13. AIM/Trend: Policy Interface

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Summary. The model for assessing the future environmental loads based on the past socio-economic trends has been developed. By using this model, the environmental trends until 2032 in the Asia-Pacific 42 countries have been estimated. This AIM/Trend model has characteristics of econometric model and communication tool to enhance discussions and search for countermeasures by envisaging environmental conditions in a consistent way. Results of AIM/Trend model show that Asia-Pacific countries have a wide range of economy, energy, and environment conditions. It makes the country-level study in this region more important to deal with the diversity of Asia-Pacific countries.

13.1 Introduction

The Asia-Pacific region is expected to lead global economy due to its rapid increase of population and economic growth in the earlier of 21st century. On the other hand, it is said this economic development will cause significant damage on regional and global environment without any appropriate measures.

Though the study on its economy, energy, and environment is becoming more important, the variety of Asia-Pacific culture, society, and natural resources in a country-level makes it difficult to understand policy and future projection. It is necessary to develop the model that evaluates the effects of each country's policy to country-level, regional, and global environment. It is also important that each country's policymakers who know well the country can use the model easily. Our team has been developing the model for assessing the future environmental loads based on the past socio-economic trends and future scenarios. By using this model, the environmental trends until 2032 in the Asia-Pacific countries have been estimated (Fig.1).

AIM/Trend model is built as a simple econometric model and written in ATPL (AIM/Trend Program Language) using VBA in Microsoft Excel. The user can change the model structure and make sensitivity analysis. Results of AIM/Trend model are used as Asia-Pacific scenario in UNEP/GEO-3 (UNEP 2002).

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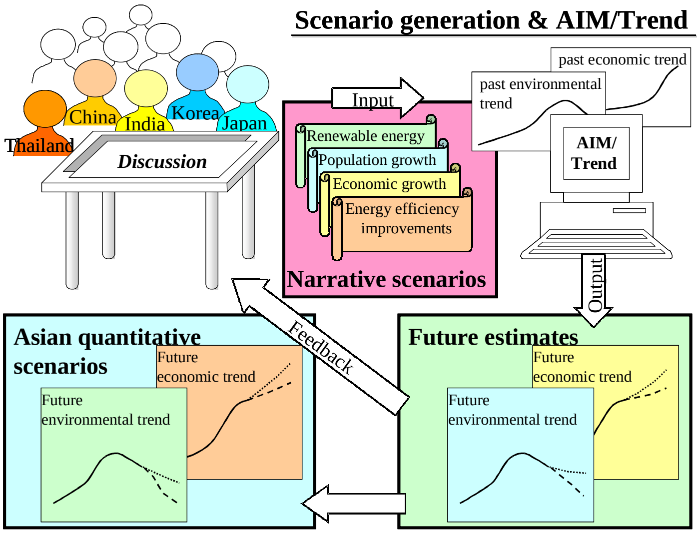

Fig. 1. Concept of AIM/Trend model (see color plates)

13.2 Structure of AIM/Trend Model

13.2.1 Framework

AIM/Trend model is an econometric model to estimates future conditions of economy, energy, and environment (Fujino 2002). It calculates the relationships between each parameter by regression method and extrapolates those relationships for the future projection. It makes simulations of energy supply and demand, GHG emissions, waste emission, water supply and demand, and so on by setting basic data –population GDP, GDP per capita, GDP share, etc. – as driving forces (Fig.2). In this chapter, the module of energy supply and demand is mainly focused.

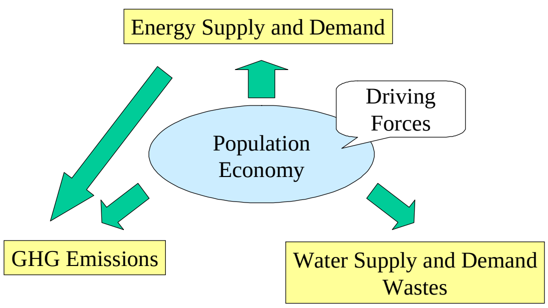

Fig. 2. Framework of AIM/Trend model

Target countries

This model covers 42 countries in the Asia-Pacific region shown in Table 1. They are divided into two categories: Model A and Model B. Model A uses detailed energy data, IEA energy statistics data. Model B uses simple energy data, UN energy data. The countries can be grouped in five regions: South Asia, Southeast Asia, East Asia, Central Asia, and ANZ and South Pacific.

