

AIM/TREND MODEL

A model for assessing environmental loads

for Asia-Pacific countries

USER'S MANUAL

October 2002

AIM Project Team

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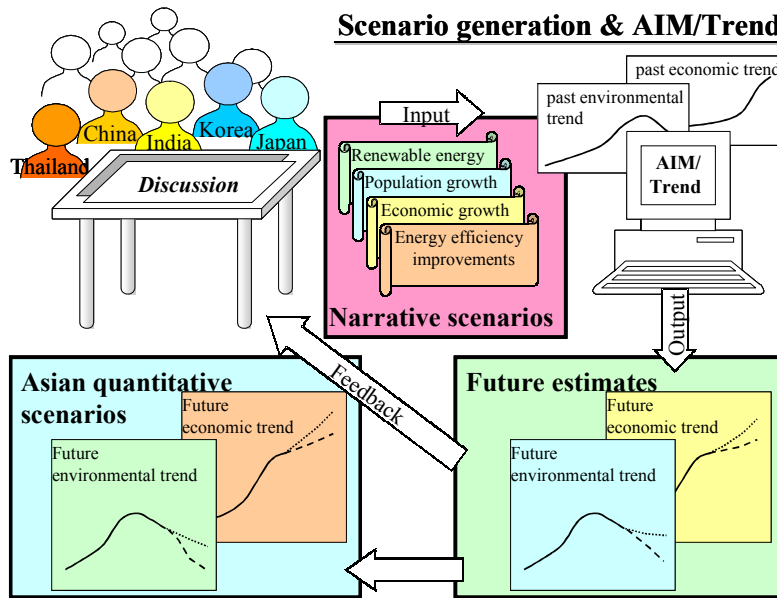
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1. Introduction

AIM project 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 through 2032 in the Asia-Pacific countries have been estimated. Following 2 types model have been developed because of accessibility to data sources;

- Model A: Based on IEA (International Energy Agency) energy data
- Model B: Based on UN (United Nations) energy data

In the following sections in this document, we will introduce the structure of each model, and describe how to use this model to prospect the future environmental trends.



Concept of AIM/Trend model

2. Model structure

2.1 Model A

2.1.1 Overview

Model A covers the countries that have the IEA energy balance table. Model B is used for the countries that do not have the IEA energy balance table.

2.1.2 Covered countries

Model A covers the following 25 countries;

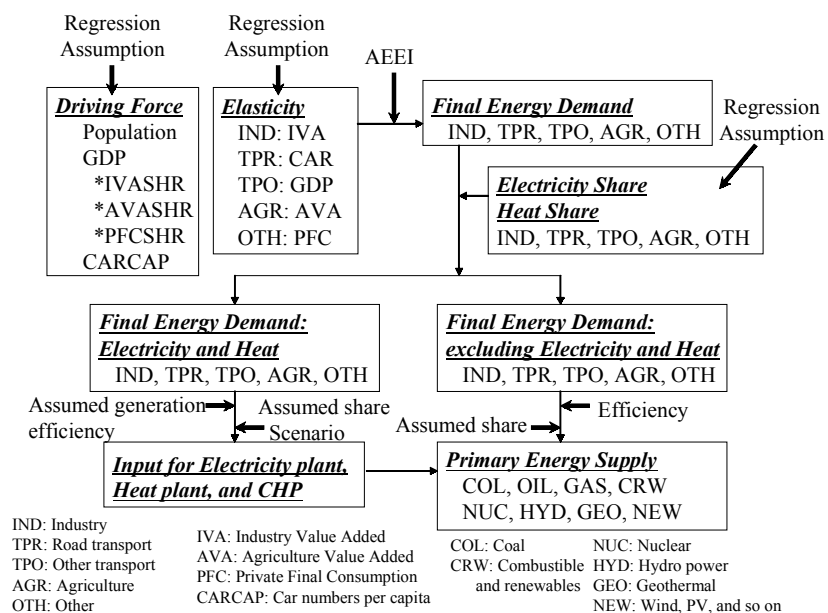
South Asia: Bangladesh, India, Iran, Sri Lanka, Nepal, Pakistan

South East Asia: Indonesia, Myanmar, Malaysia, Philippines, Singapore, Thailand, Vietnam

East Asia: China, Japan, Korea, Rep, Korea, Dem, Taiwan

Central Asia: Kazakhstan, Kyrgyz Republic, Tajikistan, Turkmenistan, Uzbekistan

South Pacific: Australia, New Zealand



Calculation flow of detailed data model (Model A)

2.1.3 Energy module

(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 (nuclear), HYD (hydro power), GEO (geothermal), NEW (wind, PV, and so on),

HET (heat), and ELE (electricity).

