10. Application of AIM/Enduse Model to Japan

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Summary. The AIM/Enduse model has been frequently applied to Japanese policy making processes. This chapter illustrates three of these applications. First, the effects of carbon tax and subsidies to reduce CO_2 emissions in Japan are introduced. CO_2 emissions through 2010 are estimated for four cases: reference case, market case, carbon tax case, and carbon tax+subsidies case. It is shown that the subsidy scheme is a useful option to reduce CO_2 emissions. Second, ancillary benefits of CO_2 reduction for regional environmental quality are presented. A module to analyze ancillary benefits of CO_2 reduction is added to the original AIM/Enduse model. Emissions of CO_2, NO_x and PM in Aichi prefecture, Japan, are estimated through 2010 and it is shown that countermeasures to reduce CO_2 emissions can also reduce air pollutants. Third, CO_2 emission scenarios in Japan are quantified based on the four narrative scenarios for Japanese society and economy by referring to IPCC SRES scenarios.

10.1 Introduction

The AIM/Enduse model has been applied extensively in Japan (Kainuma *et al*. 1999, 2000, 2001). As shown in Table 1, various stakeholders who belong to various organizations such as the national government, local governments, a public corporation, private companies, and an NGO, have used AIM/Enduse model to evaluate countermeasures to reduce CO_2 emissions. The most recent application for the national environmental policy is introduced in Section 2 as an example of analyzing effects of introducing carbon tax and subsidies. Next, the ancillary benefits of countermeasures to reduce CO_2 emissions are presented in Section 3 as an example for regional environmental quality control programs. A module to estimate emissions of air pollutants such as NO_x and PM is added to AIM/Enduse model for analyzing ancillary benefits. This model was applied to Aichi prefecture for estimating reduction of air pollutants as a consequence of countermeasures taken for reducing CO_2 emissions. Finally Section 4 presents future CO_2 emission scenarios in Japan. Four narrative scenarios consistent with the Special Report on Emissions Scenarios (SRES) of IPCC (IPCC 2000) are developed. Based on these narrative scenarios, national energy consumption and CO_2 emissions through 2020 are estimated by using AIM/Enduse model and the

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Table 1. Application of AIM/Enduse model to Japan

Year	Application	Reference
1994	Analysis of effects of carbon tax	JEA (1994)
1996	Analysis of effects of carbon tax and subsidies	JEA (1996a)
1996	Simulation of long-term CO_2 emissions	JEA (1996b)
1997	Development of scenarios for reducing CO_2 emissions	
	Analysis of policy options concerning carbon tax	JEA (1997)
	Analysis of effects of key technologies	Tsuchiya (1997)
1998	Analysis of effects of countermeasures for Fukushima and Chiba prefectures	
	Estimation of long-term energy demand	
1999	Analysis of effects of countermeasures for Aichi prefecture	
	Analysis of ancillary benefits of regional climate action plan for Nagoya city, Aichi Prefecture and the whole country	Kouken Association (1999) Shimada *et al.* (2000)
2000	Analysis of effects of carbon tax and subsidies	JEA (2000)
2001	Analysis of countermeasures in Japan	MOE (2001)
	Development of scenarios for reducing greenhouse gas emissions	Tsuchiya (2001)
	Development of CO_2 emission scenarios based on IPCC SRES	Hibino (2001)

causal relationships between national socio-economic development patterns and CO_2 emissions are studied. For each narrative scenario, one reference emission scenario and one countermeasure emission scenario were developed. In case of the reference scenarios, CO_2 emissions increase by more than 10% in 2010 as compared to 1990. CO_2 emissions in three of the four countermeasure scenarios decrease by 2-4% in 2010 as compared to 1990. Difference in CO_2 emissions between ‘global market-based’ scenario and other countermeasure scenarios increases over time because of the difference of the basic assumptions.

10.2 Application to Analysis of the Effects of Carbon Tax and Subsidies in Japan

10.2.1 Background

During these 10 years, the AIM/Enduse [Japan] model has been applied to the national environmental policy making. Year by year, the focus of the study moved, however, the main part of the argument is how to reduce the national CO_2 emission, which fulfills the Kyoto protocol. A feasible and concrete program which suits the political situation is required. Economic instruments such as carbon tax and subsidies on energy efficient devices were considered as one of the possible options, and were often analyzed from the point of their effectiveness and economic feasibility.

10.2.2 Estimation of CO_2 emissions using AIM/Enduse [Japan]

Simulation assumptions

The effects of carbon taxes and government subsidies have been analyzed. Subsidies were introduced by using the carbon tax revenues to invest in energy-conserving technologies. The assumptions of the simulation, such as GDP, population, commodity production, and energy prices, were based on the projections of the Japanese government. Future emissions were estimated for four cases: (1) reference case, (2) market case, (3) carbon tax case, and (4) carbon tax + subsidies case.

It was assumed that current technologies will be used in the reference case. There are several reasons that current technologies will be used even though there are economic benefits in changing the technologies. For example, a lack of economic understanding and social reasons may lead to preference for old technologies. Market case assumed competition among technologies based on economic criteira. No countermeasures such as carbon/energy taxes or subsidies were assumed in the market case. Technology selection in this case is based solely on a cost. A carbon tax of ¥30,000 per ton of carbon was introduced in the carbon tax case. In the carbon tax + subsidies case, a carbon tax of ¥3,000 per ton of carbon was introduced and the tax revenues were used to subsidize energy-saving technologies to lower total CO_2 emissions.

Simulation results

In the reference case, total CO_2 emissions in 2010 increase by 18% compared to 1990, as shown in Table 2. The rates of increase in the residential, commercial, and transportation sectors exceed 30%.

Table 3 shows comparisons of CO_2 emissions in different scenarios in 2010. Technology selection in market case reduces total CO_2 emissions by 6.3% in 2010. In the carbon tax case, CO_2 emissions decrease by 3% between 1990 and 2010. An examination of sector-wise CO_2 emissions shows that compared to the reference case, emissions decrease by 14.8% in the industrial sector, 34.1% in the residential sector, 22.9% in the commercial sector, 11.5% in the transportation sector, and 18.6% in the energy conversion sector. The carbon tax therefore contributes the most to the reduction of CO_2 emissions in the residential sector.

