Global Environment Research Fund

Development of Japan Low Carbon Society Scenarios

Scenario Study Team

Japan Low Carbon Society Scenarios Toward 2050

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Scenario Study Team of "Japan Low Carbon Society Scenarios toward 2050"

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I. Overview

1. Why do we need Low-carbon society (LCS)?

One important characteristic of the climate system is its inertia. Because of past and current greenhouse gas emissions, a certain increase in global temperature is unavoidable. Such increases in temperature carry profound risks. Even a small increase in temperature is likely to have significant impacts on ecosystems and species, and might lead to increased drought and extreme rainfalls, with severe consequences for our society. The Third Assessment Report (TAR) of the Intergovernmental Panel on Climate Change (IPCC) and other, more recent, studies have indicated the following:

i. An increase of even 1℃ in global average surface temperature compared to pre-industrial levels is likely to have significant impacts on fragile ecosystems including coral reefs,

ii. Negative impacts on agriculture, water resources, and human health would appear on a global scale for a temperature increase between 2 and 3℃,

iii. Serious risk of large scale, irreversible system disruption, such as reversal of the land carbon sink and destabilization of the Antarctic ice sheets, is more likely above 3℃. Such levels are well within the range of climate change projections for the century.

The Central Environment Council (advisory committee for Ministry of the Environment, Japan) proposed that it is important to steadily collect, consider, and examine the information on long-term objectives of limiting the temperature rise, and 2℃ increase of temperature from the pre-industrial level will be good starting point for further discussion on this issue.

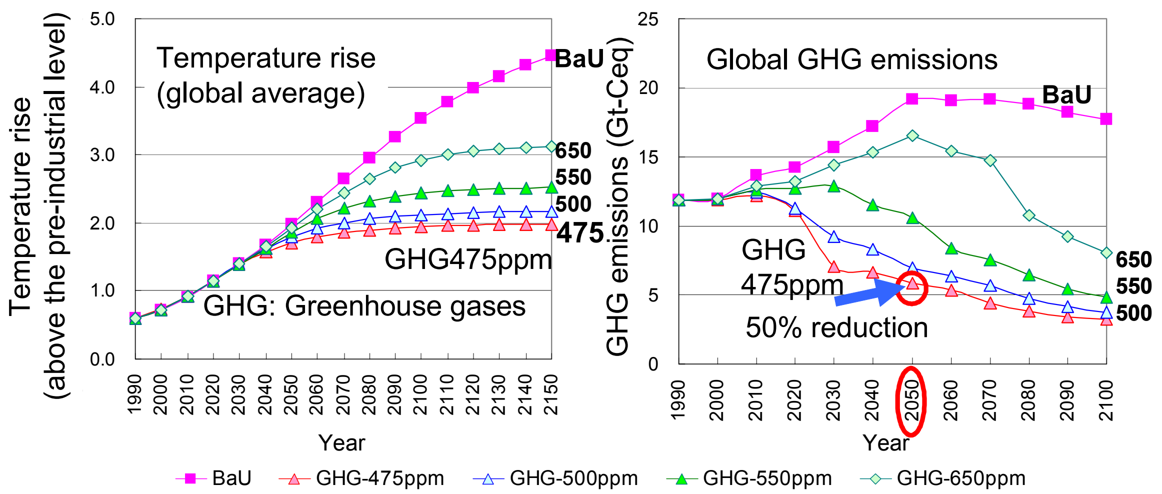


Fig. 1.1 Temperature rise and GHG emissions for BaU and different stabilization levels

According to our latest model calculations, in order that global mean temperature does not exceed 2℃ from the pre-industrial level, global greenhouse gas (GHG) reduction target needs to be about 50% of

1990's emissions level in 2050 and 75% in 2100 (Fig. 1.1). For per capita emission in 2050 to be same across the world, Japan will be required to reduce its emissions by about 80% compared to the 1990 level. However these numbers include certain amount of uncertainty arising from global warming mechanisms and climate impacts. A large amount of reduction is required considering the balance of sinks and sources of GHG. This implies that the reduction rate for Japan would have to be in the range of 60-80%. Therefore, there is a need to design Low-Carbon Society (LCS).

