Colombia: Inventory and Mitigation of Greenhouse Gas Emissions

Partner Organisation: Ministerio del Medio Ambiente, Colombia; Academia Colombiana de Ciencias Exactas, Fisicas y Naturales, Bogotá
Project Period: Phase 1: January 1995 - December 1996
Phase 2: October 1997 - July 1999
Financial Contribution: DM 750,000

Project Brief

The Preliminary Greenhouse Gas Inventory of Colombia identified the forestry sector as the main source of CO_2 emissions, followed by the energy sector. This study (Phase 1) was initiated in July 1995 as a co-operative scheme between GTZ and the Academia de Ciencias Exactas Físicas y Naturales in Bogotá. Additional technical assistance came from the Venezuelan Country Study Greenhouse Gas Inventory Team.

In the 2nd phase, the Colombian planning group sought to achieve the following objectives:

- A national mitigation plan with the appropriate participation of the key actors,
- An in-depth evaluation of priority mitigation technologies and identification of opportunities to promote technology diffusion and
- Support for implementation of the national mitigation plan through workshops and publication of results.

The action plan made use of the preliminary greenhouse gas emissions inventory that has been completed during phase 1 and relied mainly on the development of mitigation and response strategies. It contains concrete measures to reduce emissions and protect and enhance sinks.

As a continuation of the project, a study was conducted proposing a method for formulating CDM projects according to existing guidelines and preparing a generic portfolio of CDM-eligible projects for reducing emissions in Colombia's energy sector. On the basis of information obtained in the previous studies, four technologies were selected for evaluation: Wind power, cogeneration, photovoltaic solar power and fuel switching in industry. The study was part of an attempt to develop a national strategy for CDM projects.

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COLOMBIA

MITIGATION OF GREENHOUSE GAS EMISSIONS IN COLOMBIA

Partner Organisation:	*Ministerio del Medio Ambiente Academia Colombiana de Ciencias Exactas, Físicas y Naturales, Bogotá*
Project Period:	*October 1997 – December 1998*
Financial Contribution:	*DM 450 000*

BACKGROUND

The Preliminary Greenhouse Gas (GHG) Inventory of Colombia, compiled during an earlier phase of this project, identified land use change as the main source of CO_2 emissions in Colombia in 1990, followed by the energy sector.

Forest clearing was responsible for about 70% of all GHG emissions. In 1990, the country generated 166 million tonnes CO_2, of which only 30% was attributable to energy activities. The agricultural sector was the most important contributor to methane and nitrous oxide emissions.

Forest Clearing

Global Fire Monitoring Center
http://www uni-freiburg.de/fireglobe

Combustion of liquid fossil fuels emitted nearly 58% of all pollutants in the energy sector in 1990, the main source being gasoline-powered automobile engines. Biomass was responsible for about 33% of emissions, partially through the use of sugar cane bagasse and other agricultural residues by the industrial sector. Households in rural areas consumed 81% of fuel wood.

Mining and waste contributed about 7% to the country's CH_4 emissions. A large proportion of solid waste is still disposed of in open dumping, thus accounting for the relatively small number (30%) of landfills. Incidentally, these preliminary results show an average waste generation of 0.7 kg per capita and day.

The results of the first part of the project were to be expanded upon during the second part.

OBJECTIVE

The objective of the second part was to enable the government of Colombia to implement measures that will reduce GHG emissions.

MAIN ACTIVITIES

Project activities were conducted in two phases:

Phase 1: Building on the Preliminary Inventory, a scenario for energy use and GHG emissions through 2010 was developed.

Phase 2: Options for mitigation were put forward and evaluated.

SUMMARY OF FINDINGS

Phase 1: As a first step, the project team developed a **base case scenario** for the evolution of energy demand from 1998 to 2010. By 2010, Colombia will be consuming 1591 PJ of energy (excluding fuel wood). If fuel wood is added, consumption rises from 1134 PJ to 1827 PJ. The annual increase expected over the whole period under study (1996-2010) ranges between 4.03% and 3.35%.

To meet this demand, the Mining and Planning Energy Unit (UPME) of the Ministry of Mines and Energy published a plan in 1996 that presented four development strategies designed for the short, medium and long term to the various agents in the electric sector. For the long term (2001-2010), various combinations of gas, coal and hydro power plants were considered. UPME proposed four different strategies, identified as LP-1, LP-2, LP-3, and LP-4. LP-4 is the strategy with the largest component of coal-fired thermoelectric generation and thus the greatest amount of GHG emissions. It is therefore the one considered in the various emission-reduction analyses conducted in this study.

Structure of Energy Generation Capacity, 2010

Scenario	Hydro	Coal	Gas
LP-1	56.8%	7.6%	35.5%
LP-2	58.5%	11.4%	30.1%
LP-3	55.1%	10.1%	34.8%
LP-4	51.9%	13.7%	34.3%

Power-generation in Colombia is thus shifting from an expensive hydro-based (75.6%) but low-emission system in 1996, to a less capital intensive but higher-emission system by 2010 (see table above).

Diversifying its energy basket away from hydropower is very convenient for Colombia. Coal is an important fuel for the country due to the existence of huge internal resources. In addition, coal-based energy generation adds reliability to an energy system fraught with uncertainties of its hydrological resources and operative problems of natural gas-fired power plants.