(2) Economic sectors

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:

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

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

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 assumed that NEU consists of oil based on historical data.

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

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 future 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.

(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 in each sector is fixed at that in the latest year for which data are available 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 Asia-Pacific region. Share of fuel input into HTP and share of fossil fuel input into CHP are assumed to be 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 are fixed as per 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) CO₂/NO_x/ SO_x/CH₄/N₂O/CO emissions

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

2.1.4 Water module

(1) Model Features

Estimated variables:

- Domestic water withdrawal
- Industrial water withdrawal
- Agricultural water withdrawal
- Domestic water consumption
- Industrial water consumption
- Agricultural water consumption

Driving forces (explanatory variables) of future water withdrawal

- Population (Historical trend and projection)
- GDP (Historical trend and projection)
- Share of industrial value added (Projection)
- Urban and rural population supplied water service
- Urbanization ratio (Historical trend and projection)
- Irrigated area (Historical trend)
- Current amount of water withdrawal in domestic, industrial and agricultural sectors

Assumptions of parameters related with technology improvement

- Annual ratio of water use efficiency improvement in domestic sector
- Annual ratio of water use efficiency improvement in industrial sector
- Annual ratio of water use efficiency improvement in agricultural sector

(2) Domestic water withdrawal and consumption

Domestic water withdrawal is assumed to change proportionally to population that has access to water supply service (water-supplied population). Since water-saving technology is expected to improve in future in domestic sector, future change of water-use efficiency is assumed exogenously and multiplied by the withdrawal estimated from the change of water-supplied population. Water-supplied population is projected for urban and rural areas separately. The current tendency of water-supplied population change is considered to continue in future with saturation. Based on the water-supplied population in 1980 and 1990, trend of water-supplied population change is decided. For countries where ratio of water-supplied population (water-supplied population / total population) in 1990 is higher than that in 1980, it is assumed that the ratio of water-supplied population will continue to increase at the same pace. Then the increased ratio is multiplied to the future population projected by the World Bank in order to estimate water-supplied population. This assumption stands on the consideration that quality of life will continue to improve if enough resource (in this case, water resource) is available.

On the other hand, for the country where ratio of water-supplied population decreased during 1980s, it is assumed that the water-supplied population (not the rate) will change at the same pace. Usually water-supplied population still increases (reflecting population increase) even in the nation

where ratio of water-supplied population decreases. This assumption stands on the consideration that decreasing ratio of water-supplied population reflects the availability of water resources.

$$\begin{aligned}
 W_{DOM}(t) &= W_{DOM,URB}(t) + W_{DOM,RUR}(t) \\
 &= W_{DOM}(1990) / (WSP_{URB}(1990) + WSP_{RUR}(1990)) \\
 &\quad * (WSP_{URB}(t) + WSP_{RUR}(t)) * AWEI_{DOM}(t) \\
 W_{DOMC}(t) &= W_{DOM}(t) * RCON_{DOM}(t)
 \end{aligned}$$

$W_{DOM}(t)$: Domestic water demand

$W_{DOM,URB}(t)$: Domestic water demand in urban area

$W_{DOM,RUR}(t)$: Domestic water demand in rural area

$WSP_{URB}(t)$: Water-supplied population in urban area

$WSP_{RUR}(t)$: Water-supplied population in rural area

$AWEI_{DOM}(t)$: Water use efficiency improvement in domestic sector compared with 1990

$W_{DOMC}(t)$: Domestic water consumption

$RCON_{DOM}(t)$: Domestic water demand/consumption ratio

if $WSP_{URB}(1990) / POP_{URB}(1990) - WSP_{URB}(1980) / POP_{URB}(1980) > 0$

$$WSP_{URB}(1990) = POP_{URB}(t)$$

$$* \min(1, [WSP_{URB}(1990)/POP_{URB}(1990) - WSP_{URB}(1980)/POP_{URB}(1980)]) / 10 \text{years} * (t-1990)$$