2. How to develop LCS? -Backcasting-

CO_2 emissions can be disaggregated based on the following equation referred to as the Kaya identity:

$$CO_2 = (CO_2/E) \times (E/GDP) \times GDP$$

CO_2: CO_2 emissions, E: Primary energy, GDP: Gross Domestic Production

(CO_2/E) is "carbon intensity" and improves if the share of renewables and nuclear increases. (E/GDP) is "energy intensity" and improves if less energy is used for the same amount of GDP.

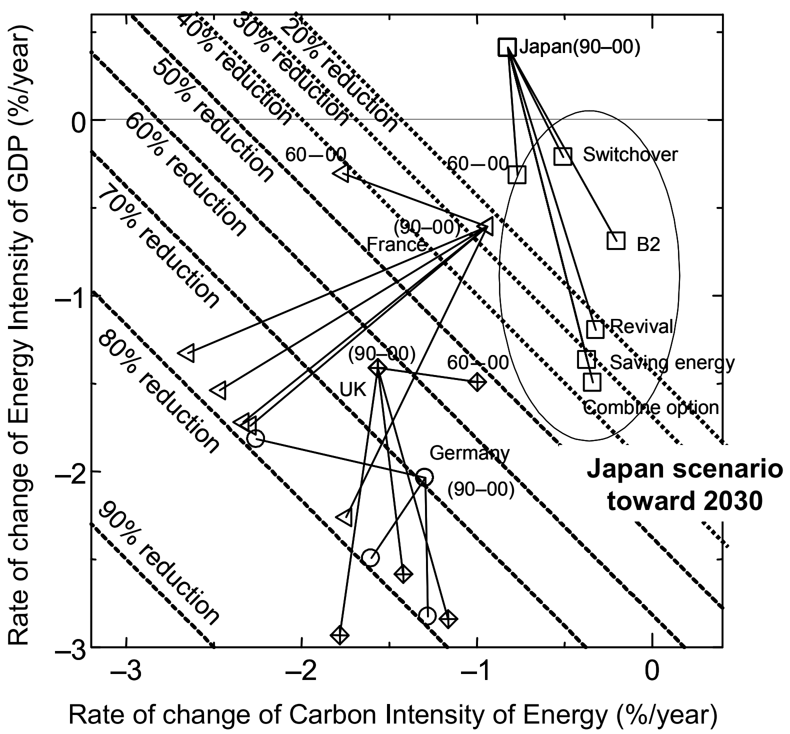


Fig. 1.2 Relationships between CO2 reduction targets and rate of change of aggregated energy intensity and carbon intensity (dotted isoquant lines show the estimated CO2 reduction over 50 years assuming annual GDP growth rate of 1% for each country; It must be noted that reduction levels shown here are not the same as those reported by each country's scenarios because they assume different GDP growth rate)

Fig. 1.2 shows relationships between CO2 reduction targets and rate of change of aggregated energy intensity/carbon intensity from historical trends, and existing GHG emissions scenarios for Japan, UK, Germany, and France. When we assume GDP growth rate of 1% per year up to 2050, CO_2 reduction rate will be at most 40% in 2050 based on existing future emissions scenarios in Japan. This is not enough to achieve LCS targets such as 60-80% reductions in 2050. Results of current researches on Japan emissions scenarios indicate that "forecasting" method, which considers future image as extension of current countermeasures, is not likely to be suitable for LCS scenario development. We need 'trend-breaking' interventions and investments. Thus we examine the "backcasting" method, which first develops emission target representing favorable LCS visions and then discusses the method to achieve it (Fig. 1.3).

