To pdf - AIM-CGE

From IAMC-Documentation

Reference card - AIM-CGE

Contents

The reference card is a clearly defined description of model features. The numerous options have been organized into a limited amount of default and model specific (non default) options. In addition some features are described by a short clarifying text.

Legend:

☐ not implemented
☑ **implemented**
☑ **implemented (not default option)**

About

Name and version AIM-CGE

Institution and users National Institute for Environmental Studies (NIES), Japan, .

Documentation AIM-CGE documentation consists of a referencecard and detailed model documentation

Model scope and methods

Model documentation: Model scope and methods - AIM-CGE

Objective AIM/CGE is developed to analyse the climate mitigation and impact. The energy system is disaggregated to meet this objective in both of energy supply and demand sides. Agricultural sectors have also been disaggregated for the appropriate land use treatment. The model is designed to be flexible in its use for global analysis.

Concept General Equilibrium with technology explicit modules in power sectors

Solution method Solving a mixed complementarity problem

Anticipation Myopic

Temporal dimension Base year:2005, time steps:Annual, horizon: 2100

Spatial dimension Number of regions:17

1. Japan
2. China
3. India
4. Southeast Asia
5. Rest of Asia
6. Oceania
7. EU25
8. Rest of Europe
9. Former Soviet Union
10. Turkey
11. Canada
12. United States
13. Brazil
14. Rest of South America
15. Middle East
16. North Africa
17. Rest of Africa

Policy implementation Climate policy such as emissions target, Emission permits trading and so on
Energy taxes and subsidies

Socio economic drivers

Model documentation: Socio-economic drivers - AIM-CGE

Exogenous drivers

- ☐ Exogenous GDP
- ☑ **Total Factor Productivity**
- ☐ Labour Productivity
- ☐ Capital Technical progress
- ☐ Energy Technical progress
- ☐ Materials Technical progress
- ☐ GDP per capita

Note: GDP is endogenous, while TFP is exogenous; but TFP can be calibrated so as to reproduce an given GDP pathway.

Endogenous drivers	☑ **GDP**	
Development	☑ **GDP per capita** ☐ Income distribution in a region ☐ Urbanisation rate	☐ Education level ☐ Labour participation rate

Macro economy

Model documentation: Macro-economy - AIM-CGE

Economic sectors	☑ **Agriculture** ☑ **Industry** ☑ **Energy**	☑ **Transport** ☑ **Services**
Cost measures	☑ **GDP loss** ☑ **Welfare loss** ☑ **Consumption loss**	☐ Area under MAC ☐ Energy system costs
Trade	☑ **Coal** ☑ **Oil** ☑ **Gas** ☐ Uranium ☑ **Electricity**	☐ Bioenergy crops ☑ **Food crops** ☐ Capital ☑ **Emissions permits** ☑ **Non-energy goods**

Energy

Model documentation: Energy - AIM-CGE

Resource use	☑ **Coal** ☑ **Oil** ☑ **Gas**	☐ Uranium ☑ **Biomass**
Electricity technologies	☑ **Coal** ☑ **Gas** ☑ **Oil** ☑ **Nuclear**	☑ **Biomass** ☑ **Wind** ☑ **Solar PV** ☑ **CCS**
Conversion technologies	☐ CHP ☐ Heat pumps ☐ Hydrogen	☐ Fuel to gas ☐ Fuel to liquid
Grid and infrastructure	☐ Electricity ☐ Gas ☐ Heat	☐ CO2 ☐ H2
Energy technology substitution	☑ **Discrete technology choices** ☐ Expansion and decline constraints	☐ System integration constraints
Energy service sectors	☑ **Transportation** ☑ **Industry**	☑ **Residential and commercial**

Land-use

Model documentation: Land-use - AIM-CGE; Non-climate sustainability dimension - AIM-CGE

Land-use	☑ **Abandoned land** ☑ **Cropland**	☑ **Forest** ☑ **Grassland**

☑ **Extensive Pastures**

Note: 6 AEZs (Agro-Ecological Zones) by Crop, pasture, forestry, Other forest, natural grassland and others There is a land competition under multi-nominal logit selection.