$POP_{URB}(t)$: Population in urban area

$POP_{RUR}(t)$: Population in rural area

if $WSP_{URB}(1990) / POP_{URB}(1990) - WSP_{URB}(1980) / POP_{URB}(1980) < 0$

$$WSP_{URB}(t) = \min(A, B)$$

$$A = (WSP_{URB}(1990) - WSP_{URB}(1980)) / 10 * (t-1990) + WSP_{URB}(1990)$$

$$B = POP_{URB}(t) * (WSP_{URB}(1990) / POP_{URB}(1990))$$

(3) Industrial water withdrawal and consumption

Industrial water withdrawal is assumed to change proportionally to industrial value added (IVA). Since water-saving technology is expected to improve in future in industrial sector, future change of water-use efficiency is assumed exogenously and multiplied by the withdrawal estimated from the change of IVA. In order to project the IVA in future, the time-series trend of the share of IVA in GDP is multiplied by the GDP of the scenario.

$$W_{IND}(t) = W(1990) * (IVA(t) / IVA(1990)) * AWEI_{IND}(1990)$$

$$W_{INDC}(t) = W_{IND}(t) * RCON_{IND}(t)$$

$W_{IND}(t)$: Industrial water demand

IVA(t): Industrial value added

AWEI_{IND}(t): Water use efficiency improvement in industrial sector compared with 1990

W_{INDC} (t) : Industrial water consumption

RCON_{IND} (t): Industrial water demand/consumption ratio

(4) Agricultural water withdrawal and consumption

Agricultural water withdrawal is closely related to the size of irrigated area. Since critical factors which govern irrigated area are different among countries, it is not easy to project future irrigated area by multi-factor regression approach. In this example, however, irrigated area is projected as the function regressed with two factors (logarithm of GDP per capita, logarithm of population) as a simplified method. For more realistic projection, factors used for regression should be selected separately for each country considering its background. For future population and GDP, projection by World Bank is derived from the database file.

$$W_{AGR}(t) = W_{AGR}(1990) * (IRGAREA(t) / IRGAREA(1990)) * AWEI_{AGR}(t)$$

$$IRGAREA(t) = F(\log(POP(t)), \log(GDP(t)/POP(t)))$$

$$W_{AGRC}(t) = W_{AGR}(t) * RCON_{AGR}(t)$$

W_{AGR}(t): Agricultural water demand

IRGAREA(t): Irrigated area

GDP(t): GDP

POP(t): Population

AWEI_{AGR}(t): Water use efficiency improvement in agricultural sector compared with 1990

W_{AGRC} (t) : Agricultural water consumption

RCON_{AGR} (t): Agricultural water demand/consumption ratio

2.2 Model B

(1) Overview

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

(2) Covered countries

Model B covers following 17 countries;

South Asia: Afghanistan, Bhutan, Maldives

South East Asia: Brunei, Cambodia, Laos

East Asia: Mongolia

Central Asia: Kazakhstan, Kyrgyz Republic, Tajikistan, Turkmenistan, Uzbekistan

South Pacific: Fiji, Kiribati, Nauru, Palau, Papua New Guinea, French Polynesia, Solomon Islands, Tonga, Vanuatu, Samoa

(3) Energy data

- UN Energy Statistical Yearbook 2000 is used.

- a) Consumption of Commercial Energy (Liquids, Solids, and Gas) *1
- b) Consumption of Commercial Energy (Electricity) *2
- c) Consumption of Commercial Energy (Total) *3

*1: "Liquids, Solids, and Gas" correspond to OIL, COL, and GAS in Model A respectively.

*2: Electricity = (Electricity from geothermal, hydro, nuclear, solar, tide, wind and wave) + imports - exports.

*3: Total = Liquids + Solids + Gas + Electricity

- In "UN Energy Statistical Yearbook 2000", *3 is the same as the total primary energy supply in IEA Energy Balance Table ("Statistical Yearbook", "Energy Statistics Yearbook").
So we use the phrase "Total Primary Energy Supply (TPES)" for "Total Consumption of Commercial Energy (CCE)".
- The share of the each energy is fixed as that in 1995.

