11. AIM/Material Model

Toshihiko Masui[1], Ashish Rana[1], and Yuzuru Matsuoka[2]

Summary. The AIM/Material model has been developed for assessing policy impacts not only on CO_2 emissions reduction but also other environmental issues, at present mainly focusing on solid waste management. Some activities for CO_2 emissions reduction are related to solid waste management. By using this model, both global climate policies and the domestic environmental policies can be assessed simultaneously. Other features of this model are as follows; not only an economic balance but also a materials balance is reproduced, and environmental industry and environmental investment to reduce environmental burdens are introduced. This model has been applied to Japan and India. In the case of Japan, the reduction of CO_2 emissions and final disposal of solid wastes in 2010 based on the Kyoto Protocol and government targets, respectively, will lead to a 0.5% loss in the GDP compared with the reference scenario. On the other hand, the introduction of environmental investment and other policies such as technology improvements and green consumption will mitigate more than half of the GDP loss. As for India, since toxic waste is a much more serious environmental problem than final disposal, this model is applied to the reduction of toxic waste.

11.1 Introduction

The AIM/Material model is a component of the AIM family and is used mainly for assessing the domestic macro economic impacts of policies on not only CO_2 emissions reduction, but also other environmental issues. AIM/Material has been developed in order to support solutions to the various environmental problems that each country may have. In the case of Japan, greenhouse gas emissions reduction is one of the most important global environmental issues, and moreover, the waste management problem is one of the most serious domestic environmental issues due to the scarcity of final disposal sites for solid wastes. In order to solve this solid waste problem, the “Basic Law for Establishing a Recycling-based Society” was enacted in May 2000, and the “Basic Plan for Establishing a Recycling-based Society” will be established in 2003 and will be reviewed every five years. In developing countries, not only climate change, but also domestic pollution problems such as water and air pollution problems are important for policy makers. Besides environmental policies, the environmental industry and environmental investment hold the key to realizing both economic development and environmental conservation. At present, this AIM/Material model can deal with both CO_2 emissions reduction and solid waste generation and treatment

[1] National Institute for Environmental Studies, Tsukuba 305-8506, Japan
[2] Kyoto University, Kyoto 606-8501, Japan

simultaneously. In this chapter, the structure of the model and its application to Japan and India are introduced.

11.2 Structure of AIM/Material Model

11.2.1 Overview

The AIM/Material model is a top-down type macroeconomic model based on the computable general equilibrium model for each country. This model has recursive dynamics year by year. One of the features of this model is that it represents a consistent approach not only to the economic balance, but also the materials balance. Due to this feature, solid waste generation and treatment can be dealt with. This section explains the structure of the AIM/Material model based on its application to Japan.

In this model, three economic agents are taken up: the production sector, the household sector, and the government. AIM/Material applied to Japan has 41 economic sectors and 49 commodities. Table 1 shows the economic sectors and commodities in the Japan model. Figure 1 represents the overall model structure. The production sectors produce economic goods through inputs of capital, labor, energy, other intermediate inputs, and pollutants. Pollutants as an input factor means the inputs necessary for the treatment of the generated pollutants, such as the cost of introducing environmental control and monitoring equipment and its operation, since it is assumed that the discharge of pollutants should not exceed the related environmental standards. That is to say, below the environmental standard, the generated pollution can be discharged into the environment, but any excess beyond the standard should be treated in appropriate ways. In the production sectors, the solid waste management sectors are different from normal production sectors. Solid wastes are mainly disaggregated into two types: industrial waste and municipal waste. Industrial waste is defined as waste from production processes, and municipal waste is from the household and business sectors. Each type of waste is disaggregated into more detailed waste categories. Table 2 shows the waste categories in this model. Each waste category of both industrial waste and municipal waste is disaggregated into 3 subsectors; direct reuse, direct final disposal, and intermediate management, such as incineration. Each sub-sector manages the solid wastes by inputting capital, labor, energy, and other intermediate inputs. The total quantity of the direct reused wastes and the reusable residual materials after intermediate management are supplied to the market as recycled materials. The total quantity of direct disposal wastes and the residue from intermediate management are dumped. In order to maintain the consistency of the materials balance, the share of recycled materials input in each sector is fixed in advance based on the capital, as shown in Table 2. The environmental industry is disaggregated from the other production sectors. In this model, the environmental industry is defined as the sector producing the environmental equipment to manage pollutants. The output of the environmental industry is supplied as an environmental investment in the other sectors.

The household sector retains labor and capital, and supplies it to the production

Table 1. Sectors and commodities in AIM/Material [Japan]

Sector		Commodity	
agr	Agriculture, forestry and fisheries		
min	Mining except energy		
m_c	Coal mining	mcc	Coking coal
		msc	Coal for general use, lignite, anthracite
m_o	Crude oil mining		
m_g	Natural gas mining		
fod	Manufacture of food		
tex	Manufacture of textile mill products		
plp	Manufacture of lumber, wood products, pulp, paper and paper products		
chm	Manufacture of chemical and allied products		
pls	Manufacture of plastic		
nmm	Manufacture of ceramic, stone, and clay products		
stl	Manufacture of iron, steel, ferrous metals and products		
nsm	Manufacture of non-ferrous metals and products		
fmt	Manufacture of fabricated metal products		
mch	Manufacture of general machinery		
elm	Manufacture of electrical machinery, equipment and supplies		
tre	Manufacture of transportation equipment		
pri	Manufacture of precision instruments and machinery		
oth	Miscellaneous manufacturing industries		
cns	Construction		
het	Steam and hot water supply		
wtr	Water supply		
sal	Wholesale and retail trade		
fin	Finance and insurance		
est	Real estate		
trs	Transportation and communications		
pub	Education, research, medical service, health & hygiene, and social welfare		
rnt	Goods renting and leasing		
rep	Car and machine repairing		
prs	Other service		
gov	Government service		
emc	Environmental industry		
sew	Sewage service		
mwm	Municipal solid waste treatment service		
iwm	Industrial solid waste treatment service		
col	Manufacture of coal products	cck	Coke
		ccg	Other coal products
		cbf	Paving materials
oil	Manufacture of petroleum	ogl	Gasoline
		ojf	Jet fuel oil
		okr	Kerosene
		olo	Light oil
		oho	Heavy oil
		onp	Naphtha
		olp	LPG
		oot	Other petroleum refinery products
gas	Manufacture of gas	gtg	Town gas
the	Thermal power generation	ele	Electricity
hyd	Hydro power generation		
nuc	Nuclear power generation		

