TECHNICAL SUMMARY

IEA

Integrated Environmental Assessment

Asia

Pacific

Environmental

Innovation

Strategy project

APEIS

June 2004

APEIS-IEA Technical Summary

1. What is APEIS-IEA?

The Integrated Environmental Assessment (IEA) sub-project of APEIS aims to address key environmental policy issues at various levels of application using a set of integrated assessment models and a strategic database. These models and database are part of the Asia–Pacific Integrated Model (AIM) family. Several AIM models have been developed to analyze policy, from global to local geographical levels, and examine how they affect concerns ranging from stabilization of greenhouse gas (GHG) emissions to air pollution, wastes, human health, land-use change, and water resource depletion.

Triggered by opportunities of globalization and domestic economic reforms, a number of developing economies are growing at a rapid pace while goals of a clean environment and sustainability stand threatened at both local and global scales. Against this backdrop, policymakers are faced with multiple and complex issues often with mutually conflicting objectives. The vast range of policy issues that AIM models and databases can jointly address, together with their user-friendly interfaces, make IEA potentially very useful to policymakers in various countries and international bodies. The impacts of various policy intervention options—such as market-based policies (for example, emissions tax), regulatory constraints, innovative technologies and systems, trade regimes, and bilateral technology transfer agreements—can be evaluated at the levels of city, country, region, and world.

The models and database include (i) the Strategic Database (SDB), used for storing data relating to socioeconomic scenarios and innovation options, assessment of innovative technologies, and provision of data to other models; (ii) the AIM/Energy model, used for local- and country-level assessment of technologies and emissions mitigation options; (iii) the AIM/Material model, used for country-level assessment of environmental investments and recycling; (iv) the AIM/Trend model, used for regional- and global-scale projections of future socioeconomic and environmental trends; (v) the set of AIM/Ecosystem, AIM/Water and AIM/Agriculture models, used for assessment of impacts on water, agriculture, vegetation, and health.

All these models and database together cover both bottom-up and top-down features. AIM/Energy and SDB have bottom-up frameworks, that is, they model detailed flows of energy through technology systems. AIM/Material and AIM/Trend are top-down models. They model the relationships among aggregate economy-wide indicators. AIM/Ecosystem, AIM/Water and AIM/Agriculture too have top-down features. A top-down representation of economy and its linkage with emissions, as shown in Box1, is an integral part of AIM/Ecosystem. AIM/Material model includes similar top-down economy-environment framework.

The IEA sub-project exchanges data and scenarios with the sub-projects “Integrated Environmental Monitoring” (IEM) and “Research on Innovative and Strategic Policy Options” (RISPO).

2. What are the Expected Products, Scientific Contributions, and Current Progress?

The models and database developed by IEA are being used for addressing various environmental issues in selected countries through collaboration with modeling and policy experts in each country (Table 1). Teams in each country have collected current year data, projected future years’ data of driving forces, designed socioeconomic scenarios, and identified abatement options for each country, in consultation with various domestic experts and policymakers. IEA model results and

analyses for each country have been used by the respective teams to contribute to domestic policymaking through various projects and forums. Researchers in Japan have collected and estimated global data, too.

2.1 Technical Framework

The framework includes models—AIM/Energy, AIM/Material, Aim/Ecosystem, AIM/Water, AIM/Agriculture and AIM/Trend—and the Strategic Database (SDB). Relevant results of one model are transferred as input to another. Each model is designed for a specific purpose, i.e. to address a specific set of policy issues. For instance, on the one hand, AIM/Energy models significant technological and energy flow details in order to answer policy questions relating to emissions by sector, technology, and fuel type, and to show the costs of intervention options for mitigating those emissions. The top-down economy level representation in AIM/Ecosystem, on the other hand, dynamically models aggregate, economy-level interactions among prices, value outputs of sectors, and trade in a general equilibrium framework, in order to answer policy questions relating to two-way impacts of economy-wide emissions and macroeconomic policies concerning trade, production, and technological progress.

Input data and results of various models are also stored in the SDB. The SDB is designed to assess the environmental impact of innovative technologies and systems, and to assess the suitability of such innovations in a local context.

2.2 Expected Products

2.2.1 AIM/Energy

AIM/Energy is a bottom-up optimization model of technology selection that simulates flows of energy and materials through complex technological systems, and the resultant emissions, at local or country levels. It selects technologies that minimize system cost. It is useful for analyzing several policy concerns at local and country levels, such as reduction potentials of specific emission removal technologies; and impacts of specific emissions taxes, emissions constraints, or end-use level improvement measures on emission levels, marginal costs, technology mix, and fuel mix. Emissions covered by AIM/Energy include CO_2, CH_4, N_2O, SO_2, and NO_x, and Suspended Particulate Matter (SPM). Its strength is the ability to model technology–energy systems in detail (Fig. 2).

AIM/Energy simulations for China indicate that the economic potential for CO_2 emission mitigation is the highest in the industrial sector, where a reduction of over 200 Mt C can be achieved in 2010 at less than US$50/t C. A significant portion of this reduction potential lies in the power, steel, and cement industries. Of this, a reduction of over 60 Mt C can be achieved by no-regret options alone (Fig. 3). The majority of CO_2 emissions in China arise from particular industrial–residential areas (Fig. 4a). Simulations show that CO_2 mitigation measures in the power and residential sectors will induce a shift away from coal, thus resulting in significant co-benefits of both CO_2 and SO_2 reduction (Fig. 4b).

AIM/Energy simulation results for India show that the scenario of 550 ppmv CO_2 stabilization will be characterized by a significant switch from coal- to gas-based power generation, especially in the coastal areas (Fig. 5). This switch arises primarily because of the relatively low delivery cost of domestically produced and imported natural gas in coastal areas, and the declining capital cost of gas turbines, making it the preferred option to meet GHG mitigation targets.