Table 1. Target countries

Detailed Data (Model A)				Simple Data (Model B)			
	Code	Country	Group		Code	Country	Group
1	BGD	Bangladesh	SA	1	AFG	Afghanistan	SA
2	IND	India	SA	2	BTN	Bhutan	SA
3	IRN	Iran	SA	3	MDV	Maldives	SA
4	LKA	Sri Lanka	SA	4	BRN	Brunei	SEA
5	NPL	Nepal	SA	5	KHM	Cambodia	SEA
6	PAK	Pakistan	SA	6	LAO	Laos	SEA
7	IDN	Indonesia	SEA	7	MNG	Mongolia	EA
8	MMR	Myanmar	SEA	8	FJI	Fiji	SP
9	MYS	Malaysia	SEA	9	KIR	Kiribati	SP
10	PHL	Philippines	SEA	10	NRU	Nauru	SP
11	SGP	Singapore	SEA	11	PLW	Palau	SP
12	THA	Thailand	SEA	12	PNG	Papua New Guinea	SP
13	VNM	Vietnam	SEA	13	PYF	French Polynesia	SP
14	CHN	China	EA	14	SLB	Solomon Islands	SP
15	JPN	Japan	EA	15	TON	Tonga	SP
16	KOR	Korea, Rep	EA	16	VUT	Vanuatu	SP
17	PRK	Korea, Dem	EA	17	WSM	Samoa	SP
18	TWN	Taiwan	EA				
19	KAZ	Kazakhstan	CA				
20	KGZ	Kyrgyz Republic	CA				
21	TJK	Tajikistan	CA				
22	TKM	Turkmenistan	CA				
23	UZB	Uzbekistan	CA				
24	AUS	Australia	SP				
25	NZL	New Zealand	SP				

Code	Group
SA	South Asia
SEA	Southeast Asia
EA	East Asia
CA	Central Asia
SP	ANZ and South Pacific

Note: Though it has IEA energy statistics data, Brunei is treated in Model B because of its special structure of energy supply and demand.

Simulation period

The Johannesburg summit was held at August 2002. The target year is set as 2032, 30 years after the summit.

Target indices

Following indices are selected and will be evaluated by AIM/Trend model (sign "*" means the element under consideration):

- Population: population, rate of urbanization
- Economy: GDP (growth rate, per capita), GDP share (agriculture, industry, service, PFC (private final consumption), car numbers
- Energy: primary energy supply by fuel, final energy demand by fuel and sector, energy plant, economic intensity, carbon intensity
- GHG emissions: CO_2, SO_x, NO_x, CH_4, N_2O, CO
- Waste: waste emission, landfill*, recovery of waste*
- Water: withdrawal, consumption (agriculture, industry, domestic), population in water stress*
- Food and Agriculture*: average daily consumption, vegetable food consumption, animal food consumption, fraction of meat from feedlots, fish production, crop production, feed production, nitrogen fertilizer consumption
- Land use*: crop land, irrigated cropland, potential cultivable land, mature forest, growing forest, pasture, protected, other land
- Human Health*: SPM (PM10, PM2.5)
- Biodiversity*: species, degree of threat to biological diversity, area of habitat remaining

13.2.2 Model structure

AIM/Trend model consists of Modal A with detailed energy data and Model B with simple energy data. The model structures of Model A and Model B are explained in following sections.

Detailed data model (Model A)

Model A covers 25 countries that have the IEA energy statistics. The calculation flow of Model A focused on energy is shown in Fig. 3. Model A is built up by following order: final energy demand, energy conversion, and primary energy.

(1) Energy classification

Following 10 energies are treated in this Model A: COL (coal), OIL (crude oil and petroleum products), GAS (gas), CRW (combustible renewables and waste), NUC

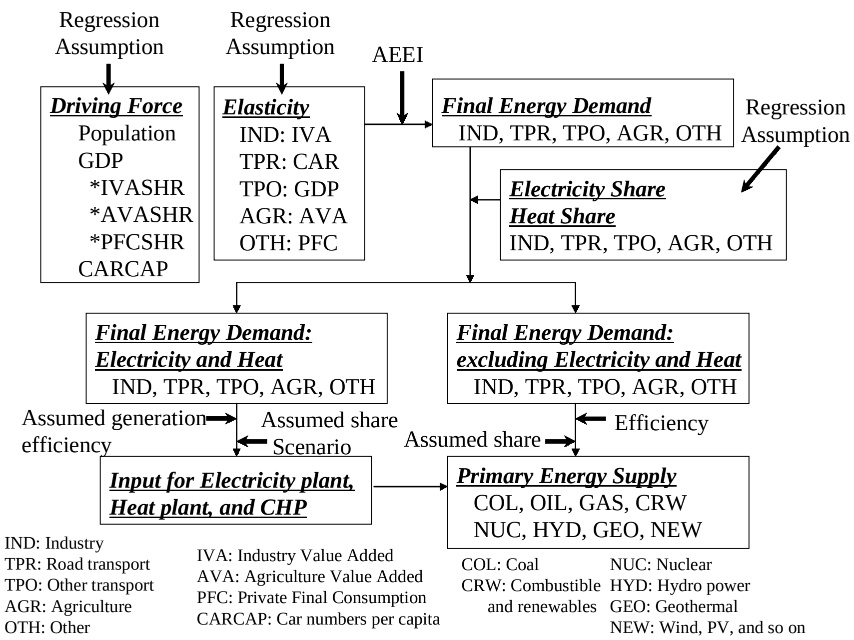

Fig. 3. Calculation flow of detailed data model (Model A)

(nuclear), HYD (hydro power), GEO (geothermal), NEW (wind, PV, and so on), HET (heat), and ELE (electricity).