(4) Primary energy supply

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:

$$PE_e(t) = A_e(t) \times PE_e(t_0) \times \{GDP(t)/GDP(t_0)\}$$

$$A_e(t) = (1 - AEEI_e(t) / 100)^{(t-t_0)}$$

$PE_e(t)$: 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, $e = \{\text{OIL, COL, GAS, ELC, TRF}\}$

t : simulation time period, t_0 : initial time period

(5) Emission Factors

Emission factors of NO_x and SO_2 are calculated from following way;

a) Case of no information on total emissions

The numbers of the emission factors are estimated based on “Greenhouse Gas Inventory Reference Manual” from IPCC.

b) Case of available information on past emissions

The numbers of emission factors of SO_x and NO_x are calculated by using the latest emission data. The changes of the numbers of emission factors in the future, and the definition of CO_2 emission factors are the same as Model A.

3. How to use Models

3.1 Installation of AIM/Trend Model

a) Installation of AIM/Trend Add-In

At the beginning AIM/Trend Add-In should be installed on your computer. Please refer to “AIM/Trend Add-In Manual” for installation of this Add-In for more detailed information.

b) Installation of AIM/Trend Models

Please copy the directory “¥AIMTrend” in the CD-ROM to your computer.

3.2 Model A

(1) File Open

Open the excel workbook “Model A.xls” in the directory ¥AIMTrend. In this workbook, following sheets have been prepared.

Interface sheet

- GUI: operational sheet for calculation.

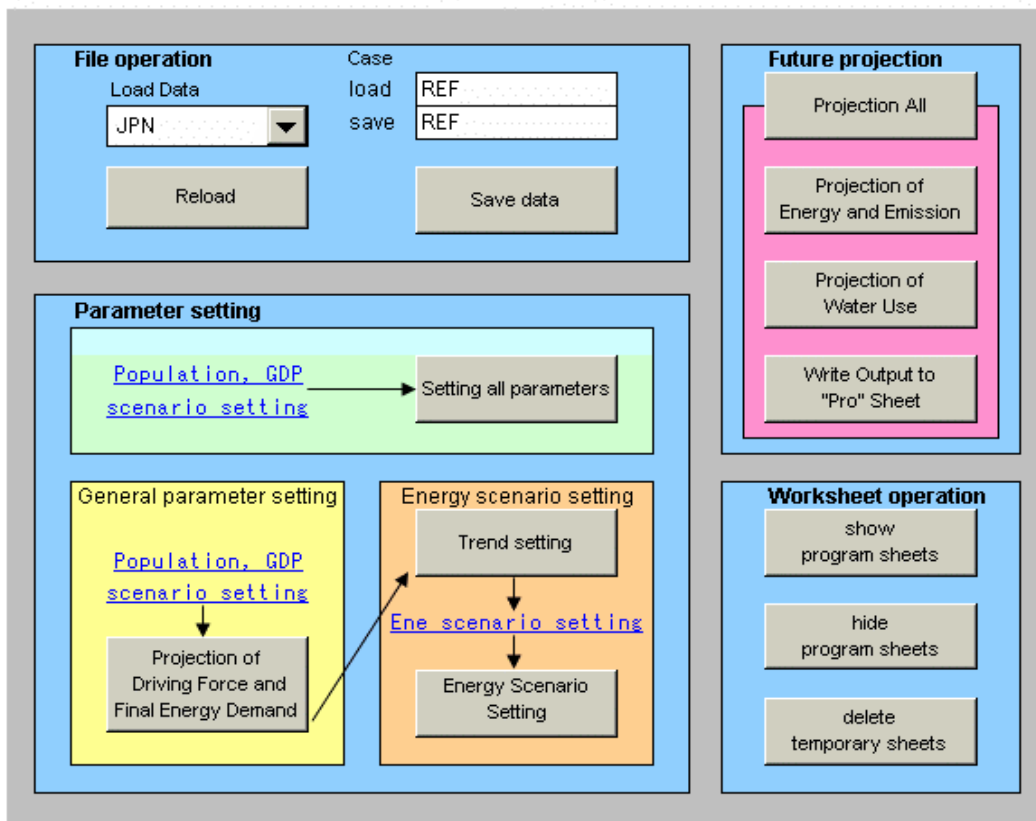
Data sheets

- Hst: past data except energy balance data.
- Bal: energy balance data.
- Pam: future scenario data.
- Ene-trend: future energy scenario data calculated by past trend.
- Ene-user: future energy scenario data set by the user.
- Ene: future energy scenario data used for projection.
- Emf: emission factor for GHG emissions.
- WatPam: future water scenario data.

