Application of AIM to APEIS-IEA Project

1. What is APEIS-IEA?

The Asia-Pacific Environmental Innovation Strategy Project (APEIS) seeks to develop and promote practical, science-based tools and policy options for enhancing environmental innovation, and thus sustainable development, in the region. In particular, these tools and options are aimed at improving the ability of policy-makers to make informed decisions on challenges related to the environment and development. APEIS is composed of three sub-projects: (1) Integrated Environmental Monitoring (IEM), (2) Integrated Environmental Assessment (IEA), and (3) Research on Innovative and Strategic Policy Options (RISPO). The Integrated Environmental Assessment (IEA) sub-project of APEIS has the following objectives:

- *Development of IEA tools*. IEA tools comprise several models and a strategic database (SDB) developed for the purpose of assessing innovative options for managing environmental problems.
- *Diffusion of IEA tools to selected Asia-Pacific countries*. IEA tools are passed to researchers and policy makers in selected Asia-Pacific countries, such as China, India, Thailand and Korea, via research collaborations and capacity-building workshops.
- *Development of quantitative innovation scenarios*. IEA tools are used to develop short- and long-term quantified scenarios in various Asia-Pacific countries and regions for the purpose of assessing environmental innovation options.

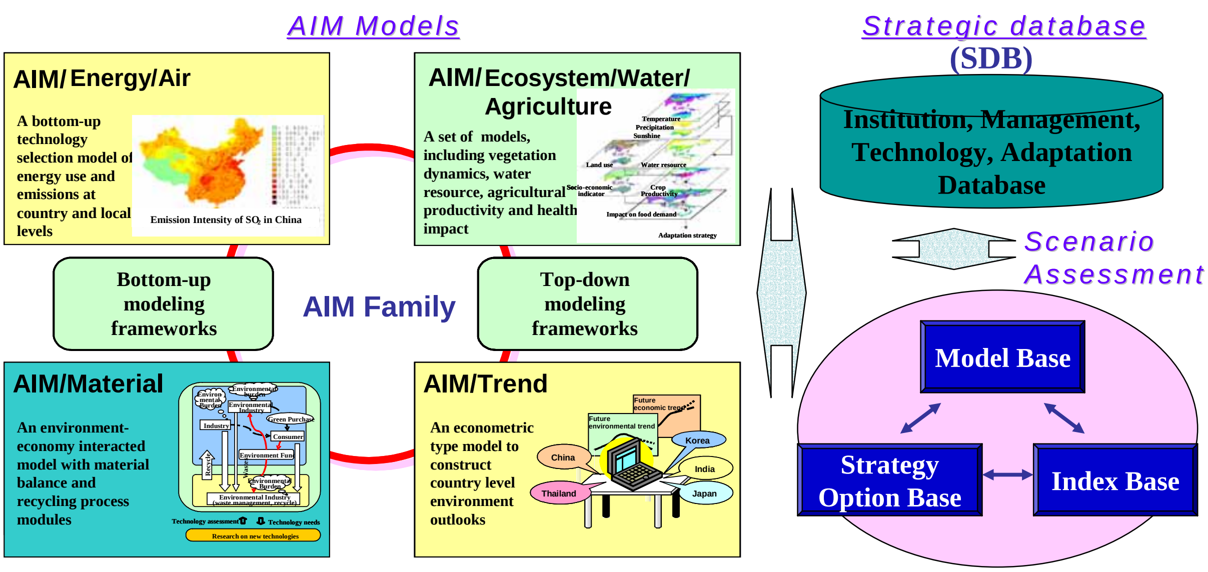


Figure 1. IEA Tools: AIM (Asia-Pacific Integrated Model) and SDB (Strategic database)

Key messages of IEA are:

- Innovations in technologies, institutions and management systems are key to aligning development and environment
- Quantitative assessment can provide information and insights for making innovative choices to deliver co-benefits
- IEA tools improve effectiveness of policy-making by linking science and policy

The SDB is used to store data relating to innovative options for technological, institutional, and behavioral systems in various sectors of a country or region. It is also used to estimate environmental burden and assess the potential of such options for mitigating emissions and other environmental problems. AIM/Material is a top-down model of economy–environment–energy linkages. It is used for analyzing macro-economic effects of environmental interventions and impacts of economy-wide policies on the environment. It can effectively assess environmental investments and recycling. AIM/Energy is a bottom-up optimization model of technology–energy–environment systems. It is used for assessing emission mitigation and technology options. AIM/Trend is an econometric model that simulates relationships between emissions and socio-economic indicators to project socio-economic and environmental trends. The set of AIM/Ecosystem, AIM/Water and AIM/Agriculture models is used to assess impacts on water, agriculture, vegetation, and health. AIM/Air, a model for simulating air pollutant distribution within a city, is used together with AIM/Water to assess health impacts. AIM/Health is a simple statistical model to assess air-induced health impacts via meta-analysis. Table 1 summarizes the characteristics and scope of IEA tools.

Table 1. Characteristics and scope of IEA tools

IEA Tool	Characteristics	Scope
SDB	Innovative options database	Innovative technology, institutional and management options
AIM/Trend	Econometric projection model	Socio-economic framework
AIM/Material	Combination of national economic model and material balance model	Macro-economy, environmental investments and material recycling
AIM/Water	Process-type water use and supply model	Water
AIM/Energy	Bottom-up-type energy-emission model	Energy
AIM/Air, AIM/Water, AIM/Health	Process-type models	Health
AIM/Agriculture	Process-type crop productivity model	Agriculture
AIM/Ecosystem	Combination of process-type eco-service model and national-scale economic model	Biodiversity

The motivation behind the IEA sub-project is to assess the potential for innovative strategies to resolve pressing environmental problems and simultaneously circumvent the trade-offs between economic development and environmental improvement. Conventional approaches assume rigid trade-offs, as shown in the left panel of Figure 2. These approaches are based on the belief that any action toward environmental improvement has a cost to the economy, and conversely, strategies toward economic development will necessarily affect the environment adversely. The alternative approach, however, begins by looking at innovative strategic options that can overcome the trade-offs and result in win–win solutions for both the environment and the economy. It is rooted in the proposition that innovative strategies, by definition, push the frontiers of technological, institutional or behavioral systems, and enable the crossover to a superior economy–environment relationship. Thus, they offer improvement in both dimensions simultaneously.