Of the energy to be generated by the LP-4 (highest emission) option, 57.2% will come from gas-fired plants, 27% from coal-fired plants, and only 15.7% from hydroelectric stations. The immediate consequence will be a decrease in capital costs from $1,300 per installed kilowatt in a wholly hydroelectric system, to $836 per installed kilowatt in the LP-4 mix, but with an increase in emissions.

In estimating emissions for the base case, the energy sector and the non-energy sector were considered separately. Total CO_2 emissions for the energy sector amounted to 66.4 million tonnes in 1996. They are expected to rise to more than 120 mio t by 2010, which means that by the end of the next decade, CO_2 emissions in the energy sector will be double the level they registered in 1990. The largest increase in emissions is expected to come from the electric sector. In 1996, the electric sector was responsible for 8% of total CO_2 emissions. By 2002, this share will be up to 14% and by 2008 as high as 22%.

Although emissions from the transport and industrial sectors will increase, their percentage shares of total emissions are expected to fall, owing to the electric sector's large increase. In 1996, their shares were 32% and 34% respectively, but by 2008 they will drop to 31% and 25% respectively. It is important to point out that the industrial sector's share of total emissions will fall from 34% to 25% mainly because of the penetration of natural gas in this sector. The percentage share of the residential-cum-commercial sector does not vary much over the period under study.

Out of total methane emissions in 1996 (146,000 tonnes), 75% consisted of fugitive emissions. This share is expected to rise to 82% in 2010 due to the expansion of coal mining and oil exploration.

The non-energy sector considered in the study consists of the forestry and farming subsectors. The main assumption with regard to the forest sector was that deforestation would proceed at a rate of 200,000 hectares per year until 2010.

As pointed out above, the energy sector's expansion from 1990 to 1998 also increased its CO_2 emissions from 52 mio t to 72 mio t. In contrast, the forestry sector's CO_2 emissions plunged from 111 mio t in 1990 to 60 mio t in 1998, as a result of tighter controls and policy changes at the national level in this regard. Over the period 1998-2010, CO_2 emissions will continue to fall in the forestry sector, down to 48 mio t by 2010, and to rise in the energy sector up to 126 mio t. Thus total emissions in 2010 of 174 mio t compared with the 1990 total of 167 mio t show an increase of barely 8 mio t in 20 years.

Phase 2: On the basis of the chosen technologies and their penetration to the year 2010, a scenario of **emission-reducing options** was developed.

The GHG mitigation programme under study envisages 24 options, 14 of which are listed in the table below. The total implementation cost amounts to $17,344 million, whereas the reference option costs only $1,623 million. The difference in cost stems from the fact that the reforestation projects are extensive and capital-intensive, making up 69.9% or $12,139 million of total cost. The proposed new technology options involve an investment increment of $5,204 million over the "business-as-usual" scenario.

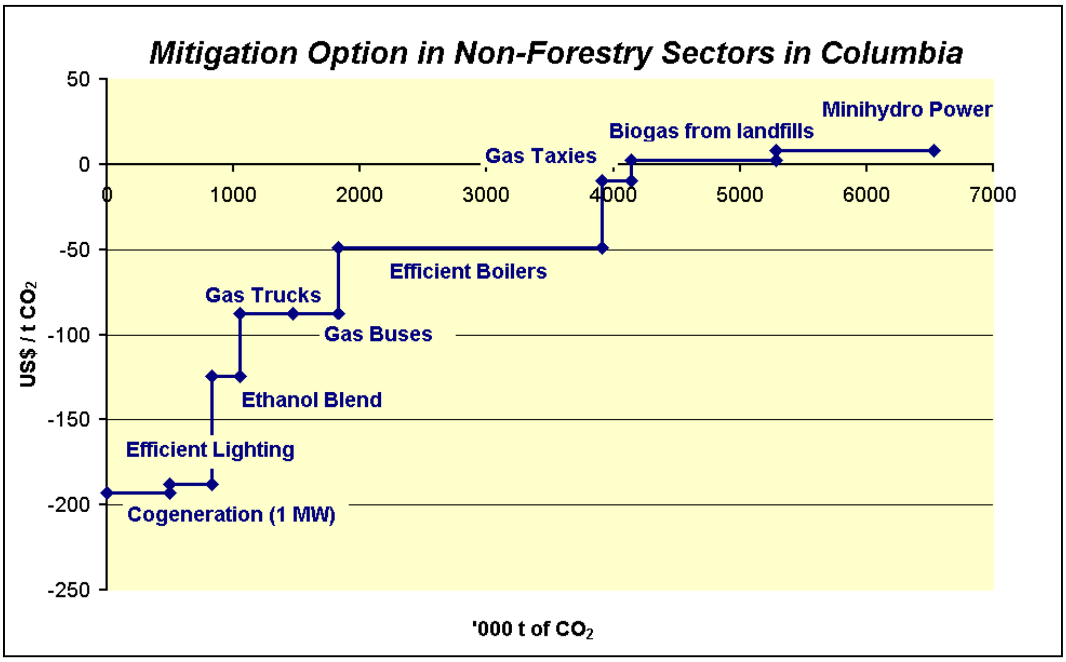
The overall potential reduction in emissions by the year 2010 is 36 mio t of CO_2. **Forestry options** are prominent, because they result in most of the reduction in emissions: 24 mio t by 2010, representing over 66% of the total. The remaining 34% of reductions fall to the energy sector.