Note: In the model, one sector can produce plural commodities using V matrix (make matrix).

sectors. As a result, households receive income as wages and rent from the production sectors. Under the constraints of income, households demand commodities based on the demand function. In the demand function, savings are also included as demand for investment goods. The demand for investment goods is determined by the fixed capital matrix.

The government sector imposes taxes on the production sectors and household sector. In this model, the tax is aggregated into 4 types: capital tax, labor tax,

Table 2. Classification of solid waste and assumption of recycling flow

			Commodity substituting to recycled waste									
			MIN	FOD	TEX	PLP	CHM	NMM	STL	NSM	CCK	OOT
Waste	ASH	Ash	○	○								
	SLD	Sludge	○	○							○	
	WOL	Slush, waste oil	○									○
	WAC	Waste acid					○					
	WAL	Waste alkali					○					
	WPL*	Waste plastics					○					○
	WPP*	Waste paper				○						
	WWD*	Waste wood		○							○	
	WTX*	Waste fiber and textile			○							
	WAP*	Animal and plants wastes		○								
	WRB*	Waste rubber					○					
	SCM*	Metal trash, scrap metal							○	○		
	WGC*	Waste glass						○				
	SLG	Slag	○									
	WCT	Construction and demolition waste	○									
	DST	Dust, soot	○									
	EXC	Animal excrement		○								
	CRC	Animal carcass		○								
Sector utilizing waste material		AGR		●								
		TEX			●							
		PLP				●						
		CHM					●					
		PLS					●					
		NMM						●				●
		STL	●						●			
		NSM								●		
		OTH					●					
		CNS	●									
		COL									●	
		OIL										●

Note: Refer Table 1 for names of sector and commodity.
* in waste category shows the classification of both municipal and industrial waste. Others are for only industrial waste.
○ means the waste indicated by row can be used as the commodity indicated by column.
● shows that the reused material indicated by column is input to the sector indicated by row.

production tax, and import tax. In the case of a reduction in CO_2 emissions and the final disposal of solid waste, the related taxes, such as a carbon tax and solid waste tax, are imposed on the agents. Based on tax revenues, the government sector provides public services and public investment.

Although this model is a country model, international trade is very significant. Especially in Japan, the importation of fossil fuels is essential to its economic activities. In this model, the international price is fixed in advance based on the small country assumption. The international prices of all commodities except for energy are fixed at the initial year. The international energy price is given according to the scenarios based on the AIM/Emissions model. Moreover the total value of imports and exports in the future is given according to the scenario, and individual imports and exports are calculated endogenously.

11.2.2 Mathematical formulation of AIM/Material

For simplicity, the model of the following three sectors as shown in Table 3 is assumed. Sectors 1 and 2 are ordinary economic sectors and sector 3 is a waste management sector. Commodities 1 and 2 are ordinary commodities and commodity 3 is a waste management service.

Market for produced commodities and production factors

The market equilibrium for produced commodities can be represented by the following equations.

Table 3. Social accounting matrix in the hypothesized economy

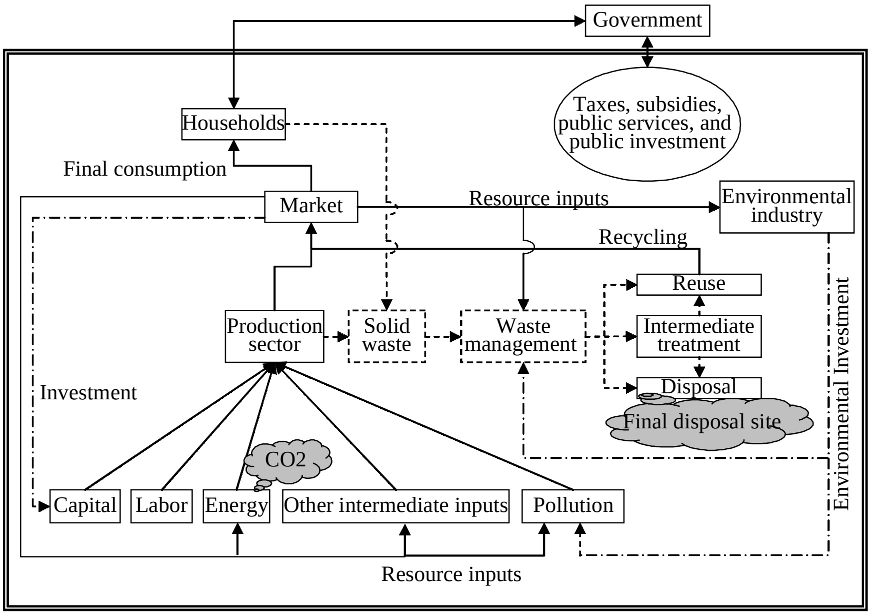
			Production sector			Final Consumption	Investment			Supply	Price	Endowment
			Sector 1	Sector 2	Sector 3		Sector 1	Sector 2	Sector 3			
Input	Intermediate inputs	Commodity 1	X_{11}	X_{12}	X_{13}	C_1	I_{11}	I_{12}	I_{13}	$Y_{11}+Y_{21}+Y_{31}$	P_1	
		Commodity 2	X_{21}	X_{22}	X_{23}	C_2	I_{21}	I_{22}	I_{23}	$Y_{12}+Y_{22}+Y_{32}$	P_2	
		Commodity 3	X_{31}	X_{32}	X_{33}	C_3				Y_{33}	P_3	
	Capital		K_1	K_2	K_3						P_K	K^*
	Labor		L_1	L_2	L_3						P_L	L^*
	Final disposal				W_3						P_W	W^*
Output	Commodity 1		Y_{11}	Y_{21}	Y_{31}						P_1	
	Commodity 2		Y_{12}	Y_{22}	Y_{32}						P_2	
	Commodity 3				Y_{33}						P_3	