Table 2. CO_2 emissions in reference case

Sector	1990	2000	2010	(1990=100)
Total	287.3	318.4	340.4	118
Industrial	141.0	144.8	147.3	104
Residential	37.7	44.7	49.5	131

Commercial	33.4	39.9	43.4	130
Transportation	58.2	69.6	80.4	138
Energy conversion	17.0	19.5	19.8	116

Unit: Mt-C

Table 3. Comparison of CO_2 emissions to reference case in 2010

	Reference case	Market case		Carbon tax case		Carbon tax + subsidies case	
Total	360.7	318.4	(-6.3)	278.9	(-18.6)	282.0	(-18.6)
Industrial	147.3	136.7	(-7.2)	125.5	(-14.8)	127.6	(-13.4)
Residential	49.5	44.1	(-11.0)	32.6	(-34.1)	33.3	(-32.8)
Commercial	43.4	39.5	(-9.0)	33.5	(-22.9)	33.9	(-22.0)
Transportation	80.4	79.6	(-1.0)	71.1	(-11.5)	71.1	(-11.5)
Energy conversion	19.8	18.6	(-6.3)	16.1	(-18.6)	16.1	(-18.6)

Unit: Mt-C (Figures in parenthesis indicate percentage change relative to reference case)

Table 4. Subsidized energy saving equipment

Sector	Energy saving equipment
Industrial	Waste plastic recycling for blast furnace, high-efficiency continuous annealing line, high-performance naphtha cracking device, high-performance industrial furnace, regene boiler, repowering for electric generation, combined cycle power plant
Residential	High-efficiency air conditioner, energy saving house, inverter type fluorescent lighting device, high-efficiency refrigerator, high-efficiency television, high-efficiency VCR, high-efficiency stereo, standby power saving, latent heat recovery type water heater, water heater with CO_2 refrigerant
Commercial	High-efficiency air conditioner, HF inverter lighting device, light system with sensor, high-efficiency mainframe, high-efficiency duplicator, high-efficiency personal computer, pumping power with VAV control, standby power saving, latent heat recovery type water heater
Transportation	High-efficiency small private passenger car, high-efficiency regular private passenger car, high-efficiency commercial passenger car

In the carbon tax case + subsidies case, CO_2 emissions decrease by 2% between 1990 and 2010. The effect is almost the same as that of the carbon tax of ¥30,000 per ton of carbon, in spite of the lower tax rate. The tax revenues are used to subsidize the energy-saving equipment shown in Table 4.

10.2.3 Discussion

With a carbon tax-only policy, it is necessary to have a tax of ¥30,000 per ton of carbon to decrease CO_2 emissions to 2% below the 1990 level by 2010. However, if all carbon tax revenues are used to subsidize energy-saving equipment and technologies, the 2% reduction can be achieved at a tax rate of ¥3,000 per ton of carbon.

It is shown that the subsidy scheme is a useful option to reduce CO_2 emissions. However, the subsidy scheme may differ due to certain characteristics of reality. One of these is the difficulty of distributing funds efficiently. The AIM model has all the necessary information concerning energy equipment and can find the optimal distribution of the tax revenues to lower CO_2 emissions. In view of this, it should be noted that a carbon tax rate of ¥3,000 per ton is roughly the lower limit for attempting to cut CO_2 emissions through national measures. Another point is that the subsidy may not conform to the polluter-pays principle. Since the subsidies proposed in this simulation are entirely funded by carbon tax revenues. Hence the objections and disputes arising from non-conformance to the polluter-pays principle are not considered.

10.3 Application of Analysis of Ancillary Benefits in Prefectures

10.3.1 Background

Many of the countermeasures to prevent global warming have beneficial side effects that improve air quality by reducing such pollutants as nitrogen oxides and other particulates. The costs of mitigating global warming are generally considered to be high. Uncertainty in benefits of measures for mitigating global warming adds to the reluctance against such investments. Since the improvements in local air environment are easily measured and seen as high priority by local communities, quantifying the ancillary benefits of global warming related investments is important.

Additionally, in order for developing countries to retain incentives for the implementation of global warming countermeasures, the countermeasures should be compatible with their economic growth while still helping to resolve the domestic problems–such as air and water pollution–that these developing countries face. In other words, there is an opportunity to integrate the environmental and resource-related policies of developing countries into an international cooperative system for global warming countermeasures (Yang *et al.* 2001).

While bearing such domestic and international trends in mind, models to quantitatively estimate the effects of measures to prevent global warming on regional air environments are being developed. These developments are likely to assist in comprehensive policy making process by integrating various countermeasures to prevent global warming and preserve the air environment.

10.3.2 Development of estimation model for ancillary benefits

Estimation model

We created an estimation model for the ancillary benefits of countermeasures to prevent global warming. Using the model, we estimated emissions of CO_2, NO_x, and PM, and analyzed the effects of global warming countermeasures in 2010. The emissions were estimated in accordance with the flowchart shown in Fig. 1. The possession rate by vintage of device indicates the rate of possession of energy service technology by device type and operating years. The usage duration expresses the number of usage hours per day and usage days per year. The service demand, such as the amount of production and the volume of transportation, is the driving force for energy consumption. The first point regarding the features of this model is that an average emission factor has been estimated by multiplying the diffusion rate and the factor by device/year type. The second point is that a questionnaire to residents and individual voluntary action plans by companies has been reflected in the countermeasures to prevent global warming.