Colombia's Greenhouse Gas Mitigation Scenario

Reduction Option	$/ton CO_2	Unit Type	Emission Reduction t CO_2/unit	Units Penetrating in 2010	Reduction in 2010 mio t/year	Cumulative Reduc. 2010 mio t/year	Reduction in 2010
Cogeneration (1MW)	-87	1 MW	2,061	400	0.82	0.82	0.47%
Efficient Lighting	-69	1 Bulb	0.05	10,000,000	0.46	1.4	0.80%
Ethanol Blend	-51	1 Plant	111,923	10	1.12	2.52	1.44%
Efficient Boilers	-2	1 Boiler	4,164	500	2.08	4.7	2.69%
Gas trucks	-2	1 Small Truck	16	26,910	0.43	5.12	2.93%
Gas buses	-2	1 Bus	16	22,425	0.35	5.48	3.14%
Biogas from Landfills	1	1 Landfill	689,816	5	3.45	9.14	5.23%
Eucalyptus Afforestation	11	14 ha	252	30,000	7.56	16.7	9.56%
Protector Reforestation	18	1 ha	18	231,000	4.2	20.9	11.97%
Pine Afforestation	25	14 ha	252	30,000	7.56	28.46	16.30%
TECA-Afforestation	31	14 ha	161	30,000	4.84	33.3	19.07%
Minihydro Power	43	1 kWh	6.2	200,000	1.24	34.69	19.87%
Microhydro	101	1 kWh	1.1	1,000	1.24	35.94	20.58%
Gas taxies	149	1 Taxi	3.5	65,665	0.23	36.17	20.71%

Colombia is a middle-income country whose long-term economic performance has been average in the context of Latin America. However, in recent years the country has been experiencing signs of an economic slowdown, accompanied by a sharp rise in unemployment. In addition, the budget deficit has deepened in the nineties.

In this context, it is worth noting that projects are fully consistent with the government's environmental intentions of restoring and conserving strategic eco-regions to improve the quality of life of the population, clean production, and upgrading the quality of urban life. Even more importantly, several of the identified options for mitigating GHG emissions could contribute to the peace process through investment and job creation in zones of social conflict,



particularly the mitigation options based on reforestation have a high domestic content. A first estimation indicates that these projects would generate some 186,600 direct jobs over the period under study, with a 100% domestic content. The new technology options have little domestic content and do not create many direct jobs compared with the forestry options. Implementation of all projects would require an annual expenditure estimated at around 1.7% of GDP. Execution of these projects, in particular the job-creating forestry projects, should be considered not only in the context of environmental concerns, but also as an important means of achieving the aims of the plan called "Changes for Building Peace". The with the further benefit of decreasing migration to urban areas.

OUTLOOK

As a continuation of the project, a study was conducted proposing a method for formulating CDM projects according to existing guidelines and preparing a generic portfolio of CDM-eligible projects for reducing emissions in Colombia's energy sector. On the basis of information obtained in the previous studies, four technologies were selected for evaluation: Wind power, cogeneration, photovoltaic solar energy conversion and fuel switching in industry. The study was part of an attempt to develop a national strategy for CDM projects.

Zambia: Inventories and Mitigation Analysis

Partner Organisation: Ministry of Energy and Water Development: Center for Energy Environment and Engineering, Zambia, Ltd. (CEEE(Z))
Project Period: September 1994 - March 1996
Financial Contribution: DM 380,000

Project Brief

In 1990, Zambia emitted about 3.2 million tons of CO_2 into the atmosphere. This corresponds to approximately 1% of Africa's total emissions.

Of these national CO_2 emissions, around 88% are due to energy use. Industrial processes contribute another 12%, mainly from production and use of cement and lime. Within the energy sector, transportation was responsible for 29% of CO_2 emissions, followed by mining with 15%.

For CH_4, the total was 457,000 t in 1990; biomass fuels, waste and agriculture are the main sources. Total N_2O emissions amounted to 3,570 t, also originating mainly from agriculture.

Land use change and forestry released a total of 59.4 million t of CO_2, mainly by forest clearing, biomass decay and on-site burning. Unlike the other emissions there was a net negative CO_2 emissions balance resulting form the large woodland forest potential.

These results are part of a project carried out to establish a greenhouse gas inventory for emissions in Zambia. In addition, this cooperation with GTZ identified technological options to reduce such emissions and determined the associated costs and benefits of those measures. The study results enable Zambian planners to find ways of integrating environmentally friendly solutions in the development of the national economy.

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Zambia:

Inventories and Mitigation Analysis

Partner Organisation:	*Ministry of Energy and Water Development: Centre for Energy, Environment and Engineering, Zambia, Ltd. (CEEE(Z)*
Project Period:	*September July 1994 - March 1996*
Financial Contribution:	*DM 380 000*

Of these national CO_2 emissions, around 88 % are due to energy use. Industrial processes contribute another 12 %, mainly from production and use of cement and lime. Within the energy sector, transportation was responsible for 29 % of CO_2 emissions, followed by mining with 15 %.

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Land use change and forestry released a total of 59.4 million t of CO_2, mainly by forest clearing, biomass decay and on-site burning. However, in view of the large woodland forest potential, there was a net balance in favour of CO_2 out of all emissions.