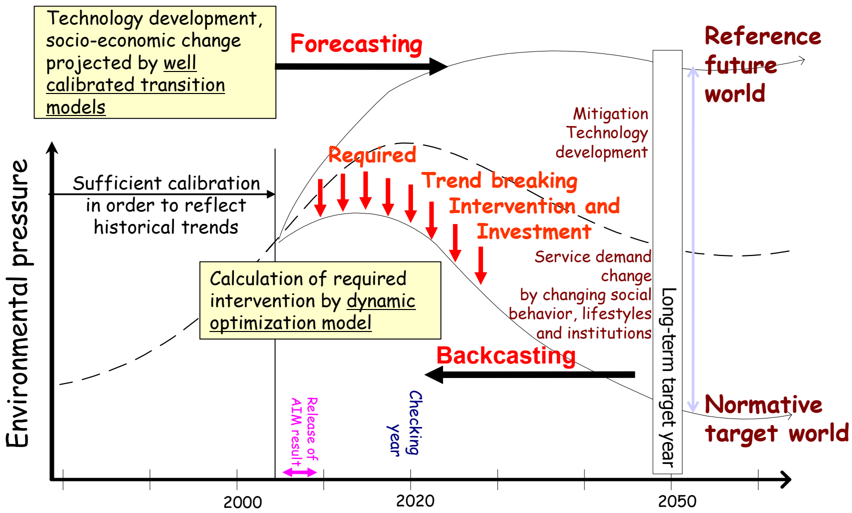


Fig. 1.3 Backcasting methodology to design LCS

3. How to find trend-breaking possibilities?

GHG emissions are related to various kinds of human activities. To achieve deep cut in GHG emissions, not only mitigation technology development but also service demand changes by changing social behavior, lifestyles, and institutions are required.

A large part of social infrastructure is likely to be replaced by 2050. It would be possible to propose concrete policy packages including institutional change, technology development, and lifestyle change toward LCS.

We have developed the narrative storylines, their quantitative scenarios, and trend-breaking countermeasures in residential sector, service sector, transportation sector, industrial sector, energy supply sector, and others. The desired Japan 2050 future images with 60-80% GHG reduction will be set and the path considering economic impact, technological possibilities, and institutional and lifestyle changes will be simulated objectively and consistently using several numerical model analyses.

II. Future scenarios and the evaluation framework -Case study in Japan-

1. Dominant trends and two socio-economic storylines

In order to examine the feasibility of the LCS in 2050, it is important to pay attention to the changes in several social factors. What would be the features of the society and the economy in 2050? The major trends in 2050 are discussed below

1.1 Dominant trends of society and economy

One of the most obvious and drastic changes in 2050 would be the population structure. The change is mainly caused by the downturn in birthrate over the long term. The trends of depopulation and aging will continue until 2050 with high certainty. In addition, progress of globalization of the markets and maturation of information society (informatization) would be the other major trends through 2050.

1.2 Two scenarios

In long-term scenarios, many uncertain factors exist, and also dominant trends as mentioned above. Although we can draw the infinite pictures about our future, it is impossible to assess all of them. The meaningful work is to represent the possibilities of drastic reductions of carbon emissions. In order to take future uncertainties into consideration, two different scenarios were developed by focusing on cause-and-effect relationships among the factors. The summaries of the two scenarios are presented below

Scenario A

Technical progresses in the industrial sectors are considerably high because of vigorous R&D investments by the government and business sectors. The economic activities as a whole are so dynamic that average annual per capita GDP growth rate is kept at the level of 2%. The other reasons for such high economic growth are high rates of consumption in both business and household sectors.

The employment system has been drastically changed from that in 2000 and equal opportunities for the employment have been achieved. Since workers are employed based on their abilities or talents regardless of their sex, nationality and age, the motivation of the worker is quite high in general.

As many women work outside, the average time spent for housekeeping has decreased. Most of the household works are replaced by housekeeping robots or services provided by private companies. Instead, the time used for personal career development has increased.

The new technologies, products, services are positively accepted in the society. Therefore, purchasing power of the consumer is strong and upgrade cycles of the commodities are short.

Household size becomes smaller and the number of single-member households has increased. Multidwellings are preferred over detached houses, and the urban lifestyle is more popular than the lifestyle of countryside.

Scenario B

Although average annual growth rate of per capita GDP is approximately 1%, people can receive adequate social services no matter where they live. Volunteer works or community based mutual aid activities are the main provider of the services. Since the levels of medical and educational service in the countryside have drastically improved, continuous migration of population from city to countryside has been observed.

The number of family who own detached dwellings has increased. The trend is especially prominent in the countryside. The size of the houses and the floor area per houses has also increased with the increasing share of detached houses.

The ways people work have also changed. The practice that husbands work outside and wifes work at home is not common anymore. In order to avoid the excessive work of the partner, the couples help each other and secure the income according to their life plan. Housework is shared mainly among family members, but free housekeeping services provided by local community or social activity organisations are also available. As a result of the changes in lifestyle, the time spent within family has increased. The time spent on hobby, sports, cultural activities, volunteer activities, agricultural works, and social activities has also increased.