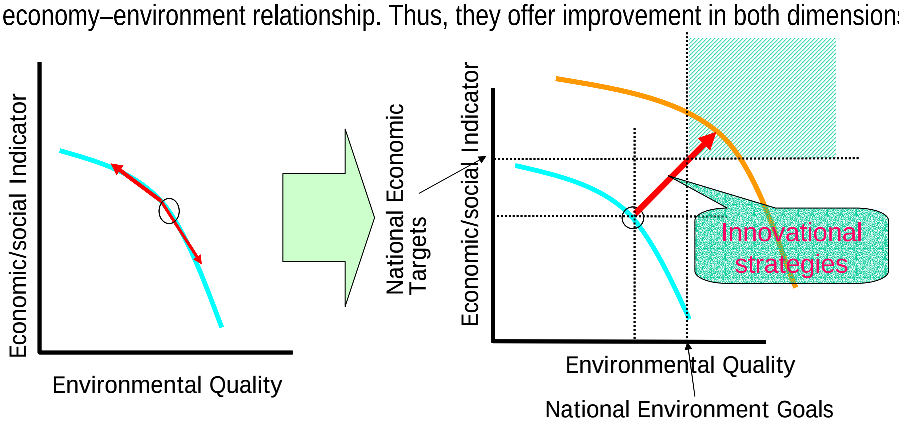


Figure 2. Circumventing economy–environment trade-off with innovative strategies

2. What IEA tools can address?

The IEA sub-project identifies and analyses innovative options to manage local, regional, and global environmental problems. Problems relating to climate change, local air pollution, waste, water, health, and other issues have been analyzed. Such problems are complex by virtue of having multiple inter-linkages among themselves as well as with the larger economic, institutional, societal, and technological systems. They also have a temporal dimension that makes them dynamic and gives them several uncertainties. The combinations of IEA tools have proved effective in dealing with such complexities.
Specific combinations of IEA tools have been used in FY 2005 for integrated studies of various issues of environment, energy, health, and sustainability in selected Asia-Pacific countries, as summarized in Table 2. The following sections discuss some of these applications and their results.

Table 2. Issues addressed using IEA tools

	Issues Considered	IEA Tools	Examples
2.1	Integration of millennium development goals, global environmental problems, and sustainability	AIM/Material AIM/Energy AIM/Agriculture	India's assessment of innovative options for meeting both millennium development goals and climate change objectives
2.2	Energy use, air pollution concentration, health impacts, and economic effects	AIM/Material AIM/Energy AIM/Air AIM/Health	China's energy use in various sectors, its contribution to air pollution concentration health impacts, and consequent economic effects; options for mitigating adverse impacts
2.3	Assessment of innovative options in a sector	SDB AIM/Energy	Thailand's environmentally sound biofuel options for transport sector and renewable energy technologies for energy supply sector
2.4	Millennium development goals and access to safe water and sanitation	AIM/Water AIM/Material SDB	Asia-Pacific countries' improved water and sanitation options and national health impacts
2.5	Air pollution at the multiple-scales – region, country, district, and city	AIM/Air AIM/Energy	China's sulfur oxides flux and concentrations due to various sources
2.6	Co-benefits, regional energy cooperation, and climate change	AIM/Material	China's assessment of sulfur reduction and co-benefit policies; India's regional energy cooperation policy

2.1 Assessment of innovative options for aligning sustainable development and climate change objectives

Millennium development goals (MDGs) comprise eight socio-economic developmental goals which all 191 United Nations member states have pledged to meet by the year 2015. United Nations Development Programme (UNDP) helps countries integrate the MDGs into their national development frameworks. Global and national MDGs have direct implications for the environment and climate change, since they involve changes in the drivers of socio-economic development and sustainability. Table 3 illustrates these relationships for India. IEA tools are being used to carry out analyses of such interactions to assess the options for aligning sustainable development targets of MDGs and climate change objectives.

Figure 3 illustrates such an analysis at global and country (India) scales using several IEA tools like AIM/Material, AIM/Energy, and AIM/Agriculture. Global emissions scenarios developed for the purpose of climate change analysis are used as a reference in analyzing the potential for meeting MDGs. For instance, emission scenarios for India are constructed following IPCC SRES. Scenario stories presume no explicit climate intervention. However differences in endogenous profiles of key drivers like technologies have profound indirect impact on GHG emissions. Across scenarios, aggregate emission trajectories vary significantly, proving that endogenous development choices are key determinants of emission paths. Hence, development policies and actions that alter profiles of key drivers of development should be essential elements of climate mitigation strategies. For instance, policies for promotion of bio-energy options can simultaneously enhance rural income, substitute oil imports, and enhance mitigative and adaptive capacity in India. Bottom-left graph of Figure 3 illustrates biomass technology trajectories assessed for various scenarios in India within the framework of development, climate change, and energy security.

Table 3. Illustration of linkages among MDGs, India's national targets, and climate change

MDGs and global targets	India's national plan targets	Interface with climate change
Goal 1: Eradicate extreme poverty and hunger Targets: Halve, between 1990 and 2015, the proportion of people with income below $1 a day and those who suffer from hunger.	Double the per capita income by 2012. Reduce the proportion of people with income below $1 a day by 15% by 2012. Contain total population growth between 2001 and 2011 to 16.2%.	Income effect would enhance choices for cleaner fuels and adaptive capacity. GHG emissions would be reduced due to lower population.
Goal 7: Ensure environmental sustainability Targets: Integrate sustainable development principles in country policies and programs to reverse loss of environmental resources. Target: Halve by 2015 the proportion of people without sustainable access to safe drinking water.	Increase forest cover to 25% by 2007 and 33% by 2012 (from 23% in 2001). Enable sustained access to potable drinking water to all villages by 2007. Electrify 80,000 additional villages by 2012 via decentralized sources. Clean all major polluted rivers by 2007 and other notified stretches by 2012.	Enhanced sink capacity; reduced GHG and local emissions; reduced fossil fuel imports; reduced pressure on land, resources, and ecosystems. Higher adaptive capacity from enhanced supply of water, health, and education in rural areas.