(2) Energy sector classification

Energy conversion sector has following 5 sub-sectors: ELP (power generation), HTP (heat supply system), CHP (combined heat and power plant), DST (distribution of energy), and TFM (transformation). The final energy demand sector has following 6 sectors: IND (industry), TPR (transport on road), TPO (other transport), AGR (agriculture), OTH (other), and NEU (non-energy use).

(3) Estimation of final energy demand

Final energy demand except NEU is described as the function of driving force (DRV). Driving force of IND, TPR, TPO, AGR, and OTH is basically defined as industrial value-added (IVA), numbers of car (CAR), GDP, agricultural value-added (AVA) and private final consumption expenditure (PFC), respectively. Elasticity between each final energy demand and driving force is calculated by regression analysis using historical data. If these data are not available, GDP can be used for the driving force. Following equation is assumed:

$$TFE_i(t) = A_i(t) \times TFE_i(t_0) \times \{DRV_i(t) / DRV_i(t_0)\}^{ELS_i} \quad (1)$$

$$A_i(t) = (1 - AEEI_i(t)/100)^{(t-t_0)}$$

where,

$TFE_i(t)$: total final energy demand for sector i, time period t

$DRV_i(t)$: driving force for sector i, time period t

ELS_i : elasticity for sector i

$AEEI_i(t)$: autonomous energy efficiency improvement for sector i, time period t

i : final energy demand sector, i ={IND,TPR,TPO,AGR, OTH}

t : simulation time period, t_0: initial time period

NEU (Non-energy use demand) is estimated from the following equations. It is supposed that NEU consists of oil by historical data.

$$NEU(t) = FE_{IND,OIL}(t) / FE_{IND,OIL}(t_0) \times NEU(t_0) \quad (2)$$

where,

$FE_{i,e}(t)$: final energy demand for sector i, energy e, time period t

e : energy, e ={OIL, COL, GAS, CRW, NUC, HYD, GEO, NEW, ELC, HET}

(4) Estimation of driving force

To estimate the trajectory of driving force (IND, TPR, TPO, AGR, and OTH), IVASHR (GDP share of IVA), CARCPT (car numbers per capita), PFCSHR (GDP share of PFC), and AVASHR (GDP share of AVA) are estimated from regression analysis using GDP per capita for independent variables. To estimate IVASHR in other way SVASHR (GDP share of SVA (service value added) is also estimated. The relationships between AVASHR, SVASHR and GDP per capita using South Asia, East Asia, and South East Asia data from 1980 to 1995 of HYDE/RIVM are shown in Figs. 4 and 5 (Klein, *et al.* 1995).

(5) Share of energy in final energy demand

Final energy demand consists of electricity, heat, and others.
a) Share of electricity: The share of electricity in each final energy sector is estimated by using the regression analysis using driving force for independent variable.
b) Share of heat: The share of heat is fixed at that in the latest data existed year in all sectors.
c) Share of other energy: The share of fossil fuel energy is estimated by using the regression analysis using driving force for independent variable.

(6) Fuel share and energy efficiency in energy conversion sector

CHP and HTP are only used in specific countries in the Asia-Pacific region. Share of fuel input into HTP and share of fossil fuel input into CHP are assumed to be