Table 2.1 Keywords of the two scenarios

Keywords		Scenario A	Scenario B
Mindset of people			
	Goal of life	· Social success	· Social contribution
	Residence	· Urban orientation	· Rural orientation
	Family	· Self-dependent	· Cohabitation
	Acceptance of Advanced technology	· Positive	· Prudent
Population			
	Birth rate	· Downside	· Recover
	Immigration of foreign workers	· Positively accepted	· Status quo
	Emigration	· Increase	· Status quo
Landuse and cities			
	Migration	· Centralization in large cities	· Decentralisation
	Urban area	· Concentration in city centre · Intensive land use in urban area	· Population decrease · Maintain minimum city function
	Countryside	· Significant population decrease · Advent of new businesses for efficient use of land space	· Gradual population decrease · Local town development by local communities & citizens
Life and household			
	Work	· Increase in "Professionals" · High-income & over-worked	· Work sharing · Working time reduction & equalization.
	Housework	· Housekeeping robots & Services	· Cooperation with family & neighbours
	Free time	· Paid - for activity · Improving carrier · Skill development	· With family · Hobby · Social activity (i.e Volunteer activity)
	Housing	· Multi-dwellings	· Detached houses
	Consumption	· Rapid replacement cycle of commodities	· Long lifetime cycle of commodities (Mottainai)
Economy			
	Growth rate	· Per capita GDP growth rate:2%	· Per capita GDP growth rate:1%
	Technological Development	· High	· Not as high as scenario A
Industry			
	Market	· Deregulation	· Adequate regulated rules apply
	Primary Industry	· Declining GDP share · Dependent on import products	· Recovery of GDP share · Revival of public interest in agriculture and forestry
	Secondary Industry	· Increasing add value · Shifting production sites to overseas	· Declining GDP share · high-mix low-volume production with local brand
	Tertiary industry	· Increase in GDP share · Improvement of productivity	· Gradual increase in GDP share · Penetration of social activity

2. Innovative trend-breaks toward LCS

The two scenarios presented above are the possible pictures of future society and economy envisioned from past trends and current situations. However, in order to achieve the goals of LCS, innovative trend-breaks must be added on the future images. What would be the potential trend-break options and countermeasures in terms of reduction in CO_2 emissions and energy consumption?

2.1 Trends in CO_2 emissions and the points of trend-breaks in each sector

A. Industrial sector

Although change in CO_2 emissions from the industrial sector has been small, it accounts for more than 40% of the national emissions. The possible countermeasures in the industrial sector include not only energy efficient technologies but also dematerialization technologies and production technologies. In addition to the technologies, changes in industrial structures and social structures (e.g. progress in informatization and increasing relative importance of the service sector changes in consumption behaviour and international relations) would also have considerable impacts on CO_2 emissions from this sector.

B. Residential and Commercial sector

CO_2 emissions from the residential sector have been increasing with the growing number of households and people's lifestyle changes. The trend is expected to continue with the spreading use of ICT appliances and housekeeping robots.

One of the effective countermeasures in the residential and commercial sectors would be the enhancement of building insulation. The share of highly insulated residential buildings is much less than that of European countries. Approximately 60% of the heating demand from the residential sector can be cut down if appropriate insulation systems are installed. It should be noted that insulation retrofit is also as important as diffusion of highly insulated new houses since the proportion of new buildings constructed every year is only a small percent of the total building stock.

Development and dissemination of high efficiency appliances would also have a great potential for reducing CO_2 emissions. The possible options would be the application of: high efficiency heat pumps (COP 6.0-8.0), high efficiency cooking appliances, fuel cells, solar photovoltaic, solar thermal, insulated bath tub, home energy management system (HEMS) and so on.

Moreover, leading the people's lifestyles towards environmental friendly ways by providing appropriate information through school education and "Eco-life-navigation" systems is crucial to achieve LCS.

C. Transportation sector

Currently, passenger transportation and freight transportation account for approximately 16% and 10% of national final energy consumption respectively, and a great portion of the consumption comes from motor vehicles.

The passenger transportation demands are heavily influenced by the lifestyle of the people and the local conditions such as urban structure, population density and infrastructures. On the other hand, the freight demands are affected by gross industrial production, gross imports, progress in dematerialization and geographical distribution of producing/consuming areas.

In order to reduce the CO2 emissions from the transportation sector, modal shift from private motor vehicles to mass transit systems such as railways, buses and LRTs, is essential. Appropriate urban planning is also a promising option. The urban planning towards compact cities is expected to shorten the average trip distances and to encourage the shift of passenger transportation from cars to walk or bike. Transportation substitution effects by the diffusion of teleworking and virtual communication systems also have potential to reduce transportation demand.