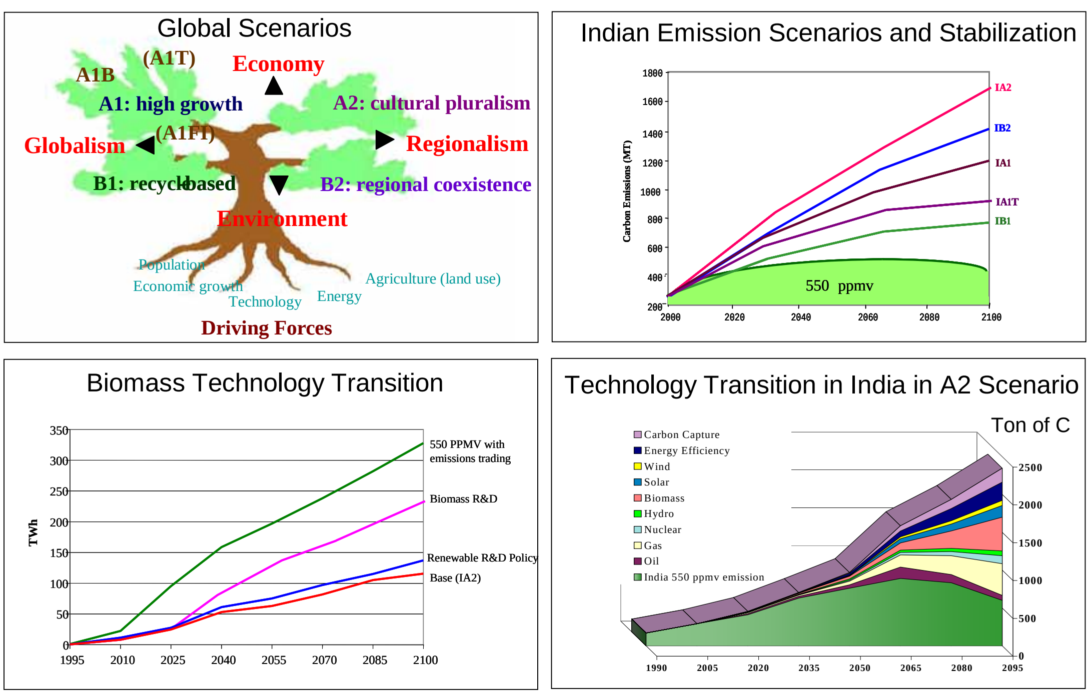


Figure 3. Linking global scenarios, Indian scenarios, and MDGs

2.2 Integrated assessment of economic activity, energy use, air pollution and health impacts

IEA provides assessment tools for analysis of air pollution and its health impacts. An integrated assessment framework linking a computable general equilibrium model for macroeconomic assessment (AIM/Material), enduse model for selection of technologies and geographic distribution of air pollutants (AIM/Energy), a pollutant concentration model (AIM/Air), and a physical health impact assessment model involving meat-analysis on morbidity induced by air pollution (AIM/Health) has been developed to analyze changes in energy use patterns, their contribution to air pollution concentration, impacts on health, and consequent economic effects. This framework is shown in Figure 4.

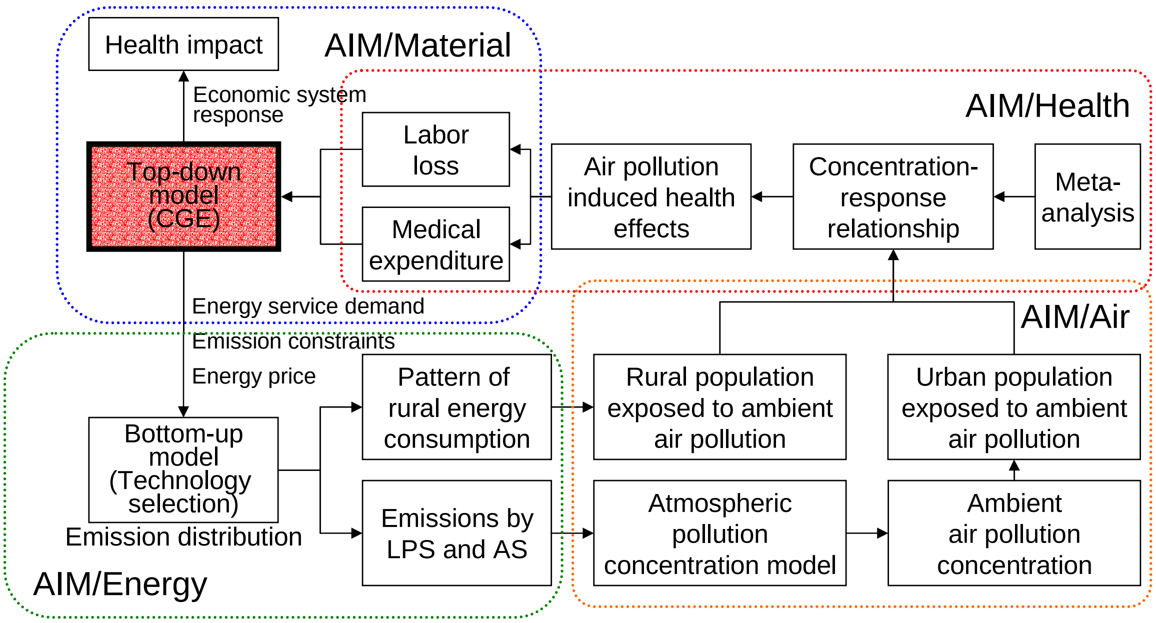


Figure 4. Framework for integrated assessment of energy use, air pollution, health impacts, and economic effects

In developing countries, the pollution problems become severe in proportion to the rapid economic growth. For instance, in China, since the coal is the main energy source, air pollution around the industrial areas is very high. Moreover, due to the increase of motorized road traffic the urban atmospheric environment becomes worse. On the other hand, in the rural areas, traditional biomass and briquette are the main energy sources from which the emissions cause indoor air pollution. Such severe outdoor and indoor air pollutions contribute to the respiratory disease, and consequently, increase of medical services demand and decrease of labor force with its negative economic impacts.

The integrated model as shown in Figure 4 is applied to China and several causal relationships related to the air pollution in China are assessed – emissions of pollutants into atmosphere, atmospheric stock of pollutants, disease occurrence induced by air pollution, labor loss and increase of medical service due to disease, and their impact on the economic activity. This analysis has been performed under BaU and Policy scenarios in China to assess the impact of policy options on emissions (Figure 5a) and ambient concentration of air pollutants (Figure 5b), and their consequent effects on health and economic activity. Air pollution policy analysis with several innovation options could help to prioritize environmental protection and determine feasible and effective environmental interventions.

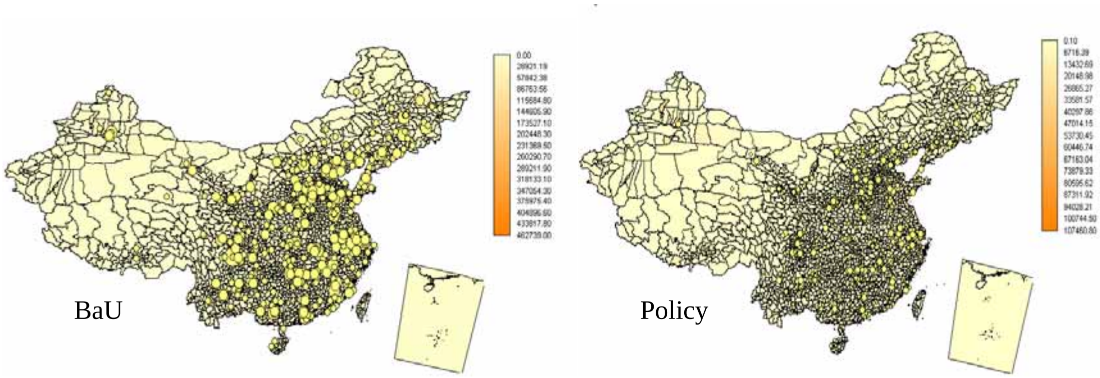


Figure 5a. Geographical distribution of PM_{10} emissions (in tons) across China in 2020