$$P_i\left\{\sum_{j=1}^{3}Y_{ji}-(\sum_{j=1}^{3}X_{ij}+C_i+\sum_{j=1}^{3}I_{ij})\right\}=0,\quad P_i\geq 0, \text{ and}$$
$$\sum_{j=1}^{3}Y_{ji}-(\sum_{j=1}^{3}X_{ij}+C_i+\sum_{j=1}^{3}I_{ij})\geq 0$$

These equations indicate the relationship between the commodity price P_i and the demand and supply of that commodity. The excess demand for each commodity *i* does not exist. In the case of a market equilibrium, that commodity has a positive price, P_i. On the other hand, in the case of a disequilibrium state, that is to say, in the case of excess supply, the price of this commodity *i* becomes 0. In the example of Table 3, there is no demand for the waste management service produced by sector 3 as investment goods. In addition, Y_{31} and Y_{32}, which are commodity 1 and 2 produced by sector 3, can be regarded as recycled goods.

The capital market and labor market also can be explained by the following equations.

$$P_K\left\{K^*-\sum_{j=1}^{3}K_j\right\}=0,\ P_K\geq 0,\ \text{and } K^*-\sum_{j=1}^{3}K_j\geq 0$$
$$P_L\left\{L^*-\sum_{j=1}^{3}L_j\right\}=0,\ P_L\geq 0,\ \text{and } L^*-\sum_{j=1}^{3}L_j\geq 0$$



Note:
- - -▶ shows the flow of solid waste. In the model, municipal waste management sector and industrial waste management sector are set by the waste category. As for the waste category, see Table 2.
—·-▶ shows the flow of the capital investment and environmental investment. Although the capital is endowed in household, for simplicity, the investment is input from market or environmental industry directly in this figure.

Fig. 1. Overview of AIM/Material

In the capital market and the labor market, total demand for these is less than the endowment of capital and labor, respectively. In a state of equilibrium for these production factors, these prices become positive values, but in a state of disequilibrium, that is to say, the supply of these factors is more than the demand, the prices become 0.

As for the quantity of disposable waste, *W*, sector 3 disposes of the residual materials generated through waste treatment. The maximum quantity of this material for final disposal is W^*. Sector 3 cannot dispose of more than W^* of the residual materials. When the quantity for disposal is equal to W^*, the marginal cost for dumping, P_W, becomes a positive value. The situation in which the quantity for final disposal is less than W^* is regarded as an excess supply, and the price of final disposal is 0. That is to say, the quantity of materials for final waste disposal can be expressed by the following equation in the same way as for capital and labor.

$$P_W \left\{ W^* - \sum_{j=1}^{3} W_j \right\} = 0,\ P_W \geq 0,\ \text{and}\ W^* - \sum_{j=1}^{3} W_j \geq 0$$

In the example of Table 3, the values of W_1 and W_2 are 0, since only sector 3 generates materials for final waste disposal. If the self management of solid wastes and the dumping of the residual materials from this self management are considered, the values of W_1 and W_2 are effective.

Production sectors

The revenues and expenditures in each production sector can be expressed by the following equation.

$$\sum_{i=1}^{3} P_i X_{ij} + P_K K_j + P_L L_j + P_W W_j = \sum_{i=1}^{3} P_i Y_{ij}$$

The left hand side of this equation shows the expenditure for buying intermediate goods and other production factors in order to produce commodities. The right hand side represents the total revenues from selling the produced commodities in each sector. This equation also shows that the revenues and expenditures are balanced in the sector *j*. In order to represent the relationship between inputs and outputs, the appropriate production function is defined. In this model, in order to maintain a materials balance besides a monetary balance, the values of the elasticity of substitution or distribution are assumed to be 0 or infinity, except for the aggregation of different type of materials, such as capital and labor.