Output sheets

- GPro: projection figures of main indexes.
- Pro: projections related to energy.

Model A



GUI of Model A

(2) Operation of GUI

1) File operation

- Select the country, which you want to calculate, and write down the case name on the “case” blanket. You can choose from 5 scenarios (REF, MF, PR, FW, GT) and your scenarios. When you want to refresh the data, please push “Reload” button. The default data are set on each worksheet.
- When you change several data on data sheets, you can save those data. If you write case name on the “save” blanket and push “Save” button, data set are saved with case name. You can see the data again by writing case name and pushing “Reload” button. If you do not write anything on the “case” blanket and push “Save” button, data are saved in “Temp” folder.
- UNEP published GEO-3: Global Environment Outlook 3 (UNEP 2002) before Johannesburg Summit and prepared following 4 scenarios: Market First scenario (MF), Policy First scenario (PR), Security First scenario (FW), and Sustainability First scenario (GT). 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.

2) Future projection

- If you want to calculate future projections related to energy use, please push “Projection of Energy and Emission” button. If you want to calculate future projections related to water use, please push “Projection of Water Use” button. After that please push “Write Output to "Result" Sheet” button to write out the results. The worksheets, “GPro” and “Pro” will show the results related to energy, emissions and water results that are reflected by latest data change. You can calculate above procedures with “Projection all” button.

3) Future Parameter

- Future parameter can set as following processes;
On “Pam” sheet
 - User sets population and GDP scenario.
 - Driving force will be projected with “Projection of Driving Force” button.
 - User can modify scenario by overwriting “#table Drv” on Pam sheet.
 - User can modify scenario by overwriting “#table ELS”, and “#table AEEI”. Final energy demand will be projected with “Projection of Final Energy Demand” button. User can also modify “#table FE” directly on Pam sheet.
- On “Ene-user” sheet
 - Energy share will be projected with “Projection of Energy Share” button.
 - User can modify energy share scenario by overwriting each table on “Ene-user” sheet.
 - User can modify other energy scenario by overwriting each table on “Ene-user” sheet.
 - The button “Energy related Parameter Setting” will set energy scenario. This process combines “Ene-user” sheet and “Ene-trend” sheet into “Ene” sheet.
- The button “Pam Set All” will set all parameters following model calculation.

4) Worksheet operation

- If you push the button “show program sheets”, the worksheets will be shown.
- “ATML” controls the GUI program and has the country code.
- “P-Eng” has the program to prospect energy related scenario. “P-Wat” has the program to

prospect water related scenario. “P-GHG” has the program to calculate GHG emissions.

“WATPAM” is the worksheet for selecting data related to water projection.

- “index” has the codes which are used in each program.
- Each program is written in ATPL.
- If you push the button “hide program sheets.”, the above worksheets will be hidden
- If you push the button “delete temporal sheets”, the temporal worksheets will be deleted.

(3) Scenario setting

The worksheets “Pam” and “Ene” have the important assumptions data about economy, energy, and emissions. If there are blank data on the table, they are interpolated at calculation.

Table Scenario variable of Model A

Name of variable	Type of variable	Descriptions	Table
POP	Time Series	Population (1000)	Basic
GDP_R	Time Series	Economic growth rate (%/year)	Basic
AEEI I={IND, TPR, TPO, AGR, OTH}	Time Series	AEEI (%/year)	AEEI
TPS.SUP.J J={NUC, HYD, GEO, NEW, ELE, HET}	Time Series	TPES (kTOE)	SUP.NFOS
ELE.ELP.CRW	Time Series	Electricity supply by CRW power plant (kTOE)	SE.CRW
ELE.CHP.TOT	Time Series	Electricity supply by CHP plant (kTOE)	ELE.CHP.TOT
ELP.SHR.J J={COL, OIL, GAS}	Time Series	Share of fossil fuel power plant in total fossil fuel power plant (%) • _J (ELP.SHR.J) = 1	SHR.ELP.FOS
ELP.IMP.J J={COL, OIL, GAS, CRW}	Time Series	Improvement rate of generation efficiency for fossil fuel and CRW power plant (%/year)	ELP.IMP
ELP.MXEFF.J J={COL, OIL, GAS, CRW}	Time Series	Maximum efficiency of generation efficiency for fossil fuel and CRW power plant (%)	ELP.MXEFF
EMS.EMF.J.L J={COL, OIL, GAS, CRW} L={NOX, SO2}	Parameter	Initial value of NOx, SO2 emission factors (Gg-NOx/kTOE, Gg-SO2/kTOE)	GHG1
EMS.RDPNT.M.L M={P1, P2} L={NOX, SO2}	Parameter	When GDP per capita is achieved at this point, emission factor is starting to reduce. (1000US\$)	GHG1