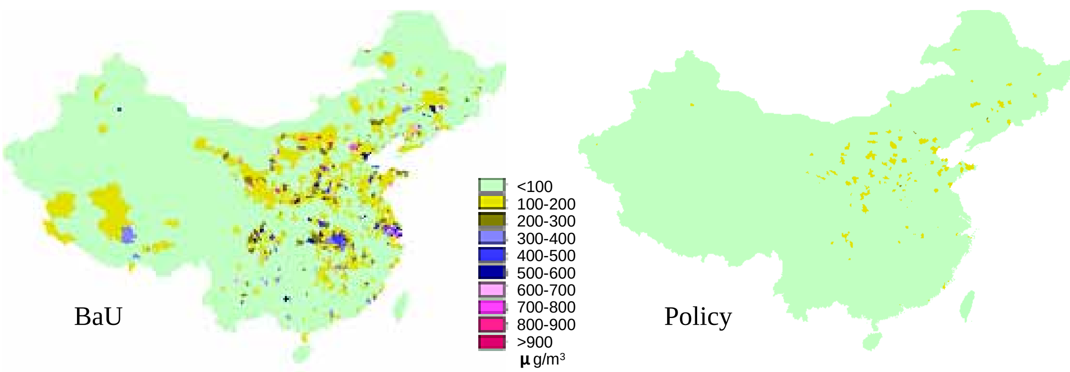


Figure 5b. Geographical distribution of ambient concentration of PM_{10} in urban areas of China in 2020

2.3 Assessment of innovation options using SDB and AIM/Energy

The SDB has been used extensively to assess multiple innovation options in various sectors. Figure 6 shows some results from assessment of biofuels in Thailand's transport sector. Roadmap for the introduction of gasohol and biodiesel were analyzed from the viewpoints of climate change and energy security. Shares of gasohol95 and biodiesel are estimated to reach about 2% and 34% respectively in 2030 under government policy scenario. In this scenario the CO_2 emission is reduced by 2.6% in 2030.

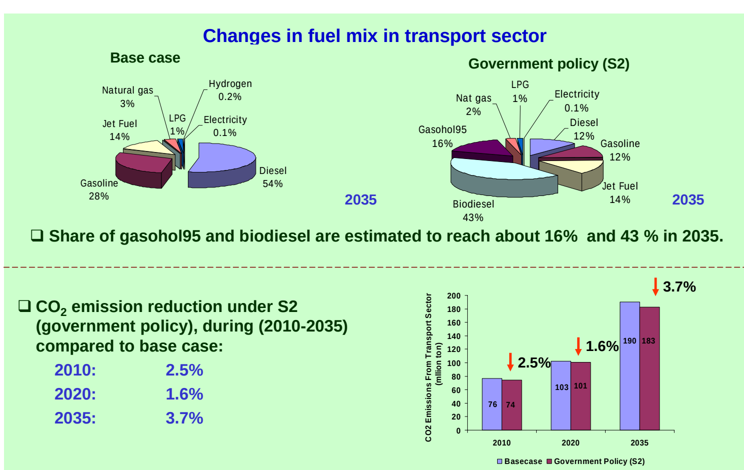
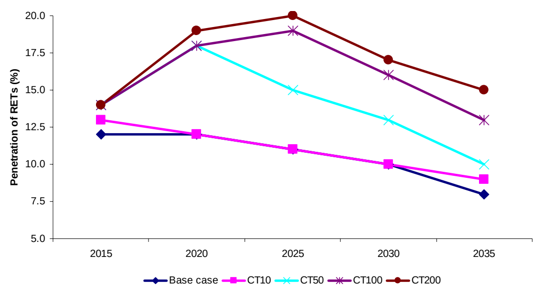


Figure 6. Assessment of the Thai biofuel program with the SDB

Carbon tax policies were analyzed for Thailand using AIM/Energy in order to explore the technological options for mitigating CO_2. Though the share of renewable energy technologies (RETs) is estimated to decrease from 15% in 2000 to 8% in 2035 in the base case, a carbon tax of US$200/tC is estimated to increase the share of RETs up to 15 per cent in 2035. When carbon tax up to US$50/tC is introduced, it results in selecting only the plantation based biomass for power generation compared to base case without carbon tax. When the taxes are considered above US$50/tC, it results in more wind and biomass based technologies for power generation. Tax rate as high as US$200/tC results in utilization of all the domestically available biomass potential for power generation. The increase in tax rate leads to a decline in CO_2 emission intensity (defined as CO_2 emission per unit of GDP). In the base case, the CO_2 emission intensity is estimated to decline from 0.94 kg of CO_2 per 1995 US$ in 2000 to about 0.61 kg of CO_2 per 1995 US$ in 2035. Under tax of US$200/tC, the corresponding figure in 2035 is estimated to be 0.54 kg of CO_2 per 1995 US$. As seen from Figure 7, the reduction in CO_2 emission intensity varies from 0.7% under tax of US$10/tC to as high as 15.9% under US$200/tC in 2035. This is due to penetration of more efficient technologies and use of renewable source of energy such as biomass.



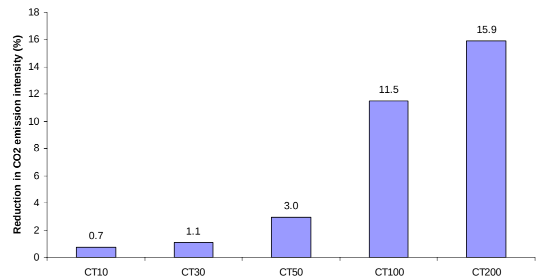


Figure 7. Penetration of renewable energy technologies (RETs) and reduction in CO_2 intensity in various carbon tax cases in Thailand (CT10 implies a tax of US$ 10/tC, and so on)

2.4 Analysis of access to safe water and sanitation using AIM/Water

Water Resource Management model has been developed as a response to the need for quantitative assessment of water supply and sanitation conditions in the Asian regions, especially the developing countries. This is part of the IEA effort to align MDGs and climate change objectives by assessing policies for mitigating the impact of global warming on water resources as well as for achieving the targets of access to safe water and sanitation. The model has several features:

- Estimation of present water demand and future projections in various sectors
- Detailed modeling of household sector's water demand, life-styles, and rate and cost of access to safe water and sanitation
- Estimation of change in water demand due to economic growth and changes in population, production structures, and life-styles
- Assessment of risk of diarrhea mortality
- Analysis of effectiveness of various water-saving technological options

Figure 8 shows the structure of the model. The model links an economic model (AIM/Material) with a global water resources model. Innovation options for analysis have been selected from SDB. These include options for improvement of management efficiency of water supply facilities, and improvement of water leakage and other unaccounted water.