Household sector

The household retains resources such as capital, *K*, labor, *L*, and the final disposal area for solid waste, *W*. The household sector supplies these resources to the production sectors, and receives the income as the counter values of these resources. The household consumes the goods to maximize its utility, subject to income constraints. The income of the household can be expressed as follows by using the rent for capital, P_K, the wages, P_L, and the marginal cost of the final disposal of solid waste, P_W.

$$H = P_K \sum_{j=1}^{3} K_j + P_L \sum_{j=1}^{3} L_j + P_W \sum_{j=1}^{3} W_j$$

On the other hand, in order to calculate the quantity of demand for each commodity, the demand function has to be specified. Here, savings are included in the demand function as the demand for investment goods I_{ij} besides the final consumption C_i. The next equations show the expenditure of the household sector, and the change in capital stock. The total of new investment is added to the existing stock depleted at δ_j. The parameters for technological change, such as energy efficiency improvements, are calculated from the new technology assumption and the new equipment as a proportion of the total capital.

$$H = \sum_{i=1}^{3} P_i (C_i + \sum_{j=1}^{3} I_{ij})$$

$$K_{j,t+1} = (1-\delta_j) K_{j,t} + \sum_{i=1}^{3} I_{ij}$$

Flow of solid waste

In Table 3, the solid wastes can be managed only by the waste management sector. However, in reality, the quantity of solid wastes managed by each sector is relatively large. As a result, this model includes not only a waste management sector, but also the self management of solid wastes in each sector. The generated solid wastes in each sector are distributed between the self management sub-sector in the sector itself or the waste management sector. After the management of solid wastes, some of the solid wastes are recycled to the market, some of them are reduced through the incineration process, and the rest are dumped at the final disposal site. The endowment W^* represents the maximum quantity of the final disposal of solid wastes. W^* can be defined with respect to each waste type. Through the definition of this solid waste treatment activity, the appropriate solid waste treatment strategies can be estimated, such as the recycling policy and introduction of innovative technologies in solid waste management.

CO_2 emissions

The CO_2 emissions from each sector are calculated from the quantities of combusted fossil fuels and their emission factors. If the CO_2 emissions exceed an upper limit, such as the Kyoto Target, a carbon tax is imposed on the combusted fossil fuels, as with the P_W in Table 3.

Government

The government sector is also one of the final demand sectors, in the same way as the household sector. However, the roles of the government sector are quite different from those of the household sector. The roles of the government in this model are defined as follows:

- The government sector collects taxes, supplies public services and makes public investment.

- When an environmental burden is beyond the standard, the government sector imposes an environmental tax. The rate for this environmental tax is equivalent to P_w in Table 3.

11.3 Application of AIM/Material to Japan

11.3.1 Economic impact of the management of CO_2 and solid wastes

Currently Japanese society has many environmental problems that require immediate attention. For example, greenhouse gas emissions reduction, waste management, air pollution, and so on. While considering these environmental problems, economic growth should not be ignored. It is generally thought that environmental conservation and economic development are in conflict. However, in order to achieve a sustainable society, these two problems need to be solved simultaneously. AIM/Material indicates one solution.

In order to apply the AIM/Material model to Japan, a social accounting matrix is constructed based on input-output tables and other related databases for 1995. Table 4 represents the database used for this application. The simulation period is from 1995 to 2010. In order to estimate the economic impacts from the environmental constraints and mitigation due to environmental policies, the following scenarios were proposed.

1) Reference scenario
2) Environmental constraints scenario
3) Environmental constraints and countermeasures scenario

In scenario 2) and scenario 3), two environmental constraints were considered. One is the CO_2 emissions reduction target based on the Kyoto Protocol. The other

Table 4. Dataset for AIM/Material [Japan]

Economy	Management and Coordination Agency ed. (1999)
Waste	Ministry of Health and Welfare (1998a) Ministry of Health and Welfare (1998b)
Investment	Management and Coordination Agency ed. (1999) Department of National Accounts, Economic Research Institute, Economic Planning Agency (1999)
Environmental industry	The Japan Society of Industrial Machinery Manufacturers
Tax	Management and Coordination Agency ed. (1999) Ministry of Finance Research institute of international trade and industry (2000)
Energy	Ministry of international Trade and Industry (1996, 1997) Agency of Natural Resources and Energy, Ministry of International Trade and Industry (1999)

Note: The names of ministries are the names when these literatures were published.

is the reduction in the final disposal of solid waste based on the government target that the quantity of materials for final disposal as waste in 2010 should be half of that in 1996. The countermeasures in scenario 3) represent the increase in environmental investment, the introduction of efficient equipment for solid waste treatment, subsidies for power generation from waste, and the shift to green consumption, that is to say replacement of ordinary commodities by eco-products. Until 2000, in order to reproduce the actual values, the parameters for technological improvements, propensity to save and so on are adjusted. Moreover, in the reference scenario, these parameters are calibrated in order to follow the future economic development path represented in the existing estimations. Figure 2 represents the GDP trajectory in scenario 1).

Figure 3 shows the change in the GDP in scenario 2) and scenario 3) based on scenario 1). From a comparison between scenario 1) and scenario 2), the

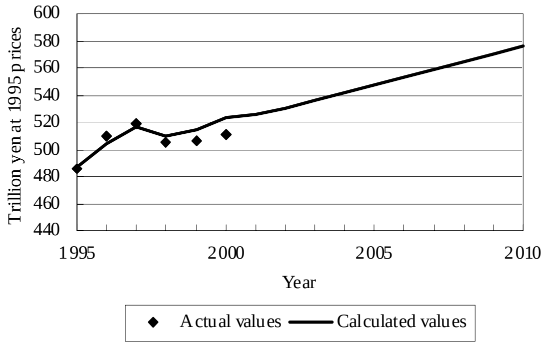


Fig. 2. GDP trajectory of scenario 1)