2.2.2 AIM/Trend

AIM/Trend is an econometric model used for projecting environmental trends in different countries. Compared to the previous year, AIM/Trend has been expanded from Asia-Pacific region to the world. Indices of economy, energy, and environment calculated by AIM/Trend are used for other AIM models. Non-CO2 gas projections have been revised.

2.2.3 AIM/Material

AIM/Material is an environment–economy interaction model with special representations of economy-wide material balances and recycling processes. It is useful for analyzing policies relating to recycling industries and their impacts on economy-wide emissions and macroeconomic performance.

Effects of economy-wide CO_2 emission constraints (increase in emissions restricted to 2% per annum) and policies promoting recycled biomass goods and technology innovations in India were analyzed with AIM/Material. Loss of GDP in 2030 under CO_2 emissions constraint is about 2% of the reference scenario. Recycling and technology innovation scenarios are expected to mitigate this loss by up to about half a percentage point in 2030 (Fig. 6).

2.2.4 AIM/Ecosystem, AIM/Water and AIM/Agriculture

These are a set of models focusing on different aspects of the interaction between natural and social environments. These include a vegetation dynamics, water resources, agriculture productivity, and health impact. These are useful for analyzing the impacts of long-term socioeconomic scenarios on vegetation, water resource depletion, agricultural productivity, and the health of people, in various regions of the globe.

Four long-term scenarios of natural and social environment were analyzed using AIM/Ecosystem. The simulations indicate that forest area will decrease at the beginning of the 21st century in all regions under all scenarios. While regional scenarios (AM and OS), characterized by pressure from general food demand, show this decline to continue until 2050 for Asia, global scenarios (GO and TG) show recovery of forest area in later periods due to pressures of globalization (Fig. 7).

AIM/Water results indicate that water demand per unit area will increase throughout the 21st century in China and Eastern Europe owing to high economic growth under the GO scenario. Under the OS scenario, high population growth in Africa, the Middle East, and South Asia will cause an increase in water demand per unit area (Fig. 8).

As described earlier, AIM/Ecosystem and AIM/Material contain explicit linkage with economy which is modeled in a top-down framework. This framework has a long-term, general equilibrium type global representation with recursive dynamics. It has representations of 18 regions of the world, 13 economic sectors, and multiple gases. It models the interactions among the economy's production sectors, government, and households, with an implicit representation of prices, trading, and emissions (Box 1). The 13 economic sectors represented in the model include natural gas, electricity, crude oil, refined oil products, coal transformation, agriculture, livestock, forestry, fishing, transport, services, energy-intensive industries, and other industries. The model represents allocation of emission rights among users in various sectors. It is useful for analyzing global-level policy interventions like free trade agreements among different regions, bilateral technology transfer agreements, and economic and trade impacts of global GHG stabilization scenarios.

The scenario of a free trade agreement among Asian countries, analyzed using top-down economy framework without the non-CO_2 GHG module, shows a significant change in both GDP and emissions in 2010 relative to the reference scenario. Free trade will increase GDP as well as SO_2 emissions in Korea and seven ASEAN countries owing to the rise in production from energy-intensive industries. However, free trade may induce a decline in SO_2 emissions in other countries, due to either the growth of industries supplying environmental processes/equipment (Japan) or a drop in production from energy-intensive industries (India) (Fig. 9).

2.2.5 Strategic Database

The APEIS Strategic Database (SDB) is designed to analyze strategies for innovative technologies and social systems required for a shift toward environmentally sound industries and lifestyles. Various innovative technologies in the fields of nanotechnology, biotechnology, and information technology, and innovative social systems, such as environmental fund schemes and awareness campaigns, can be analyzed for their impacts on reducing soil/water contamination soil/water purification, waste reduction, and climate change.

In the SDB, descriptive information on innovative strategies and socioeconomic scenarios is quantified, and the impacts of the innovations under different scenarios are analyzed. These strategies include innovative technological, management, and institutional systems that have the potential to significantly improve an environmental effect. The potential acceptance and implantation of such systems could be specific to the context of a country or region. Firstly, the user compiles a list of innovative environmental strategies based on various inputs such as interviews with experts, literature surveys, and existing data from bottom-up models like AIM/Energy. This information is compiled as 'narrative description cards', each of which presents the social, economic, technical, and environmental characteristics of a specific innovation in both descriptive and quantitative terms. The user also draws up storylines describing future socioeconomic scenarios of interest for a given country or region. These descriptive storylines are subsequently converted into quantified socioeconomic scenarios. Finally, through a user-friendly interface, the quantified information about scenarios and innovative strategies is combined to estimate the impacts of specific innovative systems under specific socioeconomic scenarios (Box 2). Several innovative technologies and systems have been identified in the process of building the innovations database for the SDB (Box 3). Analysis of innovations using the SDB is in progress for Japan, China, and India.

2.3 Contributions to Scientific and Technological Progress

The set of AIM models and the strategic database shown in Figure 1—adjusted for mutual consistency and applied together to address a wide range of environmental policy concerns—is at the cutting edge of development and application of Integrated Assessment Modeling. Each model itself has certain features that lend it an advantage over other similar models available in the literature. The set of AIM models for IEA utilizes cutting-edge modeling methods in optimization, economic equilibrium, and ecosystem simulation, and applies them innovatively for environmental policy analysis.

2.4 Current Progress on Major Tool Development

IEA has completed advanced versions of AIM/Energy, AIM/Material and AIM/Water, and a preliminary version of the integrated AIM/Ecosystem models. It has also completed an advanced version of the Strategic Database with indicators

focusing on environmental efficiency. It has carried out projections of environmental trends and assessments of innovation options for selected countries.