These results are part of a project carried out to establish a greenhouse gas inventory for emissions in Zambia. In addition, this cooperation with the GTZ identified technological options to reduce such emissions and determined the associated costs and benefits of those measures. Now, the study enables Zambian planners to find ways of integrating environmentally friendly solutions in the development of national economies.

As far as energy issues are concerned, the country is self-sufficient to a high degree, apart from in petroleum. Local energy resources include fuelwood, electricity, coal and petroleum products. Renewable energy sources such as wind and solar power are still an option to be developed in the future, however. Up to now, some photovoltaic applications for rural electrification have been installed. It is an option of increasing importance, although it is quite expensive at present.

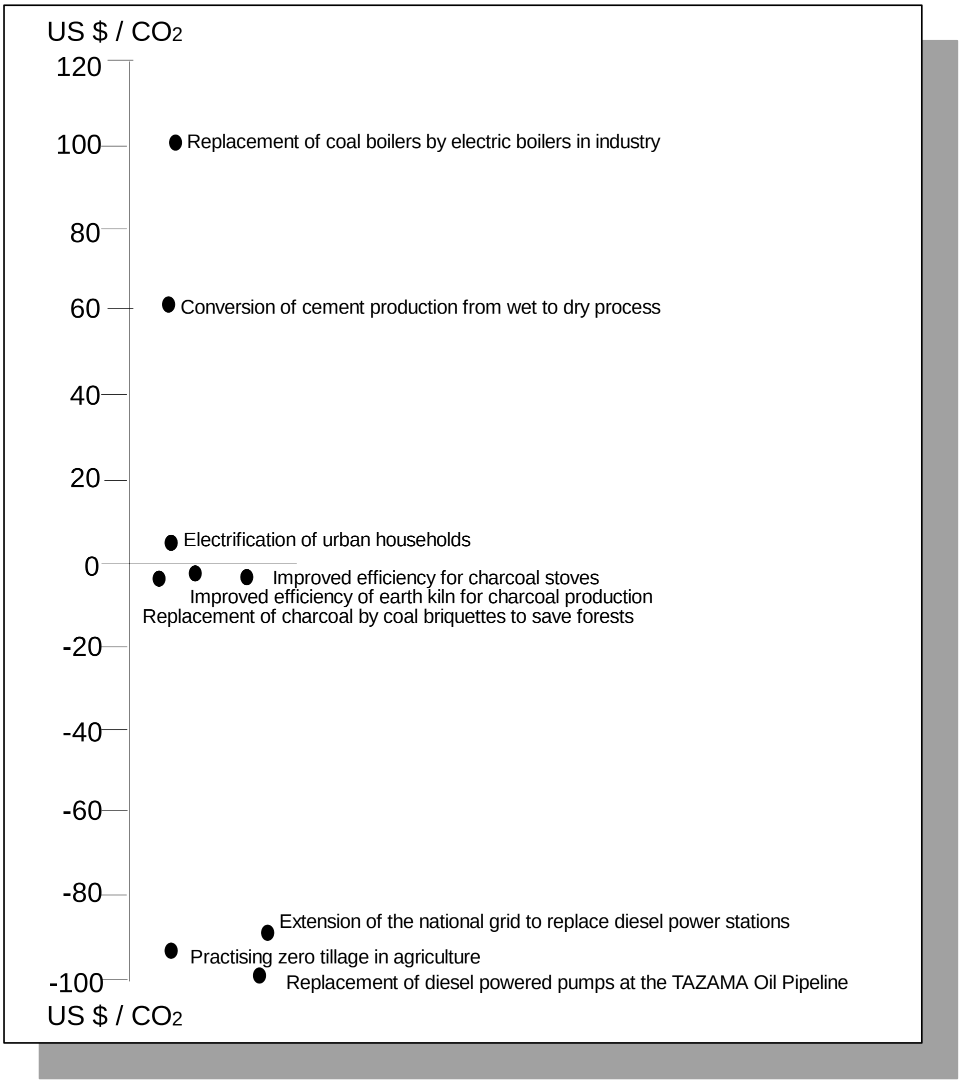
Zambia's unique situation on the supply side is its tremendous dependence on hydroelectric power: 90 % of the electricity supply, amounting to 1,670 MW, is generated by hydro, mainly on the Zambezi and Kafue basins.

The consumption of coal, on the other hand, has been declining steadily since 1975. However, this is not because of any particular energy plans but of production constraints in a specific coal mine. Though a rehabilitation programme was initiated in 1985, the colliery still needs further investment to meet local demand.

Up to now, coal has been used only in the mines and the industrial sector. In recent years, however, there have been efforts to produce coal briquettes for domestic use in households. Today, wood is the principal household fuel and the nation's largest source of energy. About 55 % of the total area is covered by woodlands. Fuelwood accounts for about 66 % of total energy consumption, climbing to 88 % in household energy needs. In urban regions it is mostly used in the form of charcoal.

Looked at from the other side, forest biomass production is the major sink for CO_2.

The national emission inventory provided the basis for subsequent mitigation analysis. For the purpose of this analysis, economic development, energy and industrial options were taken into consideration as well as projected emission levels. Some options were analysed with respect to their potential for greenhouse gas reduction and to the costs involved.



Abatement Options and Related Costs

Abatement costs were determined by annualising the capital for implementing the abatement option, and the operation and maintenance costs. These costs are presented as reduction costs per tonne of greenhouse gas in CO_2 equivalents. For the purpose of the analysis it was assumed that lower-cost options will be implemented first before moving to the higher-cost options. However, the model included the financial benefits of implementing an option.