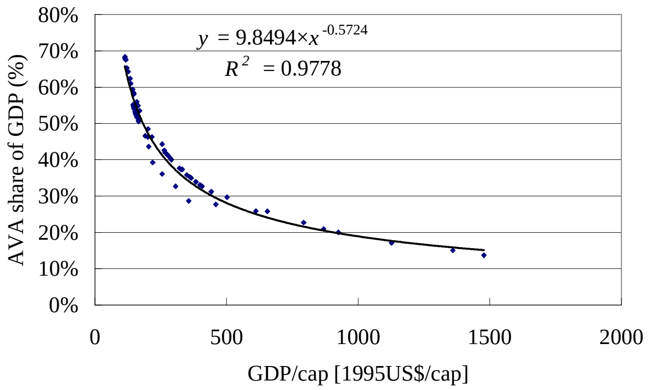

Fig. 4. Relationship between GDP per capita and AVA share of GDP

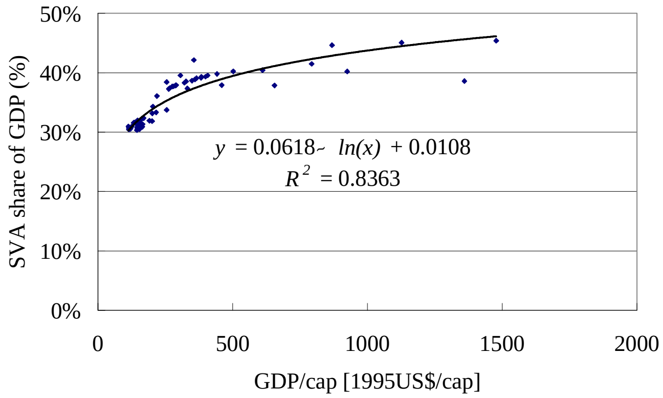

Fig. 5. Relationship between GDP per capita and SVA share of GDP

constant. Share of fossil fuel input into ELP is calculated by regression analysis. Non-fossil fuel input into CHP and ELP are depended on scenario assumption. The electricity generation efficiency of ELP and CHP with COL, OIL, GAS, and CRW is assumed by using exogenous energy efficiency improvement parameter. The generation efficiency of NUC, HYD, GEO, and NEW is fixed as IEA's definitions (NUC: 0.33, HYD: 1.0, GEO. 0.1, NEW: 0.1). The heat generation efficiency is assumed to be fixed as that in initial simulation period.

(7) Total primary energy supply

Primary energy supply is calculated with final energy demand, energy conversion process, and distribution loss. Distribution loss of fossil fuel, electricity, and heat is assumed to be constant as that in initial simulation period.

(8) GHG (CO_2, NO_X, SO_X, CH_4, N_2O, CO) emissions

Energy related GHG emissions are calculated by simulation result and assumed emission factor. NOx and SOx emissions are assumed to be reduced according to increase of GDP per capita, known as Kuznets curve.

Simple data model (Model B)

For the several countries, that are not available of IEA energy statistics data, Model B is constructed for estimation of environmental loads in the future.

UN Energy Statistical Yearbook 2000 (UN 2000) is used as energy data. Energies are categorized as Liquids, Solids, Gas, Electricity and Traditional fuelwood. Liquids, Solids, and Gas correspond to OIL, COL, and GAS in Model A respectively. Electricity (ELC) consists of supply from geothermal, hydro, nuclear, solar, tide, wind, wave, import and export. Traditional fuelwood (TRF) corresponds to CRW in Model A. Each energy supply is assumed to be decided by GDP and AEEI.

This can be given by the following equation:

$$PE_e(t) = A_e(t) \times PE_e(t_0) \times \{GDP(t)/GDP(t_0)\}$$
$$A_e(t) = (1 - AEEI_e(t)/100)^{(t-t_0)} \qquad (3)$$

$PE_e(t)$: primary energy supply for energy e, time period t

$GDP(t)$: GDP, time period t

$AEEI_e(t)$: autonomous energy efficiency improvement for energy e, time period t

e : energy, e ={OIL, COL, GAS, ELC, TRF}

t : simulation time period, t_0: initial time period

Model data

Following data are mainly used:

- Population: historical data (WB 2000), projection (UN 1998)
- GDP: historical data (WB 1999), projection (IMF 2001) (EIA/DOE 2001), IPCC/SRES scenario (IPCC 2000)
- Energy: for Model A (IEA 2001), for Model B (UN 2000)
- Emission factor: (IPCC 1996)

13.2.3 Model interface

AIM/Trend model is executed with ATPL (AIM/Trend Program Language) that is built with VBA of Microsoft Excel. Major commands consist of load, save, future parameter setting, future projection, format and regression. An illustration of AIM/Trend detailed data model (Model A) interface is shown in Fig. 6. Users can choose country and select cases for load and save. Clickable buttons such as Projection All, and Pam Set All are designed to perform simulations effectively. They are written in ATPL and users can write or change programs for their own purpose.