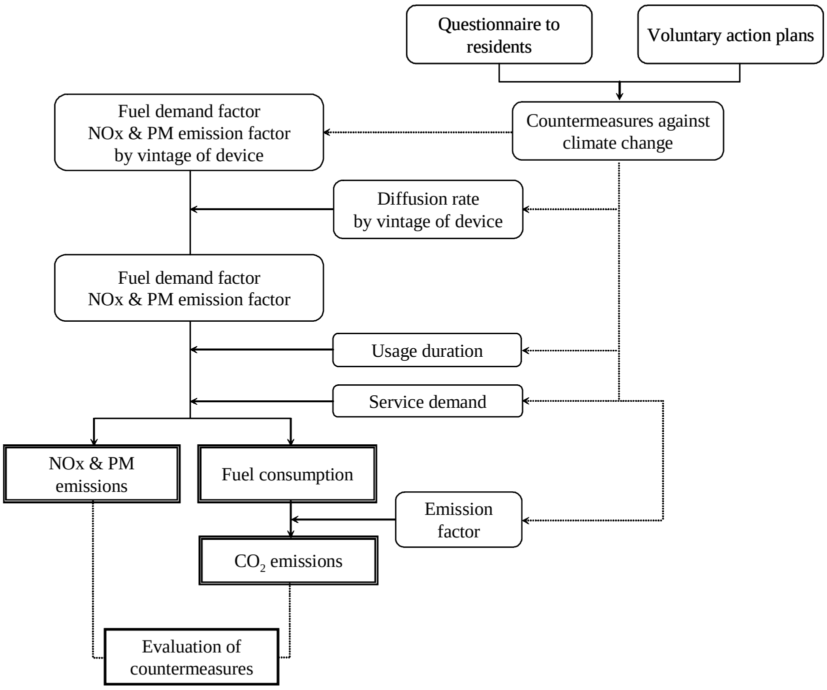


Fig. 1. Flowchart of estimation model for ancillary benefits

The emissions were estimated in four sectors: the industrial (including energy conversion sector), transportation, commercial, and residential sectors. Furthermore, we classified the industrial sector into 28 types of business, the transportation sector into 28 types, the residential sector into 45 types, and the commercial sector into 23 types of energy service technologies. As a general rule, the years used for estimation in each sector were 1990 as the base year and 2010 as the target year.

Countermeasures against global warming

Major countermeasures that have been adopted are shown in Table 5. In terms of the industrial sector, a reduction plan concerning energy consumption or CO_2 emissions for 2010 was input based on responses from companies. For companies on which research was not carried out, the Keidanren Voluntary Action Plans on the Environment were adopted. For other companies to which these did not apply, an estimate was made assuming a 1% annual energy consumption reduction in accordance with the Energy Conservation Law.

With regard to the transportation sector, the standard values of the Energy Conservation Law were used for improved fuel efficiency. Furthermore, the introduction of advanced-technology vehicles was set up by referring to the target values of Aichi prefecture. For the residential and commercial sectors, improvements in equipment efficiency were set up in accordance with the Energy Conservation Law, and improvements in efficient equipment selection rates were estimated in accordance with the prefectural plan. Furthermore, with reference to the transportation sector, infrastructural improvements such as easing of traffic congestion and promotion of modal shift for the countermeasure case were considered based on the assumption of the estimated results for automotive usage in the reference case. For the residential sector energy saving dwellings were considered, while measures such as shift to energy saving buildings were also considered for the commercial sector. Targeted numerical values for electric utilities in this area as of 2010 were used for the CO_2 emissions factor for electricity, which is common to all sectors.

Some of the countermeasures against global warming through lifestyle changes of the general public in the prefecture estimated for the countermeasure case are shown in Table 6. This was created based on responses from residents of the prefecture to questionnaires issued in October 1999. The number of valid responses was 1,364 out of a total of 2,000 questionnaires distributed. The existing implementation rate indicates the ratio that have already taken the actions concerned, while the expected implementation rate indicates the ratio that intend to carry out such actions among those who responded and includes those previously listed under the existing implementation rate.

Table 5. Major countermeasures against global warming

Sector	Countermeasures
Industrial	Voluntary plan of chemical industry
	Voluntary plan of transport machinery industry
	Voluntary plan of steel industry
Residential	Improvement in efficiency of air conditioners
	Improvement in efficiency of fluorescent lighting
	Installation of solar hot water systems
	Insulation with pair glass in existing houses
	Strengthening the structure of insulation in newly built houses
	Installation of synthetic energy-saving houses
Commercial	Improvement in efficiency of air conditioners
	Improvement in efficiency of personal computers
	Improvement in efficiency of lighting systems
	Installation of HF inverter lighting systems
	Installation of high-efficiency emergency lights
	Installation of synthetic energy-saving houses
Transportation	Improvement in efficiency of privately owned gasoline cars
	Improvement in efficiency of ordinary diesel freight vehicles
	Introduction of privately owned gasoline hybrid cars
	Modal shift from truck to rail

10.3.3 Estimation results

Emissions by sector

Figure 2 shows CO_2, NO_x, and PM emissions in the reference and countermeasure cases in the base, latest, and target years.

CO_2 emissions in the target year would be reduced by 7% from the base year by establishing the countermeasures drawn up in the prefectural plan, while NO_x emissions would be reduced by 24% and PM emissions by 32%. As for NO_x and PM emissions in the transportation sector, it was decided that the planned values under the national regulations would be specified in both the reference and countermeasure cases. Furthermore, emissions produced in the generation of electricity were allocated in the demand sector in accordance with the amount of electricity consumption.

The emission ratios for the countermeasure cases using 100% as the reference case are shown in Fig. 3. When the total emissions of the sectors are compared between the reference and countermeasure cases in the target years, the amount of CO_2 emissions is reduced by 23%, but at the same time, it can be seen that NO_x emissions fall by 11%, as do PM emissions. When the results are analyzed by sector, NO_x drops by 11% and PM by 8% in line with a 19% reduction in CO_2 from the industrial sector. As for the transportation sector, CO_2 falls by 21%, although NO_x is only reduced by 8% and PM by 5%. In terms of the residential sector, CO_2 is reduced by 33%, NO_x by 30%, and PM by 38%. In the commercial sector, NO_x is reduced by 26% and PM by 31%, broadly in line with a 34% drop in CO_2.