Which options are available now to reduce emissions? There are, for example, plans for the electrification of households. Presently, the electrification rate is only about 12 %. This means that most people have no access to electricity. The ambitious plans for electrification, however, are capital intensive.

Another option aims at the substitution of charcoal by coal briquettes produced from coal dust. Reduced charcoal production could save wood and improve the sinking capacity of the forests. One argument for this option is that the coal used for this production would otherwise spontaneously combust, thus releasing emissions. According to the study, therefore, the use of coal briquettes instead of charcoal can result in an overall reduction of emissions. However, more detailed analysis is necessary here.

The main options for the industrial sector are energy substitutions and improved efficiency. With respect to the special situation described above, it is worth examining the question of replacing coal and oil with electricity. For example, the substitution of 50,000 t of oil annually for steam production would increase electricity demand by some 300 GWh per annum, taking into account the efficiency of boilers.

According to feasibility studies, extending the national grid could also be an option. However, the estimated costs are US$ 105 million with annual operating costs of 1 %. This option is aimed at interconnecting areas that are currently supplied by diesel generators. These stations require more than 15 million l diesel per year for an installed capacity of about 8 MW and an average annual output of 15 GWh. Of course, these diesel engines contribute to emissions, and for a long-term scenario it is feasible to analyse the effects of replacement by hydro-based electricity.

Examination of the abatement cost studies identifies such measures as the negative cost options which conserve diesel fuel. These include the replacement of diesel pumps by electric pumps on an oil pipeline, for example, or extension of the grid to replace diesel generators. Incidentally it is the high costs of maintenance for the diesel engines that are responsible for the negative costs in comparison with the low costs of hydel.

The no-cost options that have been identified are reduced consumption of charcoal in households and the displacement of charcoal by coal briquettes. By making this substitution, 50 % of the trees cut for charcoal production could be saved. The improvement of charcoal kilns has a reduction potential of 6 million t per year due to present great inefficiency in charcoal production. Unfortunately, the sector is dominated by small-scale informal producers who are not able to invest in more efficient kilns.

The high-cost options were found to be in the domestic electrification and industrial sectors, because of the major capital requirements. It should be mentioned, however, that this study did not consider all possible options. The transport sector, for example, was not included.

On the basis of these investigations, total abatement costs for 2010 were calculated to be about US$ 78 million for 27 million t of CO_2. Unlike other states in the region such as Botswana, South Africa and Zimbabwe, the CO_2 emissions of Zambia do not originate so much from the energy sector but from transportation, which contributes nearly 1/3 alone. Within the energy sector, however, coal is the main source, being responsible for 29 % of total emissions.

This difference can be explained by the important role of hydroelectric energy. Even expensive household electrification is therefore considered as an option to be analysed in more detail because the hydroelectric-based power system is already CO_2-neutral. In contrast with the dominance of charcoal today, this option may reduce CO_2 emissions by 3.6 million t if fully implemented.

The mitigation options for Zambia cover a wide range of negative, zero and low-cost options. However, there is a sharp increase in positive costs represented by domestic electrification, cement plant conversion and electric boiler efficiency improvements. These three options together, though, make up 44 % of all greenhouse gas savings.

Thailand: Energy Intensity and CO_2-Emissions Reduction Potentials in the Manufacturing and Commercial Buildings Sectors

Partner Organisation: Ministry of Science, Technology and Environment: Department of Energy, Development and Promotion (DEDP), Bangkok, Thailand
Project Period: October 1994 - December 1996
Financial Contribution: DM 400,000

Project Brief

On the basis of the Energy Conservation Promotion Act (ECPA), this project studied opportunities for energy efficiency investments. These studies included not only the economics of such measures, but also the resulting reduction of greenhouse gases in Thailand.

In addition to the Act of 1992, the Thai Government initiated a comprehensive Energy Conservation Program (ENCON). Within this legal framework, the country develops appropriate regulations and provides financial and organisational resources for programme implementation as well. For this purpose, an Energy Conservation Promotion Fund (ECF) has been established with a budget of approximately 19 billion Baht (more than DM 1.1 billion) for the next five years.

This is why the Thai-German study focused on the industrial sector and commercial buildings. It is, so to speak, a detailed analysis of energy end use for important consumers in the country. The project worked out an assessment of Thailand's total and specific energy consumption in industry and commercial buildings.

In addition, it analysed technologies to reduce the emission of greenhouse gases and processes to improve the energy efficiency of specific factories. Finally, it identified individual commercial buildings and manufacturing sites for future detailed studies.

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Thailand:

Energy Intensity and CO_2-Emissions Reduction Potentials in the Manufacturing and Commercial Buildings Sectors

Partner Organisation:	*Ministry of Science, Technology and Environment: Department of Energy, Development and Promotion (DEDP), Bangkok, Thailand*
Project Period:	*October 1994 - December 1996*
Financial Contribution:	*DM 400 000*

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The Act therefore has a very direct influence on economic and industrial development. It is of course aimed at developing standards for the rational use of energy, but it will also disseminate energy-efficient technologies and renewable energy, by means of financial incentives for example. One of the most important provisions, though, is the compulsory energy conservation work in designated facilities. These include factories and buildings which either consume more than 20 TJ of energy per year or which have an installed electrical capacity of more than 1 MW.