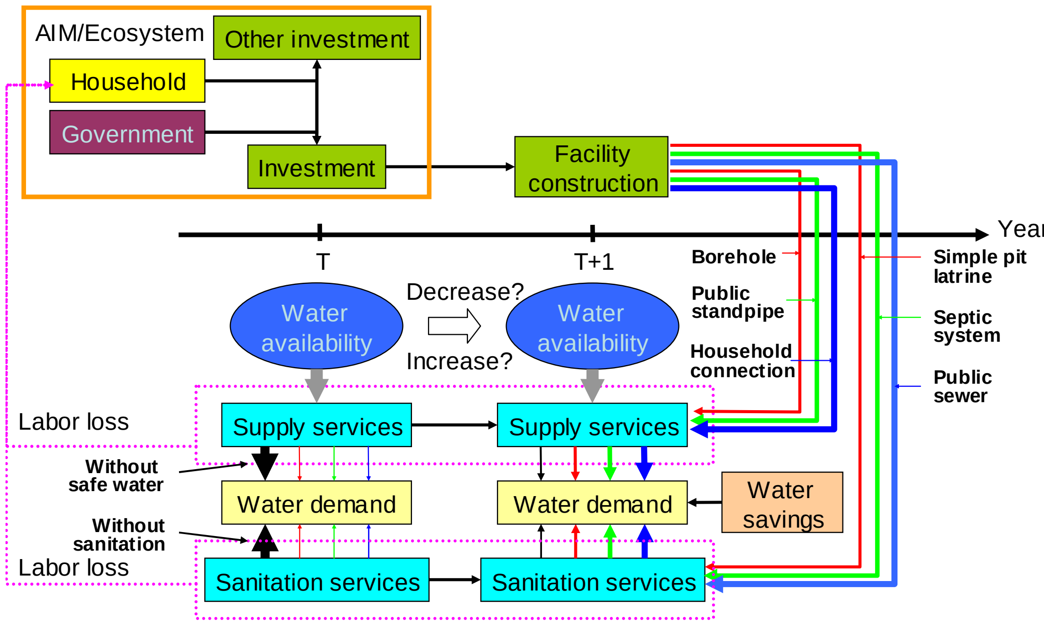


Figure 8. Structure of AIM/Water

Access to safe water is assessed under four UNEP scenarios in the Asia-Pacific region: Market First, Policy First, Security First, and Sustainability First scenarios (Figure 9). Under Market First scenario, access to safe water either remains unchanged or decreases. Under Policy First scenario, MDGs are expected to be achieved due to political and financial support. Under Security First scenario, low economic growth, high population growth and slow improvement of management efficiency inhibit improvement of access to safe water. Under Sustainability First scenario, MDGs are achieved by political support and sustainable water usage practices. To achieve MDG for safe water, it is crucial to promote both political support and sustainable water usage practices such as efficient water management, water saving and conservation.

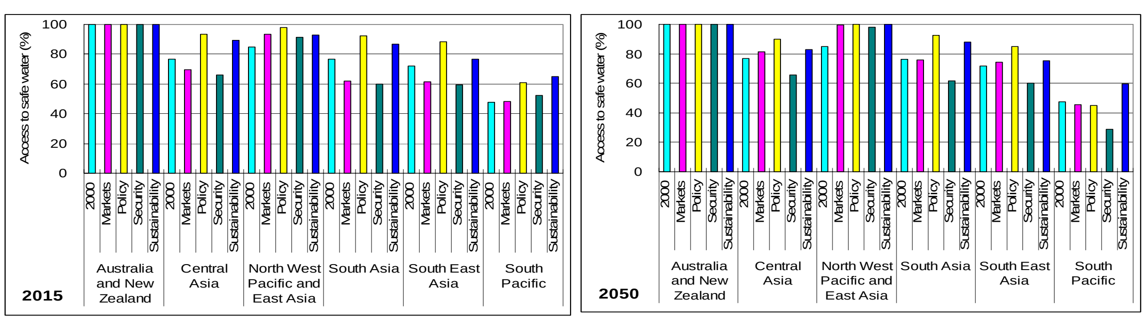


Figure 9. Access to safe water in various regions estimated for 2015 and 2050 by AIM/Water

2.5 Extension of AIM/Air and its application to China

AIM/Air has been extended to include multi-scale air pollution analysis, i.e. at the levels of region, country and city. For this purpose, the relationships between air pollutions at different scales have been analyzed and simulation tool of global scale material transportation of sulfur and nitrogen developed. The relation between meso-scale model and city level model has been depicted in Figure 10.

Using this model a process analysis of the area covering eastern part of China was carried out. From the model simulation the outflow of sulfur oxides was estimated to be 11% in summer and 33% in winter. That is, the deposition in summer was more than in winter (Figure 11). The background concentration of sulfur oxides in urban and suburban areas, whose maximum day average was 50 ppb, possibly disturbs achievement of environmental standard (Figure 12).

