fuel cost.

Table 5. Cost composition with energy tax over 2006-2025

Carbon tax rate (US$/MBtu)	Operating cost ($ millions)	Capital cost ($ millions)	Total cost ($ millions)
0	34,152	10,038	44,190
1.0	41,224	7,659	48,883
5.0	62,653	5,273	67,926
10.0	84,601	4,382	88,983

The electricity price rises significantly with energy tax. The average incremental cost of generation with an energy tax of US$ 10/MBtu would be US Cents 10.72/ kWh which is an increase of 247% over the base case.

The effect of energy tax on CO_2 emission reduction is shown in Table 6. The reduction is mainly due to the electricity demand effect at all energy tax levels and reaches 62% at an energy tax level of US$ 10/ MBtu. The total reductions of SO_2 and NOx emissions at a tax rate of US$ 10/MBtu are 82.99% and 73.79% respectively.

Table 6. Power sector impact on emissions over 2006-2025 with energy tax

	Energy Tax (US$/MBtu)				
	0.5	1.0	2.0	5.0	10.0
CO_2 mitigation due to supply side effect[1] (ΔE_{SSE})	0	0	63	765	1,327
CO_2 mitigation due to demand-side effect[2] (ΔE_{DSE})	228	476	852	1,569	1,868
Total CO_2 mitigation (ΔE_{total})	228	476	915	2,334	3,195
% CO_2 mitigation	4.45	9.30	17.87	45.58	62.39
SO_2 mitigation (10^3 tons)	1,141	2,778	8,162	19,593	28,383
% SO2 mitigation	3.34	8.12	23.87	57.29	82.99
NO_x mitigation (10^3 tons)	730	1,535	4,471	9,216	11,659
% NO_x mitigation	4.62	9.72	28.30	58.33	73.79

1 SSE-supply side effect; change in emissions due to changes in supply technologies and fuels with the imposition of energy tax

2 DSE-demand side effect; change in emissions due to the change in electricity demand with the imposition of energy tax

Figure 1 illustrates that carbon tax is more effective than energy tax in CO_2 emission mitigation in that it results in a smaller average incremental cost at the generation level to achieve the same level of CO_2 emission reduction.

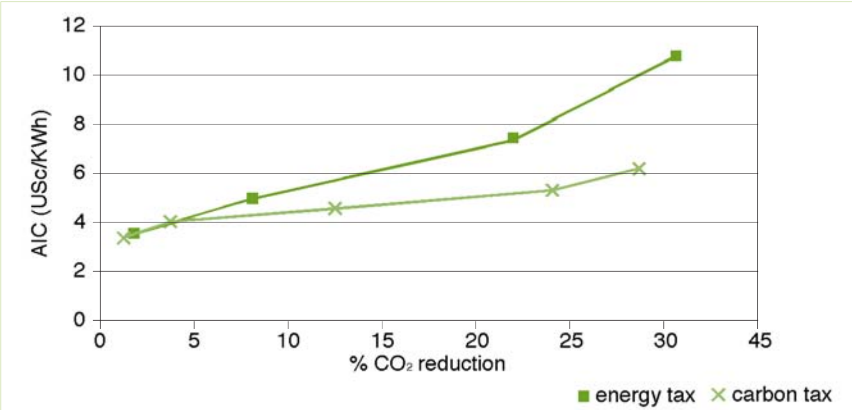

Figure 1. Average Incremental Cost vs. CO_2 emission reduction

Selection of the three most promising options

In Thailand, the most promising clean and energy efficient technologies and renewable energy technologies have been identified as:

- IGCC Integrated Gasification Combined Cycle Coal technology
- PV Solar Photovoltaic technology
- Biomass technology.

Identification and Ranking of Barriers

The Analytic Hierarchy Process was used to rank the barriers. The methodology allows decomposition of the problem and uses comparative judgments to rank the barriers based on different criteria, including the cost to remove the barriers, the life of the barriers, the level of effort required and the impact on adoption. Survey questionnaires were distributed to policy makers, energy experts, utilities and power plant developers. Interviews with the key stakeholders in the private and public sectors contributed to the identification and ranking of the barriers and the identification of the policies and measures required to remove the barriers.

The selected policies were analysed based on their economic considerations, financial viability, administrative feasibility and political acceptability and effectiveness.

Biomass technology

The Royal Thai Government's Energy Conservation Programme is aimed at promoting grid connected power schemes using non-conventional energy, waste, or renewable energy co-generation. In July 2000, an announcement was issued of the intention to invite bids for 300MW of power purchase using renewable energy from Small Power Producers (SPPs). As a result of this initiative, power purchase using renewable energy from SPPs was reported to be 300.5 MW in 2004.

The three main barriers to the adoption of biomass and measures to overcome these barriers have been studied and analysed by the researchers and their findings are summarised in the Table 7.

Table 7. Policies identified to overcome the major barriers for biomass

Barrier	Policies and measures
High capital cost.	Domestic R&D to reduce equipment cost. Privileges through Board Of Investment.
Lack of investment capital and financing instruments.	Privileges through Board Of Investment.
High interest rates.	Renewable electricity production fund.

It is recommended that support should be sought from universities and research institutes to conduct research on efficiency improvements and the reduction of equipment cost. This is in line with government policy.

Biomass plant construction should be exempted from taxes for imported machinery and materials. This is in line with the Thailand Board of Investment (BOI) policy for investment promotion especially for environmental benefits and energy diversification.

The Renewable Electricity Production Fund, like the Energy Conservation (ECON) Programme, should levy a charge to each kWh of electricity production with the long term objective to provide financial incentive to promote biomass power generation. The Ministry of Energy could monitor and evaluate the funding process. This is in line with government policy and may be acceptable for electricity utilities and SPPs.

Solar PV

Studies and research conducted by the DEDE and Silapakorn University in 1999 illustrated on a Solar Map for Thailand that the average energy produced from sunlight is 18 MJ/m^2/day. Projects in the period 2002 to 2006 include systems up to 20 MW that would supply households, hospitals and factories. Excess capacity could be sold to electricity utilities when grid connections exist.

The three main barriers to the adoption of Solar PV and measures to overcome these barriers have been studied and analysed and the findings are summarised in the Table 8.

Table 8. Policies identified to overcome the major barriers for Solar PV

Barrier	Policies and measures
High capital cost.	Subsidy for cost by government and other funds.
Lack of investment capital and financing instruments.	Privileges through Board Of Investment.
Lack of technical & financial information and demonstrated track record.	Set up pilot PV power plants. Set up technical and financial consultancy centres.

The establishment of pilot projects would add information on the technological, operational and financial viability of the PV systems and encourage the development of local R&D in these areas. This policy is already supported by the Royal Thai Government but requires more coordination and funding with the objective of providing results for investors and stakeholders to justify the rapid promotion of the technology.

The establishment of R&D and consulting centres to maintain databases, coordinate initiatives and analyse and disseminate PV technology information is in line with Ministry of Energy policy.