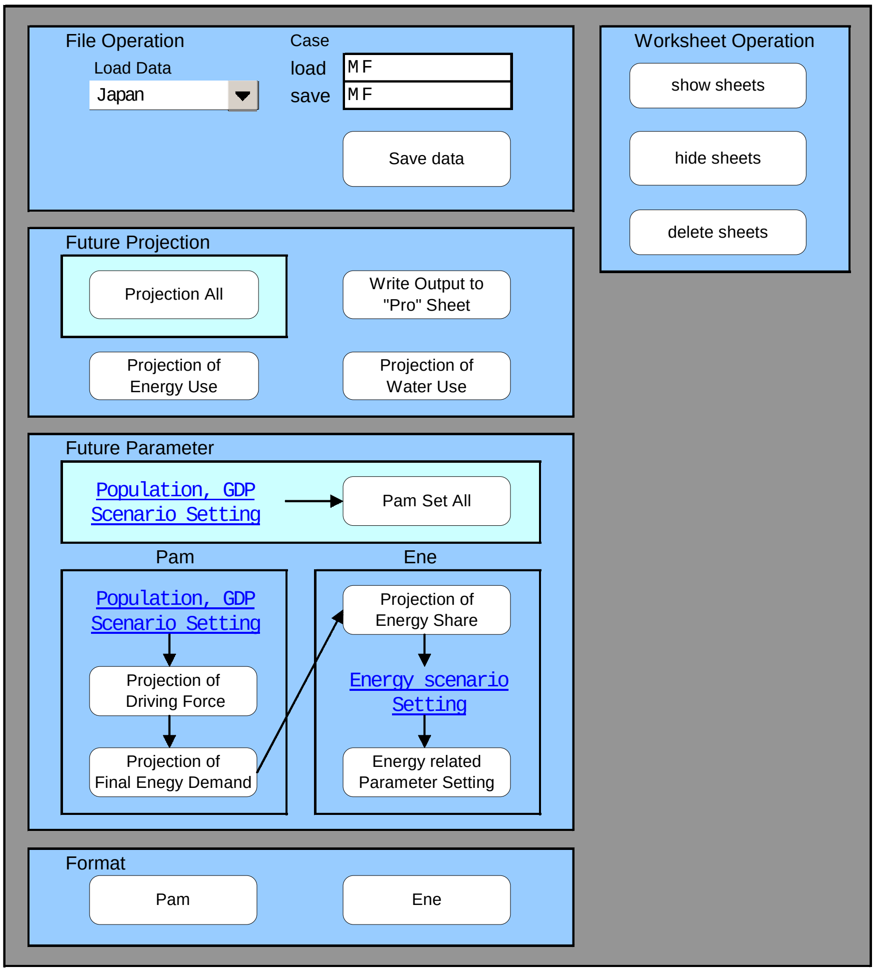

Fig. 6. AIM/Trend interface for detailed data model (Model A)

13.3 Middle-term Economy, Energy, Environment Scenario Simulation in the Asia-Pacific Region

13.3.1 Scenario study

UNEP published GEO-3: Global Environment Outlook 3 (UNEP 2002) before Johannesburg Summit. It focused on future scenarios from 2002 to 2032. The results of AIM/Trend model were adopted as the future projections in the Asia-Pacific region. GEO-3 prepared following 4 scenarios: Market First scenario, Policy First scenario, Security First scenario, and Sustainability First scenario. The Market First scenario envisages a world in which market-driven developments coverage on the values and expectations that prevail in industrialized countries; In the Policy First world, strong actions are undertaken by governments in an attempt to reach specific social and environmental goals; The Security First scenario assumes a world of great disparities, where inequality and conflict prevail, brought about by socio-economic and environmental stresses; and Sustainability First pictures a world in which a new development paradigm emerges in response to the challenge of sustainability, supported by new, more equitable values and institutions.

To address GEO-3 scenarios with AIM/Trend model, several parameters (GDP, population, AEEI, energy conversion efficiency, non-fossil energy supply, GHG emission control and so on) are set for each scenario.

13.3.2 Overview results

Figure 7 shows the historical data and future projection of major economy, energy, and environment indices in China. GEO3/Sustainablity First scenario is used to estimate future conditions of environmental loads.

Population will reach 1,500 million around 2030, though rate of increase in population will be decreasing annually. GDP will increase steadily and GDP per capita will become $5,000 in 2030. Population and GDP assumptions are given as scenario.

GDP share, which is driving force of final energy demand, is projected by regression. According to growth of GDP per capita, AVA share will decrease and SVA share will increase. This is a common phenomenon observed in developed countries. Though IVA share increased in the 4th quarter of 20th century, it will be replaced by SVA share in 21st century.

Total final energy demand will increase due to the growth of driving forces. It mainly consists of industry sector and other sectors. Total primary energy supply will also increase and it will reach at around 2,500MTOE in 2030. equivalent to 30% of 1999 total primary energy supply in the world. It is mainly formed from coal, oil, and CRW. Though CO_2 emissions will become close to 2 Gt-C in 2032, its rate of increase will slow down because of introduction of nuclear and expansion of natural gas. CO_2 intensity will also decrease after 2015. Energy intensity decreased after 1970 dramatically. This decreasing trend is projected to continue in future.

Though SO_2 emissions will increase after 2000, but it will start to decrease after 2015. NO_x emissions will also begin to decline around 2020. It is well-known as Kuznets effect that air polluting sources such as SO_2 and NO_x will be reduced according to economic growth. Kuznets effect is more pronounced and is projected to occur earlier for SO_2 emissions than for NO_x emissions.