2.5 Messages from IEA

Integrated analysis with the IEA models and strategic database suggests that (i) the potentials of technological innovations for the environment are very large but differ among countries, pointing to immense opportunities for regional collaboration; (ii) technological innovations are most effective if integrated with social innovations; (iii) policy options effective for the global environment can reduce local environmental burdens as well; (iv) investments in the recycling industry and in technological innovations can partly mitigate the loss of GDP due to environmental constraints; (v) globalization would introduce innovations mainly in emission reduction while adversely affecting the incentives to sustain ecosystems; and (vi) free trade agreements would have varied economic and environmental impacts on different Asian countries.

3. How Can the APEIS-IEA Products be Applied for Policy Formulation/Implementation Work?

IEA products have a wide range of applications to policy-making, as highlighted in Table 1. They can address a variety of environmental policy concerns at the levels of:

(i) city, country, region, and world

(ii) sector, economy, and ecosystem

(iii) short term (5–10 years), intermediate term (10–50 years), and long term (50–200 years)

(iv) technology innovations, management and institutional innovations, command and control interventions, and market-based interventions

Taken together, the IEA models and database can help policymakers at various levels of decision making to address a wide range of environmental and allied issues in an integrative manner.

Each IEA product has a user-friendly interface especially designed to meet the needs of policymakers. For instance, assumptions for scenarios can be specified on the basis of policymakers' expert judgments. A user can run the models without needing to access the models' technical formulations, and can analyze the results using tables, graphs, and maps. Analysis features of the models permit the user to view results on a wide range of policy criteria that are of relevance to various stakeholders typically involved in real-life contexts of environmental policy. The user can thus weigh various trade-offs involved in a specific context, understand the underlying inter-linkages, and arrive at informed decisions by interacting with the models.

For instance, AIM/Trend and top-down economy component of AIM/Ecosystem will enable policymakers to easily comprehend complex dynamics of economy-wide environmental policies and the inter-relationships among multiple critical elements, such as outputs of different economic sectors, prices of commodities, technological progress, trade flows, macroeconomic indicators, and environmental emissions. AIM/Material will enhance the understanding of linkages between those elements and recycling sectors. AIM/Energy will help in grasping technological details of energy extraction, energy

conversion, supply systems and enduse systems and the flows of energy and materials through them, possible pollution reduction technologies and their implications for emissions of various gases (including GHGs), and marginal abatement costs in the process of satisfying specific enduse services in various sectors of a city, province, or country. AIM/Ecosystem enables integrative understanding of interdependent phenomena such as climate change, land-use change, water availability, vegetation, crop productivity, and health impacts. The SDB guides the user through the definition and quantification of innovative systems and socioeconomic scenarios, and provides an evaluation of each innovation's impact on the environment, thus facilitating the awareness of underlying cause-and-effect relationships. Hence, regular interaction and familiarity with the IEA models will in itself enhance policymakers' awareness and appreciation of a specific environmental problem and policy context.

In the process of interaction with the IEA models and database, and by directly using these tools to address specific problems, the policymakers would equip themselves with improved capability for policy formulation and implementation. Because of the interactive and user-friendly features of the products, policymakers would be able to complement their own expertise and judgment with the models' analytical and scientific strengths.

3. Other Relevant Information

Participating organizations and relevant Internet sites:

Energy Research Institute, Beijing, China

http://www.eri.org.cn/

Institute of Geographical Sciences and Natural Resources Research, Beijing, China

http://english/igsnrr.ac.cn/

Indian Institute of Management, Ahmedabad, India

http://www.iimahd.ernet.in/

Seoul National University, Korea

http://www.snu.ac.kr/engsnu/

Korea Environment Institute, Seoul, Korea

http://www.kei.re.kr/eng/

Asian Institute of Technology, Pathumthani, Thailand

http://www.ait.ac.th/

Universiti Putra Malaysia, Serdang, Malaysia

http://www.upm.edu.my/WebsiteEnglish/

Kyoto University, Kyoto, Japan

http://www.kyoto-u.ac.jp/index-e.html

Fuji Research Institute Corporation, Tokyo, Japan

http://www.fuji-ric.co.jp/english/profile/

National Institute for Environmental Studies, Tsukuba, Japan

http://www.nies.go.jp/

Asia–Pacific Integrated Model

http://www.nies.go.jp/social/aim/index.htm

Glossary

AIM	Asia–Pacific Integrated Model
AM	Adapting Mosaic, a name of scenario for ecosystem assessment, characterized by regionally decentralized and environmentally conscious societies
ASEAN	Association of Southeast Asian Nations
CDM	Clean Development Mechanism
GDP	Gross Domestic Product
GHG	Greenhouse Gases
GO	Global Orchestration, a name of scenario for ecosystem assessment, characterized by high degree of globalization and economic growth
IEA	Integrated Environmental Assessment
MAC	Marginal Abatement Cost curve
OS	Order from Strength, a name of scenario for ecosystem assessment, characterized by regional consolidation
SDB	Strategic Database
SPM	Suspended Particulate Matter
tC	Tonnes of Carbon (Mt C: million tonnes of carbon)
TG	Technogarden, a name of scenario for ecosystem assessment, characterized by rapid increase in environmental industries supported by globalization

Table 1. Current status of IEA applications

Model/Database	Application	Policy Needs	Countries/Regions of application (until 2003)
AIM/Energy	Assessment of air pollution reduction policies and health impacts	Clean air for major cities	China, India
	Assessment of technology options for GHG mitigation	Strategy for climate change mitigation/adaptation	Japan, China, India, Korea, Thailand
	CDM assessment		China, India
AIM/Material	Assessment of effects of environmental constraints and investments	Strategies for environmental industry, waste treatment, water pollution, climate change, and health policy	Japan, China, India
	Trade-off between air pollution and health impacts		China
AIM/Ecosystem AIM/Water AIM/Agriculture	Assessment of natural capital, land-use change, water resource depletion, crop productivity, and energy supply	Strategy for ecosystem conservation	World
Top-down economy component of AIM/Ecosystem	Assessment of free trade agreements	Strategy for environmental policy through trade	World
	GHG stabilization scenarios	Strategy for climate change mitigation	World
AIM/Trend	Projection of GHG emissions, water supply and demand, and wastes	Communication tool for policymakers	Asia–Pacific (7 regions), World (14 regions)
Strategic Database	Assessment of innovation technologies under different socioeconomic scenarios	Strategies for environmental industry, waste treatment, water pollution, and climate change	Japan, China, India, Thailand

