B-15.1 Development of AIM/emission Model

Contact Person Tsuneyuki Morita, Head of Global Warming Response Team,
National Institute for Environmental Studies, Environment Agency
Onogawa 16-2, Tsukuba, Ibaraki, 305 Japan
Tel:+81-298-51-6111(ext.393) Fax:+81-298-58-2645

Total Budget for FY1991-1993 65,690,000 yen (FY1993: 22,759,000 yen)

Abstract:

The objective of this project is to develop the AIM/emission model for scenario analysis of GHGs emissions in the Asian-Pacific region. The AIM/emission model is comprised of Asian-Pacific country models, and a World model which ensures interactions between these regional and country models are consistent and links the AIM/emission model to the AIM/climate model. The major component of the country model is an end-use energy demand model. In this model, energy demand is calculated by multiplying the Energy Service (calculated using the Energy Service sub-module) by an Energy Efficiency Factor which is the product of assumptions about the introduction of new technologies for energy conservation (decided by Technology Selection sub-module) as influenced by energy prices. So far, a prototype model has been completed and applied to Indonesia, China, and Japan. We are now developing Japanese, Korean and other country models. A World model has been developed to estimate GHG emissions in other regions and to simulate global GHG emissions. GHG emissions in the Asian-Pacific region and on a global level have been estimated using these models. Policy options to reduce GHG emissions in the region have also been analyzed.

Key Words Greenhouse Gases, Asian-Pacific Region, End-use Model, Energy Conservation Technologies, Integrated Model

1. Introduction

It is predicted that global warming will have a significant impact on the society and economy of the Asian-Pacific region, and that adoption of measures to tackle global warming will force the region to carry a very large economic burden. Also, if the Asian-Pacific region fails to adopt such countermeasures, it has been estimated that its Greenhouse Gas emissions will increase to become half of all global emissions by the end of the next century.

The global warming issue has been recognized as one of the most important policy issues to be solved for the region's development. Japan's role in the region has increased through greater contributions in the fields of ODA, technology transfer, research and joint implementation of countermeasures.

In order to promote adoption of countermeasures it is necessary to predict precisely the greenhouse gas emissions in the region and also the impact of global warming. The effects of countermeasures on emission reduction and impact abatement also need to be determined, taking into account international cooperative efforts. Such predictions and analyses require an integrated simulation model for the region. The role of this study is to establish that integrated model.

2. Objectives

The objectives of this study are to develop the Asian-Pacific Integrated Model (or AIM for short), so that policy options for stabilizing global climate, particularly in the Asia-Pacific region, can be assessed from the two perspectives of reducing greenhouse gas emissions and avoiding the impacts of climate change. This sub-theme is one component of the AIM development project. The following report concerns the development of country emission model, the regional emission model and the world model.

3. Outline of AIM emission model

(1) Characteristics

The AIM model integrates emission, climate and impact models and their component processes, as well as preparing country modules and a global integrated module.

It is directly linked to, and takes account of, technological changes. With a focus on policy assessment in the Asian- Pacific region, it has the ability to prepare regional overviews. It is a collaborative project, and is being conducted with institutes of various countries in the region. There are only four such models in the world.

(2) AIM's Basic Structure

As shown in Figure 1, the three linked models are an emission model (AIM/emission), a