The high capital cost makes Solar PV plant uncompetitive compared with conventional fossil fuel plants and would require a subsidy of up to 70% of the cost of the PV systems. Although the cost is high it is considered that there would be support from the Ministry of Energy and from the ECON fund.

The development of Solar PV should be exempt from import taxes in the way proposed for biomass plants.

IGCC technology

In Thailand the policy on clean and energy efficient technologies is not limited to gas and low sulphur content coal. IGCC could be an alternative source but although its efficiency is higher it is currently less attractive on technical and economic terms.

The three main barriers to the adoption of IGCC and measures to overcome these barriers have been studied and analysed by the researchers and their findings are summarised in the Table 9.

Table 9. Policies identified to overcome the major barriers for IGCC

Barrier	Policies and measures
High capital cost.	Privileges through Board Of Investment Implementing a carbon tax.
Lack of investment capital and financing instruments.	Privileges through Board Of Investment.
High interest rates.	Clean coal technology electricity production fund .

The Clean Coal Technology Electricity Production Fund would support pilot projects to demonstrate the operational aspects of the technology in a similar way to the ECON fund. The cost of the fund support would be substantial because the IGCC installation cost would be higher than the renewable power plants.

The development of IGCC should be exempt from import taxes in the same way as proposed for biomass plants and Solar PV plants. The tax incentives could be gradually phased out with the development of the IGCC technology as the capital costs would be reduced.

Revenue from the carbon tax should be allocated to funds like the ECON fund to promote renewable and energy efficient activities. It is recognised that gaining political approval for this recommendation could be difficult.

Summary

There will be a large reduction of CO_2, SO_2 and NOx emissions from the power sector when carbon or energy taxes are introduced in the sector. When a carbon tax of US$ 200/tC is levied the CO_2 emission will be reduced by 3,003 million tons or approximately 58% of the base case while the SO_2 and NOx emissions will be reduced by approximately 80% and 63% of the base case respectively. An energy tax of US$ 10/MBtu would result in a CO_2 emission reduction of 3,195 million tons or approximately 62% of the base case, while the SO_2 and NOx emissions would be reduced by approximately 83% and 74% of the base case respectively.

Introducing carbon and energy taxes contributes to optimisation of the generation structure, reduces energy use and helps to provide a cleaner energy future. However when taxes are introduced the generation cost of the whole power sector increases significantly, which leads to a rapid increase in electricity prices of up to 98% in the case of a carbon tax of US$ 200/tC. Electricity price increases of this order would impact on the competitiveness of industries and would require further careful consideration.

The barriers to biomass energy are high capital cost, lack of investment capital, lack of financing instruments and high interest rates. The measures proposed are an increase in indigenous R&D on efficiency improvements and reduction of equipment cost, privileges through Board of Investment (BOI) and the use of a renewable electricity production fund.

The barriers to Solar PV are the same as for biomass but an additional barrier is the lack of a demonstrated track record. The measures proposed include privileges through the BOI and especially the establishment of pilot projects to build expertise and the introduction of technical and financial consulting centres.

The barriers to IGCC, which have common characteristics to the cases of biomass and Solar PV, are overcome through privileges through the BOI, implementing carbon tax and the establishment of a clean coal technology electricity production fund.

selected ARRPEEC publications

Publications from Phase III

Biomass energy

Elauria, J.C. (2005). Sustainable Use of Biomass as Greenhouse Gas Mitigation Option in the Philippines. Biomass-Asia workshop, 19-21 January. Tsukuba and Tokyo, Japan.

Chungpaibulpatana, S., B. Sajjakulnukit, Limmeechokchai, B., Santisirsomboon, J., S.C. Bhattacharya (2004). Application of AHP for Prioritizing Barriers on the Implementation of Improved Biomass Cooking Stoves in Thailand. World Renewable Energy Congress VIII (WREC). Editor: AAM Sayigh. Elsevier Ltd.

Ravindranath, N.H., H.I. Somashekar, S. Dasappa and C.N. Jayasheela Reddy (2004). Sustainable Biomass Power for Rural India, Case Study of Biomass Gasifier for Village Electrification. *Current Science,* 87(7): 932-941.

Chungpaibulpatana, S., Limmeechokchai, B., Santisirsomboon, J., B. Sajjakulnukit, S.C. Bhattacharya (2003). Promising Biomass Energy Technology in Thailand: The Characterization of Paddy Husk Combined Heat and Power. First International Conference on Sustainable Energy and Green Architecture (SEGA), 8-10 October.

Power sector

Bundit Limmeechokchai, Somporn Tanatvanit, Jerasorn Santisirisomboon, and Ram M. Shrestha (2003). The CDM Potential of GHG Mitigation in the Thai Power Sector. The Second Regional Conference on Energy Technology towards a Clean Environment, 12-14 February. Phuket, Thailand.

Bundit Limmeechokchai, Pawinee Suksuntornsiri and Ram. M. Shrestha (2004). Implications of Carbon Tax on Economy-Wide CO_2 Mitigation in Thailand: An Input-Output Analysis. The Joint International Conference on “Sustainable Energy and Environment (SEE), 1-3 December. Hua Hin, Thailand.

Bundit Limmeechokchai, Supachart Chungpaibulpatana, Ram. M. Shrestha and Anula Abeygunawardana (2004). Least Cost Electricity Generation Expansion Planning with Carbon and Energy Taxes: The Case of Thailand. The Joint International Conference on “Sustainable Energy and Environment (SEE), 1-3 December. Hua Hin, Thailand.

Limmeechokchai, B., S. Chungpaibulpatana, S. Tanatvanit, J. Santisirisomboon, and R.M. Shrestha (2003) Barriers to Adoption of Clean and Energy Efficient Technologies in Thai Power Sector. The First International Conference in Sustainable Energy and Green Architecture (SEGA), 8-10 October. Bangkok, Thailand.

Limmeechokchai B., Santisirisomboon J., and Ram M. Shrestha (2004). Impacts of Carbon and Energy Taxes on Biomass Power Generation Expansion Planning. World Renewable Energy Congress VIII, 29 August - 3 September . USA.

Priyantha D.C. Wijayatunga, Kanchana Siriwardena, W.J.L.S. Fernando, Ram M Shrestha, Rahula A. Attalage (undated). Strategies to Overcome Barriers for Cleaner Generation Technologies in Small Developing Power Systems: Sri Lanka Case Study. *Energy Conservation and Management,* Elsevier, Accepted for publication.

Priyantha D.C. Wijayatunga (2005). Barriers to Greenhouse Gas Mitigation Options in Developing Economies Like Sri Lanka and Strategies to Overcome Them. Presented during 22nd Session of the Subsidiary Body for Science and Technological Advice of the United Nations Convention of Climate Change (UNFCCC), 23 May. Bonn, Germany.

Yamgar S., Nanda G., Srivastava S.C., Singh S.N., Gupta P., Dharam Paul, Shrestha R.M., (2004). Implications of Carbon Tax on Generation Expansion Plan and GHG Emission: A Case Study on Indian Power Sector. ICPS 2004 Proceedings, 3-4 November. Kathmandu, Nepal.