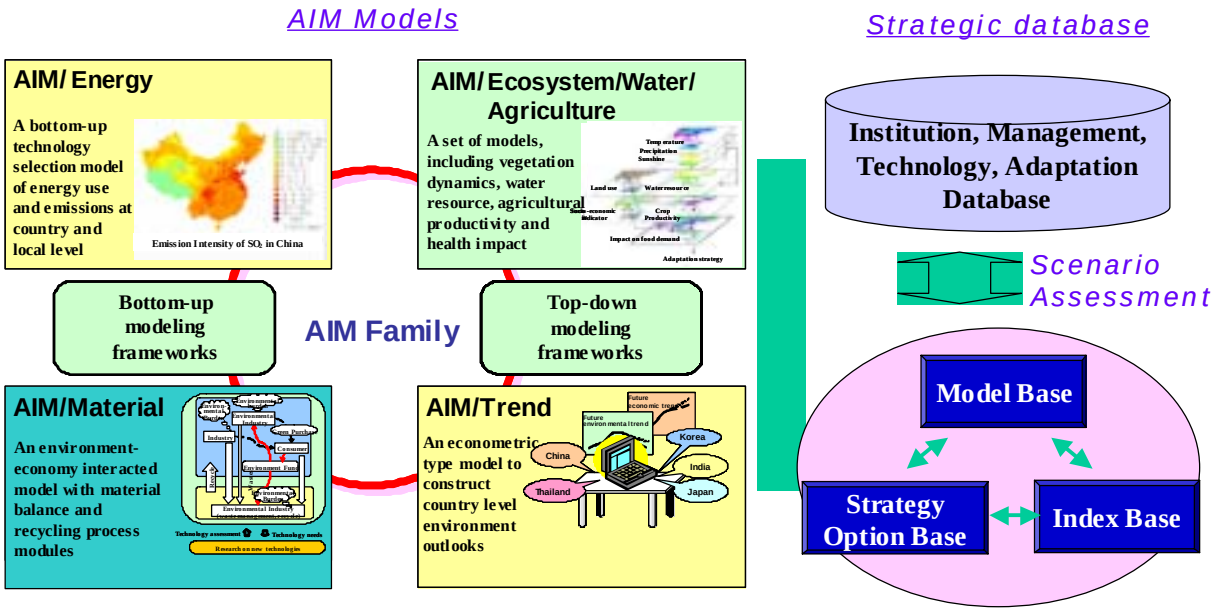


Figure 1. AIM Models and Strategic Database for APEIS

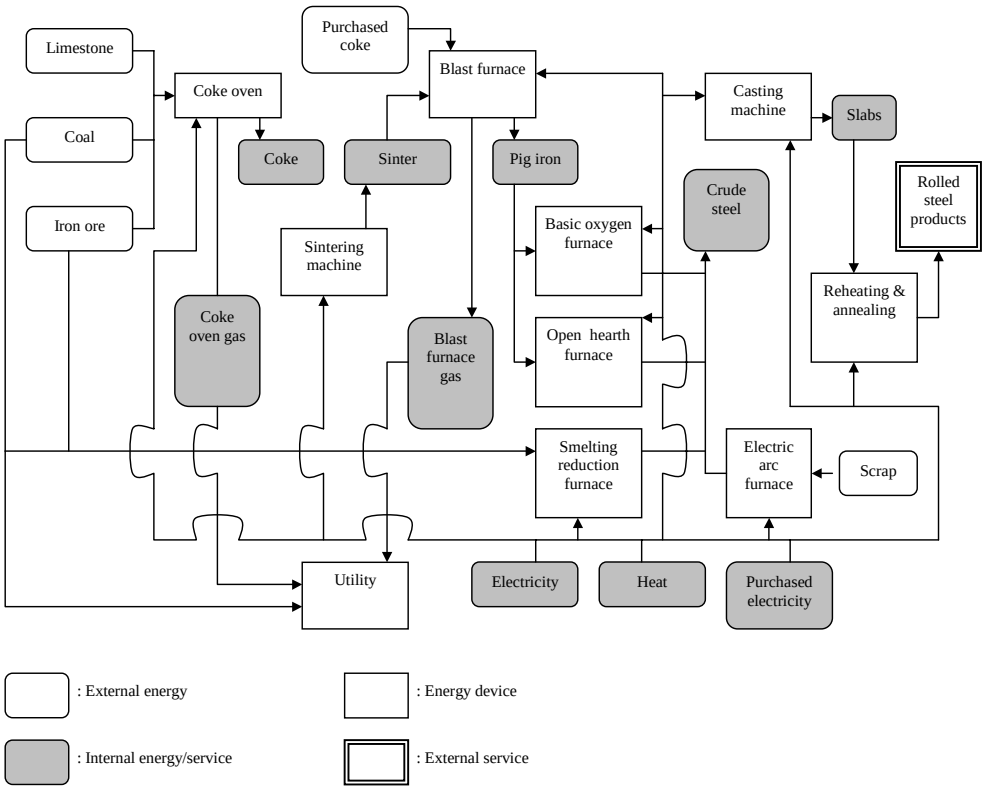


Figure 2. Example of the technology system of the steel industry in the AIM/Energy model for India