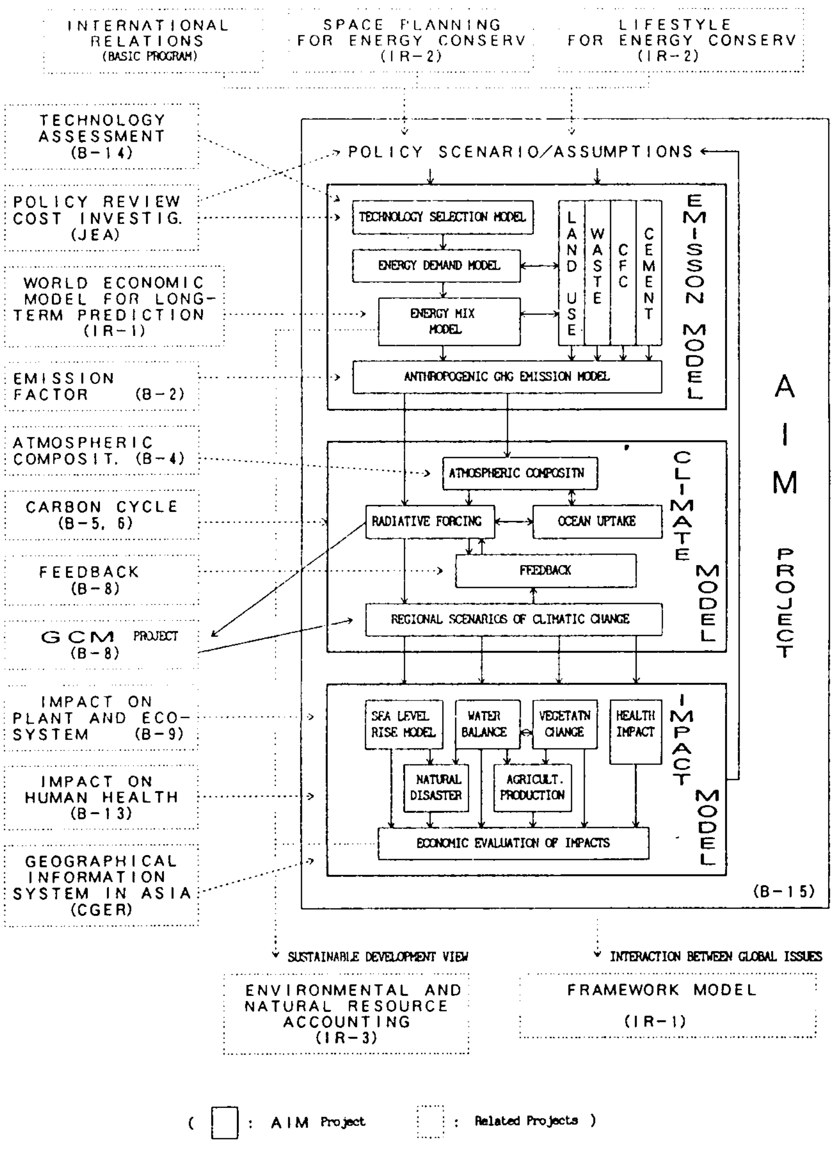

Fig.1 Outline of AIM and Related Research Project in Global Environmental Research Program

climate model (AIM/climate), and an impact model (AIM/impact). The emission model combines an end-use energy model and a technological selection model. More than 100 technologies are evaluated for their potential to improve energy efficiency, and energy demand estimates are linked to a top-down economic model. One component of the emission model is the forest resources alternation model to estimate the global greenhouse emissions from land-use changes. The climate model was created by developing original linkages to join other established models, such as the box-diffusion oceanic model, the IPCC radiative forcing model, the GCM for regional climate change model and the AMAC model for atmospheric composition. The impact model has a spatial water balance model, an ecological matching model and a malaria distribution model. Other related models are being developed.

(3) Outline of AIM/emission

The AIM/emission model is comprised of Asian-Pacific country models which are integrated into a regional model. This in turn is linked to a Rest of the World model (6 regions) that ensures interactions between these regional models are consistent. A variety of global and regional assumptions about such things as population, economic trends, as well as government policies, are then entered into the model and interact with the regional and country models to provide estimates of energy consumption, land-use changes, etc. which ultimately give predictions of GHG emissions.

Figure 2 shows the outline of the Country Energy Demand Model. In each Country model, energy demand is calculated by multiplying the energy service (calculated by the Energy Service sub-module) by an energy efficiency factor. This factor is determined by the Energy Efficiency sub-module, and is the product of assumptions made about the introduction of new technologies for energy conservation as influenced by energy prices. The Technology Selection sub-module decides which technologies will be introduced.