Table 6. Selected countermeasures against global warming through lifestyle changes

Sector	Countermeasure	R1	R2
Transportation	Reduction of sudden acceleration from rest 10 times a day	37	87
	Removal of any unnecessary luggage (10 kg) prior to driving	27	78
	Reduced idling of cars by five minutes a day	33	86
	Driving with appropriate tire pressure	40	60
Residential	1°C reduction in temperature setting of air conditioners	24	88
	1-hour reduction in heater use	0	60
	Reduction in use of lights	40	98
	Reduction in shower running time (3 minutes a day)	26	94
Commercial	Changing heater temperature setting to more appropriate one	42	92
	Changing cooler temperature setting to more appropriate one	42	91
	Turning off lights during lunch breaks	40	92

R1: Existing implementation rate (%), R2: Expected implementation rate (%)

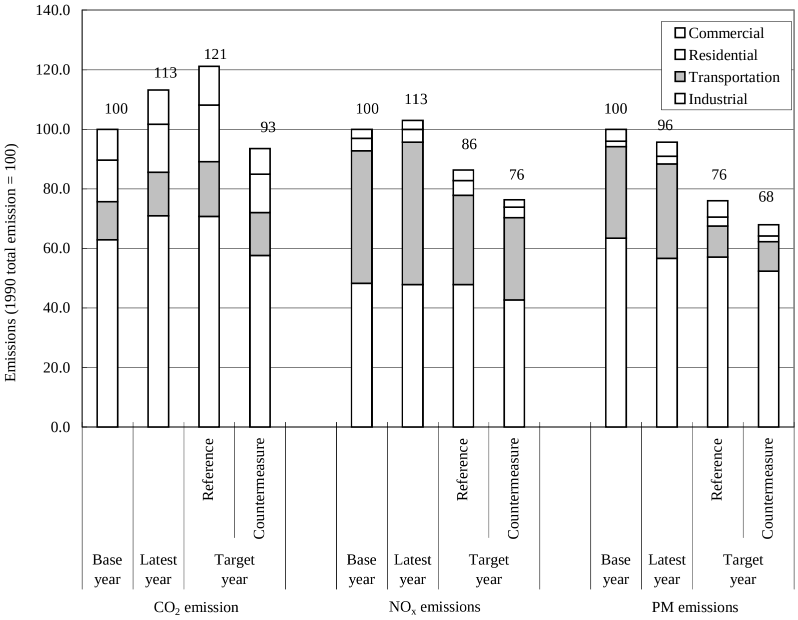


Fig. 2. CO_2, NO_x, and PM emissions in Aichi prefecture

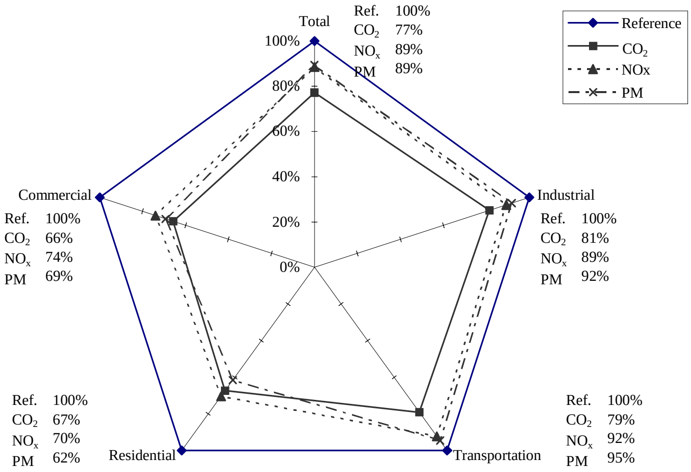


Fig. 3. Comparison between reference and countermeasure cases

Analysis of CO_2, NO_x, and PM reduction effects by countermeasure type

Table 7 shows the CO_2, NO_x, and PM reduction contribution rates of each countermeasure type. The reduction contribution rate mentioned in this section indicates the ratio of the amount of reduction for each action with respect to emission amounts in the reference case for the target year. The reduction effects on each gas by global warming-related countermeasures against CO_2, NO_x, and PM are analyzed as follows.

Major reduction contribution rates for CO_2 result from the voluntary plan of the steel industry (6.3%), improved fuel efficiency for privately owned gasoline cars (6.6%), and improved efficiency of domestic air conditioners (heaters) (3.2%). Major reduction contribution rates for NO_x result from the voluntary plan of the steel sector (5.1%), modal shift promotion (2.4%), and installation of solar hot water systems (6.4%). Major reduction contribution rates for PM result from the voluntary plan of the chemical industry (3.4%), modal shift (2.6%), and improved efficiency of domestic air conditioners (heaters) (5.4%). Furthermore, high reduction contributions are shown for a reduction in the emission factor of electricity in the residential and commercial sectors; that is, 5.1 to 5.9% for CO_2, 3.2 to 3.7% for NO_x, and 3.8 to 8.7% for PM.

Table 7. Contribution of each countermeasure to total reduction

Sector	Countermeasure	CO_2	NO_x	PM
Industrial	Voluntary plan of chemistry industry	1.2%	2.4%	3.4%
	Voluntary plan of steel industry	6.3%	5.1%	3.1%
	Voluntary plan of transport machinery industry	1.5%	0.4%	-0.6%
	Reduction in emission factor of electricity	3.3%	0.8%	1.1%
Transportation	Improvement in efficiency of privately owned gasoline cars	6.6%	0.0%	0.0%
	Introduction of privately owned gasoline hybrid cars	1.7%	0.9%	0.0%
	Reduction of sudden acceleration from rest 10 times a day	2.0%	1.1%	0.8%
	Driving with appropriate tire pressure	1.4%	0.8%	0.5%
	Modal shift from truck to rail	1.2%	2.4%	2.6%
Residential	Improvement in efficiency of air conditioners (heaters)	3.2%	2.0%	5.4%
	Installation of solar hot water systems	3.0%	6.4%	0.0%
	1-hour reduction in heater use	2.4%	1.8%	1.6%
	Reduction in use of lights	2.2%	1.4%	3.7%
	Reduction in shower running time (3 minutes a day)	3.0%	5.5%	0.9%
	Reduction in emission factor of electricity	5.1%	3.2%	8.7%
Commercial	Improvement in efficiency of air conditioners	2.1%	1.3%	1.3%
	Improvement in efficiency of lighting systems	5.2%	3.3%	3.4%
	Improvement in efficiency of personal computers	3.3%	2.1%	2.1%
	Changing heater temperature setting to more appropriate one	2.5%	4.2%	5.8%
	Installation of synthetic energy-saving houses	2.0%	3.0%	3.2%
	Reduction in emission factor of electricity	5.9%	3.7%	3.8%

10.3.4 Discussion

In order to quantitatively understand the effects of countermeasures against global warming on the regional air environment, we developed a model and conducted estimates/analyses by applying this model to Aichi prefecture as a case study. The results obtained are summarized as follows.