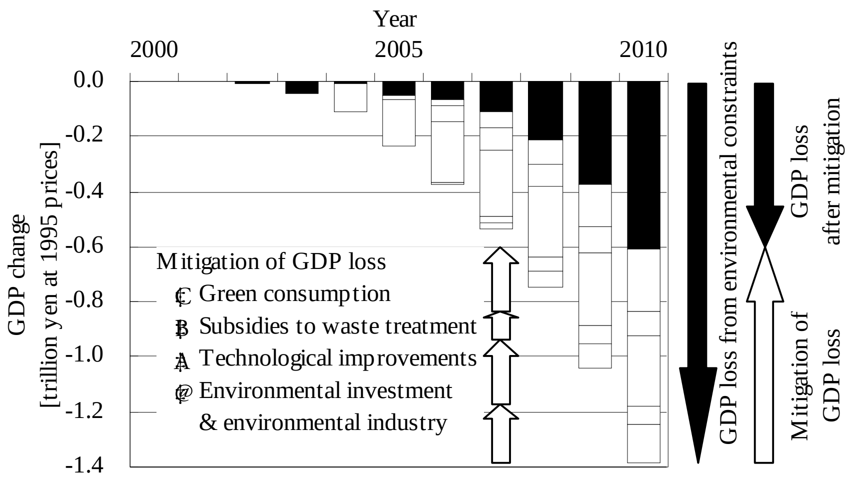


Fig. 3. GDP loss from environmental constraints and its mitigation

environmental constraints will have a negative impact on the economy. In 2010, the GDP loss will be 0.5 % of the GDP in scenario 1). On the other hand, introducing various countermeasures as shown in scenario 3) will make it possible to recover more than half of the economic losses suffered from the environmental constraints.

The reasons for the mitigation of the GDP losses are considered to be as follows. Firstly, the mitigation of environmental constraints will be achieved by these countermeasures. The second reason is the increase in environmental investment and green consumption will activate environmental industries and the production sectors that produce the eco-products. Moreover, the increase in environmental investment and eco-products has the potential to reduce the environmental burden. These advantages affect the mitigation of the GDP loss and economic activities.

11.3.2 Linkage of AIM/Material to the bottom-up model

AIM/Material is a top-down model. In order to solve the AIM/Material model, assumptions related to the efficiency of technology and social change are required. The solution of AIM/Material can reproduce consistent interaction among sectors. In order to assess the feasibility of the introduction of technology, the support of a bottom-up model, such as the AIM/Emissions model, is inevitable.

In order to meet the needs, a technology model on sewage sludge treatment has been constructed and linked to the AIM/Material model as a trial. Since the structure is too complex and the numbers of the variables are too large when the technology model is included in the AIM/Material, AIM/Material and the technology model are linked serially year by year. The concept for this linkage is shown in Fig. 4. In this linkage, the quantity of sewage sludge generation, the price of final disposal and materials recycling demand calculated in AIM/Material from one model are used for the assumptions in the technology model. The efficiency of sewage sludge treatment from the technology model is used for the

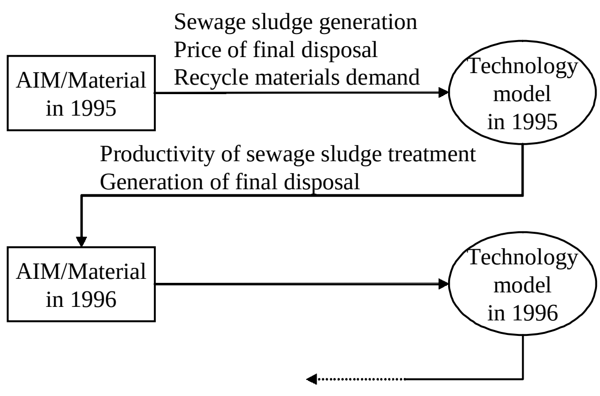


Fig. 4. Linkage of AIM/Material and technology model

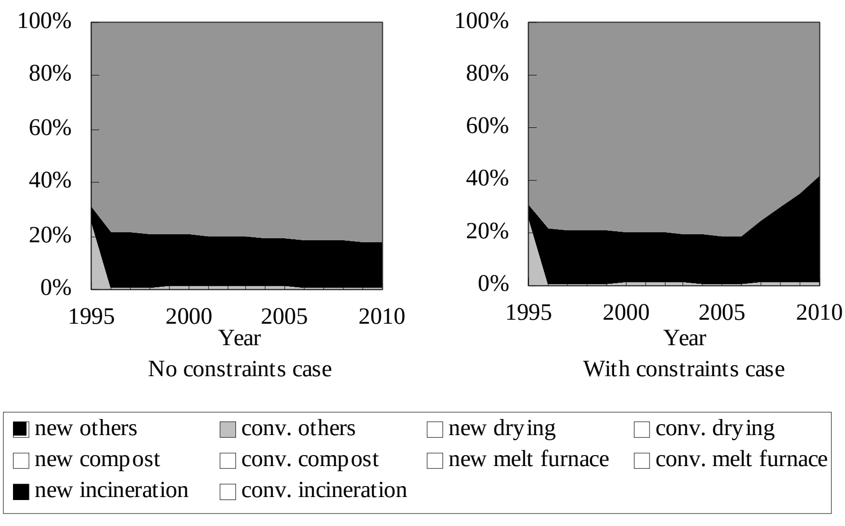
assumption in AIM/Material. Figure 5 shows the changes in the technologies under different constraints in relation to the final disposal of solid wastes. In the case of the reference case without constraints on final disposal sites, only standard technologies will be introduced. On the other hand, the scenario with constraints on final disposal sites introduces new technology that is more efficient, although the cost is higher.

By linking these two types of models, a top-down model and a bottom-up model, more realistic countermeasures can be assessed. The AIM team is now trying to expand the technology model in order to analyze other fields.

11.3.3 Effects on CO_2 emissions from changes in the tax rates on fossil fuels

In Japan, taxes imposed on fossil fuels are very high at present. The current tax rates are tentative, and are planned to be reduced to almost half in 2003. Table 5 represents the values for the tax rates. These high tax rates have a role in reducing CO_2 emissions, just like a carbon tax. If the tax rates are now returned to the original (after 2003) values, the opposite effect of a carbon tax, that is to say, an increase in CO_2 emissions, may occur. By using AIM/Material and changing the taxation rates on fossil fuels, the changes in CO_2 emissions can be estimated.