4. Country Energy Demand Model

(1) Indonesian model : simple technological assumptions

The Indonesian model uses a 4 sector Energy Service model comprising a transport sector, an industrial sector, a residential sector, and a commercial sector. In a "Business-as-

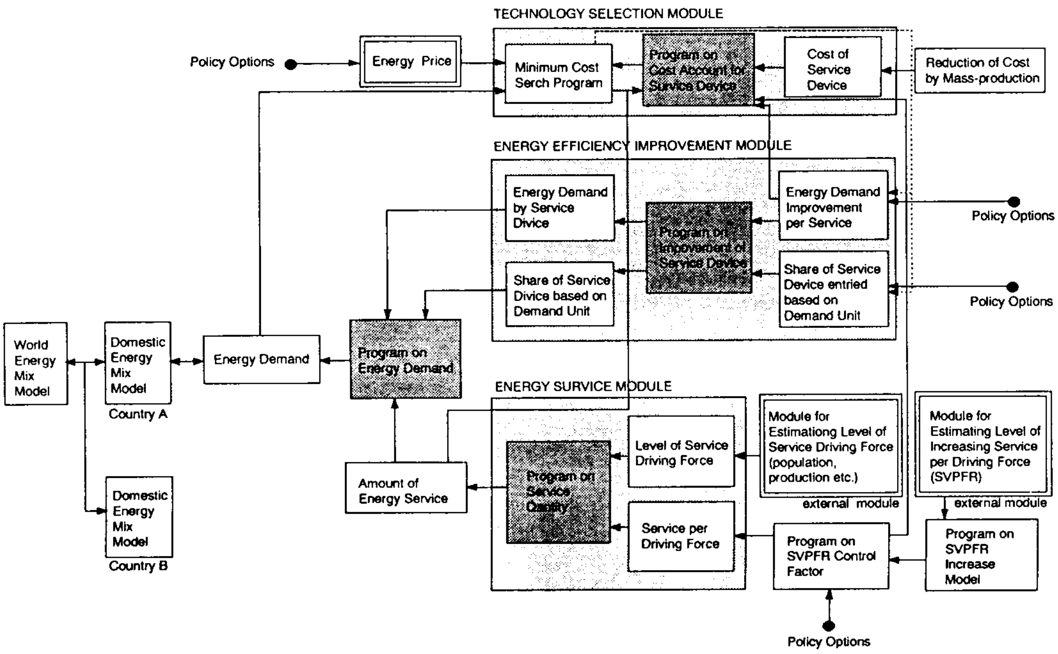

Fig.2 Outline of AIM End-use Energy Model

Usual(BaU)" scenario, the improvement in energy efficiency was simply assumed to be linear, at the rate of about 1% per annum. Other major assumptions were: a population of 340 million at 2100; a GNP increase of 4.1% per annum up to 2025, followed by 3.3% per annum; an urbanization rate of 73%; and a deforestation rate of 2.2 million ha per year. Figures 3 and 4 show the predicted emissions of CO_2 and CH4 over the next 100 years. CO_2 emissions from deforestation increase into early the next century and then decline as the remaining forests disappear. Emissions from other sources increase steadily, but at different rates. The main contributors of CH_4 emissions will be rice cultivation and leaks from pipelines.