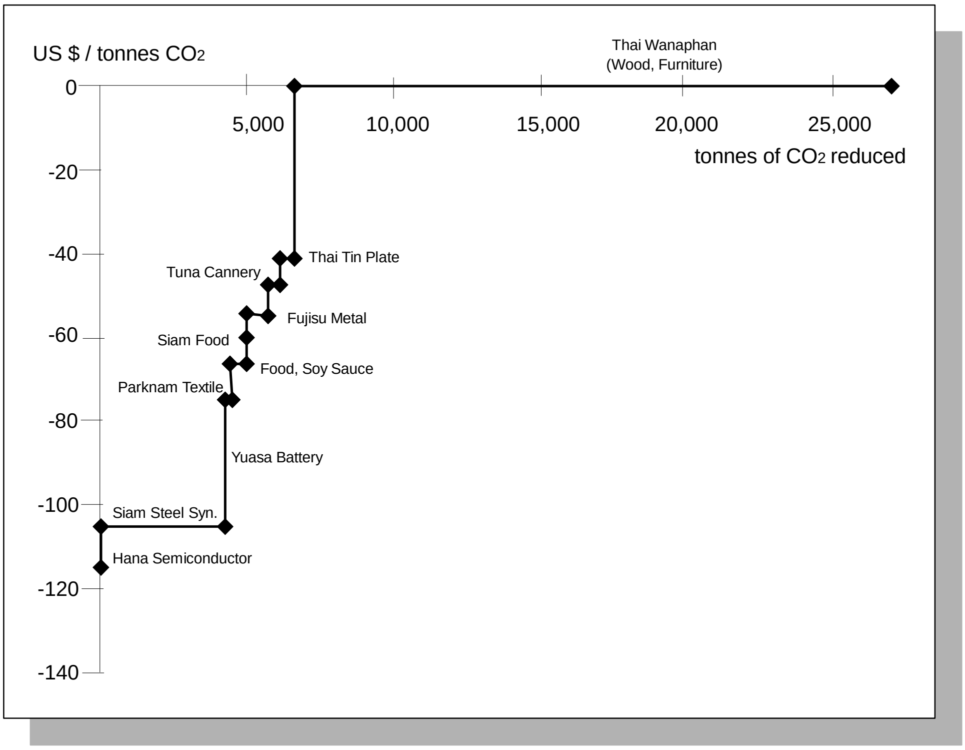
This is why the Thai-German study focused on the industrial sector and commercial buildings. It is, so to speak, a detailed analysis of energy end use for important consumers in the country. The project worked out an assessment of Thailand’s total and specific energy consumption in industry and commercial buildings. Additionally, it analysed technologies to reduce the emission of greenhouse gases and processes to improve the energy efficiency of specific factories. Finally, it identified individual commercial buildings and manufacturing sites for future detailed studies.

Generally speaking, the recommendation of suitable processes in this sense was preferred as a better option, if possible. Normally they will be attractive for direct investment, because the rational use of energy pays off very quickly in many cases.

In 1994, Thailand had a total final energy consumption of 43.8 Mtoe (million tons of oil equivalent). As the manufacturing sector needed 31 %, and the residential/ commercial sector another 26 %, this study covered sectors with more than a half of the country’s energy demand. Over the last decade, annual energy growth rates averaged about 10 % with an upward trend.

The energy consumption data for nine manufacturing sectors identify the food and beverage industries as the leading energy consumer. Non-metallic products followed in second place, and chemicals/chemical products were third. On the other hand, non-metallic products exceed foods and beverages in terms of energy costs. This is because of the intensive use of low-cost biomass in the food sector.

In order to compare different manufacturing processes, therefore, it is helpful to define the energy intensity, measured as final energy consumption per unit of added value. In this case, non-metallic products rank first, followed by basic metal and food industries. The potential for energy saving, though, presents yet a different picture. When compared with corresponding figures from U.S. industry, food and beverages are at the top with a potential saving of 81 %. Fabricated metal products rank second and chemicals/chemical products third. These figures do not reflect



Savings of CO_2-Mitigation in Selected Industries

possible differences in the structures of these sectors in the two countries, however.

Nevertheless, high energy-saving potentials of this type helped in the selection of representative factories for detailed analysis. High specific energy consumption and processes involving high labour intensity served as additional guides for this procedure. On this basis, 14 factories from seven different sectors were identified for further studies. One commercial building was included as well.

Afterwards, all of these sites were visited by the project team for a preliminary energy audit. As a result, several kinds of energy management measures or equipment replacement were proposed. They are all aimed at minimising energy intensities and at decreasing the CO_2 emissions of the underlying processes at the same time.

For the purpose of both micro-economic and macro-economic estimation, these measures were divided into two categories. The first comprised all improvements that pay back in four years or less. This group was used to calculate a moderate scenario. The second category comprised all measures with longer pay-back periods and served as a basis for the calculation of an intensive scenario.

The savings of energy, CO_2 and costs were calculated on the assumption that all proposed measures are implemented. For the moderate energy conservation policy scenario, the comparison showed a reduction of about 7 % in energy input and approximately the same proportion for CO_2. The intensive scenario, on the other hand, identified an additional energy-saving potential of 3 %, and additional reductions in CO_2 of the order of 5 %. As a single measure, the replacement of old boilers in some factories would yield the biggest savings. The implementation of those measures are followed up by the Thai-German project on the rational use of energy.

