1. What is APEIS-IEA?

The Integrated Environmental Assessment (IEA) sub-project will provide a set of computer simulation models and a strategic database that can be used to systematically assess strategies for environmentally sympathetic development in the Asia-Pacific region. The development of the models and database is based on the AIM (Asia-Pacific Integrated Model) group of computer simulation models created to analyse the impacts of climate change and mitigation policies for the region.

The IEA sub-project will be able to use the models to analyse the results from the Integrated Environmental Monitoring (IEM) sub-project to prepare scenario options for the Research on Innovative and Strategic Policy Options (RISPO) sub-project in its research on innovations and strategic policy options. Also, as economic growth in the region comes up against social, economic and environmental limits, the models and database will provide policy makers with innovative strategies that help make development more environmentally benign and socially acceptable. In particular, the outcomes of the IEA sub-project will help policy makers to understand the relationships between economic growth and environmental conservation, and to imagine different future scenarios for socio-economic development that break through the conflicts between these two forces. Policy makers will be able to estimate the effects of innovations on sustainable development and use the models and databases to train experts for their local situations.

The IEA sub-project has three stages that overlap somewhat. In the first and current stage, a family of models based on those of the AIM project is being developed **(Figure 1)**. The second stage, which has begun for some models, will forecast future environmental and economic trends in the region and assess innovation strategies. In the third stage, the strategic database (the design and preparation of which is occurring during the earlier stages) will be established to store collected data, input assumptions and simulated outputs from the innovation strategies. The database will also be organised so that policy makers can use it to prepare sustainable development policies.

By the end of 2004, the IEA sub-project will provide APEIS with a database of policy, investment and technological innovations as well as integrated models of the economy and environment. These will be used to project regional socio-environmental trends and assess strategies for environmentally sympathetic development in the Asia-Pacific region. The models include a multi-regional simple trend model (AIM/Trend), overall integrated models (AIM/CGE [Computable General Equilibrium] as part of AIM/Top-down, and AIM/Bottom-up), a material-economy integrated model (AIM/Material), an energy technology model (AIM/Energy), and a set of ecosystem models covering water, agriculture, vegetation and health (AIM/Ecosystem and AIM/Water).

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

The IEA team has already made significant advances in the development of its models, so expectations for model development and modelling outcomes are high. The final versions of AIM/Trend and AIM/Energy are complete, and preliminary versions of four other models, AIM/CGE, AIM/Material, AIM/Ecosystem and AIM/Water, have been developed.

The six models that comprise the AIM/APEIS IEA family will be able to assess environment–economy interactions as well as innovation strategies in the Asia-Pacific region. Each of these models has a specific role in the family.

2.1. AIM/Trend

AIM/Trend is a multi-regional model with a simple structure that projects future socio-economic trends and environmental change to 2032 for all 42 countries in the Asia-Pacific region **(Figure 2)**.

It was used to examine some energy and environmental consequences of four scenarios (Market Forces, Policy Reform, Fortress World and Great Transition[1]) prepared by the United Nations Environment Program's Global Environment Outlook 3 for the Asia-Pacific region. It found that the diversity of results for CO_2 emissions emphasised the importance of specific country-level studies. Specifically, the 'Fortress World' scenario did nothing to reduce energy-related CO_2 and SO_2 emissions, 'Policy Reform' was the only scenario to reduce emissions by 2032. It was also used to simulate the market-scale development of the environmental industry in each country in Asia by using these four scenarios. Japan, China, India and Korea are seen as the basis for the growth of the environmental industry **(Figure 3)**.

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[1] The main assumptions for each of the four scenarios are as follows:
Market Forces: Most of the world adopts the values and expectations prevailing in today's industrialised countries. The wealth of nations and the interplay of market forces dominate social and political agendas.
Policy Reform: Decisive initiatives are taken by governments in an attempt to reach specific social and environmental goals. A coordinated pro-environment and anti-poverty drive balances the momentum for economic development at any cost.
Fortress World: This scenario assumes a world of striking disparities where inequality and conflict prevail. Socio-economic and environmental stresses give rise to waves of protest and counteraction.
Great Transition: A new environment and development paradigm emerges in response to the challenges of sustainability, supported by new, more equitable values and institutions.