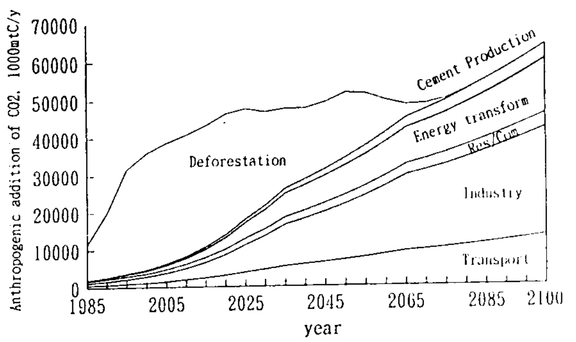

Fig.3 A Prediction of CO2 Emissions from Indonesia (BaU case)

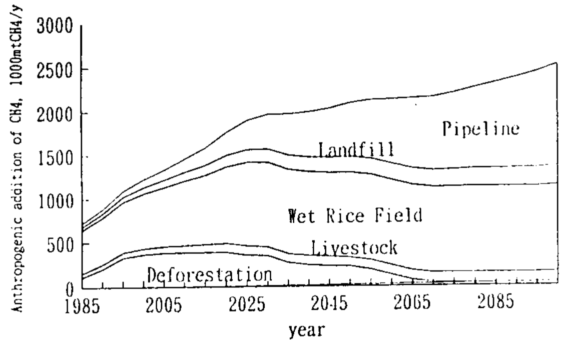

Fig.4 A Prediction of Methane Emissions from Indonesia (BaU case)

(2) Chinese model : complex technological assumptions

As with the Indonesian model, a 4 sector Energy Service model was used. However, estimates of energy efficiency improvements were the result of individual scenarios for each of 30 different technologies. In the "Business as Usual" case, these improvements ranged from 0.5-1.0% per annum. When allowances were made for energy conservation policy implementation, the improvements increased to a little more than 1% per annum. The population was assumed to grow to 1.66 billion at 2100, while the GNP growth rate was 5.3% per annum until 2025, then 3.9% per annum. Figure 5 illustrates the "Business as Usual" forecast, with energy consumption increasing from 25 EJ in 1985, to 170 EJ in 2050 and 250 EJ in 2100. If energy conservation policies are implemented as assumed, total energy consumption growth is half that of the "Business as Usual" case. See Figure 6.

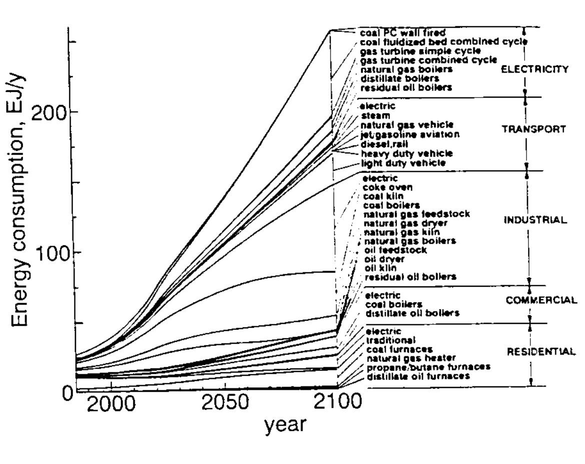

Fig.5 A Prediction of Energy Consumption in China (BaU case)

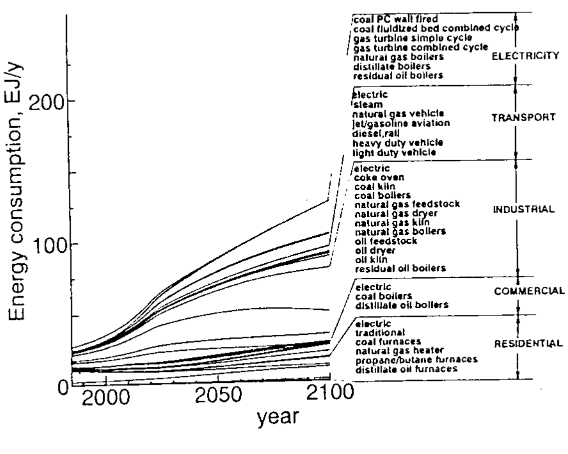

Fig.6 A Prediction of Energy Consumption in China (Improved Efficiency case)

(3) Japanese model : technological selection model

Development of the Japanese model is well-advanced. One main feature of this model is the integration of the technological selection module into the energy demand model. As described in the AIM outline, energy efficiency improvements depend on the introduction of energy-conservation technologies, which in turn is influenced by energy price. Table 1 provides a list of these technologies. More than 100 technologies for energy conservation used in the industrial, residential, commercial and transport sectors were examined, and their purchase price, maintenance cost, market share, energy conservation potential, pay-back time, etc. were input into the model.