In addition to the option of reducing the motor vehicle transportation demands, improvement of energy efficiency and fuel switching of cars and trucks are also important since those modes are expected to have an important role in 2050 as door-to-door personal transportation systems, especially in less populated areas, and as suitable facilities for small lot cargos. In particular, weight saving, application of regenerating brake, diffusion of fuel cell vehicles, electric vehicles, and bio fuel vehicles are the promising options.

D. Energy supply

More than 50% of the today's electricity is generated from fossil fuel fired plant. In order to supply CO2 free electricity, electricity from fossil fuels would be restricted by the capacity of carbon capture and storage (CCS). The other way is power generation from CO2 free energy sources such as nuclear power, renewables and hydrogen. Current hydrogen production processes of on-site fossil fuel reforming need to be changed since it would be economically difficult to capture the CO2 from widely dispersed power generation. As for heat sources, consumption of kerosene, LPG, heavy oil, coal and natural gas need to be replaced by renewable energy, heat from fuel cell cogeneration systems and heat pumps. As a transportation fuel, carbon-neutral biofuels would be a possible option besides CO2 free electricity and hydrogen.

E. Social system (Stock and waste management)

Since lifetimes of buildings and constructions have been long in general, some of the existing and newly constructed infrastructures will still be used even in 2050. Therefore, considerable time is required until the desired effects of the trend-breaking options are achieved in this sector and an appropriate planning with a long-term perspective is required.

Infrastructure development and housing demand is affected by the amount of stocks in the society. Since the stock in our society is almost saturated, substantial increase in the demand is not expected hereafter.

As for durable products, the tendency of lighter and smaller products with high add-value has been observed so far. Considering the trends, the substance and materials of the goods of the future will not be the same as those of today.

In addition, considering population decrease and shift in the people's mindset from material wealth to spiritual richness, the increase in demand of final consumption goods and investment goods would be limited. It is important to accelerate the decoupling of economic growth and materialization.

On the other hand, considerable amounts of waste would be generated as the existing constructions end thier lives. Since some of the materials contained in waste are used as resources, recycling is an important issue.

2.2 The trend-breaking options in the two scenarios

The effects and feasibilities of the trend-breaking options illustrated above are heavily dependent on the conditions of the society. In this chapter, combinations of the options suitable for scenario A and B are discussed.

In Scenario A, based on high technological development of the society, advent and maturation of advanced technologies such as fuel cells, electric vehicles, next-generation nuclear power, CCS and other energy efficient technologies would be the main options. Since economic growth in scenario A is relatively high, the pace of technology advancement could compensate the effect of increase in driving forces associated with economic growth and, therefore, cut-down the CO2 emissions.

In scenario B, on the other hand, relatively low economic growth and population decrease would lead to reduction in energy demand. However, the effects of technology development cannot be expected as in scenario A. It is assumed in this scenario that the public hesitates to accept nuclear power and CCS, and fuel cells and electric/hydrogen vehicle technologies are not mature enough for market penetration. Alternatively, changes in people's lifestyle by appropriate education systems would be one of the major countermeasures in scenario B. In addition, application of renewable energy technologies such as solar photovoltaic, biomass fuel, and wind should be introduced as much as possible.

Table 2.2 Possible trend-breaking options of the two scenarios

Sector	Scenario A	Scenario B
Industry Residential and Commercial	・Energy efficient production technology ・Insulation of the building ・Diffusion of all-electric home ・Diffusion of high efficiency heat pump air conditioner and water heater ・Development and diffusion of fuel cells ・Optimal energy control by HEMS	・Energy efficient production technology ・Insulation of the building ・Installing PV (especially in detached houses) ・Use of biomass fuels for cooling ・Diffusion of solar water heating ・Education (Eco life navigation system)
Transportation	・Shortening trip distance for commuting by intensive land use ・Modal shift from cars to mass transit systems (buses, railways, LRTs) ・Diffusion of motor drive cars such as electric vehicles and fuel cell vehicles	・Urban structures becoming more compact ・Infrastructure development for foot and bike passengers（sidewalk, bikeway, cycle parking） ・Diffusion of biomass hybrid cars ・Modal shift from cars to railways and to ship for freight transportation
Energy supply	・Expansion of nuclear power generation ・Electric load levelling and expansion of electric storage (ex. Store the electricity generated in night time and use it for electric vehicles ・High efficient fossil fuel technologies+CCS ・Hydrogen production from fossil fuel+CCS ・Infrastructure development for hydrogen production, transportation, storage, application	・Expansion of renewable energy use (wind, photovoltaic, solar thermal, biomass) ・Application of Information technologies (IT) for load adjustment
Stock and waste management	・Less material use for production by technology development ・Advancement of recycling technologies	・Expanding lifetime of the goods ・Decrease in final demand due to departure from material wealth yardsticks ・Recycled product preference of the consumer