Recently, the IEA team began to modify AIM/Trend so that it can be applied to the demand for biomass, such as food consumption **(Figure 4)**. The accessibility of AIM/Trend for users continues to be improved, and work on this and the development of a version in MS Word are major tasks for 2003.

2.2. AIM/CGE (Asia)

AIM/CGE is a top-down, multi-regional, multi-sectoral, general-equilibrium-type world economic model with environmental modules for regional use **(Figure 5)**. It will be used to assess the environmental and economic effects of new market establishment, new investment, technology transfer and international trade.

This model is now being further developed to cover 17 countries and 24 industrial sectors in the Asian region until 2100. AIM/CGE (Asia) is a central component of AIM/Trend, being integrated with bottom-up technology and land-use models for the Asia-Pacific region. It will use the simulations from AIM/Trend as benchmarks for assessing future scenarios for different Asian countries.

The top-down approach allows identification of the most efficient and innovative options for countermeasures to environmental problems through investment in natural resource management and technology transfer, including sources of funding from domestic and/or foreign capital. Current work on the first version of the model includes collection and modification of energy data; determining balances in economic and material flows; inclusion of regional economic characteristics; and describing technologies.

2.3. AIM/Energy

AIM/Energy is a bottom-up technology selection model of energy use for selected countries in the region **(Figure 6)**. It will reproduce the process of technology selection for energy supply and demand. The model includes data on 400 technologies to help choose the best mix of technologies in a future with defined socio-economic conditions **(Box 1)**.

AIM/Energy, in its different forms and uses, has been applied to China, India, Korea, Vietnam and Japan. These applications showed the potential to minimise the emissions produced by rapid economic growth over time, using different methods most suited to each country. It illustrated the reasons behind China's substantial improvements in energy efficiency and CO_2 reduction during the 1990s. These reasons are: technological progress in China's steel, power generation and building materials industries; China's use of cleaner fuels; changes in the structure of the Chinese economy; and China's introduction of stringent environmental policies. The marginal cost of further emission reductions in China is very high, but this is not the case for India, for example, which could relatively cheaply invest to produce greater energy efficiencies **(Figure 7)**.

A preliminary end-use model, which uses standardised technologies, has been prepared for a group of about 30 Asian countries. Future work includes designing specific technologies for each country and applying AIM/Energy to other countries in the region. AIM/Energy will be used for more detailed analyses of climate change in the region, and will be extended to include the impacts of methane and N_2O. Whereas the analyses of the impacts of CO_2 emissions were based on fossil-fuel-driven technologies, the analyses of methane and N_2O will be extended to include technologies based on other fuels, such as biomass. Also, the model will be used for analyses of Clean Development Mechanisms to identify potential future technologies.

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Box 1: Frontier 1

Information on more than 400 technologies has been collected for use with AIM/Energy. This includes initial and maintenance cost data; technology lifetimes; relationships with other technologies; efficiency; and use of energy and materials. The technology selection process is reproduced in AIM/Energy. These technology-based simulations are very important in determining the parameters of economic models.

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Box 1 AIM technology file (extract)