SMI sector

Kumar S., Visvanathan C., Peng S., Rudramoorthy R., Herrera A.B., Senanayake G. and Son L.D. (2005). Greenhouse Gas Mitigation in Small and Medium Scale Industries of Asia. Asian Institute of Technology, Thailand.

Kumar S., Visvanathan C., Peng S., Rudramoorthy R., Herrera A.B., Senanayake G. and Son L.D. (2005). Barriers to Promoting Energy Efficient and Environmentally Sound Technologies to SMIs in Asia. Asian Institute of Technology, Thailand.

Peng S., Liu Y., Shi H. and Ping Z. (2005). Studies on Barriers for Promotion of Clean Technology in SMEs of China, Chinese Journal of Population. *Resources and Environment,* 3(1).

Proceedings of All India Conference on Energy Conservation and Policy Options for Small and Medium Scale Industries (2004). PSG College of Technology, 23-24, July. Combatore, India.

Herrera, A. B. (2004) Prioritizing the Barriers Inhibiting the Promotion of Energy Efficient and Environmentally Sound Technologies (E3ST): Metal Casting and Ceramic Industries in the Philippines. *The Energy Manager,* April-June, 22(2).

SMI Newsletter (2004). Volume 6, Issues 20-22.

Thiruchelvam, M., Kumar, C. and Visvanathan, C. (2003) Policy Options to Promote Energy Efficient and Environmentally Sound Technologies in Small and Medium Scale Industries. *Energy Policy,* Volume 31, Issue 10, August, pp: 931-1045.

SMI Newsletter (2003). Volume 5, Issues 16-19.

SMI Newsletter (2002). Volume 4, Issues 13-14.

SMI Newsletter (2002). Special Issue: Desiccated Coconut, March.

Urban transport sector

Jiang Kejun, Zhu Songli, Hu Xiulian (2004). Impact of Clean Transport Technology on Energy and Environment. China Energy Issue Study 2003, China Planning Publishing House (Under print).

Jiang Kejun, Hu Xiulian, Zhu Songli (2004). China Transport Perspective. Proceeding of IPIECA Workshop on Climate Change and Transport, 12-13 October. Washington, D.C.

Jiang kejun, Zhu Songli, Hu Xiulian (2005). Clean Transport Future in Beijing. China *Energy Policy Study* (Under print).

Jiang Kejun (2004). Vehicle Development Strategy. Beijing Youngth Newspaper, 13 October.

Puji Lestari, Meidhy Praharsa Utama, Adrisman Tahar and Ucok Siagian (2003). Estimation of Ambient Air Quality from Transport Sector Using Simple Dispersion Model for Bandung City. Better Air Quality Conference, December. Manila, Philippines.

Ram M. Shrestha, G. Anandarajah, S. Adhikari, K. Jiang and Z. Songli (2005). Energy and Environmental Implications of NOx Emission Reduction from the Transport Sector of Beijing: A Least-cost Planning Analysis. *Transportation Research Part D:* (10), pp: 1-11.

Sudhakar Yedla and Ram M. Shrestha (2004). Co-benefits from Urban Transportation Strategies - Comparative Analysis of Local Emission Control Strategies vis-a-vis GHG Mitigation Strategies, Better Air Quality in Asia and Pacific Rim Cities. 6-8 December. Agra, India.

Sudhakar Yedla (2004). Transportation Trends, Alternatives and Policy Issues. India Development Report, Eds. Radhakrishna and Parikh. Oxford University Press.

Yedla S., J. K. Parikh and Ram M. Shrestha (2003). Sustainable Urban Transportation: Impact of CO_2 Mitigation Strategies on Local Pollutants. *International Journal Environment and Pollution,* 19(5): 475-482.

Yedla S., and Ram M. Shrestha (2003). Multi-criteria Approach for the Selection of Alternative Options for Environmentally Sustainable Transport System in Delhi. *Transportation Research Part A: Policies and Practice,* 37(8): 717 - 729.

Sudhakar Yedla, Ram M. Shrestha, and Gabrial Anandarajah (2005) Environmentally Sustainable Urban Transportation - Comparative Analysis of Local Emission Mitigation Strategies vis-a-vis GHG Mitigation Strategies. *Transport Policy,* Vol. 12 pp: 245-254 .

Dissemination booklets

ARRPEEC (2005).

- Technologies for Mitigation of Greenhouse Gas Emissions: Barriers and Promotional Approaches, A Comparative Study in Asia. A study by the Asian Regional Research Programme in Energy, Environment and Climate Phase III. Asian Institute of Technology, Bangkok, Thailand.
- Technologies for Mitigation of Greenhouse Gas Emissions: Barriers and Promotional Approaches, China. A study by the Asian Regional Research Programme in Energy, Environment and Climate Phase III. Asian Institute of Technology, Bangkok, Thailand.
- Technologies for Mitigation of Greenhouse Gas Emissions: Barriers and Promotional Approaches, India. A study by the Asian Regional Research Programme in Energy, Environment and Climate Phase III. Asian Institute of Technology, Bangkok, Thailand.
- Technologies for Mitigation of Greenhouse Gas Emissions: Barriers and Promotional Approaches, Indonesia. A study by the Asian Regional Research Programme in Energy, Environment and Climate Phase III. Asian Institute of Technology, Bangkok, Thailand.
- Technologies for Mitigation of Greenhouse Gas Emissions: Barriers and Promotional Approaches, Philippines. A study by the Asian Regional Research Programme in Energy, Environment and Climate Phase III. Asian Institute of Technology, Bangkok, Thailand.
- Technologies for Mitigation of Greenhouse Gas Emissions: Barriers and Promotional Approaches, Sri Lanka. A study by the Asian Regional Research Programme in Energy, Environment and Climate Phase III. Asian Institute of Technology, Bangkok, Thailand.
- Technologies for Mitigation of Greenhouse Gas Emissions: Barriers and Promotional Approaches, Thailand. A study by the Asian Regional Research Programme in Energy, Environment and Climate Phase III. Asian Institute of of Technology, Bangkok, Thailand.
- Technologies for Mitigation of Greenhouse Gas Emissions: Barriers and Promotional Approaches, Vietnam. A study by the Asian Regional Research Programme in Energy, Environment and Climate Phase III. Asian Institute of Technology, Bangkok, Thailand.

Publications from Phase II

Biomass energy

Bhattacharya, S.C, P. Abdul Salam, Hu Runqing, H.I. Somashekar, D.A. Racelis, P.G. Ratnasiri, and Rungrawee Yingyuad (2005). An Assessment of the Potential for Non-plantation Biomass Resources in Selected Asian Countries for 2010. *Biomass and Bioenergy,* September, 29 (3): 153-166.

Boonrod Sajjakulnukit, Rungrawee Yingyuad, Virach Maneekhao, Veerawan Pongnarintasut, S. C. Bhattacharya and P. Abdul Salam (2005). Assessment of Sustainable Energy Potential of Non-plantation Biomass Resources in Thailand. *Biomass and Bioenergy,* September, 29 (3): 214-224.