Name of variable	Type of variable	Descriptions	Table
EMS.MXFCT.L.M L={NOX, SO2} M={P1, P2}	Parameter	Emission factor \geq EMS.EMF.J.L * EMS.MXFCT.L.M.	GHG1
EMS.RDR.M.L L={NOX, SO2} M={P1, P2}	Parameter	Reduction rate of emission factors (%/year)	GHG1
URAT	Time Series	Urbanization rate (%)	Urat-m
AWEI.I I={IND, AGR, DOM}	Time Series	AWEI (%/year)	AWEI

3.3 Model B

(1) File Open

- Open the excel workbook “Model B.xls” in the directory ¥AIMTrend. In this workbook, following sheets are prepared.

Interface sheet

- GUI: operational sheet for calculation.

Data sheets

- Pam: future scenario data.
- Hst: historical data.
- PERIOD: set for time period

Output sheets

- Pro: projection results.
- GPro: projection figures of main indexes.

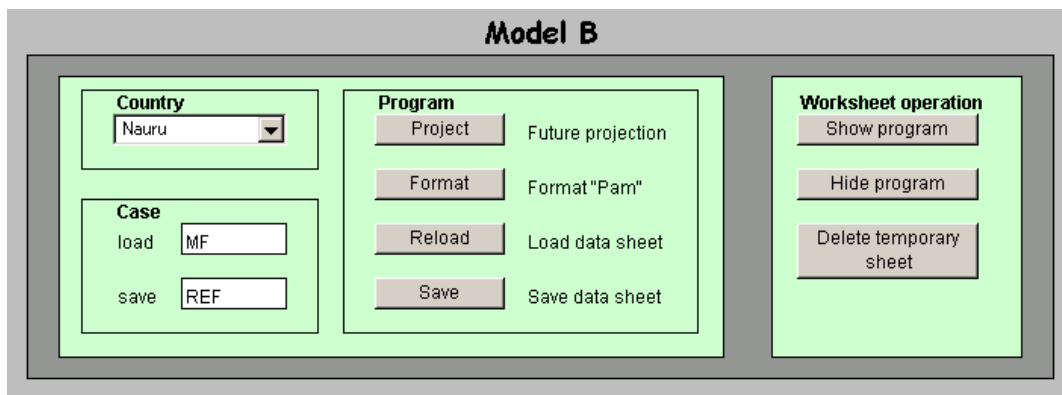


Fig. GUI of Model B

(2) Operation of GUI

1) File operation

- Select the country, which you want to consider. When you want to refresh the data those you already changed, please push “Reload” button. The default data are set on each worksheet.
- When you change several data on data sheets, you can save those data. If you write case name on the “case” blanket and push “Save” button, data set are saved with case name. You can see the data again by writing case name and pushing “Load data” button. If you do not write anything on the “case” blanket and push “Save” button, the data are saved in “temp” folder.

2) Future projection

- Please push “Project” button on the sheet “GUI” to start projection.

3) Worksheet operation

- If you push the button “show program sheets”, the worksheets, “ATMC”, “index”, “P-Pro”, “INDEX”, and “PERIOD” will be shown.
- If you push the button “hide program sheets”, the above worksheets will be hidden
- If you push the button “delete temporary sheets”, the worksheets “Wrk”, which are used for calculation, will be deleted.

(3) Scenario setting

Table Scenario variable of Model B

Name of Variable	Type of variable	Descriptions	Table name
POP	Time series	Population (1000)	DRV
GDP_R	Time series	Economic growth rate (%/year)	DRV
AEEI	Time series	AEEI (%/year)	AEEI