Classification	Technologies (equipment)
Iron & Steel	Coke oven, Sintering machine, Blast furnace, Open hearth furnace (OH), Basic oxygen furnace (BOF), AC-electric arc furnace, DC-electric arc furnace, Ingot casting machine, Continuous casting machine, Continuous casting machine with rolling machine, steel rolling machine, Continuous steel rolling machine, Equipment of coke dry quenching, Equipment of coke wet quenching, Electric power generated with residue pressure on top of blast furnace (TRT), Equipment of coke oven gas, OH gas and BOF gas recovery, Equipment of co-generation.
Non-ferrous metal	Aluminum production with sintering process, Aluminum production with combination process, Aluminum with Bayer, Electrolytic aluminum with upper-insert cell, Electrolytic aluminum with side-insert cell, crude copper production with flash furnace, crude copper production with electric furnace, Blast furnace, Reverberator furnace, Lead smelting-sintering in blast furnace, Lead smelting with closed blast furnace, Zinc smelting with wet method, Zinc smelting with vertical pot method.
Building materials	Cement: Mechanized shaft kiln, Ordinary shaft kiln, Wet process kiln, Lepol kiln, Ling dry kiln, Rotary kiln with pro-heater, dry process rotary kiln with pre-calciner, Self-owned electric power generator, Electric power generator with residue heat; Brick & Tile: Hoffman kiln, Tunnel kiln; Lime: Ordinary shaft kiln, Mechanized shaft kiln; Glass: Floating process, Vertical process, Colburn process, Smelter.
Chemical industry	Equipment of synthetic ammonia production: Converter, Gasification furnace, Gas-making furnace, Synthetic column, Shifting equipment of sulphur removing; Equipment of caustic soda production: Electronic cell with graphite process, Two-stage effects evaporator, Multi-stage effects evaporator, Equipment of rectification, Ion membrane method; Calcium Carbine production: Limestone calciner, Closed carbine furnace, Open carbine furnace, Equipment of residue heat recovery; Soda ash production: Ammonia & salt water preparation, limestone calcining, distillation column, filter; Fertilizer production: Equipment of organic products production, Equipment of residue heat utilization
Petrochemical Industry	Facilities of atmospheric & vacuum distillation, Facilities of rectification, Facilities of catalyzing & cracking, Facilities of cracking with hydrogen adding, Facilities of delayed coking, Facilities of light carbon cracking, Sequential separator, Naphtha cracker, de-ethane separator, diesel cracker, de-propane cracker, facilities of residue heat utilization from ethylene.
Paper-making	Cooker, facilities of distillation, facilities of washing, facilities of bleaching, evaporator, crusher, facilities of de-water, facilities of finishing, facilities of residue heat utilization, facilities of black liquor recovery, Co-generator, Back pressure electric power generator, condensing electric power generator.
Textile	Cotton weaving process, Chemical fiber process, Wool weaving & textile process, Silk process, Printing & dyeing process, Garment making, Air conditioner, Lighting, Facilities of space heating.
Machinery	Ingot process: Cupola, Electric arc furnace, fan; Forging process: coal-fired pre-heater, Gas-fired pre-heater, Oil-fired pre-heater, Steam hammer, Electric-hydraulic hammer, Pressing machine; Facilities of heat processing: Coal-fired heat processing furnace, Oil-fired heat processing furnace, Gas-fired heat processing furnace, Electric processing furnace; Cutting process: Ordinary cutting, high speed cutting.
Irrigation	Diesel engine, Electric induct motor
Farming works	Tractor, Other agricultural machine
Agricultural products process	Diesel engine, Electric induct motor, processing machine, coal-fired facilities.
Fishery	Diesel engine, Electric induct motor.
Animal husbandry	Diesel engine, Electric induct motor, Other machines.
Space heating in resident	Heat supplying boiler in thermal power plant, Boiler of district heating, Dispersed boiler, Small coal-fired stove, Electric heater, Brick bed linked with stove (Chinese KANG).
Cooling in resident	Air conditioner, Electric fan.
Lighting in resident	Incandescent lamp, Fluorescent lamp, Kerosene lamp.
Cooking & Hot water in resident	Gas burner, bulk coal-fired stove, briquette-fired stove, Kerosene stove, Electric cooker, cow dung-fired stove, firewood-fired stove, methane-fired stove.
Electric Appliance	Television, Cloth washing machine, Refrigerator, others.
Space heating in service sector	Heat supplying boiler in the thermal power plant, Boiler of district heating, dispersed boiler, Electric heater.
Cooling	System of central air conditioner, Air conditioner, Electric fan.
Lighting	Incandescent lamp, fluorescent lamp.
Cooking & Hot water	Gas burner, Electric cooker, Hot water pipeline, Coal-fired stove.
Electric Appliance	Duplicating machine, computer, Elevator, others.
Passenger & freight transport	Railway (passenger & freight): Steam locomotive, Internal combustion engine locomotive, Electric locomotive.; Highway (passenger & freight): Public diesel vehicle, Public gasoline vehicle, Private vehicle, Large diesel freight truck, Large gasoline vehicle, small freight truck. Waterway (passenger & freight): Ocean-going ship, Coastal ship, Inland ship. Aviation (passenger & freight): Freight airplane, passenger airplane.