2.3 Tools for envisioning coherent future images

In order to evaluate the feasibility and social impacts of the trend-breaking options discussed above, the driving forces associated with social changes in each sector need to be simulated. In the simulation, the characteristics and constraint conditions of each sector should be taken into account. It is also important to ensure consistency among the sectors.

In the project, “Low carbon society scenarios towards 2050”, several element models are developed to ensure the consistency of the envisioned future society. The following table illustrates relationships between the items to be taken into account in each sector and the element models. Detailed descriptions of each model are given in Appendix A-J.

Table 2.3 Items to be considered in each sector and related models

		Items to be considered	Developed Models
Industry	a.	Changes in industrial structure and technological development on energy consumption as well as productivity	• Inter-sector and Macro Economic Model
Domestic and Commercial	b.	Changes in building distribution by climatic zone	• Building Dynamics Model (b-e) • Household Production and Lifestyle Model (f)
	c.	Changes of the share of detached and multidwelling houses	
	d.	Diffusion rate of insulated detached and multidwelling houses	
	e.	Lifetime changes of the dwellings	
	f.	Lifestyle changes on household consumption and allocation of the time	
Transportation	g.	Changes in population distribution and local characteristics	• Passenger Transportation Demand Model (g-i) • Freight Transportation Demand Model (j-m)
	h.	Changes in social environment and human activities	
	i.	Changes in selectivity of the mode of passenger transportation by area	
	j.	Changes in industrial structure	
	k.	Dematerialization	
	l.	Changes in producing/consuming area	
	m.	Changes in selectivity of the mode of transportation by distance	
Energy supply	n.	Function of load management and uncertainties of both energy supply and demand	• Energy Supply and Demand Balance Model (n-p)
	o.	Combination of small consumer and small energy sources + Electricity/Hydrogen	
	p.	Feasibility of local production for local consumption	
Social system	q.	Relationship between economic activities and stock/flow of the materials	• Material Stock and Flow Model (q-s)
	r.	Amount of waste derived from the stock	
	s.	Effectiveness of recycling and its impacts	
Cross-sectional	t.	Ensuring consistency among the sectors in terms of energy demand and supply	• Menoco Model (t) • EDB (u) • Inter-sector and Macro Economic Model (v)
	u.	Impacts of future technological choices on social energy efficiency	
	v.	Ensuring economical consistency of LCS	

3. Scenarios towards LCS

By using the element models mentioned above, scenarios for LCS were developed. Fig. 2.1 illustrates the framework and relationship between the element models.