Figure 6 shows the results for CO_2 emissions. CO_2 emissions in 2010 will increase by 6.5 MtC according to the change in the tax rates. These values are equivalent to 2.2 % of the emissions in 1990. That is to say, more than half of the amount of the carbon sink under the Bonn agreement, 3.9% of the emissions in 1990, are offset.



Note: “Conv.” means “conventional.”

Fig. 5. Changes of technology share in two scenarios

Table 5. Tax rate of gasoline and light oil in Japan

	Present (tentative) rate	Original (after 2003) rate
Gasoline	53.8yen/l	28.7yen/l
Light oil	32.1yen/l	15.0yen/l

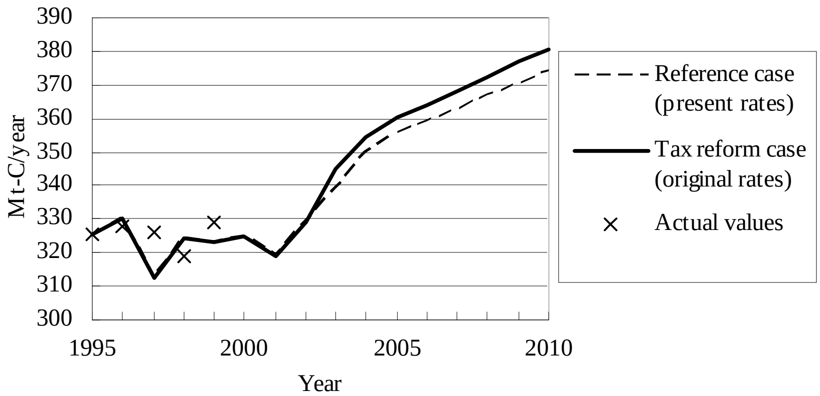


Fig. 6. CO_2 emissions change by tax reform

11.4 Application of AIM/Material to India

11.4.1 Modifications to the model

For the application of AIM/Material to India, some changes were incorporated taking into consideration the specific environmental problems of India as well as problems related to the availability of data that is as detailed as in the case of Japan. In India the problem of hazardous waste has a higher priority than dealing with other types of industrial solid waste. To take this into account, a significant modification in the India model is the separate treatment of hazardous, or toxic, waste and its disposal. A separate limit is set for the discharge of toxic waste into the environment. This limit is similar in character to the limit on the final disposal of waste, W^*, described in section 11.2.2.

Due to the limited data, the present version of AIM/Material [India] has 26 economic sectors and 24 commodities as shown in Table 6. The base year is taken as 1994 and the model is calculated year by year until 2010. Solid wastes are categorized into 15 types, including toxic waste, as shown in Table 7. Furthermore, solid wastes are classified as either industrial or municipal wastes. The industrial wastes are defined as wastes generated from production processes, and municipal wastes are defined as wastes from households and business activities.

11.4.2 Data sources

An input-output table, with data on the energy sector and data on solid wastes is required for the model. The input-output tables for 1993-94 available from the Central Statistical Organization of the Government of India were utilized (CSO 2000). Data on the energy sectors were taken from TEDDY 2000-2001 (TERI 2001). To estimate solid wastes from individual sectors, data on waste generation intensities for industries available from the documents of the Central Pollution Control Board of India (CPCB, various issues) and some other published sources was compiled. Typically, waste generation intensities are tabulated by waste type and production quantities in the base year and are applied to arrive at an estimation of the total waste generated in the sector. Usually the task is not straightforward as the waste generation intensities as well as waste types may differ within a single sector, depending on the technology in use. For example, in the case of the paper industry, large and medium-sized paper mills use wood as

Table 6. Classification of sectors and commodities in AIM/Material [India]

ID	Description	ID	Description
AGR	Agriculture, forestry, fishing	WTR	Water supply
MIN	Mining	SRV	Services
FOD	Food	MWM	Municipal waste management
TEX	Textiles	IWM	Industrial waste management
PLP	Paper and pulp	EMC	Environment industry
CHM	Chemicals	GOV	Government service
NMM	Non-metallic minerals	COL	Coal
BMT	Basic metals	OIL	Oil
FMT	Fabricated metals	GAS	Gas
MCH	Machinery	HYD+	Hydro power generation
ELM	Electrical machinery	THE+	Thermal power generation
TRE	Transport equipment	NUC+	Nuclear power generation
OTH	Other manufacturing	ELE*	Electricity
CNS	Construction		

+ Only sector; * Only commodity

Table 7. Classification of solid wastes in AIM/Material [India]

ID	Description	ID	Description
ASH	Ash	SCM**	Scrap metal
SLD	Sludge	WGC**	Waste glass
WOL	Waste oil	SLG	Slag
WPL**	Waste plastic	WCT	Construction waste
WPP**	Waste paper	DST	Dust
WWD	Waste wood	WZZ**	Other waste
WTX**	Waste textile	WWT	Toxic waste
WAP**	Animal and plant waste		