2.4. AIM/Material

AIM/Material is a country-based environment–economy-integrated model dealing with environmental investment and the environmental industry **(Box 2)**. A bottom-up technology selection model will be constructed to support AIM/Material. Material balance and recycling process modules for India and China have also been developed.

AIM/Material was used to assess the direct reuse of waste as an effective environmental policy. The results indicated that such direct reuse helps solve waste disposal problems, but delays improvements in energy efficiencies. The development and integration of a new module into the model will assist further investigation of this topic. 'AIM/Material Japan' examined different reforms to taxation in Japan and the introduction of new environmental policies. It found that the impacts of policy changes on the nation's GDP can be ameliorated by expansion of the environmental industry, technological improvements, an expansion of green consumerism, and subsidisation of waste treatment.

New simple models of AIM/Material were developed for India and China, and a comparative analysis was begun for these two countries on the effects of implementing Clean Development Mechanisms (CDMs). The work on China found that the effects of CDM investment will extend to the national economic level through changes in investment patterns, technological improvements in production efficiencies, and pollution control. The work on India will be conducted during 2003, and it is intended to include Japan in the comparison.

The structure of the Indian model was also modified so that it could be applied to natural resource use, and trial simulations examined suitable policies for sustainable development that included constraints on natural assets and potential countermeasures to these constraints. The simulations showed that investment in the environmental industry could substantially compensate for economic restrictions caused by policies that reduce production of industrial wastes. Also, they showed that early investment in land conservation measures could provide substantial national financial benefits **(Figure 8)**.

Initial attempts have been made to integrate a general equilibrium model with information on natural systems in order to reproduce environmental loads as well as their feedbacks to the economy. Preliminary results indicated that investment in land management and ecosystem protection at an early stage can help economic growth later, when related environmental constraints become severe. However, there are also undesirable impacts in other environmental fields that require complementary countermeasures.

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Box 2: Frontier 2

AIM/Material has the prime objective of maintaining economic and material balance. It was constructed so that it could simultaneously analyse policies on the global climate and domestic environmental issues, and in particular solid waste management. Three linked modules allow this to occur. A module on the environmental industry disaggregates this

industry from ordinary production sectors; a module on pollution management disaggregates this function and includes data for pollution control as inputs for the production function; and a module on solid waste management directs the reuse, final disposal and intermediate management of residues for reuse or disposal.