- When the reference case was compared to the countermeasure case in the target year after carrying out the measures specified in the prefecture’s regional promotion plan for global warming-related countermeasures, NO_x and PM emissions were both reduced by 11% against a 23% reduction in CO_2 emission.
- When the reference case was compared to the countermeasure case for the target year after implementing measures to reduce CO_2 emissions, equivalent or higher percentages of NO_x and PM reductions could be achieved in the residential and commercial sectors. In the industrial and transportation sectors, reductions in NO_x and PM of between a quarter and a half of those for CO_2 could be achieved.
- The contribution of each action to the amount of CO_2 reduction in the countermeasure case as compared to the reference case has also been analyzed. In terms of CO_2, the voluntary plan of the steel industry, improvement in the efficiency of gasoline engines in privately owned cars, and improvement in the efficiency of lighting systems demonstrate comparatively large reduction contribution rates. As regards NO_x, the voluntary plan of the steel industry, reduced running of showers, and changing heater temperature settings in offices to more appropriate ones produce comparatively high reduction contribution rates. For PM, the voluntary plan of the chemical industry, improvement in the efficiency of domestic air conditioners (heaters), and changing heater temperature settings in offices to more appropriate ones offer comparatively high reduction contribution rates. Furthermore, reductions in the emission factor of electricity in the residential and commercial sectors significantly contribute to reductions in CO_2, NO_x, and PM emissions.

An ancillary-effects estimation model was developed and applied to Aichi prefecture. Through this study of co-benefits, we also looked at the implication for future environmental policies. Our observations are as follows.

- It has become possible to quantitatively understand air pollutant emission reduction effects from countermeasures to prevent global warming by developing a model that can simultaneously estimate greenhouse gases and air pollutants. Its use allows comprehensive measures that functionally link global warming and air preservation-related measures to be studied. For example, the importance of the industrial and transportation sectors has been clarified in terms of CO_2, NO_x, and PM emissions in the case of Aichi prefecture. It has also been clarified that measures taken by the residential and commercial sectors are important from the perspective of ancillary effects.

- CO_2, NO_x, and PM reduction characteristics by measure are shown simultaneously, which could be useful in deciding the priority for measures in accordance with the regional characteristics of local public organizations. Through these estimates, the voluntary plan of the steel sector and reductions in the emission factor of electricity may be seen as measures or areas in which significant reductions in the amounts of NO_x and PM emissions, as well as CO_2, can be realized. Understanding the correlations of these ancillary reduction effects will be useful for determining future measures.
- Analysis of the effects of area separations required to study any countermeasures against air pollution onsite will be possible by linking this estimation tool to the geographical information system (GIS).
- As suggested by the Eco Policy Linkage that was proposed in Environment Congress for Asia and the Pacific, this estimation model can be utilized in developing countries as a tool to promote global warming countermeasures. Developing countries need an approach in which the effects of countermeasures against local pollutants such as sulfur oxide on greenhouse gas emission reductions are analyzed. This model can also be used for this purpose.

10.4 Development of CO_2 Emission Scenarios in Japan

10.4.1 Background

With the Kyoto Protocol due to come into effect soon, specific measures to ensure its compliance are a matter of urgency in Japan. Furthermore, as a preliminary step for the next and future negotiations, we are at a stage where we need to thoroughly discuss issues ranging from emission forecasts to the effectiveness of the measures for the second commitment period starting in 2013. In order to estimate future greenhouse gas emissions–a prerequisite for such discussions–we first require social and economic scenarios as a basis of these estimates for future greenhouse gas emissions. However, since many aspects concerning the future course of society and the economy are unclear, it is thought desirable to hold discussions using data on future emissions derived from simulations under various possible scenarios, rather than a single scenario. Four alternative scenario families of future emissions and their driving forces have been assumed by IPCC (IPCC 2000). Accordingly, the Working Group to Draw up Japanese Emissions Scenarios organized by the Ministry of the Environment has presented four narrative scenarios. The authors also estimated Japan’s future CO_2 emissions for each narrative scenario using the AIM/Enduse [Japan] model. From these results, consideration was given to the causal relationship between Japan’s growth pattern and the significance of measures to control greenhouse gases.

10.4.2 Japan's narrative scenarios and synopses

The Working Group to Draw up Japanese Emissions Scenarios presented four alternative scenarios for Japan, with due consideration for consistency with the emissions scenarios formulated by IPCC (Fuji Research Institute Corporation 2001) . An outline of each is given below.

A1 scenario (global market-based scenario)

In the A1 scenario, the Japanese economy shifts toward a market-based economic system that attaches greater importance to the economic rationale for survival under a global market economy. Investments are targeted to increase productivity, with the aim of fueling economic growth. Also, employment opportunities will increase for the elderly, women, and foreign nationals—in other words, there will be more equal opportunities—indicating a shift toward merit-based employment regardless of age or gender in such a competitive business world.

In terms of lifestyles, active consumer spending based on high purchasing power will be brought about. Time saved by outsourcing housekeeping tasks resulting from a focus on economic efficiency will be spent on recreation and education.

Moreover, the population and capital will be centralized into a megalopolis. Transportation networks will be developed featuring railways and automobiles in the central area, and automobiles in the suburbs.

In the energy industry, price competition will intensify in line with reductions in the cost of electricity following deregulation. As a result, demand for electricity derived from fossil fuels (mainly coal and oil) will increase.

A2 scenario (scenario featuring regions and traditions)

In the A2 scenario, economic development follows the same trends as the existing social and economic systems, instead of altering these systems rapidly. Accordingly, the economy will remain relatively depressed, and society will be inwardly stable without social and economic structural reform.