Table 1 Energy Conservation Technologies for Japan

Industrial Sector	
Steel	continuous annealing furnace for waste heat, high temperature casting slice continuous caster, DC electric water cooling wall-type electric arc furnace, processing heat treatment device at hot rolling mill, thin copperplate form control device, direct use of chrome ore at basic oxygen absorbing furnace, high performance high frequency at blast furnace, high performance high frequency guidance heating system, high performance sheet metal processing device, dry waste pressure recovery device, materials preheating device for electric furnace, coal moisture control, oxygen combustion device, high performance slag water mill device, high performance copper divest gas device, high efficiency copperplate continuous coating device, total process of manufacture for continuous, coal pre-process device for coke, high heat copperplate direct device, DC electric arc furnace, gas recovery converter, scrap preheating device, high pressure power generation at blast furnace, coke dry quenching, direct smelting reduction furnace, hot charge rolling, hot direct rolling
Cement	roller method energy saving mill, roll brace device, SP/NSP kiln, reliminary crushing mill, energy saving mill/finishing, energy saving mill/raw materials pulp/paper
Pulp/paper	pre-filtration continuous cooking, high performance pulp washing device, deoxidization lignin device, defuser bleaching, high performance size press, black liquid recovery boiler, high performance bearing dehydration device, high performance dryer hood, high performance, waste paper pulp making device
Petrochemical	high performance disjointing reaction device, high performance deoxidization reaction device, high performance polypropylene vapor conversion, low pressure demethane device, high performance polymerization system for basic vinvl resin, high efficiency compression device, reuse device of carbon dioxide, waste gas process device at catalytic combustion method, high performance anhydride maleic acid manufacturing device, high efficiency decarbon dioxidedevice, two vapor turbine
Others	air operation of low air at boiler , waste gas boiler, VVVF

Residential Sector	
Air control	improvement of heating structure (newly built detached houses), improvement of heating structure (newly builttownhouses), improvement of heating structure (existing detached houses), improvement of heating structure (existing town houses), gas air conditioner, passive solar hous
Hot water supply	solar thermal water heater, solar system
Light	inverter lights
Household electric appliances	liquid crystal TV sets, efficiency improvement of air-conditioner, efficiency improvement of refrigerators, energy conservation by awakening peoples environmental awareness, afforestation of the housetop
Others	electric multifunctional heat pumps, engine heat pump
Commercial Sector	
Air control	adiabatic material+pair glass, gas air conditioner, cogeneration system(gas engine), gas turbine, diesel engine, regional air cooling and heating, afforestation of the housetop
Transport Sector	
electric vehicle(midget passenger car), electric vehicle(light cargo vehicle), electric vehicle(compact passenger car), electric vehicle(compact cargo vehicle), hybrid vehicle(compact truck), hybrid vehicle(ordinary truck), hybrid vehicle(bus), natural gas vehicle, methanol vehicle, high efficiency electric locomotive, vessel waste heat boiler, vessel propulsion axis electric power using generation	
Energy Conversion Sector	
solar photovoltaic power generation, wind power generation, garbage burning generation, power generation using waste, cogeneration for industrial use, fuel cell, repowering of power generated by users	

Scenarios up to the year 2010 were prepared for population growth, industrial production, as well as the expansion of the average home area and office floor space, and used as assumptions for predicting Energy Service demand. Computer simulations were made of 5 different situations:

1) No changes in technology; no carbon tax or subsidies
2) Technology selection with no carbon tax or subsidies - the Base Case
3) Base case with a carbon tax of ¥30,000/tC
4) Base case with a carbon tax of ¥30,000/tC, and a subjective extended period of pay back over a maximum of 20 years
5) Base case with a carbon tax of ¥3,000/tC, and recycling of the carbon tax revenue as a subsidy for the introduction of energy conservation technologies.