Elauria, J.C., M.L.Y. Castro, M. M. Elauria, S.C. Bhattacharya and P. Abdul Salam (2005). Assessment of Sustainable Energy Potential of Non-plantation Biomass Resources in the Philippines. *Biomass and Bioenergy,* September, 29 (3): 191-198.

Li Junfeng, Hu Runqing, Song Yangin, Shi Jingli, S.C. Bhattacharya and P. Abdul Salam (2005). Assessment of Sustainable Energy Potential of Non-plantation Biomass Resources in China. *Biomass and Bioenergy,* September, 29 (3): 167-177.

Perera, K.K.C.K., P.G. Rathnasiri, S.A.S. Senarath, A.G.T. Sugathapala, S.C. Bhattacharya and P. Abdul Salam (2005). Assessment of Sustainable Energy Potential of Non-plantation Biomass Resources in Sri Lanka. *Biomass and Bioenergy,* September, 29 (3): 199-213.

Ravindranath, N.H., H.I. Somashekar, M.S. Nagaraja, P. Sudha, G. Sangeetha, S.C. Bhattacharya P. Abdul Salam (2005). Assessment of Sustainable Non-plantation Biomass Resources Potential for Energy in India. *Biomass and Bioenergy,* September, 29 (3): 178-190.

Bhattacharya S.C., P. Abdul Salam, H.L. Pham and N.H. Ravindranath (2003). Sustainable Biomass Production for Energy in Selected Asian Countries. *Biomass and Bioenergy,* 25 (5): 471-482.

Boonrod Sujjakulnukit and Prasert Verapong (2003). Sustainable Biomass Production for Energy in Thailand. *Biomass and Bioenergy,* November, 25(5): 557-570.

Elauria, J.C., M.L.Y. Castro, and D.A. Racelis (2003) Sustainable Biomass Production for Energy in Philippines. *Biomass and Bioenergy,* November, 25(5): 531-540.

Kumar, A., S.C. Bhattacharya and H.L. Pham (2003) Greenhouse Gas Mitigation Potential of Biomass Energy Technologies in Vietnam Using the Long Range Energy Alternative Planning System Model. *Energy* 28: 627-654.

Li Junfeng, and Hu Runqing (2003) Sustainable Biomass Production for Energy in China. *Biomass and Bioenergy,* November 2003, 25(5): 483-499.

Perera, K.K.C.K, P.G. Ratnasiri, and A.G.T. Sugathapala (2003) Sustainable Biomass Production for Energy in Sri Lanka. *Biomass and Bioenergy,* November 2003, 25(5): 541-556.

Sudha, P., H.I. Somashekar, Sandhya Rao and N.H. Ravindranath (2003) Sustainable Biomass Production for Energy in India. *Biomass and Bioenergy,* 25(5): 501-515.

Koh, M. P., and W. K. Hoi (2003) Sustainable Biomass Production for Energy in Malaysia. *Biomass and Bioenergy,* 25(5): 517-529.

Bhattacharya, S.C. (2002) Biomass Energy and Densification: A Global Review with Emphasis on Developing Countries. Invited paper, First World Pellets Conference, 2-7 September. Stockholm, Sweden.

Bhattacharya, S.C. (2002). Biomass Energy for Sustainable Development. RITE International Workshop, 7-8 March. Hiroshima, Japan.

Bhattacharya, S.C. (2002). Biomass Energy in Asia: A Review of Status, Technologies and Policies in Asia. *Energy for Sustainable Development,* 6(3): 5-10.

Bhattacharya, S.C. and P. Abdul Salam (2002). Low Greenhouse Gas Biomass Option for Cooking in the Developing Countries. *Biomass and Bioenergy,* 22: 305-317.

Bhattacharya, S.C., D.O. Albina and Aung Myint Khaing (2002). Effects of Selected Parameters on Performance and Emission of Biomass-fired Cookstoves. *Biomass and Bioenergy,* 23: 387-395.

Bhattacharya, S.C., D.O. Albina and P. Abdul Salam (undated). Emission Factors of Wood and Charcoal-fired Cookstoves. *Biomass and Bioenergy,* 23: 453-469.

Bhattacharya, S.C., R.M. Shrestha, C. Visvanathan, S. Kumar and Kim Oanh (2001). Co-operative Research Programme, Experience of the Asian Regional Research Programme in Energy, Environment and Climate. 12th Global Warming International Conference and Expo, 8-11 April. Cambridge, UK.

Boonrod Sajjakulnukit, Virach Maneekhao and Veerawan Pongnarintasut (2002). Policy Analysis to Identify the Barriers to the Development of Bioenergy in Thailand. *Energy for Sustainable Development,* 6(3): 21-30.

Elauria, J.C., M.L.Y Castro and M.M. Elauria (2002). Biomass Energy Technologies in the Philippines: A Barrier and Policy Analysis. *Energy for Sustainable Development,* 6(3): 40-49.

Koh Mok Poh, Hoi Why Kong (2002). Renewable Energy in Malaysia: A Policy Analysis. *Energy for Sustainable Development,* 6(3): 31-39.

Li Junfeng, Zhu Li, Hu Runqing, Zhang Zhengmin, Shi Jingli and Song Yangqin (2002). Policy Analysis of the Barriers to Renewable Energy Development in the People's Republic of China. *Energy for Sustainable Development,* 6(3): 11-20.

Sugathapala, A.G.T. (2002). Policy Analysis to Identify the Barriers to the Promotion of Bioenergy Technologies in Sri Lanka. *Energy for Sustainable Development,* 6(3): 50-58.

Usha Rao, K. and N.H. Ravindranath (2002). Policies to Overcome Barriers to the Spread of Bioenergy Technologies in India. *Energy for Sustainable Development,* 6(3): 59-73.

Power sector

Fernando, W. J. L. S., Priyantha D. C. Wijayatunga and Ram M. Shrestha (2002). Least Cost Supply-side Options for Mitigating GHG and other Harmful Emissions from the Power Sector; Sri Lanka Case Study. *Energy for Sustainable Development,* 6(1):72-82.

Limmeechokchai B., S. Tanatvanit, and Ram M. Shrestha (2003). Impacts of Independent Power Producers on CO_2 Emission in the Thai Power Sector. *ASEAN Journal on Science & Technology for Development,* 20(3).

Limmeechokchai, B., S. Tanatvanit, and R.M. Shrestha (2002). Impacts of independent power producers on electricity generation expansion planning and CO_2 emission. First International Conference on Sustainable Energy Technologies, 12-14 June. Porto, Portugal, paper EP4.

Limmeechokchai, B., S. Tanatvanit and R.M. Shrestha (2002). Mitigating CO_2 emissions from the power sector: least-cost analyses of policy options in Thailand. *ASEAN Journal on Science &Technology for Development,* 19(1): 69-76

Ram M. Shrestha and Charles O.P. Marpaung (2004). Supply-and Demand-side Effects of Power Sector Planning with Demand Side Management Options and SO_2 Emission Constraints, *Energy Policy,* April, 33(6), pp: 815-825.