In terms of employment, thanks to the retention of the orthodox Japanese management system, employment levels will be maintained despite the stagnant economy. However, there will be no significant increase in employment opportunities for the elderly, women, or foreign nationals. Furthermore, the working hours per person will be longer than those of any other scenario because there is no material enhancement in labor productivity.

In terms of lifestyle, consumption will remain at current levels. In terms of urban structure, the population and capital will be more diversified across a number of core cities. Thus, automobiles will be the main form of transportation for both cargo and passenger services across a road network connecting these cities, and also owing to active public investment in rural areas.

In terms of energy, electricity will become heavily reliant on nuclear power under an expansion of the former energy security policy.

B1 scenario (environmental-technology-led scenario)

This is a highly technology-oriented scenario that tends to favor both economic development and dematerialization through technological innovation. Investment in environmental preservation is preferred, and thus dematerialization will be advanced. Moreover, the economic growth rate will rise (though not as much as in the A1 scenario), led by the environmental industry and environment-related investments.

Employment opportunities for women and the elderly will increase. In this scenario, women’s employment will rise, supported by outsourcing of child-care and nursing, in line with the growth of a welfare industry suited to an aging society with a declining birthrate, due to a focus not only on environmental preservation but also on welfare.

In terms of housing and transportation, an environmentally harmonious society will be built without any reduction in service demand, through resource optimization led by technological development. Items such as super heat pumps, fuel cells, etc., will become more popular, as well as long-life houses and advances in insulation through technological development. Also, inner-city transportation will be created using light rail transit (LRT) and urban monorails as cities will become more compact and diversified across the nation, rather than being congregated into a megalopolis. Fuel cells will become more popular not only in housing but also in automobiles.

In terms of energy, natural gas will be the main source following the adoption of natural gas thermal power stations and fuel cells.

B2 scenario (new independent areas scenario)

B2 is a scenario in which regions coexist symbiotically with independent and sustainable production areas for each. City structures will be very compact, in which communities will be the key decision-making elements in the socioeconomic system. Nongovernmental organizations (NGOs) and non-profit organizations (NPOs) will play important roles under such a socioeconomic system.

In the B2 scenario, a cyclical economy will be formed with arterial and venous industries cooperating in independent production areas. It is a scenario intended to harmonize the economy with the environment just as the B1 scenario does. However, such an environmentally harmonious society will be formed on the basis of changed lifestyles due to an altered sense of values in B2, not by technology as is the only solution in B1. For example, purchase-cycles for housing, furniture, appliances, automobiles, etc., will all be extended, so that expenditures on consumer goods will decrease, while on the other hand, consumer demand for longer lasting goods will increase despite their higher cost. Moreover, service industries such as the refurbishment and repair industry will be bolstered to support longer life cycles for these products. Manufacturers will also be transformed from companies that simply produce and sell goods into service-lease companies. As a result, they will strive for environmental harmony in all stages of their goods' life cycles, from production through usage to disposal.

In the realm of transportation, public transport and bicycles will take the place of automobiles thanks to the close proximity of living and business areas.

In employment terms, opportunities for women and the elderly will increase thanks to work-sharing schemes to promote social involvement of various types of people. Although the welfare system to support them will be enhanced, the role played by local communities under such welfare systems is important. As a result of work sharing, fewer hours will be allocated per person, and recreational periods will be spent doing various activities in the local community.

In terms of energy, service demand in the energy industry will be lower than in any of the other cases, due to a transition toward more environment-friendly lifestyles. Also, since people will be far more conscious of environmental matters and decision-making by local communities will be emphasized, environment-friendly energy systems will be adopted although they cost more. Accordingly, no new nuclear power plants will be built, while the building of new thermal power plants will be kept to a minimum—with an emphasis on natural gas power plants—because demand for large-scale power plants will decrease following the adoption of fuel cells based on local energy sources such as biomass energy, in addition to falling electrical demand due to changes in lifestyles.

10.4.3 Estimation of CO_2 emissions using AIM/Enduse [Japan]

Simulation assumptions

Using AIM/Enduse [Japan], we estimated the long-term profile of CO_2 emissions based on the four aforementioned scenarios. An estimation of the energy service demand per sector assumed on the basis of these four scenarios is shown in Table 8. Future CO_2 emissions in Japan were estimated using AIM/Enduse [Japan] for the following reference and countermeasure cases.

a. Reference case (fixed technology case)
   CO_2 emissions until 2020 were estimated on the assumption that the usage shares of energy technologies will not change.
b. Countermeasure case (carbon tax case)
   CO_2 emissions were estimated assuming the adoption of energy saving and renewable technologies with a marginal cost limited to ¥30,000, which will be realized by charging a ¥30,000 carbon tax per ton of carbon used for secondary energy.

Table 8. Energy service demand assumed in AIM/Enduse [Japan]

			2010				2020			
			A1	A2	B1	B2	A1	A2	B1	B2
General	Economic growth rate	(%/year)	2.1	0.9	1.6	0.5	1.9	0.6	1.4	0.6
	Population	(million)	127	126.3	128.4	127.6	123.6	121.4	126.4	124.1
Industrial	Crude steel	(10,000 t)	8,887	9,860	9,120	9,119	7,876	9,584	8,265	8,268
	Cement	(10,000 t)	8,398	8,194	8,264	7,727	8,667	8,245	8,422	7,161
	Ethylene	(10,000 t)	668	701	640	645	616	687	573	598
	Paper and paperboards	(10,000 t)	3,052	3,311	3,010	3,004	2,891	3,366	2,836	2,848
	Share of tertiary industry	(%	65.9	64.1	65.4	64.8	68	64.3	67.1	66.4
Residential	Households	(million)	49.6	49	49.4	48.8	50	48.4	49.7	48.2
	Heating service per household	(2000 = 100)	100	92	97	89	101	86	88	77
	Cooling service per household	(2000 = 100)	145	137	145	133	145	145	145	143
	Information appliances per household	(2000 = 100)	128	116	122	116	154	127	139	127
	Fuel cell cogeneration	(million kW)	0	0	1	0	0.5	0.5	5	2.5
Commercial	Floor space	(million m^2)	1,804	1,710	1,796	1,702	1,957	1,749	1,922	1,766
	Fuel cell cogeneration	(million kW)	0	0	1	0	0.5	0.5	5	2.5
Transportation	Passenger transportation	(mil. pass.-km)	1,387	1,343	1,367	1,323	1,402	1,325	1,377	1,291
	Fuel cell vehicles	(%)	0	0	0	0	0	0	20	10
	Freight transportation	(million t-km)	593	544	559	506	660	552	584	478
Power generation	Nuclear power plants	(MW)	53,248	57,546	49,580	44,917	53,819	63,819	49,521	41,190