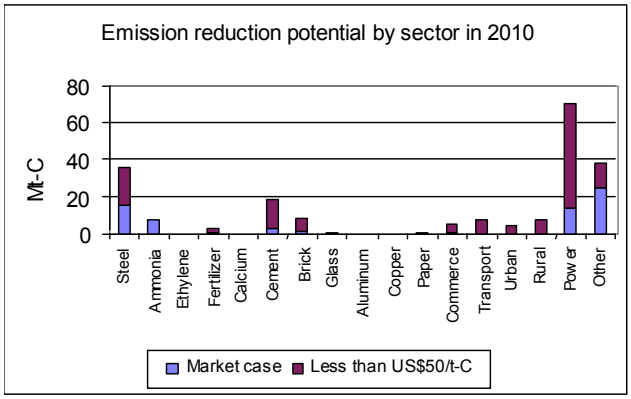


Figure 3. CO_2 mitigation potential in China in two selected scenarios as compared to reference scenario in 2010

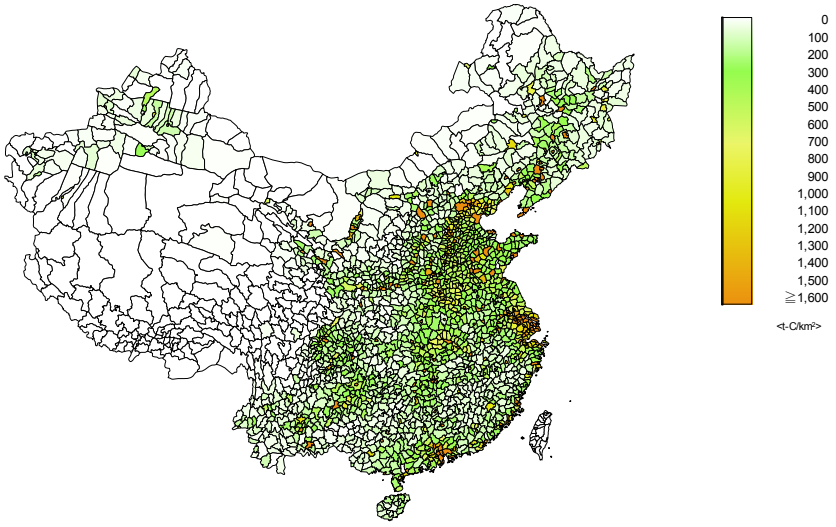


Figure 4a. CO_2 emission intensity in China in 2010

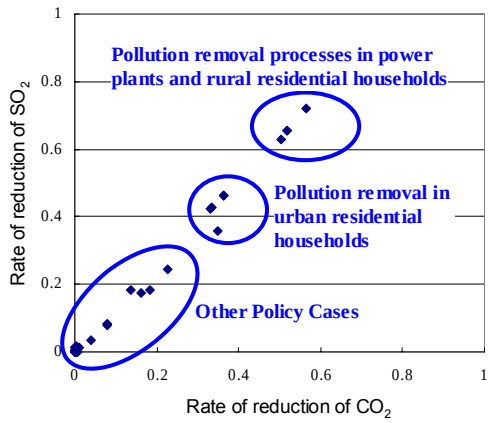


Figure 4b. Co-benefits of CO_2 reduction in China in different sectors

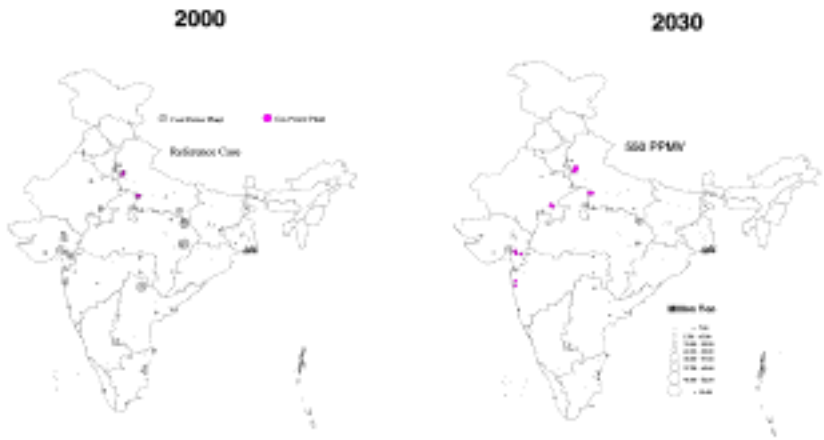


Figure 5. CO_2 emissions from large power plants in India under the reference scenario in 2000 (left) and the 550 ppmv stabilization scenario in 2030 (right)

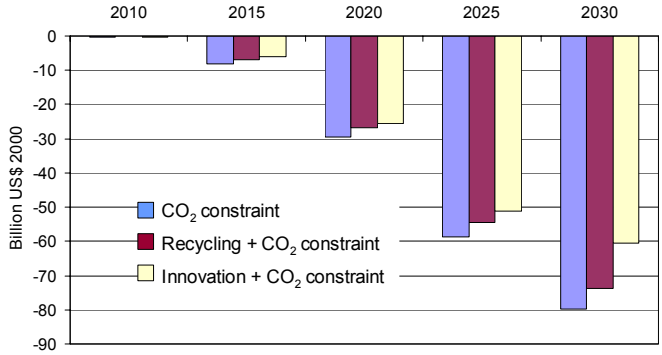


Figure 6. Change in GDP in India under 'CO_2 emissions constraint', 'Recycling and emissions constraint', and 'Technological innovation and emissions constraint' scenarios