Other resources

Model documentation: Non-climate sustainability dimension - AIM-CGE

Other resources	☐ Water	☐ Cement
	☐ Metals	

Emissions and climate

Model documentation: Emissions - AIM-CGE; Climate - AIM-CGE

Green house gasses	☑ **CO2**	☑ **HFCs**
	☑ **CH4**	☑ **CFCs**
	☑ **N2O**	☑ **SF6**
Pollutants	☑ **NOx**	☑ **OC**
	☑ **SOx**	☐ Ozone
	☑ **BC**	
Climate indicators	☑ **CO2e concentration (ppm)**	☑ **Temperature change (°C)**
	☑ **Radiative Forcing (W/m^2)**	☐ Climate damages $ or equivalent

Model Documentation - AIM-CGE

The AIM is an integrated assessment model framework which consists of 4 models. The core of the model is AIM/CGE. The whole economic activities are represented in the AIM/CGE, but energy, agriculture and land use are relatively disaggregated than other sectors. AIM/PLUM deals with spatial explicit land use downscaling and also provides bioenergy supply curve. AIM/Dynamic provides global total emissions constraints for AIM/CGE incorporating MAC (Marginal Abatement Cost Curve) and non-CO2 information from AIM/CGE. The climate outcomes are made by MAGICC. This wiki page mostly explains about AIM/CGE.

1) Model scope and methods - AIM-CGE

The Asia-Pacific Integrated Modeling/Computable General Equilibrium (AIM/CGE) model was developed to analyze the climate change mitigation and its impact. To meet this objective, the energy system is disaggregated into energy supply and demand sides. Agricultural sectors are also disaggregated for appropriate land-use treatment. The model is designed to have the flexibility to be used at a global and individual country scale.

1.1) Model concept, solver and details - AIM-CGE

The AIM/CGE model was developed to analyze the future climate change mitigation and its impact on economic conditions. AIM/CGE is classified as a computable general equilibrium model, which covers all economic goods while considering production factor interactions. The trade of goods and services is also considered.

To meet this objective, the energy system is disaggregated into energy supply and demand sides. Agricultural sectors are also disaggregated for appropriate land-use treatment. The model is designed to have the flexibility for use at global and individual country scales.

The model is implemented for GAMS/MCP (Mixed Complementarity Problem), and PATH is used as a solver. The model is a dynamic recursive model using a 1-year time step. The simplified climate component is connected through soft links using MAGICC6. The CGE

model itself has no feedback from the climate component.

1.3) Temporal dimension - AIM-CGE

In terms of temporal scale, the base year of AIM/CGE is 2005. AIM/CGE can be run for the 2005--2100 period. For some applications, the model is run up to 2050. The time step of the model solution is one year.

1.4) Spatial dimension - AIM-CGE

The geographical resolution of this system is 17 socio-economic regions. The regional classification is shown below.

Code	Description	Code	Description
JPN	Japan	TUR	Turkey
CHN	China	CAN	Canada
IND	India	USA	United States
XSE	Southeast Asia	BRA	Brazil
XSA	Rest of Asia	XLM	Rest of South America
XOC	Oceania	XME	Middle East
XE25	EU 25	XNF	North Africa
XER	Rest of Europe	XAF	Rest of Africa
CIS	Former Soviet Union		

1.5) Policy - AIM-CGE

AIM/CGE can assess several types of policy. Key areas where policy responses can be introduced in to the model are:

- Climate policy
  - Mitigation (e.g. carbon tax and recycle, emissions trading)
  - Adaptation (e.g. food consumption aid or subsidy)
- Energy policy (e.g. air pollution, energy taxes)
- Land use and agriculture policy
- Other policies (e.g. income tax change, subsidy change and so on)

2) Socio-economic drivers - AIM-CGE

Socio-economic drivers are typically informed by a scenario narrative that in qualitative terms describes the overall logic behind the scenarios. In the case of AIM/CGE, the Shared Socio-economic Pathways (SSPs, see O'Neill et al., 2014 [1]) provide this overall scenario logic based on which the main socio-economic drivers, population and GDP, have been quantified. The subsections of this chapter describe how these quantitative drivers are used in AIM/CGE.

2.1) Population - AIM-CGE

Demography
Future demographic change is one of the key drivers to change the demand for goods in the future, including energy and food. The production side is also affected by demographic changes through labor participation. Population and labor forces are exogenous parameters in AIM/CGE. Currently, the Shared Socioeconomic Pathways (SSPs) population data made available by the International Institute for Applied Systems Analysis (IIASA) is used as the reference demographic assumption which is originally represented at the country level SSP database (https://tntcat.iiasa.ac.at/SspDb/dsd?Action=htmlpage&page=welcome). Usual model exercise, AIM/CGE uses SSP2 scenario.