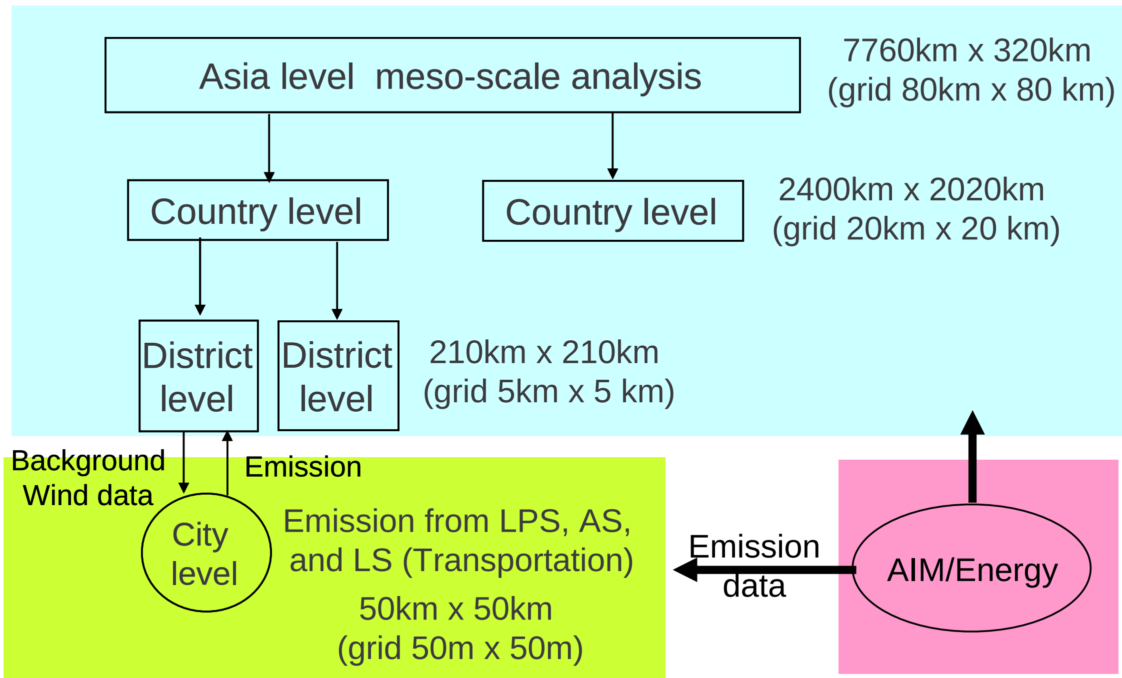


Figure 10. Relation between meso-scale model and city model in AIM/Air

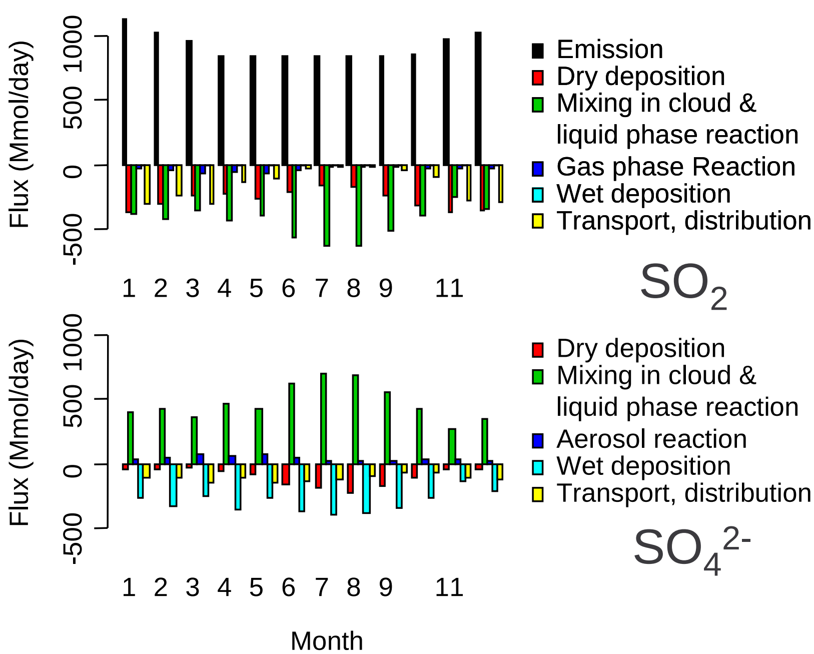


Figure 11. Monthly flux profile of sulfur oxides by each process in China

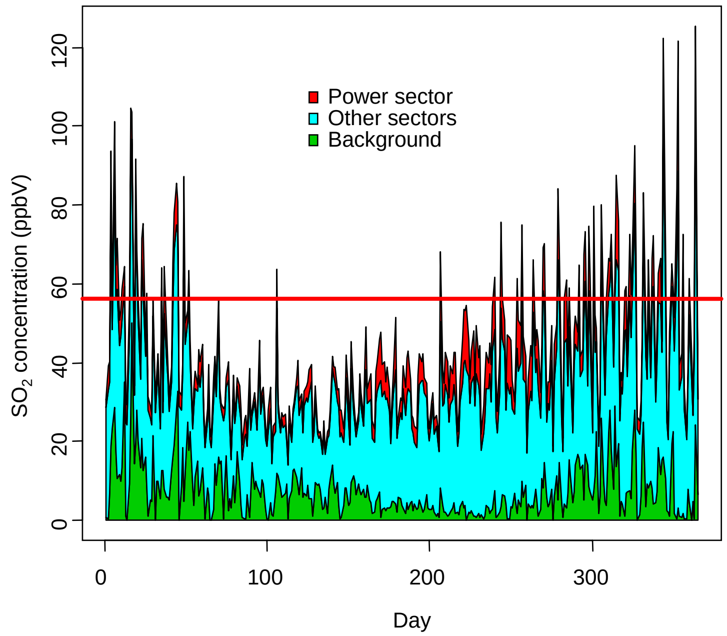


Figure 12. SO_2 concentration in China (red line shows the environmental standard of about 56 ppb)

2.6 Capacity-building initiatives by the IEA sub-project in selected Asian countries

A capacity-building workshop was held in November 2005 as a follow up to the previous year's workshop to train researchers from China, India, and Thailand in the use of the AIM/Material model for country level environmental policy analysis at NIES, Tsukuba, Japan. A team from each country carried out analysis using the model and presented the results. Researchers from China, India, Thailand, and Taiwan participated in the 2005 workshop. Prototype models for China, India, and Thailand have been developed and environmental innovation options assessed. Figures 13 and 14 show some results for China and India. AIM/Material model for China comprises 30 commodities and 30 sectors including 8 energy goods. It was used to analyze the impact of SO_2 tax and SO_2 constraint policies and to compare them with the policy aimed at energy efficiency improvement. AIM/Material model for India, comprising 35 aggregated commodities and 4 energy sectors, assessed the impact of South-Asian regional energy cooperation in the natural gas sector.

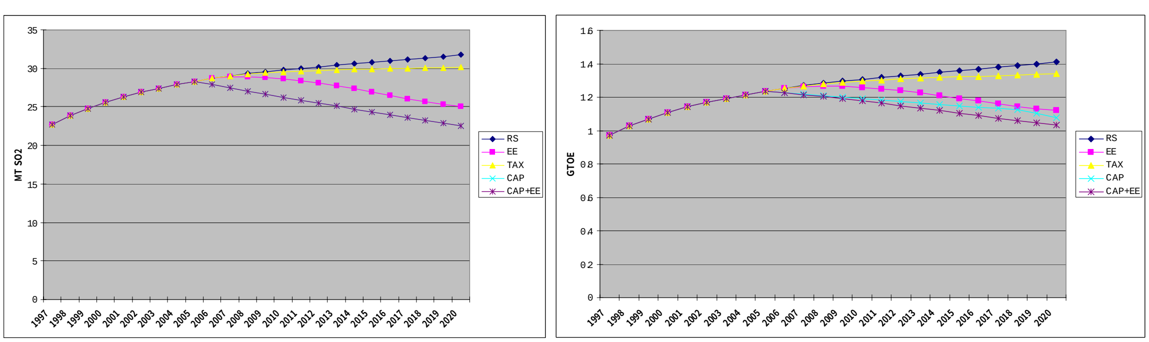


Figure 13. Results for SO_2 emissions (left) and energy consumption (right) in various scenarios from AIM/Material model for China (Legend for scenarios: RS – Reference; EE – Energy efficiency improvement; TAX – SO_2 tax; CAP – SO_2 constraint; CAP+EE – Mixed SO_2 tax and constraint)

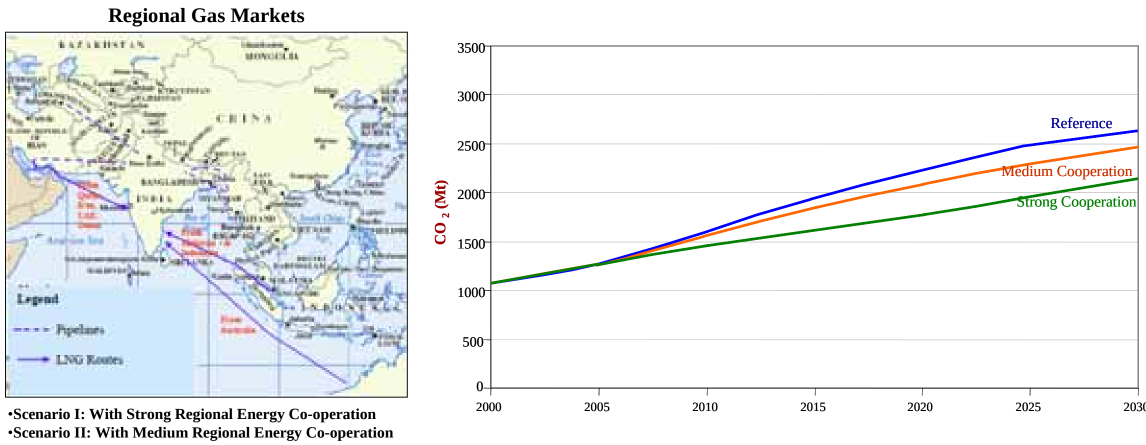


Figure 14. Results for CO_2 emissions in two regional energy cooperation scenarios from AIM/Material model for India

3. SDB structure and applications

The SDB has been enhanced to include (i) a more user-friendly form and a warehouse of material for data developers, and (ii) a module for estimation of future environmental burden. The tables in SDB store data related to characteristics of technology, institution, and management options. These characteristics have the possibility of being changed with reference to technology, institution, lifestyle, and other factors. The level of the change depends on social trend and countermeasure in policy scenarios. Left panel of Figure 15 depicts this mechanism of SDB for estimating environmental burden. Through a simple interface, the user can access a comprehensive list of innovation options and their quantitative and qualitative characteristics. The user can construct scenarios of demand, price, penetration rate of an option and other variables, perform simulation, and view results (right panel of Figure 15). Figures 16 and 17 show examples of SDB applications to the transportation sector.