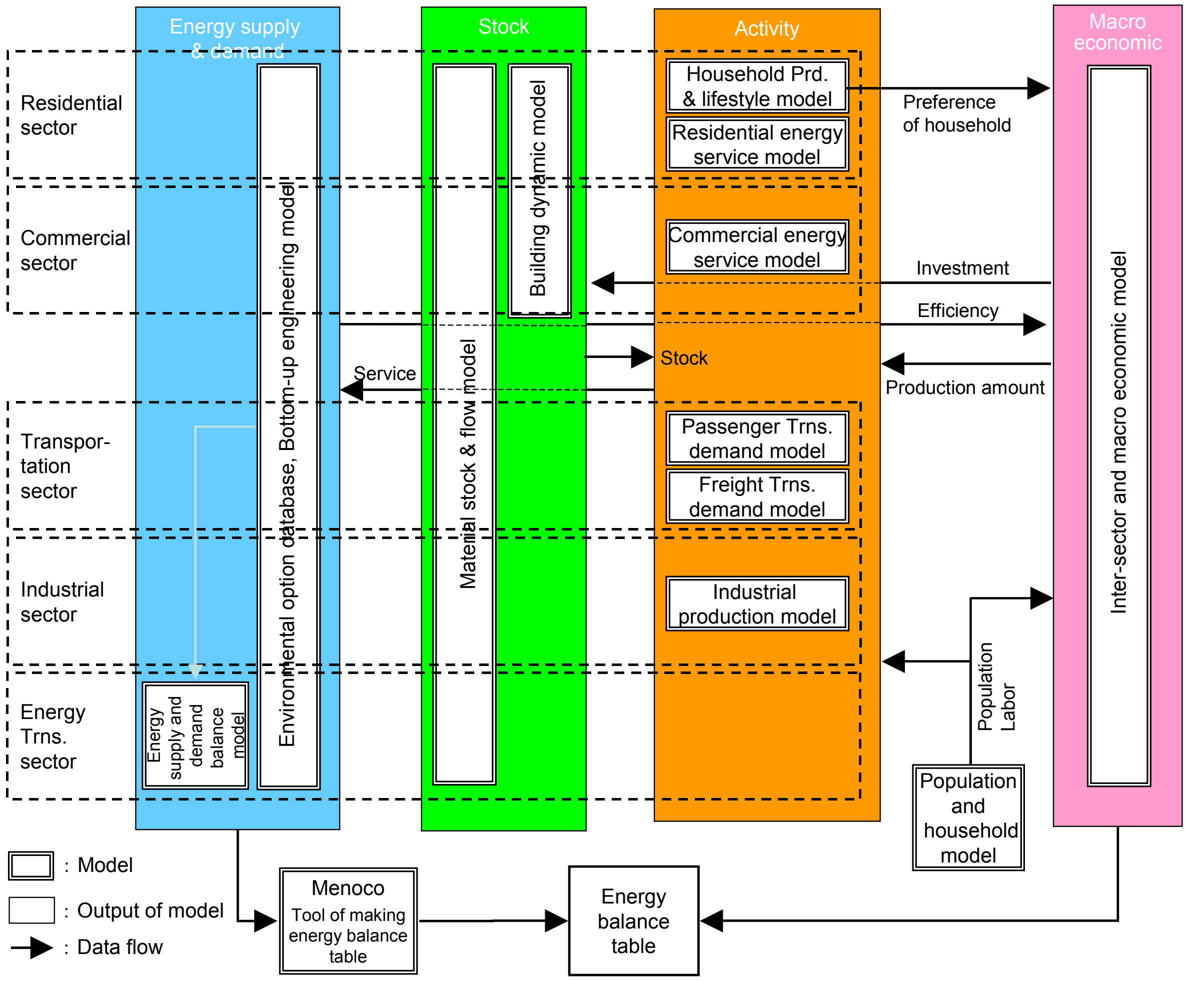


Fig. 2.1 Relationship among element models

The Menoco model estimates 2050's CO_2 emissions for scenarios A and B using the output from the element models. Fig. 2.2 shows CO_2 emissions in 2050 by sector. 2050's CO_2 emissions for both scenarios decrease by 27% compared to 2000 and by 30% compared to 1990. This result shows that the scenarios described in Chapter 2 can achieve LCS by 2050.