Results of simulations

CO_2 emissions of simulation cases are shown in Table 9 and Fig.4. CO_2 emissions will be largest, increasing by 33% compared to 1990, in the A1-reference case that emphasizes economic efficiency in a highly competitive market society. When we look at changes in GDP per capita as shown in Fig. 5, although the economic scale is larger than that of the other scenarios and energy demand is expected to increase, energy intensity drops dramatically in accordance with an industrial shift toward services. Furthermore, this scenario offers the worst situation in terms of carbon intensity, due to the maintenance of oil/coal-based energy systems with a worldwide stabilization in the energy status. In transportation terms, the development and adoption of fuel cell-powered vehicles does not advance due to relatively low gasoline prices. Coal and oil would also likely be chosen by electric utilities under free market conditions as low-cost energy sources. Moreover, in the A1-countermeasure case, CO_2 emissions increase by 2% in 2010 and by 5% in 2020, compared to 1990.

Energy intensity is largest in the A2 scenario. An industrial shift toward services cannot advance much because factors such as the comparative advantages of Japanese manufacturers remain the same under these circumstances in which a global economic market does not penetrate to a high degree, or stable demand for civil engineering and construction work led by old-style public investment maintains the current level of domestic steel and cement production, all of which result in a high energy intensity. Conversely, carbon intensity shows a certain

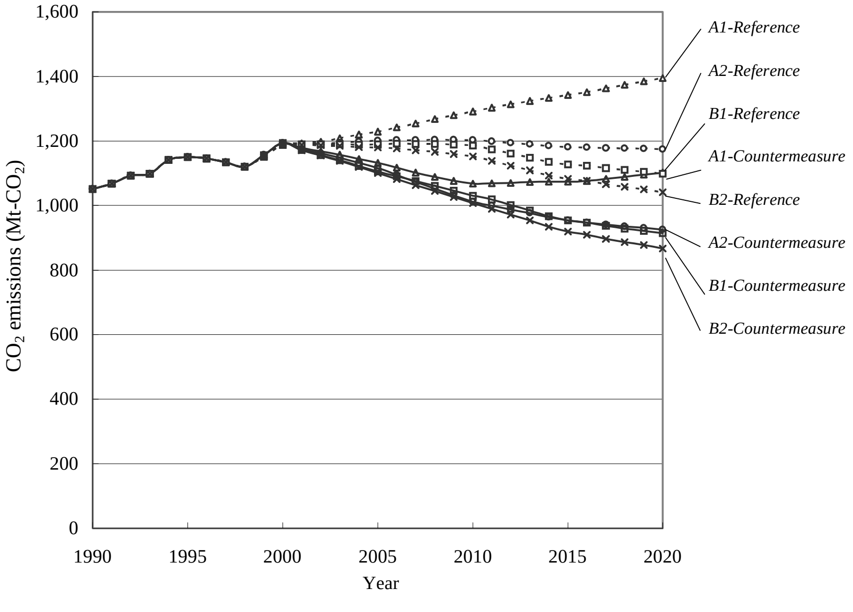


Fig.4. CO_2 emission profiles of simulation cases

drop. This is because the number of nuclear power plants continues to increase under circumstances that require energy security due to global instability in terms of energy supplies. In this scenario, CO_2 emissions would dramatically decrease from 1990 levels, showing drops of 4% by 2010 and 12% by 2020.

In the B1 scenario, relative compatibility between economic growth and dematerialization will be achieved by development and distribution of environmental technologies. Technologies to reduce the amounts of waste for disposal (i.e., eco-cement, biodegradable plastic) will have been developed and adopted for the industrial sector, as well as technologies for comfortable lifestyles (such as insulation systems) for the residential sector, countermeasure technologies against air pollution and noise (i.e., fuel cell vehicles and next-generation public transportation) for the transportation sector, and natural gas-based systems as countermeasures against air pollution (natural gas thermal power generation, fuel cell cogeneration) in the energy field. As a result, CO_2 emissions will be reduced. Both energy intensity and carbon intensity will be smaller, and CO_2 emissions will be significantly small even though the scale of economy is comparatively larger. If countermeasures to reduce CO_2 emissions are implemented, a significant reduction from the 1990 level will be possible as in the A2 scenario, with a reduction of 2% in 2010 compared to 1990, increasing to 13% by 2020.