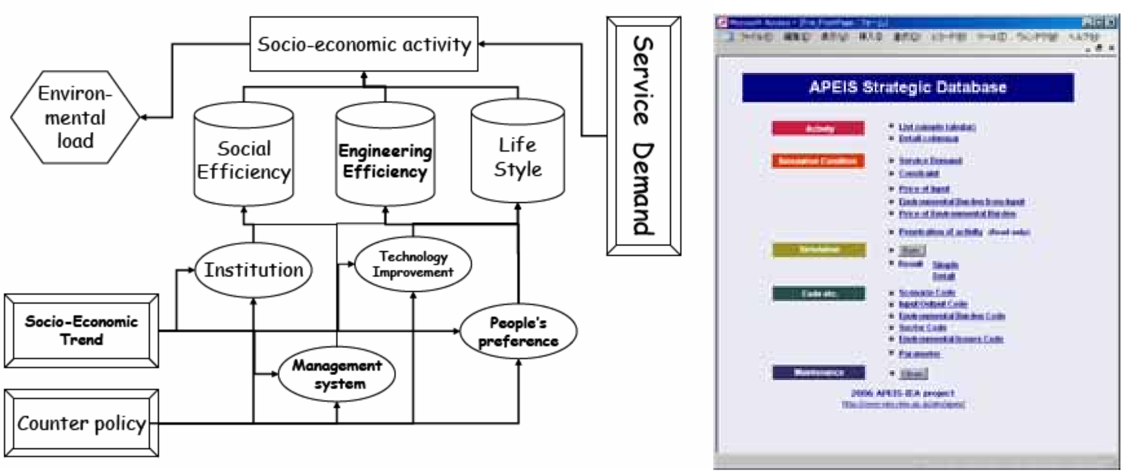


Figure 15. Mechanism in SDB to estimate environmental burden (left); SDB front-end form (right)

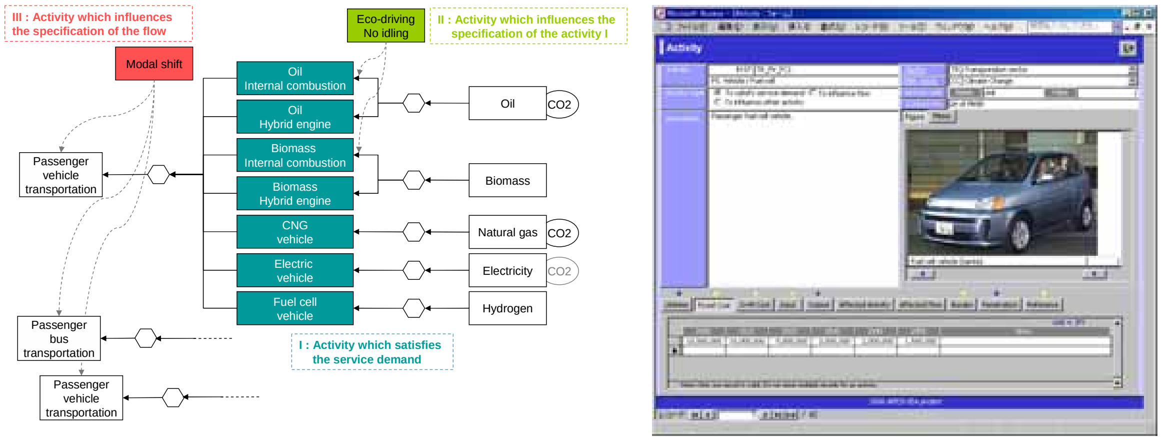
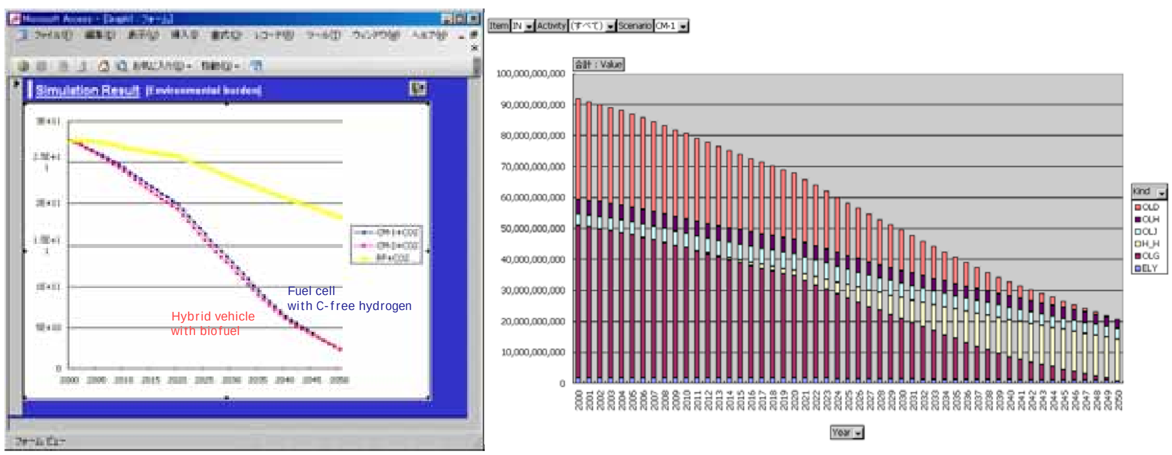


Figure 16. Example of SDB flow diagram and an innovation option for transportation sector



CO_2 emission

Energy consumption

Figure 17. Sample results of SDB application to transportation sector

4. Contribution of APEIS-IEA project

4.1 How can the APEIS-IEA products be used for policy formulation / implementation work?

APEIS-IEA tools have been directly used for providing input to policy analysis and implementation in selected Asia-Pacific countries. Country, district, and city level air pollution analyses carried out by IEA collaborating teams in China, India, and Thailand have been providing inputs to their national policy forums. Use of IEA tools for integrated analysis of millennium development goals, domestic concerns of economic growth and sustainability, and climate change has enabled the collaborating teams in each country to carry out comprehensive assessments and provide recommendations that are more acceptable to their policy makers.