2.2) Economic activity - AIM-CGE

Macro-economy
The future macro-economic assumption also causes changes in the supply and demand of goods. The macroeconomic assumption is also an

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Map of AIM/CGE regional classification.

exogenous assumption. There are two ways of treatment of macroeconomic assumption differentiating between baseline and mitigation scenarios. In baseline scenario, GDP is assumed as exogenous. Instead, TFP is assumed as endogenous. Usually, the change in GDP is used for the macroeconomic assumption for future scenario simulation. However, the actual outcome from the model is not exactly the same as the assumptions. Therefore, the GDP assumption is used to calculate the total factor productivity (TFP), and this is a totally exogenous parameter of the model. In mitigation scenario, we use the TFP values which is calculated in baseline scenarios.

3) Macro-economy - AIM-CGE

AIM/CGE represent whole economic activity. The production activities are represented as production functions which is mostly formulated by multi-nested CES function. The household expenditure is based on Stone-Geary utility function which derives LES consumption function (https://en.wikipedia.org/wiki/Stone%E2%80%93Geary_utility_function). The consumption, production and trade of goods and services are

determined by market prices. Capital and labor allocation is also determined by wages and return of capital. Hence, Macroeconomy is a results of those activities.

The industrial classification is shown below

Agricultural sectors	Energy supply sectors	Other production sectors
Rice	Oil mining	Mineral mining and other quarrying
Wheat	Gas mining	Food products
Other grains	Coal mining	Textiles, apparel, and leather
Oil seed crops	Petroleum refinery	Wood products
Sugar crops	Coal transformation	Paper, paper products, and pulp
Other crops	Biomass transformation (1st generation)	Chemical, plastic, and rubber products
Ruminant livestock	Biomass transformation (2nd generation with energy crop)	Iron and steel
Raw milk	Biomass transformation (2nd generation with residue)	Nonferrous products
Other livestock and fishery	Gas manufacture distribution	Other manufacturing
Forestry	Coal-fired power	Construction
	Oil-fired power	Transport and communications
	Gas-fired power	Other service sectors
	Nuclear power	CCS services
	Hydroelectric power	
	Geothermal power	
	Photovoltaic power	
	Wind power (onshore)	
	Wind power (offshore)	
	Waste biomass power	
	Other renewable energy power generation	
	Advanced biomass--- power generation	

4) Energy - AIM-CGE

AIM/CGE is a computable general equilibrium model which deals with detailed sectoral representation in energy sectors. The energy demand is determined by production function in industrial activities and consumption function in the household sector. The industrial activities have substitution between energy and value-added and household consumption is formulated by LES (Linear Expenditure System) function. The fossil resource cost is associated with cumulative resource extraction. The energy transformation sectors are represented by multi power generation sectors and refineries for oil and biomass.

AIM/CGE covers all greenhouse gas (GHG)-emitting sectors, including energy, industrial processes as well as agriculture and forestry. The emissions of the full basket of greenhouse gases including CO2, CH4, N2O and F-gases (CF4, C2F6, HFC125, HFC134a, HFC143a, HFC227ea, HFC245ca and SF6) as well as other radiatively active gases, such as NOx, volatile organic compounds (VOCs), CO, SO2, and BC/OC is represented in the model. AIM/CGE is used in conjunction with MAGICC (Model for Greenhouse gas Induced Climate Change) (cf. Section Climate of AIM-CGE) for calculating atmospheric concentrations, radiative forcing, and annual-mean global surface air temperature increase.

4.1) Energy resource endowments - AIM-CGE

The energy resource endowments are explained for each subsections.

4.1.1) Fossil energy resources - AIM-CGE

4.1.2) Uranium and other fissile resources - AIM-CGE

4.1.4) Non-biomass renewables - AIM-CGE

4.2) Energy conversion - AIM-CGE

AIM/CGE includes petroleum refinery, coal transformation, biomass transformation, town gas, and power generation sectors. Energy conversion occurs in production sectors. The share of energy consumed by a particular source of power generation is determined by a logit function which is often used for selection of several alternatives (https://en.wikipedia.org/wiki/Logit). Biomass transformation is also included in biofuels. Almost all sectors can install carbon capture and storage (CCS) as one of their CO2 emission-reduction measures, with the exception of town gas.
There are sectors which provide CCS service to corresponding sectors (coal power generation) and they install at certain carbon price level. The input of all energy conversion sectors is formulated as a Leontief-type production function (fixed input-output coefficient) to deal appropriately with the energy balance condition or energy conversion factor.