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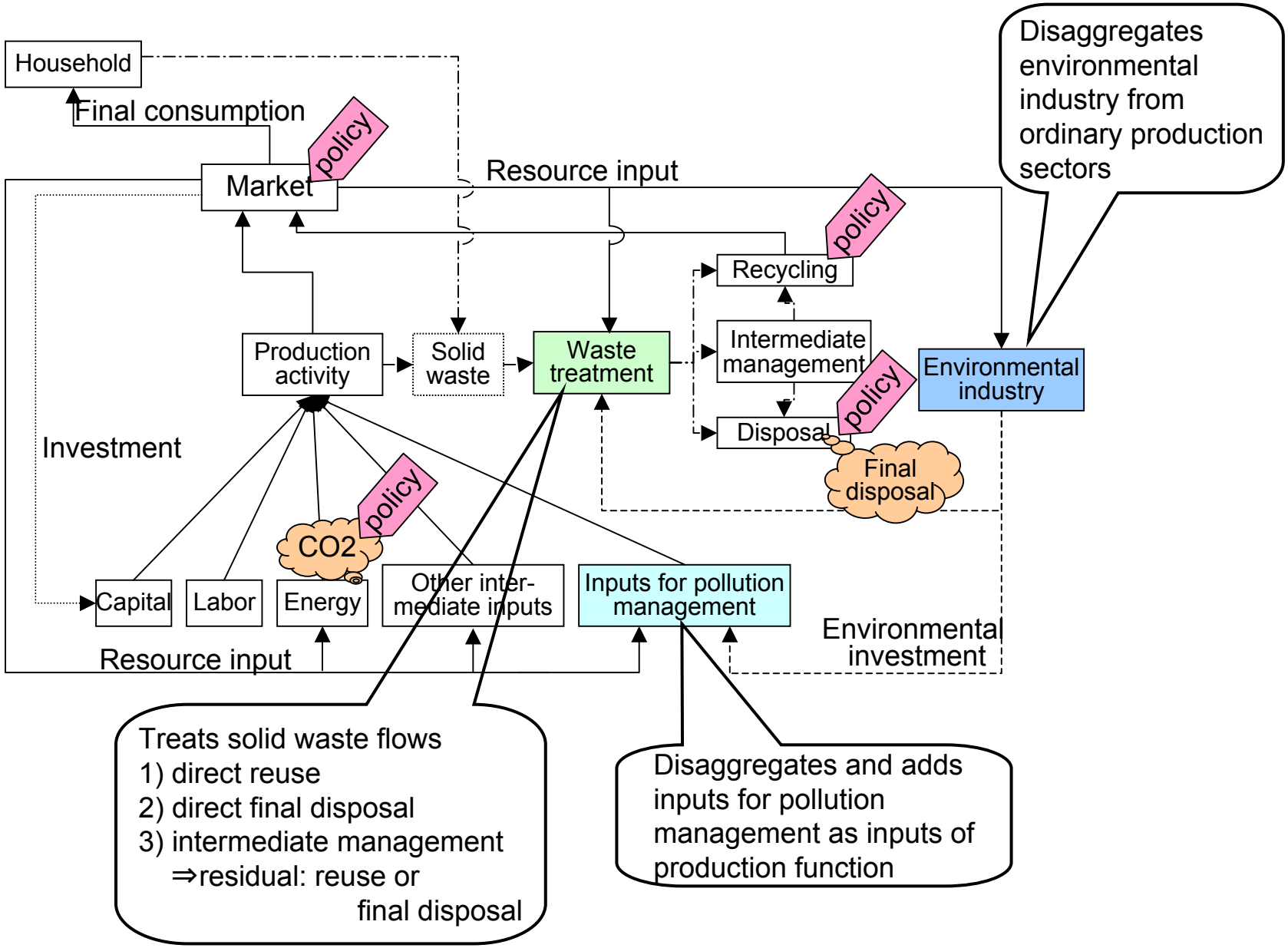

Box 2 Features of AIM/Material

2.5. AIM/Ecosystem

AIM/Ecosystem is a group of models that simulate water discharge, vegetation dynamics, agricultural productivity, natural processes of ecosystem change, land-use changes and socio-economic changes (such as human health and economic impacts) caused by changes to ecosystems **(Box 3)**. These models can be linked for integrated assessments of ecosystem changes, and for the APEIS-related research they will be linked for integrated studies of each country. AIM/Water is included in the group of AIM/Ecosystem models, but is also used by itself.

AIM/Ecosystem and other AIM models have been used in preliminary assessments of Millennium Ecosystem Assessment (MA) scenarios. These assessments found **(Figure 9)** that:

- a 'Global Policy Focus Scenario' (globalisation-based development) would protract ecosystem degradation
- a 'Technology Focus Scenario' would polarise regional ecosystem conditions into two extremes and
- a 'Cross-scale Management Focus Scenario' (regional-based development) would sustain high regional incentives for ecosystem conservation.

Part of AIM/Ecosystem was used to model the stress on regional water resources caused by the interaction between economic development and ecosystem change **(Figure 10)**.

AIM/Ecosystem will continue to be used to produce integrated quantification of changes resulting from the five MA scenarios for a future world. Currently, it is being developed by linking it with an ecological model to illustrate impacts on ecosystems and the costs of those impacts, and related feedbacks and the economic impact of those feedbacks. It will also be applied to other problems, such as air and water pollution, land degradation, loss of biodiversity, and the implications of household preferences for those problems. Researchers will use the model to investigate the environmental consciousness of households and their willingness to pay for environmental services. This will be reflected in the development of future scenarios.