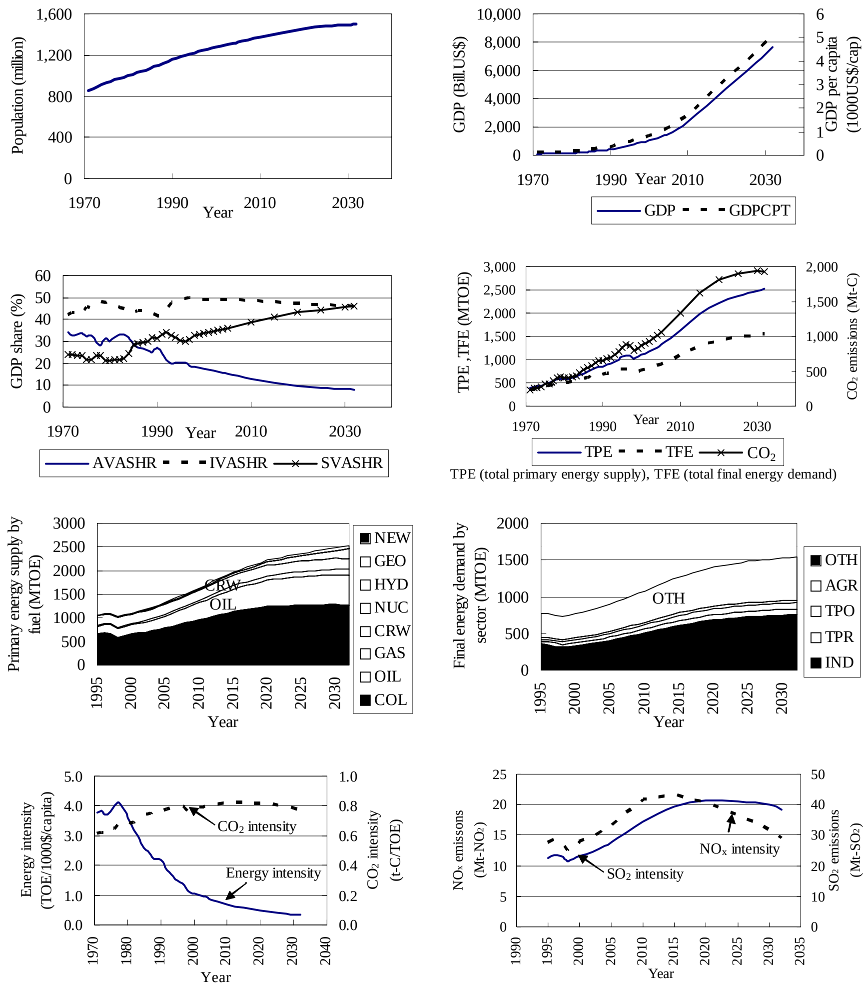

Fig. 7. Projection of each index for China

Figure 8 shows the projection of CO_2 emissions per capita for each country in GEO3/Sustainability First scenario. Countries are arranged in order of CO_2 emissions per capita in 2032. China and India, which have larger population in Asia-Pacific countries, will be located in the middle position in 2032. Singapore and Brunei, which have special energy structure, will stay at larger CO_2 per capita emissions through 2032.

Asia-Pacific countries exhibit a wide range of CO_2 per capita emissions. This highlights the importance of country-level study in this region.

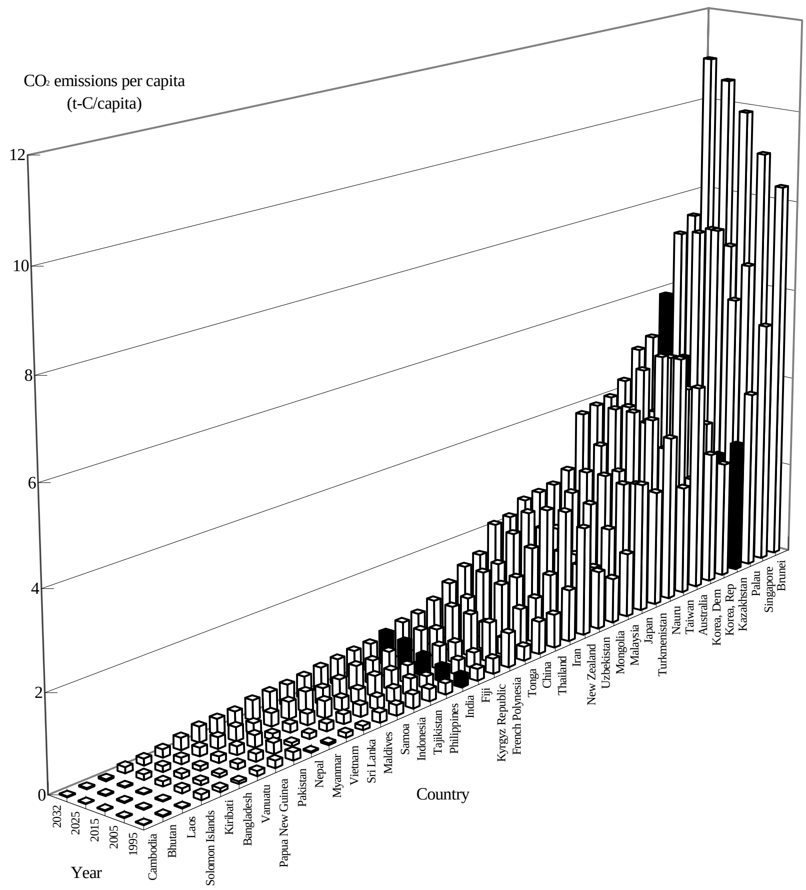

Fig. 8. Projection of CO_2 emissions per capita for each country

13.3.3 Energy related GHG emissions results

Energy related CO_2 emissions

Figure 9 shows the energy related CO_2 emissions in the Asia-Pacific region in the four scenarios. Compared to Policy First and Sustainability First, emissions of CO_2 increase more rapidly in Markets First circumstances because of high economic growth. In Policy First, advanced technologies are introduced to reduce CO_2 emissions. Because a Sustainability First society shifts from conventional to sustainable lifestyles, CO_2 emissions are somewhat mitigated. On the other hand a Security First society holds on to technologies with low energy efficiency. CO_2 emissions increase most rapidly in this scenario everywhere except in Central Asia where low economic activities mitigate CO_2 emissions vis-à-vis Markets First.