A number of fundamental measures were recommended as a very general result of the work on these scenarios. For example, knowledge of what equipment is actually in operation has to be improved. To achieve this, a database of capacities, efficiencies, age structure etc. for certain facilities should be established at the national level.

One important factor in the success of the Energy Conservation Program (ENCON) is proper marketing of technologies that fit in with the concept of the rational use of energy. A good strategy to adopt for this is to set up demonstration projects. The great attention paid to energy efficiency in Thailand is a good basis with which to start.

One of the significant conclusions derived from the two scenarios is that more energy can be saved when longer pay-back periods are accepted. Currently, though, it is not very popular to invest in projects with pay-back periods longer than four years.

Nevertheless, a great deal of investment in energy efficiency measures is expected for the near future. Research should therefore be directed at meeting the purpose and needs of ENCON. In addition to information on existing equipment, knowledge of key technologies such as boilers or motors should be disseminated to the various industrial subsectors.

A reliable database in combination with details of the best technologies available is a good means of producing simulations and scenarios as a basis for discussing long-term energy efficiency improvement. The implementation of a dynamic simulation model can provide answers as to the consequences of alternative strategies that are under discussion.

Indonesia: Technology Assessment for Energy Related CO_2 Reduction Strategies for Indonesia

Partner Organisation: Ministry of State for Environment, Indonesia; Agency for the Assessment and Application of Technology (BPPT), Office of the State Minister of Environment
Project Period: May 1994 - December 1995
Financial Contribution: DM 430,000

Project Brief

A fast rate of economic growth and fundamental structural changes are expected in Indonesia over the coming decades. For example, oil has been the major export up to now, with revenues at their highest in 1981. However, the oil price collapse in the mid-eighties brought about some major structural reforms.

As a consequence, the share of oil in total export revenues dropped from two thirds to 13% in 1993. Because of limited reserves and growing domestic demand, oil exports will continue to decrease. It may even be the case that the country will have to import oil products from 2005 onward in order to meet demand.

The German-supported study is a rough summary of recommendations, which covers a time period of 35 years, defined by the seven five-year plans from 1989 to 2024. For the detailed analysis, Indonesia was divided into four regions: Java, Sumatra, Kalimantan, and the Other Islands. To represent the energy system as it is today and as it may develop in the future, separate technologies were looked at for these regions.

Indonesia:

Technology Assessment for Energy Related CO_2 Reduction Strategies for Indonesia

Partner Organisation:	*Ministry of State for Environment, Indonesia; Agency for the Assessment and Application of Technology (BPPT), Office of the State Minister of Environment*
Project Period:	*May 1994 - December 1995*
Financial Contribution:	*DM 430 000*

As a consequence, the share of oil in total export revenues dropped from two thirds to 13 % in 1993. Because of limited reserves and growing domestic demand, oil exports will continue to decrease. It may even be the case that the country will have to import oil products from 2005 onward in order to meet demand.

The export of goods other then oil or gas has therefore been the motor of economic growth during the last decade. In terms of sectors, manufacturing industry shows the highest growth rates now with an average of about 7 %. Labour-intensive products such as garments and fabrics dominate exports, as well as resource-based products such as plywood.

In terms of energy equivalents, oil reserves amount to 62,650 PJ, gas reserves to 113,710 PJ, and reserves of coal to some 800,000 PJ. Coal is available in large quantities, however, and is also the cheapest primary energy source in the country. Unfortunately, because of its high carbon content, the burning of coal results in huge CO_2 emissions. In terms of mitigation policies, therefore, the substitution of coal is a most favourable solution.

Besides its limited gas reserves, Indonesia has hydropower and geothermal energy potentials of 75 GW and 16 GW respectively. However, to develop this potential in its entirety requires a great deal of capital, and this is not economic in every case under today's conditions. Insolation rates are sufficient for the use of solar collectors to prepare hot water and of photovoltaic systems to generate electricity. Economic limitations have applied up until now, however.

On the other hand, biomass is available virtually without limitation and is the major fuel for cooking in rural areas. Even industries are significant consumers in those areas. Incidentally, less than 30 % of fuelwood comes from forests. The major source for households is garden plantations. In urban regions, however, there is a shortage of biomass fuel.

The options for cultivating fuelwood are very limited, though, especially on Java. The land is needed for food production for the population, which is still increasing. This also limits the cultivation of energy plants for the production of ethanol in most cases. Only a moderate increase is therefore conceivable for biomass use, whether for residential or industrial purposes.

Clear measures for energy saving and substitution are recommended in order to bring about these economic and structural changes. A long term programme of this kind seems more effective in terms of emission mitigation than a mere announcement of fixed reduction targets.

Generally speaking, the achievement of standards for buildings and road vehicles can be an appropriate means in this sense. The same is true for licences and fees on electrical or fossil-fuelled heat generation by households. However, in order to establish a pertinent programme, such measures should be updated regularly. Another option might be the co-generation of heat and electricity, for example. But in addition to those means which involve energy, some mitigation options outside the energy sector should be considered.

Such measures include forestry, organic fertilising and rice cultivation. Apart from their effect of reducing greenhouse gases, they also save important resources. The protection of forests and soils, water and energy is an important factor for the sustainable development of the country as the population is still growing.