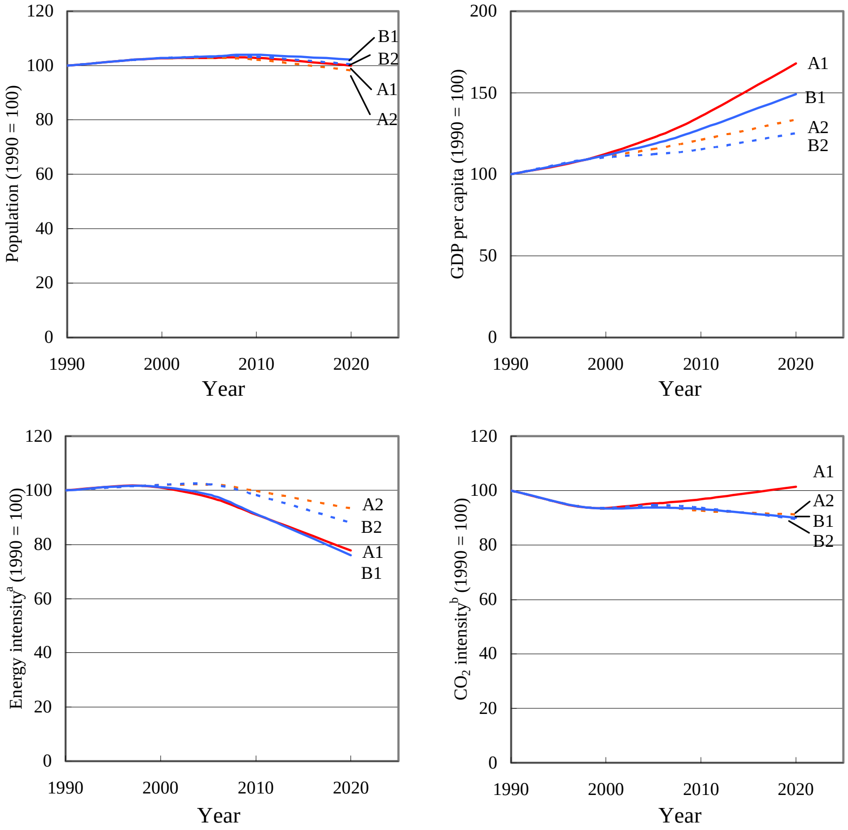
The B2 scenario emphasizes local issues and equitability. From the viewpoint of revitalization and local equitability, job-sharing enables both a reduction in working hours and guaranteed employment at the same time. Direct decision-making by residents will be adopted for local issues, and decisions that might result in pollution or destruction of the local environment or even prove fatal will be replaced. In concrete terms, energy diversification rather than the new development of nuclear power plants, the purchase of recycled or long-lasting goods rather than building waste incinerators, and the use of fuel cell vehicles rather than gasoline-powered vehicles that cause air pollution will be chosen. The scale of economy will be relatively small and the speed of development and adoption of environmental technologies will be slower than in the B1 scenario,

Table 9. CO_2 emissions of simulation cases

	1990	1998		2010		2020	
A1 - Reference	1,051	1,120	(107)	1,292	(123)	1,394	(133)
A2 - Reference	1,051	1,120	(107)	1,202	(114)	1,174	(112)
B1 - Reference	1,051	1,120	(107)	1,186	(113)	1,099	(105)
B2 - Reference	1,051	1,120	(107)	1,152	(110)	1,041	(99)
A1 - Countermeasure	1,051	1,120	(107)	1,068	(102)	1,102	(105)
A2 - Countermeasure	1,051	1,120	(107)	1,012	(96)	926	(88)
B1 - Countermeasure	1,051	1,120	(107)	1,030	(98)	914	(87)
B2 - Countermeasure	1,051	1,120	(107)	1,008	(96)	867	(83)

Unit: Mt-CO_2, (1990 = 100)

which stimulates the environmental industry under a market economy. However, CO_2



Note: a: Energy intensity = Energy consumption / GDP, b: CO_2 intensity = CO_2 emission / Energy consumption

Fig. 5. Population, GDP per capita, energy intensity, and CO_2 intensity in reference cases

emissions will still be at the same level as in B1, in the event that society and the economy are headed toward the end indicated in the B2 scenario. Over the long term, CO_2 emissions are the smallest among the four scenarios provided that greenhouse effect countermeasures are adopted, resulting in decreases of 4% in 2010 and 17% in 2020 compared to 1990. CO_2 emissions in Japan are smallest under the B2 scenario; however, the same is true under the B1 scenario in SRES by IPCC. This is because there is no significant difference in population increase between the Japanese scenarios, and the difference in economic growth between B1 and B2 directly affects the emissions, in contrast to B2 of SRES, in which the population increase causes larger emissions.

10.4.4 Discussion

As described above, energy consumption and CO_2 emissions in Japan up to 2020 were estimated using AIM/Enduse [Japan] on the assumption of four narrative scenarios of Japan’s society and economy. When we compare the CO_2 emissions with the proviso that measures to reduce CO_2 emissions are adopted, possibilities for reductions to below the level of 1990 are demonstrated in three of the four cases, with the A1 scenario being the exception. Each case can be characterized as follows. The A2 scenario reduces carbon intensity by increasing nuclear power output. The development and adoption of environmental technology in the B1 scenario leads not only to economic growth but also to a reduction in greenhouse gases. In the B2 scenario, a social system is formed on a regional basis, with bottom-up decision-making that can be followed by reduction of greenhouse gas emissions. The means of achieving the reduction differ greatly from one scenario to the other. Furthermore, the emissions in 2010 when countermeasures are implemented will be almost the same for A2, B1, and B2, but will differ in 2020 (it should be noted that the scale of economy in B1 and A2 are significantly different, although their estimated emissions in 2020 are similar). In other words, when we examine long-term (i.e., 20 to 30 years) countermeasures against global warming, there must be sufficient discussion to understand which development pattern will be adopted and whether or not the countermeasures that are being planned or implemented are appropriate to that pattern, rather than merely discussing global warming countermeasures by themselves.

10.5 Concluding Remarks

Various decision-makers have used the AIM/Enduse model. Due to wide use of the modeling approach for dealing with the global warming problem, it is expected that the application of AIM/Enduse will spread to various involved parties in Japan. The following are some expected applications of AIM/Enduse in the near future.

- Governments will develop an integrated management system for the atmospheric environment with linkages between emission inventories and AIM/Enduse so as to address both air pollution and global warming simultaneously.
- Governments will analyze the effects of various policy combinations, such as voluntary plans, energy efficiency regulation, emission regulation, emission trading, energy tax, and emission tax.
- Private companies will analyze the impact of their own products on global warming using AIM/Enduse linked with their environmental accounting system.
- Private companies will develop strategies for emission trading using AIM/Enduse.

- Citizens will analyze their activities using a system linking environmental household account books and AIM/Enduse.

In order to meet these requirements, we need to develop additional modules for AIM/Enduse such as a user-friendly interface, expansion of target gases, linkages with material and top-down models, linkages with statistical tools and emission inventories, and so on.

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