These simulations wrote several Japan's future scenarios of CO_2 emissions shown in

Figure 7, and they provide the following results:

- If the Japanese people come to understand the economic benefits of energy conservation, then energy conservation technologies will be able to be promoted and introduced without any tax or subsidy. As a result, it would be possible to stabilize CO_2 emissions in the industrial sectors, but impossible to stabilize them in other sectors without a carbon tax and subsidies, because of the rapid increase of energy service demand.
- If Japan introduces a carbon tax of about ¥20,000 - 30,000/tC, then energy consumption in the residential, commercial and transport sectors would be reduced, but this alone cannot stabilize total CO_2 emissions.
- To stabilize CO_2 emissions in the residential and commercial sectors, the subjective period of payback must be extended by specific countermeasures such as public awareness, soft loans and government subsidies.

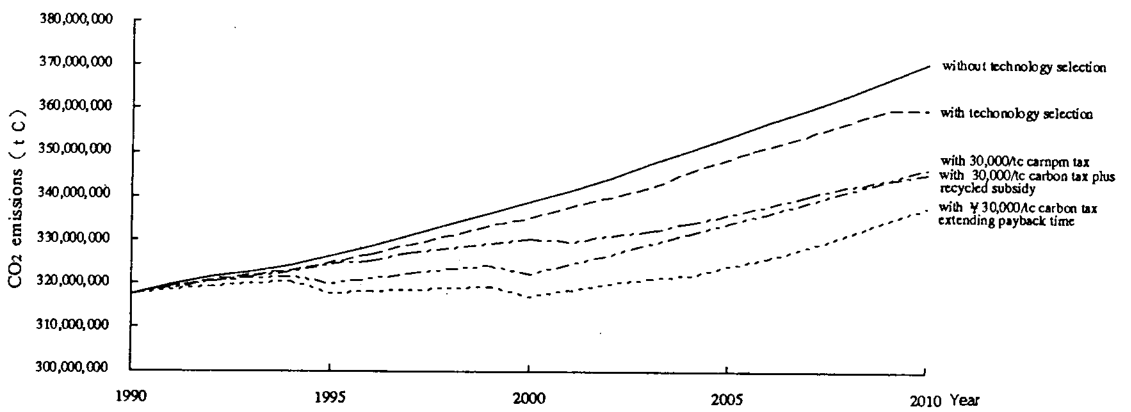

Fig.7 A Prediction of Carbon Dioxide Emissions in Japan

- In spite of the rapid growth of energy consumption in the transport sector, effective strategies to promote the introduction of energy conservation technologies could not be found. This sector will be the most severe obstacle to the stabilization of CO_2 emissions.
- The combination of a carbon tax and a subsidy from recycling tax revenue would have a significant effect over the short term. Even a ¥3,000/tC carbon tax with a recycled subsidy would be as effective as a ¥20,000-30,000/tC carbon tax with no subsidy. However, the potential conflict with the 'Polluter Pays Principle' needs to be considered.
- In summary, to stabilize CO_2 emissions in Japan, we must introduce mutually-reinforcing policies, such as a combination of a carbon tax, payback period extensions and subsidies.

5. Regional and Global Model

(1) Regional and Global Emission Model

All of the country models for the region have not yet been completed, but we have developed a rough emission model, not only for three regions of the Asian-Pacific, but also for six regions of the World. This nine region emission model was developed using the Edmonds-Reilly model, which is a partial equilibrium world model.