Ram M. Shrestha and Charles O.P. Marpaung (2002). Supply- and Demand-side Effects of Power Sector Planning with CO_2 Mitigation Constraints in a Developing Country. *Energy the International Journal.* 27: 271-286.

Shrestha, R.M., Van Xuan Anh and Shankar K. Karki (2000). An Assessment of a Clean Development Mechanism (CDM) Project in the Power Sector under Different Baseline Considerations: A Case of Vietnam. 23rd Annual International Conference of the International Association for Energy Economics, 8-10 June. Sydney, Australia.

Shrestha, R.M., and R. Shrestha (2001). Reducing CO_2 Emission through Technical and Policy Options: Case of the Power Sector in Thailand. International Workshop on Climate Policies in Asia, 17-18 December. Tokyo, Japan.

Shrestha, R.M. and R. Shrestha (2004). Economics of Clean Development Mechanism Power Project under Alternative Approaches for Setting Baseline Emission. Submitted to *Energy Policy,* August, 13(12), pp: 1363-1374.

Shrestha, R.M. (2002). Reducing CO_2 emissions from the Power Sector. International Workshop on Climate Change Policy Dialogue with Thailand (IGES), 27-28 May. Bangkok, Thailand.

Shrestha, R.M. and Le, Tuan A. (2002). Energy Efficiency and Environmental Emission Reductions: A Factor Decomposition Analysis. Proceeding of the IASTED International Conference, (POWER AND ENERGY SYSTEMS), 6th IASTED International Symposium on Power Generation and Renewable Energy Sources, 13-14 May. Marina del Rey, California, pp: 36-41.

Srisastra P., B. Limmeechokchai, Ram M. Shrestha and Rabin Shrestha (2003). Impacts of Distributed Power Generation on Electricity Generation Expansion Planning and CO_2 Emission: A Case Study of Thailand. *International Journal of School Technology,* 8(2): 33-44.

Srivastava A.K., Ram M. Shrestha, S.C. Srivastava, Rabin Shrestha and Dharam Paul (2003). Power Sector Development in India with CO_2 Emission Targets: Effects of Regional Grid Integration and the Role of Clean Technologies. *International Journal of Energy Research,* 27: 671-685.

Srivastava, S.C., B.K. Barnwal, A.K. Srivastava, D. Paul, P. Gupta, R. M. Shrestha, and R. Shrestha (2002). A Study on Environmental & Utility Planning Implications of Distributed Power Generation for a Regional Electricity Board in India. Power System Conference 2002: Impact of Distributed Generation, 13-15 March. Clemson University, South Carolina, USA.

Srivastava, S.C., A.K. Srivastava, U.K. Rout, M. Sharma, D. Paul, P. Gupta, R.M. Shrestha, and S. Karki (2001). Identification of Projects under Clean Development Mechanism for a Regional Electricity Board in India. Proceedings of Thirty-third Annual North American Power Symposium, 15-16 October. Texas A&M University, Texas, USA, pp: 606-611.

Srivastava, S.C., A.K. Srivastava, U.K. Rout, B.K. Barnwal, M. Sharma, D. Paul, P. Gupta, R. M. Shrestha, and R. Shrestha (2001). A Study on Environmental Impact of Independent Power Producers in Northern Regional Electricity Board of India. Proceedings of IASTED International Conference on Power and Energy Systems, International Association for Science and Technology Development, 19-22 November. Tampa, Florida, pp: 334-339.

Srivastava, S.C., A. K. Srivastava, U.K. Rout, D. Paul, P. Gupta, and R. M. Shrestha (2000). Least Cost Generation Expansion Planning for a Regional Electricity Board in India Considering Greenhouse Gas Mitigation. Proceedings of International Conference on Power System Technology (POWERCON 2000), 4-7 December. Perth, Australia, pp: 31-36.

Tanatvanit S., B. Limmeechokchai and Ram M. Shrestha (2004). CO_2 Mitigation and Power Generation Implications of Clean Supply-Side and Demand-Side Technologies in Thailand. *Energy Policy,* 32: 83-90.

Tanatvanit S., B. Limmeechokchai, and R.M. Shrestha (2000). Integrated Resource Planning with Demand-side Management Programs and CO_2 limitations in Thailand. RCETC Conference, 1-2 December. Chiang Mai, Thailand.

Wijayatunga P. D. C., W.J.L.S. Fernando and Ram M. Shrestha (2004). Impact of Distributed and Independent Power Generation on Greenhouse Gas Emissions: Sri Lanka. *Energy Conversion and Management*, December, 45(20), pp: 3193-3206.

Wijayatunga P.D.C. , W.J.L.S. Fernando, Ram M. Shrestha (2003). Greenhouse Emission Mitigation in the Sri Lanka Power Sector Supply-side and Demand-side Options. *Energy Conservation and Management,* 44: 3247-3265, .

SMI sector

Kumar S., Visvanathan C., Senanayake G., and Basu B. (2003). Desiccated Coconut Industry of Sri Lanka: Opportunities for Energy Efficiency and Environmental Protection. *Energy Conversion and Management,* 44(13): 2205-15.

Small and Medium Scale Industries in Asia: Desiccated Coconut Sector (2002). Regional Energy Resources Information Center (RERIC), Asian Institute of Technology, Thailand. 73: ISBN: 974-8208-47-8.

RERIC (2002). Small and Medium Scale Industries in Asia: Policy Interventions to Promote Energy Efficient and Environmentally Sound technologies in SMI. Regional Energy Resources Information Center, Asian Institute of Technology, Thailand. 59: ISBN: 974-8209-01-6.

RERIC (2002). Small and Medium Scale Industries in Asia: Tea Sector. Regional Energy Resources Information Center, Asian Institute of Technology, Thailand. 73: ISBN: 974-8208-49-4.

Kumar S., Visvanathan C., Kannan R. and Herrera, A.B. (2002). Networking to Promote Energy Efficient and Environmentally Sound Technologies in Small and Medium Scale Industries. *International Journal of Global Energy Issues,* 17(3): 171-188.

SMI Newsletter, Volume 3, Issues 9-12, 2001.

Priambodo, A. and Kumar, S. (2001). Energy Use and Carbon Dioxide Emission of Indonesian Small and Medium Scale Industries. *Energy Conservation and Management,* 42(2001): 335-1348.

Herrera, A.B., Visvanathan C. and Kumar, S. (2001). Energy Efficient and Environmentally Sound Technologies for the SMEs. Submitted to Third Asia-Pacific Roundtable for Cleaner Production held on 28 February - 2 March. Manila, Philippines.

Han S. and Dietmar R. (2000). Sustainable Industrial Development in China. German-Chinese Business Forum, Volume IV, Number 5, December.