** Both industrial and municipal waste categories well as agricultural residues for pulp making, while small industries use wastepaper as inputs, which results in a substantial difference in the quantity and quality of their waste generation. In the fertilizer industry, solid waste generation is 0.085 tons per ton of fertilizer production. Steel plants produce solid waste in the form of slag and dust. The amount of slag and dust produced is about 500 kg and 25 kg per ton of pig iron produced from blast furnaces. Pig iron is converted to steel through an open-hearth furnace or oxygen furnace, producing about 22 kg of dust per ton of steel. The manufacture of sulfuric acid generates solid waste in the form of sulfur sludge which amounts to 2.5 – 2.8 kg/ton of sulfuric acid. Construction activity generates solid wastes, which include sand, gravel, concrete, stone, bricks, wood, metal, glass, plastic, paper, etc. The management of construction and demolition waste is a major concern for town planners due to the increasing quantities of demolition rubble, a continuing shortage of dumping sites, increases in transportation and disposal costs and, above all, growing concern about pollution and environmental degradation. The Central Pollution Control Board has estimated that waste from the construction industry accounts for 25% of the total volume of solid waste generated in India. Such a high volume of waste puts enormous pressure on solid waste management systems. Municipal solid waste data is based on the Planning Commission report published in 1995.

Data on toxic waste is mainly drawn from the report of the High Powered Committee (HPC) established in 1997 by the Supreme Court of India to produce a comprehensive study related to hazardous wastes in the country. In its detailed final report in 2000, the committee clearly indicates the dubious nature of data that is reported by industry with respect to the hazardous wastes generated by them (High Powered Committee on the Management of Hazardous Wastes 2000). The data, made available at its behest and further refined by officials, records 4.4 million tonnes of hazardous waste being generated per year within the country. This is further classified under various toxic waste categories according to the Hazardous Waste Rules 1989 guidelines. For the present study, the categories of toxic sludge that contributed the largest proportion were considered, covering around sixty percent of the total volume of toxic waste. This was done in order to make it possible to easily attribute the generated waste to the relevant waste generating sectors. Dealing with all categories together poses a challenge of attribution, in the absence of other data.

11.4.3 Scenarios

Three scenarios were constructed for this application.

Scenario 1: This is the reference or business-as-usual scenario and there are no interventions to limit waste disposal.

Reference case, Scenario 1, depicts an average annual GDP growth of 5.85% for the period 1994-2010 for India. Figure 3 shows the match between the actual statistics for the GDP and that simulated using the model in the overlapping periods. Total industrial waste generation is simulated to grow at 4.9% during the model period. Growth in the disposal of non-toxic waste is 3.5% per year while that for toxic waste disposal is 3%. The growth rate for the waste management service sectors (IWM and MWM) is 5% and the environment industry grows at 6.28%.

Scenario 2: Toxic Constraints Scenario – In this scenario a limitation on the discharge of toxic wastes is imposed.

This scenario is not driven by a government target but represents the effect of a combination of many actions that are expected to be taken by state governments and pollution control boards. The aforementioned HPC on Hazardous Waste has made several recommendations regarding the siting of secure landfills, the first of which states that reliance on land-based disposal should be minimized or eliminated as land-based disposal is the least favored method of managing hazardous wastes. Open dumping contaminates drinking water from underground and surface supplies and this practice can lead to real hazards for human health and the environment. Corrective action is bound to be expensive, complex and time consuming. Hence, reliance on land-based disposal should be minimized or eliminated. Other actions include stopping indiscriminate disposal of toxic waste, shutting down illegal dumping sites, relocation of industries away from ecologically sensitive sites, strict adherence to environment impact assessment criteria for sites, and so on. Scenario 2 is constructed by limiting the amount of resources, or endowment, for toxic waste disposal. From the year 2002, the available endowment for toxic waste disposal is decreasing at a rate of 10 percent every year.

Scenario 3: In this scenario countermeasures are introduced through increased environmental investment and labor efficiency improvements in the waste management sector.

Environmental investment is one way of boosting the capacity for the treatment

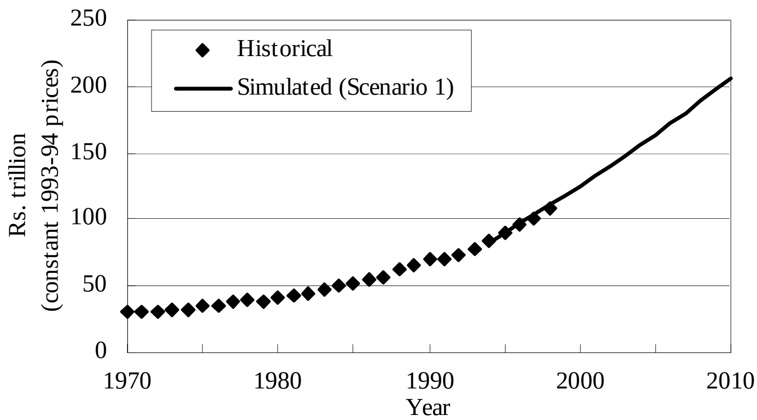


Fig. 7. Historical GDP and GDP in Scenario 1

and management of waste, thereby relieving the constraints posed in Scenario 2. At the same time, as mentioned earlier, it is clear that much of the mitigation can be achieved at a low marginal cost through improvements in waste management systems, improvements in organizational efficiency and other low-tech measures, such as greater segregation of wastes. A 5% increase in environment investment accompanied by labor efficiency improvements of 10% are taken into consideration in Scenario 3 from 2005.

11.4.4 Results

When faced with a constraint in Scenario 2, the following effects are observed in the economy. Toxic waste disposal is restricted to 1.29 Mt by 2010, a reduction of more than 60% over Scenario 1 for the same year, while disposal of other (non-toxic) waste decreases marginally over Scenario 1 (Fig. 8). Reduced toxic waste disposal is accompanied by restraint on the part of the toxic waste producing sectors as well as other sectors due to cross-linkages between them. By comparing the sectoral GDP in Scenario 2 in various years with that in Scenario 1, the overall GDP loss in 2010 can be observed to be around 2% over Scenario 1.