4.2.3) Gaseous fuels - AIM-CGE

AIM/CGE deals with town gas.

4.3) Energy end-use - AIM-CGE

Energy end-use is formulated differently in each sector, and therefore, the explanation of those sectors are in each section Transport, Residential and commercial sectors, and Industry.

4.3.1) Transport - AIM-CGE

The transport sector in the IAM usually includes industrial activities that provide transport services and household (i.e., own-use) car driving. The former is formulated as part of the industrial activity in AIM/CGE, and the latter is considered part of the consumption of household goods.

4.3.2) Residential and commercial sectors - AIM-CGE

In terms of the commercial sector, energy demand is determined as for the industrial sector.

For the residential sector, there are two options. One is the use of LES functions which Stone-Geary utility function is the basis (https://en.wikipedia.org/wiki/Stone%E2%80%93Geary_utility_function). The parameters that determine expenditure preference are recursively updated according to the given income elasticity. The other option enables the consideration of bottom-up energy technological information and the energy demand explicitly determined by detailed energy technologies. The default treatment is LES.

4.3.3) Industrial sector - AIM-CGE

The model has two options for determining energy demands from the industrial sector. One is the use of traditional functions such as the CES function for production sectors. The other option enables the consideration of bottom-up energy technological information and the energy demand explicitly determined by detailed energy technologies. Usually, for relatively long-term analysis (such as 2100), the Constant Elasticity Substitution (CES) function is used. The nested structure and elasticity values are shown in fiugre 1.

5) Land-use - AIM-CGE

A function is used whereby land is an input for the production of crops and livestock products, and landowners change its use in accordance with the prices of goods produced on cropland, pastureland, and in forests. The model has a land nesting strategy, which is similar to the treatment in Sands and Edmonds (2005) and Wise and Calvin (2011). Land is categorized as one of nine ecological zones, and there is a land market for each zone. Allocation of land by sector is formulated as a multinominal logit function to reflect the differences in substitutability across land categories with land rent. Multinominal logit function allows us multi level nesting structure in logit selection. The function assumes that the landowner of each region and Agro-Ecological Zone (AEZ) decides on the land distribution among the possible options, with the land rent dependent on the production of each land type (i.e., crops, livestock, and wood products). We deal with all land excluding desert, rock, ice, tundra, and built-up land. The original social accounting matrix data has 18 AEZ classifications but the model deals with

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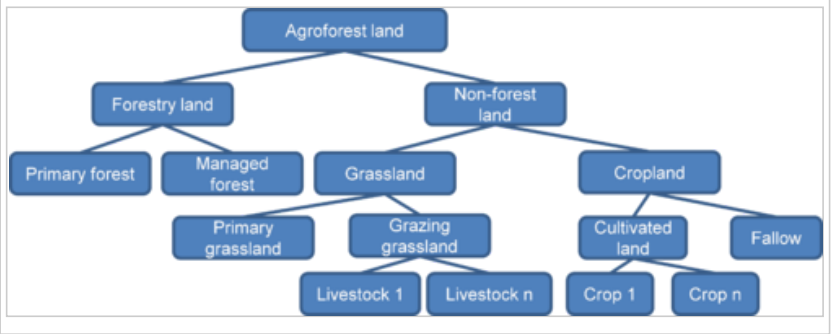
Figure 1: Industrial structure for non-energy industry sectors

aggregated 9 classification.



The figure shows the nesting diagram for land using AEZ classification. We consider all land excluding desert, rock, ice, tundra, and built-up land. There are 18 AEZ classifications. At the top is all land, which is divided into two main nodes: forestry land and non-forest land. The forestry-land node contains two competing uses: primary forest (unmanaged forest) and secondary forest (managed forest). The non-forested land can be divided into grassland and cropland. The grassland can be further divided into primary grassland (unmanaged pasture) and grazing grassland (managed pasture that feeds marketed livestock); the latter is further divided into livestock types (1 to n). The cropland could be divided further into cropland for each crop type (1 to n) and fallow land. The nesting strategy is based on the assumption that the land regions are small enough that all competing options are equally substitutable. This assumption implies that it is as easy to switch from forest to wheat as it is to switch from corn to wheat. However, this conversion would not happen unless wheat was more profitable than forest or corn. The function assumes that the landowner of each region and AEZ subregion decides on the land distribution among the possible options depending on the land rent obtained from production with each land use (i.e., crops, livestock, and wood products). To calibrate the function for both the managed and unmanaged land in the base year, we took the mean base-year land rent of the managed land to be that of the unmanaged land because data for the unmanaged land were lacking. The carbon stock on forest land was evaluated by the price in the case of the climate mitigation scenario. The land rent of forest areas includes both the revenue from wood products and the price of the carbon stock.