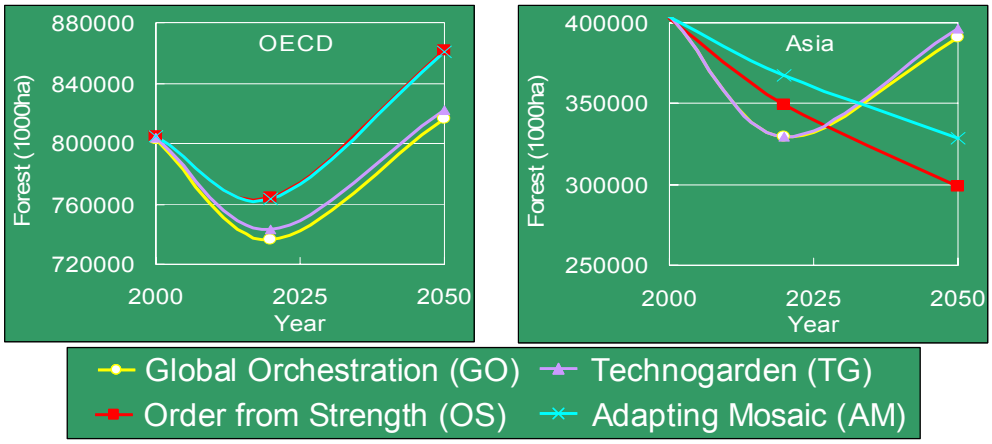


Figure 7. Estimation of forest area in selected regions under different long-term scenarios of natural and social environment

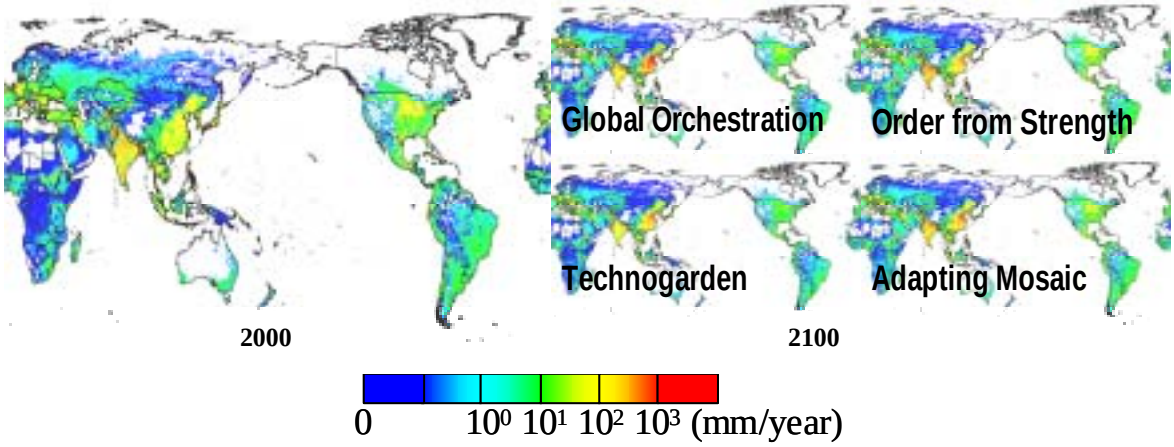


Figure 8. Estimation of water withdrawal per unit area under different long-term scenarios of natural and social environment

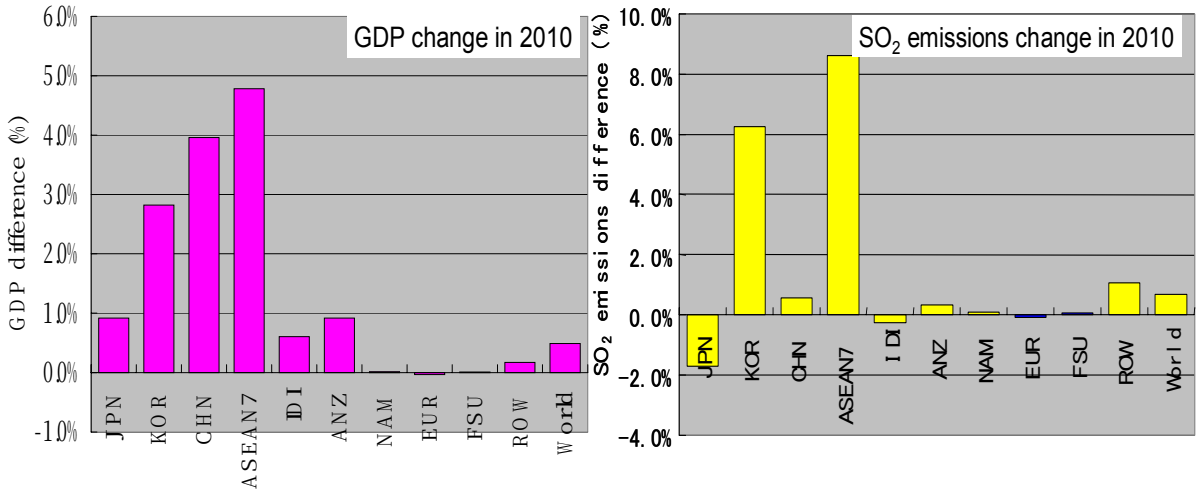
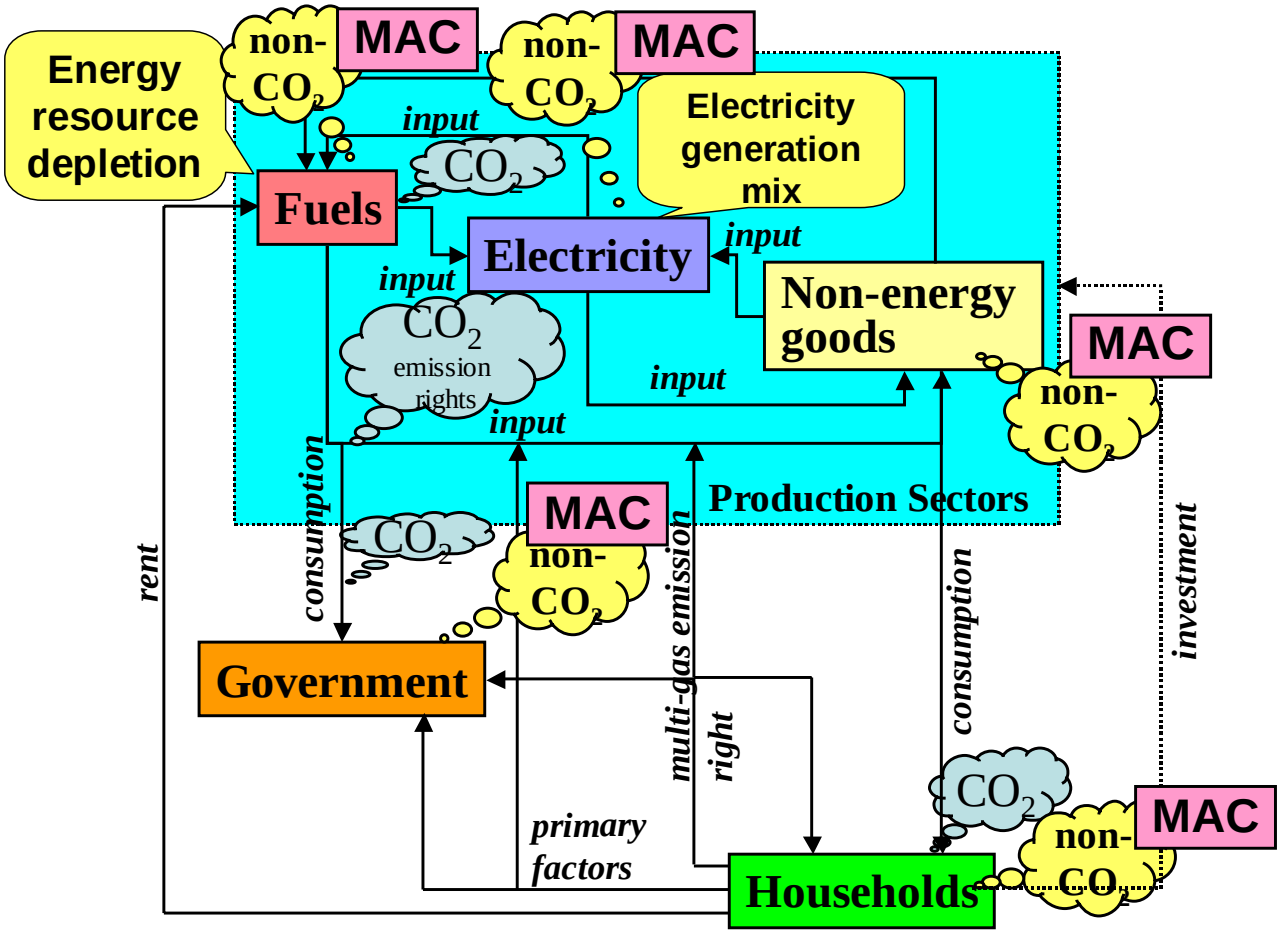