Figure 10 shows change in energy related CO_2 emissions by 2032 relative to 2002 in sub-regions of the Asia-Pacific region. China in the East Asia sub-region, India in South Asia, and Kazakhstan in Central Asia experience maximum change in CO_2 emissions over the 30 year period while the ANZ and South Pacific sub-region including Australia and New Zealand experiences least change in all the scenarios. An interesting observation is that the ANZ and South Pacific sub-region and Japan show a decline in CO_2 emissions in the Policy First scenario. In all sub-region but Central Asia, CO_2 emissions are higher in the Security First scenario than in the Markets First scenario for the reason mentioned in the previous paragraph.

Energy related SO_2 emissions

As with the CO_2 emission factor, SO_2 emission factor is set for each country. Kuznets curve, which postulates an inverse U relationship between income level and pollution, are assumed to deal with the change of emission reduction rate according to economic growth. In modeling this phenomenon, thresholds are set as the function of GDP per capita and the emission reduction rate changes at these thresholds.

SO_2 emissions will increase most rapidly in the Security First scenario because little money is invested to reduce SO_2 emission in a low economic growth world (Fig.11). On the other hand, in the other scenarios, the increase of SO_2 emissions will be slow as measures are taken to avoid severe air pollution. This is especially true in Policy First and Sustainability First where SO_2 emissions will be controlled more strictly. Due to the Kuznets effect, a downward trend is observed in Policy First and Sustainability First scenarios from around 2015 while it is observed in Markets First from around 2025. It is not observed in Security First scenario. Results for changes in SO_2 emissions between 2002 and 2032 (Fig.12) provide some interesting observations. In the ANZ and South Pacific, SO_2 emissions are reduced by 40 to 50 percent between 2002 and 2032 in all scenarios. In modeling the scenarios, it is assumed that all the industrialized countries would reduce their SO_2 emissions regardless of the scenario. Australia dominates emissions in the ANZ and South Pacific and therefore the whole area appears to be decreasing its

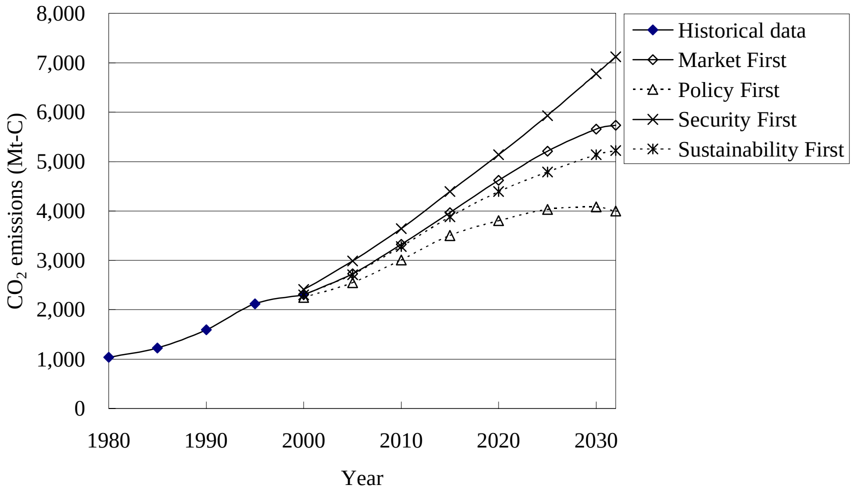

Fig. 9. Energy related CO_2 emissions in the Asia-Pacific region (see color plates)

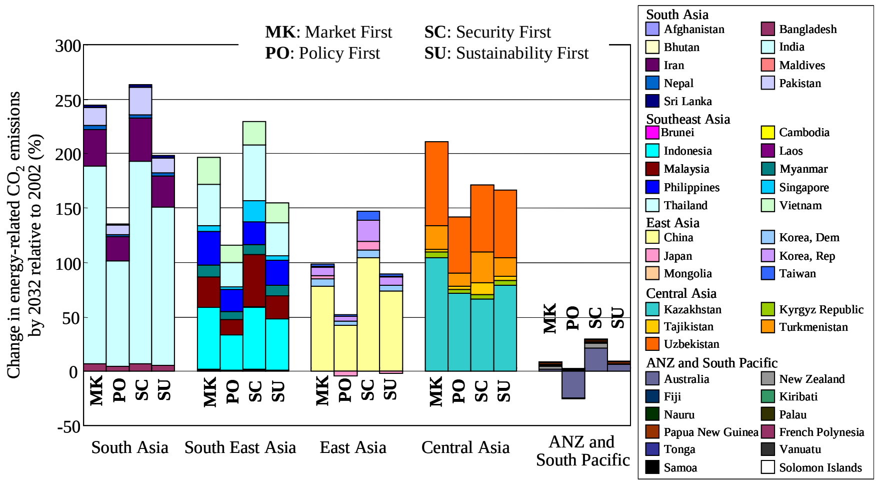

Fig. 10. Energy related CO_2 emissions in sub-regions of the Asia-Pacific region (see color plates)