5.1) Agriculture - AIM-CGE

There are three cereal sectors, three other aggregated crop sectors, and two aggregated livestock sectors in AIM/CGE. Producers are assumed to maximize profits subject to the availability of appropriate technology (production functions) and the price of inputs. The first-order conditions for profit maximization essentially define the factor demands and output supply behavior of producers. The production structure is the same as for other industrial sectors except for the treatment of land input. The land input is assumed by multiplying output by a coefficient. However, in some cases, this fixed coefficient approach makes it difficult to solve the program if the land constraint is substantially critical. Therefore, the term related to output price elasticity is assumed. If price elasticity is very small (e.g., 0.05) and the model results can be interpreted, the land input is treated almost as a Leontief-type input.

6) Emissions - AIM-CGE

In the sub-sections of this chapter, the GHG and non-GHG emissions included in AIM/CGE are presented.

6.1) GHGs - AIM-CGE

AIM/CGE simulates emissions from long-lived GHGs (CO2, CH4, N2O, F-gases, Montreal Protocol gases, HFCs). CO2 emissions from fuel combustion are calculated based on energy sources with fixed coefficient. CO2 resulting from land-use changes is endogenously calculated as a consequence of the land use (taking difference of land use from previous year). Other CO2 emissions, CH4, and N2O emissions are basically associated with each sector's activity level. Emissions of the other gases are calculated based on constant income elasticity. Reduction in energy-related emissions is associated with detailed technological options, which provide both improved energy efficiency and a carbon factor reduction. The CO2 resulting from land-use changes is reduced under the scenario including the pricing of carbon stock. Other reduction measures for the non-CO2 emissions use models based on the marginal abatement cost (MAC) curve with an exponential function.

6.2) Pollutants and non-GHG forcing agents - AIM-CGE

Air pollution implications are derived with the help of the GAINS (Greenhouse gas–Air pollution INteractions and Synergies) model which allows for the development of cost-effective emission control strategies to meet environmental objectives on climate, human health and ecosystem impacts until 2030. These impacts are considered in a multi-pollutant context, quantifying the contributions of sulfur dioxide (SO2), nitrogen oxides (NOx), ammonia (NH3), non-methane volatile organic compounds (VOC), and primary emissions of particulate matter (PM), including fine and coarse PM as well as carbonaceous particles (BC, OC). The results of such scenarios are used as input to global IAM frameworks to characterize air pollution trajectories associated with various long-term energy developments.

7) Climate - AIM-CGE

Climate in AIM/CGE is modeled by the MAGICC6 model. The MAGICC model is a simple climate model that has been calibrated based on historical data and data from more complex climate models. It can therefore represent individual climate models that were used in CMIP3 and C4MIP. The main inputs into the MAGICC model are emissions of greenhouse gases and air pollutants that are the outcomes of the CGE simulations. These are fed into MAGICC. The main outputs are the changes in global mean temperature and radiative forcing levels. For more information about the model, see www.magicc.org (http://www.magicc.org/).

7.1) Modelling of climate indicators - AIM-CGE

Climate in AIM/CGE is modeled by the MAGICC6 model. The MAGICC model is a simple climate model that has been calibrated based on historical data and data from more complex climate models. It can therefore represent individual climate models that were used in CMIP3 and C4MIP. The main inputs into the MAGICC model are emissions of greenhouse gases and air pollutants that are the outcomes of the CGE simulations. These are fed into MAGICC. The main outputs are the changes in global mean temperature and radiative forcing levels.

8) Non-climate sustainability dimension - AIM-CGE

Food security dimension is treated with risk of hunger, its DALY and VSL.

8.1) Air pollution and health - AIM-CGE

8.2) Water - AIM-CGE

8.3) Other materials - AIM-CGE

8.4) Other sustainability dimensions - AIM-CGE

9) Appendices - AIM-CGE

9.1) Mathematical model description - AIM-CGE

9.2) Data - AIM-CGE

10) References - AIM-CGE

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