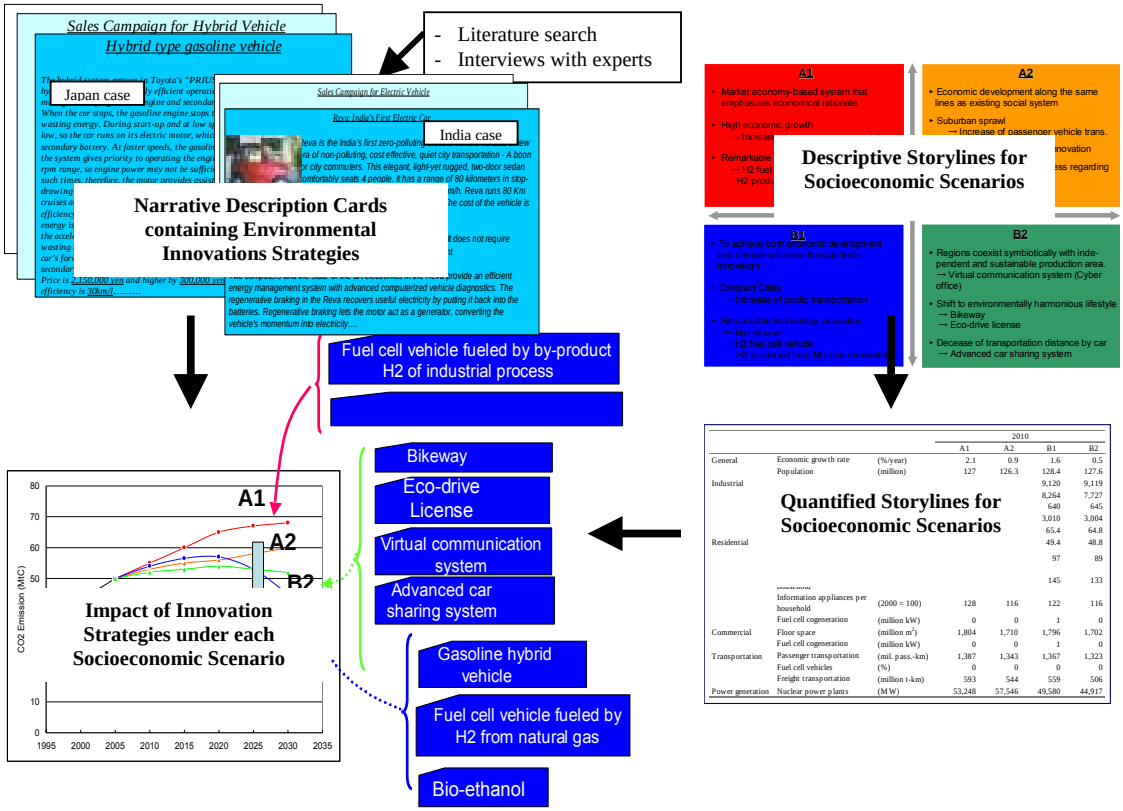
Figure 9. Impact of free trade agreement among Asian countries in 2010 relative to reference scenario (JPN: Japan, KOR: South Korea, CHN: China, ASEAN7: Seven ASEAN countries (Indonesia, Malaysia, Thailand, Philippines, Singapore, Burma, and Vietnam), IDI: India, ANZ: Australia & New Zealand, NAM: USA and Canada, EUR: West-European countries, FSU: Former Soviet Union, ROW: Rest of World)