AIM/Water is a component of AIM/Ecosystem. It reproduces the processes of water discharge, water demand, water supply and water pollution **(Figure 11)**, and will be important in assessing the interactions between city development and environmental impact as urbanisation continues in the Asia-Pacific region.

AIM/Water is currently being developed by the AIM team to analyse issues related to water use, and will incorporate an existing AIM model on agricultural water use. When AIM/Water is integrated with this model, it will be able to:

- analyse water demand and availability to determine the level of water stress
- evaluate the costs, benefits and effectiveness of environmental policies and investment

- conduct analyses of long-term scenarios of water use, taking into account changes in socio-economic factors, life-styles and climate change.

In its preliminary form, AIM/Water was used to examine the use of treated water in metropolitan Tokyo's 23 wards **(Figure 12)**. It estimated water consumption by domestic, industrial and commercial users, and the experience gained from this exercise will be used when modelling the water use of other Asian cities and countries.

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Box 3: Frontier 3

AIM/Ecosystem treats natural resources and environmental services as indispensable inputs to economic production and people's lives. It uses descriptions of these services, environmental protection activities and interactions that produce economic consequences, such as air quality control, water regulation and erosion, to model the interactions between human activities and environmental processes. The structure of the model is similar to that of AIM/CGE, but includes a sector for protecting natural capital ('Natural Capital Maintenance') and a sector to express the production of environmental goods and services ('Environmental Goods/Services Production'), which are linked through 'Natural Capital' (land, water, air and other natural ecosystems). These provide feedback on environmental impacts into the model by using inputs from the market and the household and government sectors.

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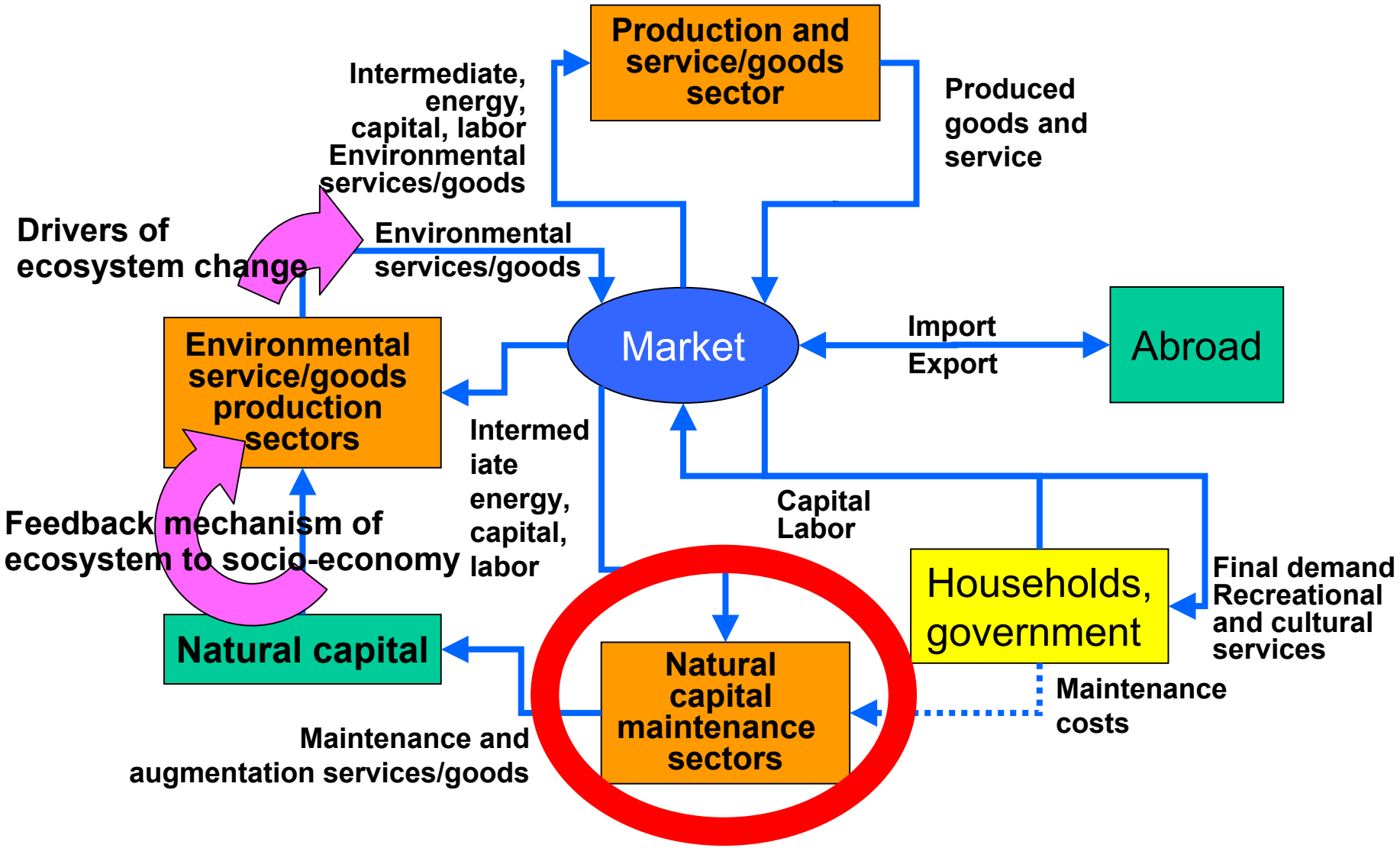