Herrera, Alice B. (2000). Promotion of Energy Efficient and Environmentally Sound Technologies to SMEs. *The Energy Manager,* XVIII (3): 22-24.

Kumar, S. Visvanathan, C. Rudramoorthy, R. and Puranik, V.S. (2000). Need for Energy Efficiency and Promotion of Cleaner Production in the Foundry Sector in India. Proceedings of the International Conference on Energy Environmental Management in Metallurgical Industries (EMMI), 14-16 December. Varanashi, India, pp: 329-335.

Kumar, S. and C. Visvanathan (2000). Developing the Capacity to Reduce Environmental Impacts of Energy Consumption: Energy Efficiency's Role in Cleaner Production. *UNEP Industry and Environment,* 23(3): 52-56.

Rudramoorthy, R., Puranik V.S. and Velavan, R. (2001). Computational Energy Management of the Charging Process in a Foundry. Proceeding of the National Seminar on Non Conventional Energy Sources in Community Development, 16-17 February. Annamalai University, Annamalainagar, India, pp: 5-12.

Rudramoorthy, R., Puranik, V.S., Rajeshwaran A. (2001). Energy Control in Spinning Mills. Proceedings of 14th National Convention of Textile Engineers held at PSG College of Technology, 11-12 January.

Rudramoorthy, R., Puranik, V.S., Velavan R. (2001). Information Technology for Energy and Environmental Data Analysis for a Foundry Industry. 49th Indian Foundry Congress, 16-18 February. New Delhi, pp: 149-155.

Rudramoorthy, R., Puranik, V.S., and Velavan R. (2001). Energy Economics of Energy Efficient Motors for Electrical Energy Conservation. National Conference on Energy Conservation and Management (NCECM-2001), 11-13 June. Rajarambabu Institute of Technology, Raja Ram Nagar, Sakharale Sangli, pp: 21-25.

Rudramoorthy, R., Kumar C. P.S., and Sivasubramaniam S. (2001). Environmental Issues and Pollution Mitigation Opportunities in Brick Industry. Proceedings of National Conference on Control of Industrial Pollution and Environmental Degradation, 14-15 September. PSG College of Technology, Coimbatore, pp: 148-156.

Rudramoorthy, R. and Kumar C.P.S. (2001). Environmental Improvements in Brick Industry. Proceedings of the 43rd National Convention of Indian Institution of Industrial Engineering, 7-8 September. Chennai, pp: 117-124.

Rudramoorthy, R. and Kumar C.P.S. (2001). Scope for Energy Efficiency Improvement and Pollution Prevention in Brick/Tile Industry-Case Study. Proceedings of the Fourth International Conference on Mechanical Engineering (ICME), 26-28 December. University of Engineering and Technology, Dhaka, Bangladesh.

Rudramoorthy, R., Puranik, V.S. and Velavan R. (2001). Development of Effective Energy Monitoring and Targeting System [EEMTS] for a Foundry Using Statistical Model Technique. Fourth International seminar (ICME), 26-28 December. Buet, Dhaka.

SMI Newsletter (2000).Volume 2, Issues 5-8.

Rudramoorthy, R., Vinod S. Puranik and A. Rajeshwaran (2000). Energy Control in Spinning Mills. Journal of Institution of Engineers, August, 8: 05-09. India.

Rudramoorthy R., Kumar C.P.S, Velavan R. and Sivasubramaniam S. (2000). Innovative Measures for Energy Management in Tea Industry. 42nd National Convention of Indian Institute of Industrial Engineering, 29-30 September. Coimbatore, India, pp: 163-167.

Rudramoorthy, R. Kumar C. P.S.., Sivasubramaniam S. (2000). Energy Efficiency in Tea Manufacture. National Seminar on Energy Efficient Systems, XI Annual Convention of ISTE-Kerala Section, 14 October. Rajiv Gandhi Institute of Technology, Kottayam.

Rudramoorthy, R., Puranik, V.S., and Velavan R. (2000). Energy and Environmental audit analysis of Textile Industry through Case Studies Proceedings of one day seminar on Strategy for Sustainability of Energy Efficient & Environmental Friendly Technologies in Small and Medium Scale Sector, 24 November, pp: 12-20.

Rudramoorthy, R., Kumar C.P.S. and Sivasubramaniam, S. (2000). ENCON & E3ST in Brick Industry. Proceedings of the one-day Seminar on Strategies for Sustainability of Energy Efficient & Environmental Friendly Technologies in Small and Medium Scale Sector, 24 November. PSG College of Technology, Coimbatore.

Rudramoorthy, R., Kumar C.P.S. and Sivasubramaniam, S. (2000). Identification of ENCON Measures and E3ST for Sustainable Development of Tea Industry. Proceedings of the one-day Seminar on Strategies for Sustainability of Energy Efficient & Environmental friendly Technologies in Small and Medium Scale Sector, 24 November. PSG College of Technology, Coimbatore.

Rudramoorthy, R., Puranik, V.S. and Velavan R. (2000). Necessity of energy Efficient and Environmentally Sound Technologies for Small and Medium Scale Foundry Sector. Proceedings of one-day seminar on Strategy for Sustainability of Energy Efficient & Environmental Friendly Technologies in Small and Medium Scale Sector, 24 November, pp: 1-11.

Rudramoorthy, R., Puranik, V.S., Visvanathan, C. and Kumar, S. (2000). Need for Energy Efficiency and Promotion of Cleaner Production in the Foundry Sector in India. EMMI-2000 International conference at BHU-Varanasi, 14-16 December, pp: 329-335.

Rudramoorthy, R., Kumar S., Sivasubramaniam S. and Rajenthirakumar D. (2000). Quality of Made Tea Through Efficient Drying. International Conference on Quality, Reliability and Information Technology at the Turn of the Millennium, 21-23 December. Indian National Science Academy, New Delhi.

Rudramoorthy, R., Puranik, V.S., Velavan R. and Rajeswaran, A. (2000) The Reengineering Process Approach for Energy Efficiency and Pollution Free Environment in Foundries. Proceedings of the International Conference on Energy Environmental Management in Metallurgical Industries (EMMI), 14-16 December. Varanashi, India, pp: 39-43.

Rudramoorthy R., Puranik V.S. and Rajeswaran, A. (1999). Study of Energy Efficiency Improvement in a Medium Scale Spinning Mills. National Seminar organised by Indian Institute of Plant Engineers, 16-17 December. Bangalore, India, pp: 40-51.

Visvanathan, C. Kumar S., Priambodo A. and Vigneswaran S. (2000). Energy and Environmental Indicators in The Thai Textile Industry. Proceedings of the Third Asia-Pacific Conference on Sustainable Energy and Environmental Technologies, 3-6 December. Hong Kong, pp: 524-528.

SMI Newsletter (1999).Volume 1, Issues 1-4.

Visvanathan C., Kumar S., and Priambodo A. (1999). Energy Efficient and Environmentally Sound Brick Kilns. *ASEP Newsletter,* Volume 15, No.4, December, pp: 1-3.