Box 1. Structure of Top-down Framework of Economy-Environment Linkage as a part of AIM/Ecosystem



Note: MAC stands for Marginal Abatement Cost curve

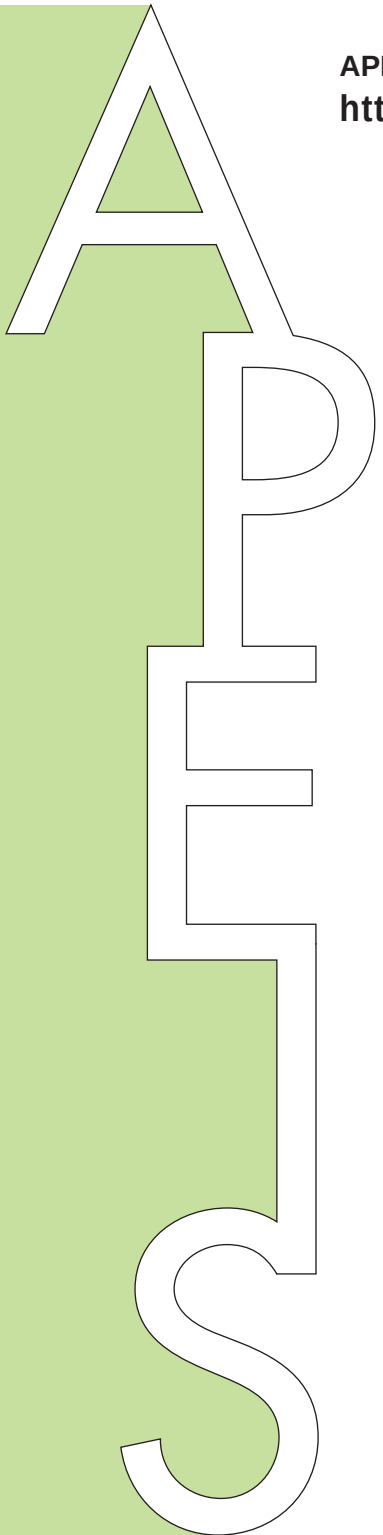
Box 2. Framework of the Strategic Database (SDB)



Box 3. Selected Examples of Innovations

Sector	Objective of environmental burden reduction	Innovation classification	Innovation name
Agriculture, Forestry & Fisheries	Agricultural production improvement	Biotechnology	High-efficiency organic farming with microorganisms
			Fodder production from microorganism protein
		Other technologies	Multifunctional and multi-effect natural food materials
			Agricultural production improvement using insects
	Water conservation	Biotechnology	Soil moisture fixing by grass plantation
		Other technologies	Drip irrigation, Micro irrigation
Manufacturing	Monitoring	Information technology	Monitoring and information dissemination for local pollution
			Continuous flood monitoring of Himalayan river systems
		Other technologies	Marine pollution status tracking by satellite radar
			Tropical forest reduction status tracking by satellite
		Policy	Estimation and public dissemination of environmental burden
	Energy saving	Other technologies	Steel: Dry coke quenching facility
			Steel: Direct current electric furnace
			Cement: Vertical type mill
			Cement: High-efficiency clinker cooler
			Brick: Vertical shaft brick kiln
			Petrochemistry: Naphtha catalytic cracking
			Paper and pulp: Press drying/impulse drying
			High-speed switching-type regenerative burner
	Air pollution	Other technologies	Activated carbon catalyst type desulfurization equipment
			Fertilizer production from desulfurization byproduct
	Soil and groundwater pollution	Biotechnology	Elimination of mercury by microorganisms
			Bioremediation
		Nanotechnology	Groundwater purification by photocatalysts
		Other technologies	Low-temperature decomposition of pollutants by additives
			Soil purification by colloidal iron
		Policy	Superfund law
	Water pollution	Biotechnology	Removal of organic tin from seawater by microorganisms
			Treatment of marine oil pollution by microorganisms
			Water purification by microorganisms using carbon fiber
Energy industries	Energy conversion	Other technologies	Ceramic gas turbine
			Superconducting generator
	Energy storage	Other technologies	Storage of electric power by superconducting flywheel
	Energy transportation	Other technologies	Low-loss material for pillar transformers
			Energy networking using low-loss electric power elements
	Photovoltaic power generation	Nanotechnology	Efficient solar cell with thin-film layer controlled at nanolevel
		Other technologies	Crystal system solar cells
			Amorphous system solar cells
			Sunlight convergence and tracking system
	Biomass	Biotechnology	Fuel production from waste materials
			Production of vehicle fuel from waste cooking oil
			Conversion of organic wastes to methane

Sector	Objective of environmental burden reduction	Innovation classification	Innovation name
Service industries	Education	Information technology	Decrease in building investment by e-learning
			Decrease in movement of people by e-learning
	Consulting	Other technologies	Environmental auditing
			Environment risk management
	Leasing industry	Information technology	Car sharing
	Finance	Other technologies	Environmental venture business bond exchange market
			Emission trading market
		Policy	Duty-free measures for green money
Transportation	Improvement of transportation efficiency	Information technology	Delivery efficiency by integrated vehicle dispatching system
			Global Positioning System to determine vehicle location
		Policy	Space pricing
			Eco-driver's license
	Automobiles	Nanotechnology	Hydrogen direct-loading fuel cell vehicle
			Platinum catalyst for fuel cells using carbon nanotubes with uniform differential scattering function
		Other technologies	Hybrid vehicle
			Car lightening by use of aluminum



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National Institute for Environmental Studies