Box 3 The structure of AIM/Ecosystem

2.6. Database

The strategic database will store all IEA simulation results and statistics related to the AIM/APEIS family of models, as well as the monitoring and processing data from the IEM sub-project and information related to the RISPO case studies **(Figures 13 and 14)**. It will contain data on several hundred social and technical innovations, basic data on Pressures, States, Responses, Driving Forces and Social and Institutional Capacities related to environmental issues in each country, and detailed information on countermeasure scenarios and their impacts. It will be able to select the best mix of innovative options by Nation and other specific fields using the data that it stores. It will also store information on Environmental Indicators and Environmental Innovation Indicators that can be used to represent the changing conditions of socio-environmental problems and the impacts of the application of different innovations.

Preparation of the Strategic Database and Indicators advances well. As the basic framework for the database has been completed, staff have begun collecting suitable data on social and technological innovations and environmental indicators for input **(Figure 15)**. Also, work continues on improving the human–machine interface for this user-friendly software.

The main tasks over the next 12 months are to add data on costs, organization, environmental effects and lifetimes of more than 400 technical and social innovations; input information on the pressure, state, response, driving force and capacity of basic data and baseline ('business as usual') projections for each country and policy intervention scenario; and develop a simple calculation module to estimate the effects of innovations. The module will identify the top 10 innovations for specific environmental protection situations.

2.7. Scenario development

Long-term emission scenarios were supplied to the International Panel on Climate Change (IPCC). These were based on simulations using AIM/CGE and AIM/Energy. **Figure 16** shows projected CO_2 and SO_2 emission scenarios over the next 300 years. These scenarios will be input into climate simulations for the IPCC assessment report, and are aimed at stabilising atmospheric CO_2 concentrations at 450–750 ppm.

The United Nations Environment Program (UNEP) Global Environmental Outlook (GEO) prepared four future development paths. The resulting scenarios were Market Forces; Policy Reform, based on Market Forces, Fortress World and Great Transition. The emission scenarios were supplied from AIM/Energy and AIM/Trend. **Figure 17** shows that a comprehensive emission policy is needed for the Asian region to reduce CO_2 emissions.

Three scenarios of the Millennium Ecosystem Assessment were simulated to clarify the relationships between ecosystem change and socio-environmental change. These scenarios were Globalisation, Regionalisation and Technology Introduction. **Figure 18** shows the projected NO_x emissions released by the burning of biomass for the three

scenarios in six regions. Technological innovation is very necessary to reduce biomass-energy-related emissions. **Figure 19** shows the projected change in the area of cropland for the three scenarios and six regions. The Regionalisation scenario produces serious competition between agricultural land-use and forest protection / nature conservation. This kind of tension in land use could encourage technical innovations for regional ecosystem management, and the modelling of the Regionalisation scenario illustrates this potential.