Urban transport sector

Abrenica, Ma. J.V. (2002). Analysing Barriers to Adoption of Technical Options to Mitigate Greenhouse Gas Emissions Using Analytical Hierarchy Process. 24 January, Graduate Studies for International Development, Nagoya University. Nagoya, Japan.

Jiang, K. and X. Hu (2001). Technology Progress: A Key Issue for Energy and GHG Reduction in China. Sixth AIM International Workshop. NIES, Japan.

Jiang, K. and S. Zhu (2001). Go to a Clean Future: Policy Implementation for Climate Change within the Framework of Sustainable Development. International Workshop on Climate Policies in Asia, 17-18 December. Tokyo, Japan

Jiang, K. (2001). Response for Climate Change: Perspective of China. IPIECA International Workshop on Climate Change, October. Boston, USA.

Jiang, K. and X. Hu (2001). Couple with Sustainable Development Strategy: Climate Change Policies Perspective in China International Workshop on Regional Collaboration for Climate Change, September. Moscow.

Jiang, K. (2001). Technology Assessment for Climate Change in China. International Workshop on Key Technology for Environment, August. Hangzhou, China.

Lubis, Harun R.S., Isnaeni, M. and Tatang H. Soerawidjaja (2001). Analysis of Transport Demand Management Strategies for Mitigating Environmental Emission from the Urban Transport System. *Journal of the EasternAsia Society for Transportation Studies,* 4(4): 203-218.

Shrestha, R.M., R. Shrestha and G. Anandarajah (2002). Technical Options for Mitigating GHG Emission from the Urban Transport System. Workshop of IGES/APN Mega-City Project and Symposium on Sustainable Urban Development in Asia, 23-25 January. Kitakyushu, Japan.

Zhu, S. and K. Jiang (2001). Energy and Emission Scenario for Transport System in Beijing. *Energy of China* (in Chinese).

Zhu, S. and K. Jiang (2001). Technology Options for Transport System in Beijing to Response to Climate Change. *Energy of China* (in Chinese).

Zhu, S. and K. Jiang (2001). Energy and Emission Scenario for Transport System in Beijing. Second Symposium on Climate Change in China (in Chinese), 27-28 December. Beijing, China.

Dissemination booklets

ARRPEEC (2002).

- Energy, Environment and Climate Change Issues: A Comparative Study in Asia. A study by the Asian Regional Research Programme in Energy, Environment and Climate Phase II. Asian Institute of Technology, Bangkok, Thailand.

- Energy, Environment and Climate Change Issues: China. A study by the Asian Regional Research Programme in Energy, Environment and Climate Phase II. Asian Institute of Technology, Bangkok, Thailand.
- Energy, Environment and Climate Change Issues: India. A study by the Asian Regional Research Programme in Energy, Environment and Climate Phase II. Asian Institute of Technology, Bangkok, Thailand.
- Energy, Environment and Climate Change Issues: Indonesia. A study by the Asian Regional Research Programme in Energy, Environment and Climate Phase II. Asian Institute of Technology, Bangkok, Thailand.
- Energy, Environment and Climate Change Issues: Philippines. A study by the Asian Regional Research Programme in Energy, Environment and Climate Phase II. Asian Institute of Technology, Bangkok, Thailand.
- Energy, Environment and Climate Change Issues: Sri Lanka. A study by the Asian Regional Research Programme in Energy, Environment and Climate Phase II. Asian Institute of Technology, Bangkok, Thailand.
- Energy, Environment and Climate Change Issues: Thailand. A study by the Asian Regional Research Programme in Energy, Environment and Climate Phase II. Asian Institute of Technology, Bangkok, Thailand.
- Energy, Environment and Climate Change Issues: Vietnam. A study by the Asian Regional Research Programme in Energy, Environment and Climate Phase II. Asian Institute of Technology, Bangkok, Thailand.

Publications from Phase I

Biomass energy

Bhattacharya, S.C. and P. Roy (1997). A Review of Residue Carbonization and Recent Advances. Second ASEAN Renewable Energy Conference, 5-9 November. Phuket, Thailand.

Bhattacharya, S.C. (1998). State of the Art of Biomass Combustion. *Energy Sources,* 20: 113-135.

Bhattacharya, S.C. and Mahen Sharma (1997). A Review of Biomass Densification Technology and Recent Advances. Second ASEAN Renewable Energy Conference, 5-9 November. Phuket, Thailand.

Bhattacharya, S.C. (1997). State of the Art of Biomass Gasification. International Symposium on Advances in Alternative & Renewable Energy, 22-24 July. Malaysia.

Bhattacharya, S.C., Venu M. Singamsetti, and P. Abdul Salam (1996). Assessment of Bioenergy Potential in Asia. Presented in the Asian Seminar on Fuel Cell Technology for Rural Electrification, 25-26 April. Coimbatore, India.

Bhattacharya, S.C., Elson R. Homes and P. Abdul Salam (1997). Emission of Greenhouse Gases From Charcoal Making. Solar Energy Congress, 24-29 August. ISES, Korea.

Ghulam Qambar Amur and S.C. Bhattacharya (1999). A Study of Biomass as a Source of Energy in Pakistan. *RERIC International Energy Journal,* Vol. 21, No. 1, June.

Tran Minh Khoa, S.C. Bhattacharya and Ghulam Qambar Amur (1999). A Study of Biomass as a Source of Energy in Vietnam. *RERIC International Energy Journal,* Vol. 21, No. 1, June.

Bhattacharya, S.C., Jossy M. Thomas and P. Abdul Salam (1997). Greenhouse Gas Emissions and the Mitigation Potential of Using Animal Wastes in Asia. *Energy,* 22(11): 1079-1085.

Bhattacharya, S.C., M. Arul Joe, Zahed Kandhekar, P. Abdul Salam and R.M. Shrestha (1999). Greenhouse-Gas Emission Mitigation From the Use of Agricultural Residues: The Case of Ricehusk. *Energy,* 24: 43-59.

Bhattacharya, S.C., P. Abdul Salam and Mahen Sharma (2000). Emissions From Biomass Energy use in Some Selected Asian Countries. *Energy,* 25: 169-188.

Bhattacharya, S.C., R. A. Attalage, M. Augustus Leon, G.Q. Amur, P. Abdul Salam and C. Thanawat (1999). Potential of Biomass Fuel Conservation in Selected Asian Countries. *Energy Conversion & Management,* 40: 1141-1162.

Elauria, J.C., R.E.T. Quejas, M.I. Cabrera and R.V. Liganor, S.C. Bhattacharya and N.L.J. Predicala (1999). Biomass as Energy Source in the Philippines. *RERIC International Energy Journal,* 21(1): 37-54.

Kumaradasa, M.A., S.C. Bhattacharya, P. Abdul Salam and G.Q. Amur (1999). A Study of Biomass as a Source of Energy in Sri Lanka. *RERIC International Energy Journal,* 21(1): 55-68.