In Scenario 3, however, some GDP loss is recovered as the capacity to manage waste is enhanced (Fig. 9). The output for most of the sectors is also recovered in Scenario 3 (Fig. 10). Only 8 out of 26 sectors show a slight decrease in their GDP over Scenario 2. These sectors are Agriculture (AGR), Food (FOD), Water services (WTR), Government (GOV), Gas (GAS), and the two waste management sectors - MWM and IWM. None of these sectors generates hazardous waste, but due to the increased output of other sectors there is some level of demand switching. The reason for the decrease in the output of the waste management sectors is that there is a reduction in demand for their services since the cost of direct disposal is lower in this scenario. Among other sectors, the environmental

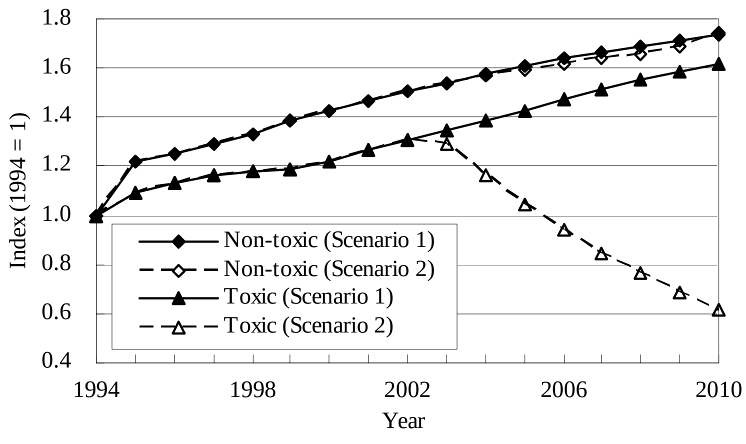


Fig. 8. Trajectories of final disposal of waste

industry (EMC) output increases substantially and its growth rate in this scenario is projected to be more than 20% and, compared with other equipment industries (MCH and ELM), to experience lower growth. (EMC is not shown in Fig. 10 because of the scale.) This result indicates the importance of this industry for pollution control.

Simulation results for toxic disposal constraints and mitigation do not indicate any significant effect on CO_2 emissions mitigation. Effects on waste recycling were not studied in detail since the information provided for the model is limited.

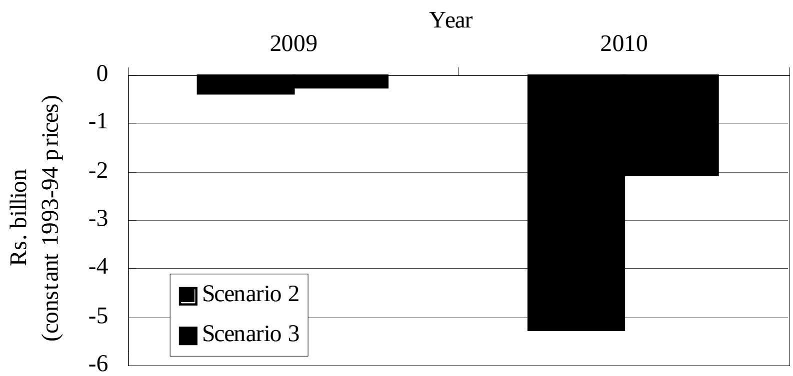


Fig. 9. GDP change in scenario 2 and scenario 3

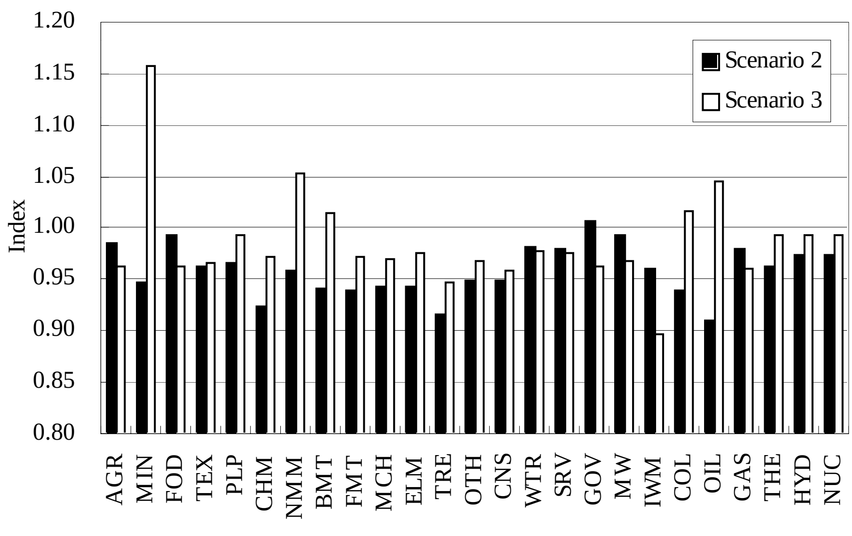


Fig. 10. Economic sectors showing change in output in 2010 over Scenario 1

11.5 Conclusion

As shown in the application of AIM/Material to Japan and India, various countermeasures can be assessed from the viewpoint of both a reduction of the environmental burden and the mitigation of economic losses. AIM/Material is a significant tool for assessing the policies designed to achieve sustainable development not only in the developed countries, but also in the developing countries. Although this is the top-down model, the solutions with the reality based on technology can be presented by linking it to the bottom-up model. Now the AIM team is trying to include other environmental problems, such as waste water treatment, and to apply it to other countries in the Asia-Pacific region.

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