Using the rough model for these countries in conjunction with the detailed completed models, and making them consistent with the Rest of the World model, we prepared preliminary estimates of regional GHG emissions for the year 2100. CO_2 emission intensities are shown in Figure 8, and when compared with the recent situation, the areas where major growth in CO_2 emissions will occur can easily be identified. They include, Korea, China, Thailand, Malaysia, Indonesia, India and Bangladesh.

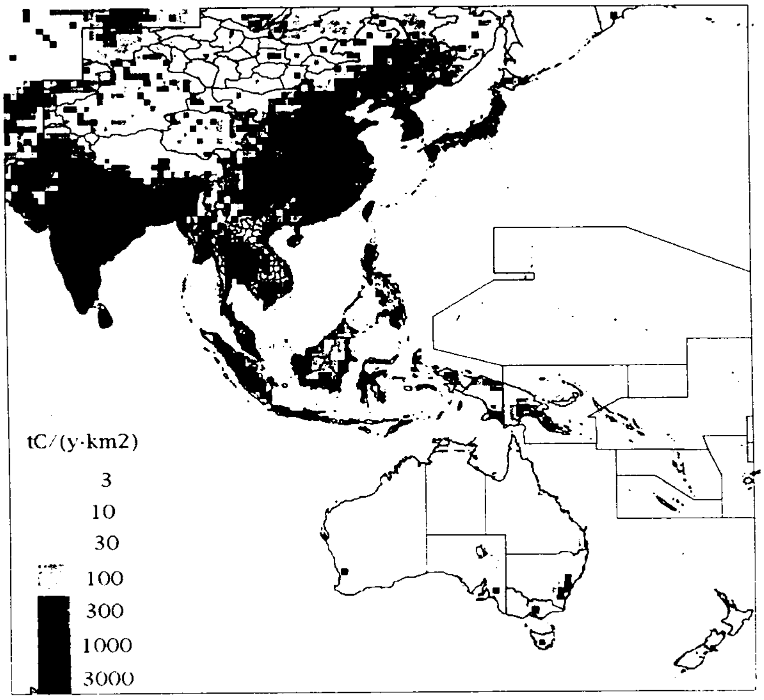

Fig.8 CO_2 Emission Intensity from the Asian-Pacific Region in 2100

(2) AIM/climate Model

As well as the emission models, we have developed a World Climate Model using original linkages to join other established models. It comprises the revised AMAC model for atmospheric composition, the IPCC radiative forcing model, a box-diffusion ocean uptake model, the Rashof feedback model, and a model for regional scenarios of climate change based on GCM outputs. The AIM/climate model was linked to the AIM/emission model to evaluate the effects of GHG emission increases on the climate. It is planned to also link it to the AIM/impact model.

6. Concluding Remarks

During these past three years, we completed the World models for emissions and climate, and also developed some prototype countrywide models and applied them to emission scenario analysis and policy evaluation. We plan to prepare country models for the Asian-Pacific region in cooperation with institutes in each country and develop the project on a regional basis.

References

Morita, T. (1991) Regional program on global climate change. International Conference on Global Warming and Sustainable Development, Bangkok. 11-13 June, 9 pages.

Matsuoka, Y., T. Morita, and M. Kainuma (1992) Scenarios on Global Warming and Their Model Analysis. Proceedings of JSCE, No.449/IV-17, 1-16 (written in Japanese, to be published in English).

Morita, T., Y. Matsuoka, M. Kainuma, H. Harasawa and K. Kai (1993) AIM - Asian Pacific Integrated Model for Evaluating Policy Options to Reduce GHG Emissions and Global Warming Impacts. Proceedings of the Workshop on Global Warming Issues in Asia, Bangkok, 8-10 September, 26 pages (to be published as a book from AIT).

AIM/Japan Project Team (1994) An Energy-technology Model for Forecasting Carbon Dioxide Emissions in Japan. F-64-'94/NIES, National Institute for Environmental Studies, 90 pages (written in Japanese with English abstract).