Scenarios were also supplied to the International Energy Agency, the Economic and Social Commission for Asia and the Pacific) ESCAP, ECO-ASIA and international academic societies, such as the Energy Modelling Forum at Stanford University and the Global Scenario Comparison conducted by Kassel University.

2.8. Capacity building

The IEA team has integrated capacity building into the process of developing and applying its models to ensure that its work is distributed and used in the Asia-Pacific region. Input from foreign experts, especially those in developing countries, is essential for further model development in Japan and for cooperation in the adaptation of models to suit local conditions and perspectives.

Work on capacity building by the sub-group has had three facets. The first was the preparation of Guideline Manuals for AIM/Trend and AIM/Energy. These manuals were transferred to appropriate experts in foreign countries. Also, the AIM team has invited four researchers – two from China and two from India – to train in Japan using the AIM models. The team has held two training workshops in India and China, which were well attended and most successful. The activities of the Indian workshop can be found at http://www.nies.go.jp/social/aim/workshop.htm.

2.9. Preliminary Message

The preliminary work from the IEA sub-project has produced a number of useful and important conclusions:

1. The potential for introducing technological innovations for environmental protection in the region is very large, but differs between countries

2. The effects of technological innovations would be increased by combining them with social innovations, and regional cooperation is needed to achieve this

3. Integration of top-down and bottom-up incentives would encourage innovation introduction, and investment in protecting natural capital would bring double dividends through environmental protection and socio-economic development

4. The following of globalisation policies on development and the environment would support the introduction of innovations for reducing waste emissions, but would hinder the introduction of innovative policies for ecosystem conservation

5. Introducing technological innovations alone encourages polarisation of the region's capacity for managing environmental issues

These preliminary conclusions will be subject to more detailed assessment and tested and refined over the next 12 months.

3. How can the APEIS-IEA products be applied for policy formulation/implementation works?

The environmental assessments of IEA can provide policy-makers with the ability to visualize the consequences of environmental policies and the benefits of environmental innovations such as changes in consumption patterns, development of the eco-industries, and deployment of advanced technologies. Sophisticated models help policy-makers understand the complicated relationships between economic growth and environmental protection, as well as the power of innovation to steer human activities in a sustainable direction.

There are several strands to the intended activities of the IEA sub-project. AIM/Trend will be extended to other regions to compare their trends and changes, so that it can be applied at a global level. Full versions of AIM/CGE, AIM/Material with material balance and recycling process modules for India and China, AIM/Water and the full version of AIM/Energy for extended countries will be completed. A preliminary version of AIM/Ecosystem will be prepared. The strategic database and indicators for the Asia-Pacific region, concentrating on 'environmental efficiency', will be finalised, and full projections of environmental trends and full assessments of innovative options focusing on selected countries will be provided. The sub-project will also hold training workshops in the region at locations yet to be decided.

The ultimate objective of this work is to help policy makers understand the relationships between economic growth and environmental conservation, as well as the role of innovations, to break through the trade-offs between these factors and create sustainable socio-economic development. The models and databases will be able to be used to train experts on local areas who can play crucial roles in such processes.

Specifically, using the AIM modules and databases, local modellers and policy/decision makers will be able to develop the most appropriate innovation strategies for specific socio-environmental problems in their areas, taking into account local social, economic and environmental conditions.

By using the strategic database, policy makers will be able to review future scenarios and related information and suggest narrative changes to the modellers, who will be able to transform the suggested changes into new simulations. This process of discussion and revision can continue until desirable future scenarios are achieved.

4. Relevant Information

Participating organisations and relevant Internet sites

Energy Research Institute, Beijing, China

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/

Sangmyung University, Chung Nam, Korea

http://libnt.smuc.ac.kr/index.htm

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/

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Asia-Pacific Integrated Model

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