Another key area in which IEA tools have contributed to policy is the assessment of clean development mechanisms (CDM). CDM is one of the flexibility mechanisms of Kyoto Protocol that allows emission trading reduction projects creating sustainable development in developing countries to generate certified emission reductions for use by the investors. Analysis using IEA tools by collaborating teams in China, India, Thailand, and Korea has provided robust estimates of marginal costs of mitigation in various sectors in those countries. These estimates have been useful in deciding benchmarks for CDM projects.

4.2 What has APEIS contributed to the scientific community?

Each of the IEA tools is a new model developed to assess certain environmental issues and answer a specific set of policy questions. These tools have been designed to be used both independently and complementarily. Various combinations of these tools provide a comprehensive framework to assess multiple dimensions of environmental problems and perform integrative analysis of such problems together with other concerns like economic growth, sustainable development, and health impacts. Such dimensions could include technologies, institutions, policy instruments, regional scope, time horizon, GHG emissions and other environmental pollutants. For instance, the SDB and AIM/Material can be used together to design business-as-usual and intervention scenarios and assess their impacts on emissions of various gases, costs, macro-economic indicators such as changes in GDP and capital formation, health and other developmental indicators. The AIM/Energy and AIM/Material models can be used together to assess impacts of policy measures such as emission constraints, carbon taxes or permit trading on technology mix, fuel mix, and macro-economic indicators. Such analyses can be undertaken over short or long runs and at the level of city, country, or region. AIM/Material, AIM/Energy, AIM/Air, and AIM/Health models can be used effectively for a comprehensive assessment of changes in energy use patterns, their contribution to air pollution, health impacts, and consequent economic effects.

The IEA models and strategic database are especially suitable for application to developing countries where, on the one hand, collecting extensive and reliable data is difficult but, on the other hand, innovative options are expected to play an extremely critical role, since many of those countries are witnessing rapid socio-economic transitions. IEA tools are designed to facilitate estimation, storage, and use of relevant data for environmental assessment in such contexts. This characteristic is not adequately present in other existing models. This is one of the reasons why IEA tools are already being extensively used by researchers in major developing countries of the Asia-Pacific region, such as China, India, and Thailand, and are providing inputs to their policy discussions. IEA tools have helped in the scenario development processes in these countries.

4.3 Cooperation with international organizations

The APEIS-IEA sub-project has been actively contributing to several international projects, such as CAPaBLE, UNEP/SEFII, and UNEP/GEO4. APEIS-IEA tools are providing useful analyses in the CAPaBLE project for assessing mitigation options and sustainable development opportunities in developing countries. In the UNEP/SEFII Great Mekong project, IEA tools such as the SDB, AIM/Water, and AIM/Air have proved useful for contributing to the database and for analysis of countermeasures for assessing regional environmental problems of water, air, waste, and forests. IEA tools have also contributed to the construction of future scenarios for emissions of CO_2, SO_2, and NO_x and generation of municipal solid waste in the UNEP/GEO4 project. Figure 18 shows the participants of the CAPaBLE Workshop held at Beijing in September 2005, and the participants of the UNEP/SEFII Workshop held in Bangkok in April 2006.

Figure 18. Participants at the CAPaBLE Workshop 2005 (top), and at the UNEP/SEFII Workshop 2006 (bottom)

APEIS-IEA has been continuously collaborating with a network of organizations in the Asia-Pacific region in order to develop tools to suit the diverse social, institutional, and economic contexts of the region, and to carry out assessments useful to its policy making processes.

AIM Network

The research project of AIM started in 1990 and has been specifically developed using a collaborative approach of Asian region, based on international collaboration programs with participation of governments and developing countries to get their own Integrated Assessment tools, and these countries have already applied own Integrated Assessment Models to their actual policy making processes.

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Collaborating Institutes

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Asia-Pacific Integrated Model (AIM)

The Asia-Pacific Integrated Model (AIM) is one of the main tools of developing policy options for the Asia-Pacific region. It is a set of integrated computer simulation models used to assess policy options for sustainable development in this region. It started as a tool to evaluate policy options to mitigate climate change and its impacts, and extended its function to analyze other environmental issues such as air pollution control, water resources management, land use management, and environmental industry encouragement. More than 20 modules have been developed so far, and models to evaluate climate policy options are classified into emission models, climate models and impact models from the viewpoints of climate policy assessment. These models have been used as single models or in combination depending on the policy needs (Figure 19).

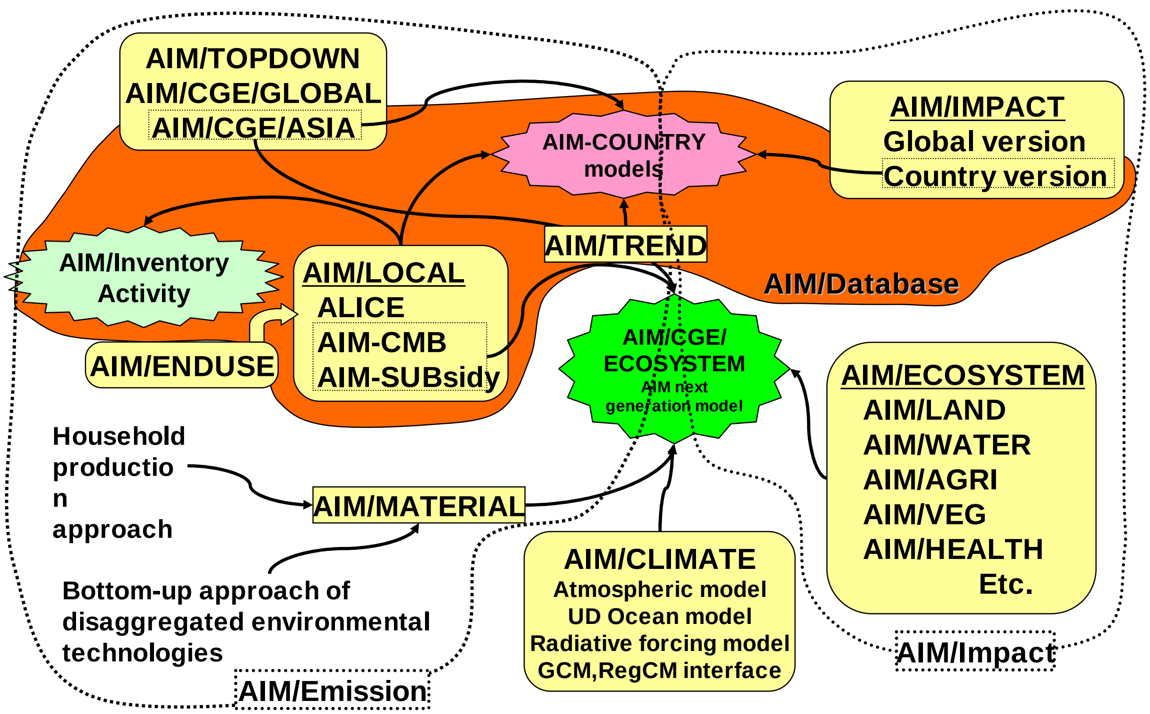

Figure 19. Roadmap of the AIM family

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