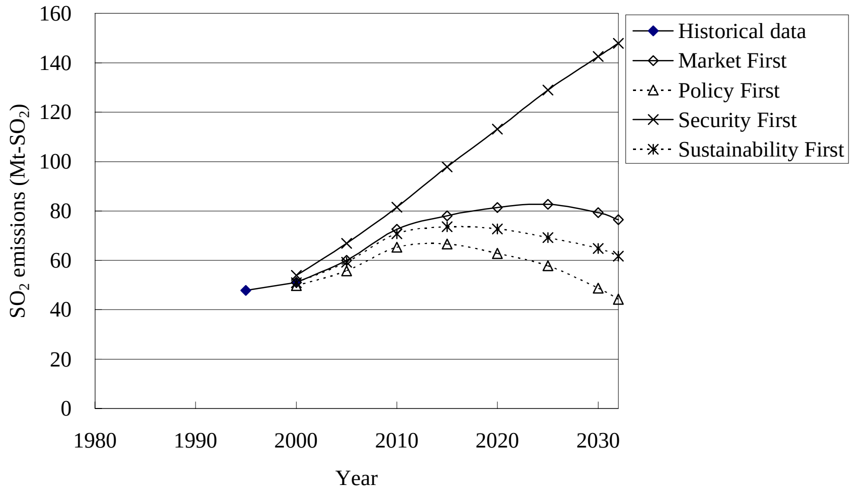

Fig. 11. Energy related SO_2 emissions in the Asia-Pacific region (see color plates)

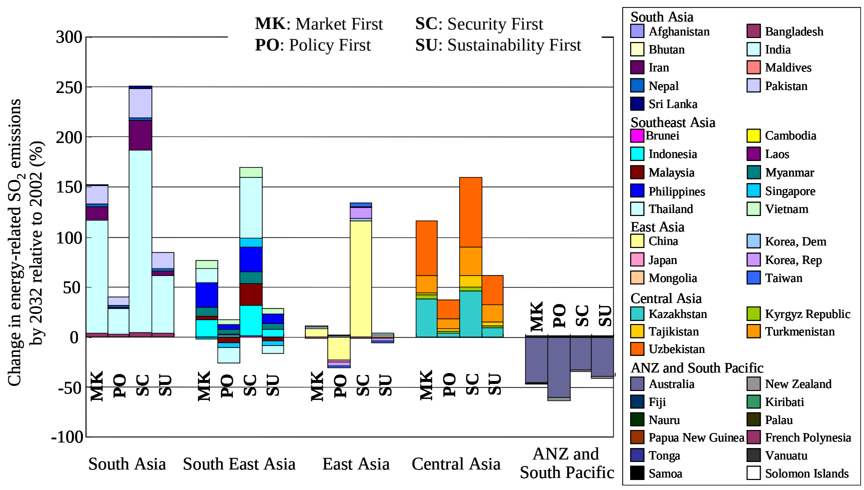

Fig. 12. Energy related SO_2 emissions in sub-regions of the Asia-Pacific region (see color plates)

SO_2 emissions. In the East Asia sub-region, China's emissions reduce at a slower rate than those of Japan. As a result, the sub-region on the whole increases its emissions in all scenarios except Policy First scenario. Emissions also reduce for some countries in Southeast Asia and East Asia sub-regions under Policy First and Sustainability First scenarios. In all the regions except ANZ and South Pacific emissions increase most rapidly in Security First scenario because of relatively low investment in emissions reduction, especially in India and China where the emissions more than double over the 30 year period.

13.4 Concluding Remarks

In this chapter, the framework of AIM/Trend model and its results are presented. This model has been developed to assess the future environmental loads based on the past socio-economic trends and scenarios though 2032 in the Asia-Pacific 42 countries of the Asia-Pacific region. It is built as a simple econometric model and written in ATPL using VBA in Microsoft Excel. The user can change the model structure and make sensitivity analysis easily. Results of AIM/Trend model show that the Asia-Pacific region is going to experience a rapid growth in CO_2 emissions in all UNEP/GEO-3 scenarios, and Asia-Pacific countries have a wide range of economy, energy, and environment conditions. It makes the country-level study in this region more important to deal with the diversity of Asia-Pacific countries. In future, AIM/Trend model will be improved to make people interested in immediate actions to control the incidence of increased environmental loads on air, land as well as water.

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