Narang, H.P., D.C. Parashar, S.C. Bhattacharya and P. Abdul Salam (1999). A Study of Biomass as a Source of Energy in India. *RERIC International Energy Journal,* 21(1): 11-24.

Oanh, N.T.K., L.B. Reutergårdh and N.T. Dung (1999). Emission of Polycyclic Aromatic Hydrocarbons and Particulate Matter from Domestic Combustion of Selected Fuels. *Environmental Science and Technology,* 33(16): 2703-2709.

Qingyu, J., and He Yuan-bin, S.C. Bhattacharya, Mahen Sharma and Ghulam Qambar Amur (1999). A Study of Biomass as a Source of Energy: China. *RERIC International Energy Journal,* 21(1): 1-10.

Sharma, M., and S.C. Bhattacharya (1997). A Study of Biomass as a Source of Energy: Nepal. *Energy for Sustainable Development,* 3(5).

Power sector

Reddy, B.S. and Shrestha, R.M. (1998). Barriers to the Adoption of Efficient Electricity Technologies: A Case Study of India. *International Journal of Energy Research,* 22: 257-270.

Shrestha, R.M., B., Wahidul K. Biswas and Rabin Shrestha (1998). The Implications of Efficient Electrical Appliances for CO_2 Mitigation and Power Generation: The Case of Nepal. *International Journal of Environment and Pollution,* 9(2-3): 237-251.

Shrestha, R.M, B. Natarajan, K.K. Chakravarti and Rabin Shrestha (1998). Environmental Emission Mitigation Potential of Energy Efficient Appliances: A Case of India. *Energy-The International Journal,* 23(12), 1065-1072.

Shrestha, R.M, B.K. Karmacharya and T.N. Sandasiri (1999). Factors Affecting Household Adoption of Energy Efficient Lamps in Sri Lanka. *Pacific and Asian Journal of Energy,* 9(1): 93-102.

Shrestha, R.M., Pojanie Khummongkol (1998). CO_2 Mitigation Potential of Efficient Demand-side Technologies: A Case of Thailand. *Energy Sources,* 20 (4-5): 301-316.

Shrestha, R.M., W.J.L. Fernando, and Rabin Shrestha (1998). GHG Mitigation Potential of Efficient Eelectrical End Use Devices in Sri Lanka. *International Journal of Energy Research,* 22(10): 923-933.

Shrestha, R.M. and B.K. Karmacharya (1998). Testing of Barriers to the Adoption of Energy-efficient Lamps in Nepal. *The Journal of Energy and Development,* 23(1), 71-82.

Shrestha, R.M., A.I. Jalal, M. Latif and W.K. Biswas (1998). Mitigation of Power Sector Environmental Emissions through Energy Efficiency Improvements: The Case of Pakistan. *Journal of Environmental Management,* 54: 249-258.

Industry

Mohanty, B., G. Senanayake, and C. Visvanathan (1998). Energy Efficient and Environmentally Sound Industrial Technologies in Asia. Part II: Industry's Organizational Structure and the Role of External Factors, Industry & Environment. UNEP Industry and Environment, p: 43.

Porial, Marisol. Porial, C. Visvanathan, and B. Mohanty (undated). Energy Efficiency and Environmental Management in Pulp and Paper Industries in the Philippines. *Asian Society for Environmental Protection,* 14(1): 11.

Senanayake, G., B. Mohanty and C. Visvanathan (1998). Energy Efficiency Improvement in a Cement Industry in Sri Lanka. Tech Monitor, March- April, p: 38.

Mohanty, B., G. Senanayake, and C. Visvanathan (1998). Energy Efficient and Environmentally Sound Industrial Technologies in Asia. Part I: Assessment of the Economic Viability of Technological Options. UNEP Industry and Environment, p: 70.

Mohanty, B., C. Visvanathan (1997). Energy Efficient and Environmentally Sound Industrial Technologies: A Cross-Country Comparison. School of Environment Resource and Development (SERD), Asian Institute of Technology (AIT). Bangkok, Thailand.

Mohanty, B. (1997). Technology, Energy Efficiency and Environmental Externalities.
Vol. 1-In the Cement Industry;
Vol. 2-In the Iron & Steel Industry;
Vol. 3-In the Pulp & Paper Industry;
Vol. 4-Regulatory Measures and Technological Changes In the Cement, Iron & Steel, and Pulp & Paper Industries. School of Environment, Resources and Development, Asian Institute of Technology. Bangkok, Thailand.

Dissemination booklets

ARRPEEC (2000).

- Energy, Environment and Climate Change Issues: A Comparative Study in Asia. A study by the Asian Regional Research Programme in Energy, Environment and Climate. Asian Institute of Technology, Bangkok,Thailand.
- Energy, Environment and Climate Change Issues: China. A study by the Asian Regional Research Programme in Energy, Environment and Climate. Asian Institute of Technology, Bangkok,Thailand.
- Energy, Environment and Climate Change Issues: India. A study by the Asian Regional Research Programme in Energy, Environment and Climate. Asian Institute of Technology, Bangkok,Thailand.
- Energy, Environment and Climate Change Issues: Nepal. A study by the Asian Regional Research Programme in Energy, Environment and Climate. Asian Institute of Technology, Bangkok,Thailand.
- Energy, Environment and Climate Change Issues: Philippines. A study by the Asian Regional Research Programme in Energy, Environment and Climate. Asian Institute of Technology, Bangkok,Thailand.
- Energy, Environment and Climate Change Issues: Sri Lanka. A study by the Asian Regional Research Programme in Energy, Environment and Climate. Asian Institute of Technology, Bangkok,Thailand.
- Energy, Environment and Climate Change Issues: Thailand. A study by the Asian Regional Research Programme in Energy, Environment and Climate. Asian Institute of Technology, Bangkok,Thailand.

Asian Regional Research Programme in Energy, Environment and Climate (ARRPEEC)

The Asian Regional Research Programme in Energy, Environment and Climate (ARRPEEC) was initiated in 1995 with the broad aim of enhancing capacity and preparedness of the Asian developing countries regarding identification and assessment of national Greenhouse Gas (GHG) mitigation options. ARRPEEC was supported by the Swedish International Development Cooperation Agency (Sida) and coordinated by the Asian Institute of Technology.

The first phase of ARRPEEC was undertaken during 1995-1998 and focussed on power sector, large energy intensive industries, biomass energy and emission of polycyclic aromatic hydrocarbons. The second phase (1999–2001) and third phase (2002-2005) of ARRPEEC consisted research activities related to GHG mitigation options in the power, small and medium industries, and urban transport sectors, as well as on biomass energy technologies.

ARRPEEC involved twenty-one research institutions from seven Asian countries in the third phase: China, India, Indonesia, Philippines, Sri Lanka, Thailand, and Vietnam.

The major impacts of ARRPEEC have been the strengthening of capacities of the participating national research institutions in identification of GHG mitigation options, and barriers to climate friendly technologies as well as policies and measures to promote the cleaner technologies. ARRPEEC has provided an effective model for regional research, capacity building and networking to address the energy, environment and climate issues in Asia.

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