These recommendations are a rough summary of the German-supported study, which covers a time period of 35 years, defined by the seven five-year plans from 1989 to 2024. For the detailed analysis, Indonesia was divided into four regions: Java, Sumatra, Kalimantan, and the Other Islands. To represent the energy system as it is today and as it may develop in the future, separate technologies were looked at for these regions.

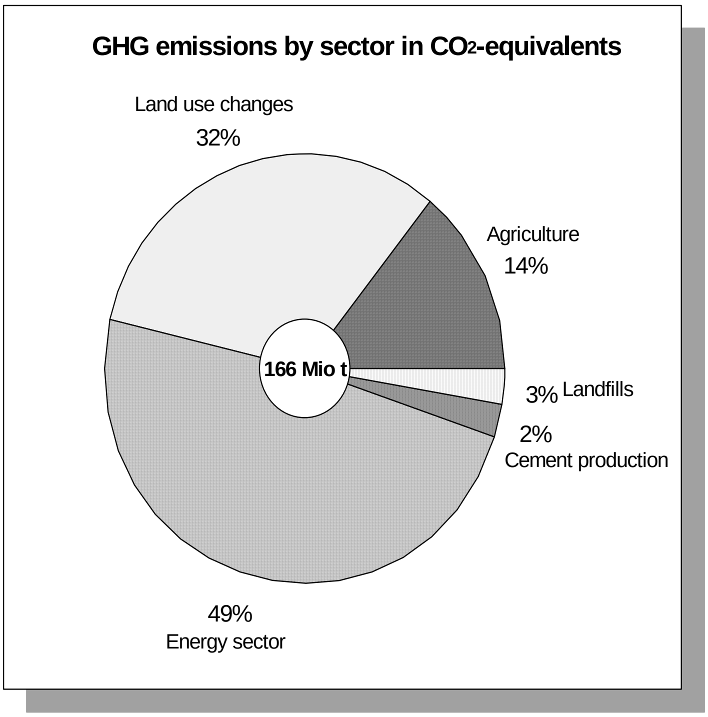
The technological options for CO_2 emission reduction were analysed with the aid of an existing database, which was built up in a former Indonesian-German project. The purpose of that project was to find out about the environmental impacts of energy strategies. Because of the changing economy and expansion schedules, the database has been updated constantly. The same is true with regard to specific emission reduction options, which had to be worked out.

Using standard computer modelling instruments for scenarios and abatement costing, it was possible to analyse the influence of emission reduction gains and the associated costs for medium- and long-term reduction efforts with respect to different options of energy use.

A baseline scenario was drawn up in the former project, mentioned above. On the one hand it considered a “business as usual” case, which is in general an extrapolation of today’s technologies. For the emission of SO_2, NO_X, volatile hydrocarbons and particulates, calculations showed an increase of between 50 % and more than 100 % every ten years compared to 1991.

Such emissions are of course completely unacceptable. The deposition of pollutants would affect the ecosystem in many parts of Java. In about 14 % of the area, soil acidification and soil contamination would affect plant growth in the year 2020. Another 40 % would be rapidly approaching the critical level at that time. In addition, ground water contamination is likely to become a problem in 27 % of the area in 2020 under these circumstances.

Consequently, on the other side of the coin, a “reduced emission” case was also considered as the starting point for the baseline scenario. This case includes new technologies and standards to



Comparison of non-energy CO_2, CH_4, N_2O and CO_2 emissions form energy use

define a more sustainable technology mix for a future energy system.

This scenario assumes for example that new power plants as well as industrial firing systems have to meet German standards. It includes environmental restrictions for new road vehicles on Java comparable to those in the USA. For future stages, the scenario includes technically advanced options such as fluidised-bed combustion, and capital-intensive options such as geothermal and hydroelectric power.

Following on from the baseline scenario, a set of abatement scenarios can be derived by adding options beyond those which are part of the former scenario for reduced emissions. Possible options were selected with a view to efficient energy use and the substitution of high CO_2-emitting technologies. Additionally, the effects of different targets for CO_2 reduction rates were analysed for the reference years 2006 and 2021 respectively.

To establish a realistic model, the options under consideration should be on the market in the country. This means that the technology is applicable under normal conditions, and adequate service can be provided. In Indonesia this is true for advanced power plants, for example: They are able to replace today's technology and penetrate the market.

The end-use sector, however, may produce some measures that are due to different local conditions. Promising measures for improved energy efficiency or energy substitution must therefore be elaborated for individual cases such as buildings or towns. Such analysis can, however, result in common conclusions applicable to other objects of a similar type as well.

In this way, communal and regional energy planning can set standards and identify a number of very effective solutions. In order to concentrate on options that can be recommended for implementation in many instances, a few measures were analysed within the framework of the scenarios for the energy sector.

For the residential sector, improved lighting conditions were examined. This can be achieved by fluorescent lamps, for example, or by photovoltaic solar home systems instead of kerosene lamps. Secondly, the introduction of energy-saving refrigerators onto the market was also analysed.

For the industrial sector, the co-generation of heat and power was considered as well as the installation of variable-speed motors. For the power sector, however, highly sophisticated options such as pressurised fluidised-bed combustion or gas-fuelled fuel cells were added to the established technologies.

Taking such scenarios as a basis, programmes can now be initiated consisting of measures that are clearly defined by technical specifications and implementation dates. In terms of emission reduction, this seems more promising than the announcement of reduction targets alone.