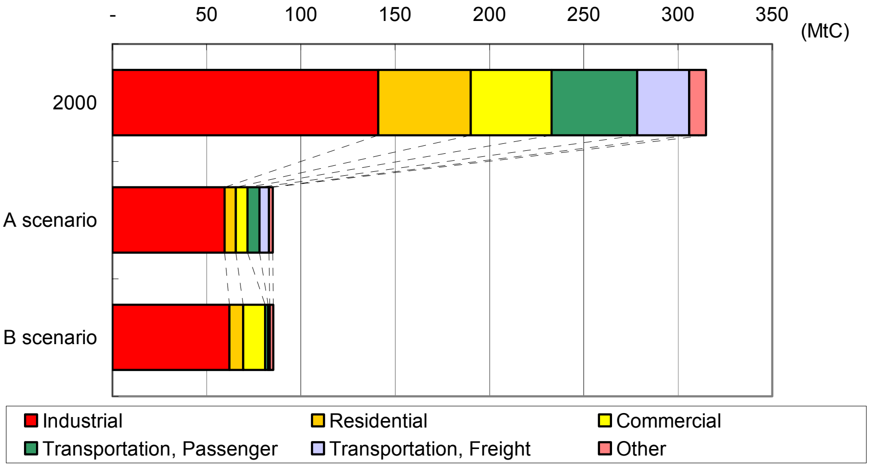


Fig. 2.2 CO_2 emissions by sector

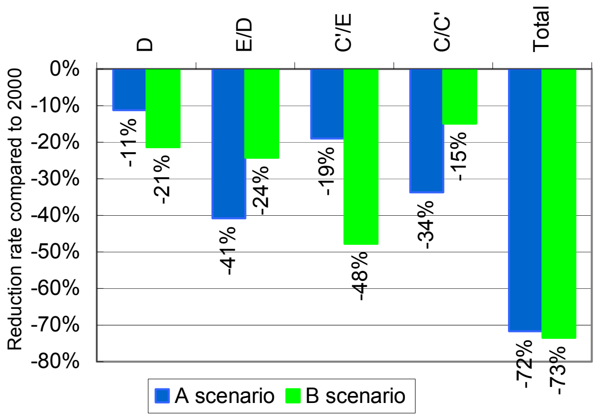


Fig. 2.3 Factor analysis of CO_2 emission

Fig. 2.3 shows factor analysis of 2050's CO_2 emission compared to 2000's. CO_2 emissions reduction is divided as follows:

$$\frac{\Delta C}{C} = \frac{\Delta D}{D} + \frac{\Delta (E/D)}{(E/D)} + \frac{\Delta (C'/E)}{(C'/E)} + \frac{\Delta (C/C')}{(C/C')} + \text{Cross term}$$

D: Driving Force（Service Demand)
E/D: Energy Intensity
C'/E: CO_2 Intensity in end-use sector (without measures in power generation)
C/C': Change of CO_2 intensity by measures in power generation.

All the factors contribute to reduce CO_2 emissions in scenarios A and B, but the reduction ratio by each factor significantly differs between the two scenarios. Reduction of demand for raw materials like steel, cement, paper and ethylene contributes to reduce driving force (D) in the both scenarios. Besides, the reduction of warming demand with diffusion of super-insulated buildings, reduction of transportation volume through urban structures becoming more compact contribute to the reduction of D. The reduction ratio of driving force in scenario B is larger than in A due to lower economic growth. Energy efficient technologies contribute to reduce energy intensity (E/D) in both scenarios. The reduction rate of E/D in scenario B is larger due to diffusion of advanced technologies such as efficient heat pumps, electric vehicles and fuel cell vehicles. The increase in the electricity's share and diffusion of photo voltaic contribute to reduce carbon intensity in the end-use sector (C'/E) in both scenarios. The reduction rate of C'/E in scenario B is larger due to the large amount of biomass consumption which is equivalent in volume to oil and gas consumption. Efficient steam power plants contribute to reduce carbon intensity in the power generation sector in both scenarios. The reduction of C/C' in scenario A is larger because the share of nuclear power is kept and the introduction of carbon capture and storage (CCS).

III. Opportunities for change

In this project, concrete images of LCS and their feasibilities are examined not only from environmental viewpoints but also from economic and social points of view. Firstly, dominant trends and uncertain factors of the future society were discussed and two scenarios, A and B, were developed. Secondly, possible trend-breaking options suitable for the two scenarios were identified and detailed information of the options was collected. Thirdly, appropriate element models were developed so that the changes in driving forces and other important factors can be quantitatively considered in the scenarios. Finally, the feasibility of the options and the consistencies of the pictures of the future society were evaluated using the element models.

The results of the study illustrate two different examples of LCS societies. The important implication of the study is that LCS can be achieved regardless of the social background and the conditions if the goals of LCS are shared by the people and appropriate countermeasures are applied. This in-depth study would continue so that the worlds pictured in this project become more concrete and full of hope for as many people as possible.

However, it should be kept in mind that only people's actions could create a brighter future. Without strong wills, efforts and actions of the people, the scenarios would end up in "pie in the sky". Although, the challenges we are facing are obviously not easy to overcome, we should neither shift the blame on to the others nor weep for the upcoming climate change. The best and the only things to do would be to tackle and address the issue squarely and earnestly.

The future is full of uncertainty. In other words, it has unlimited possibilities. We should be aware that our today's actions shape the basis of the 21st century. In order to achieve the goals of sustainable development, we might need to modify our old values and social systems. It is time to change and the challenge has already begun.

We sincerely hope that the scenarios would encourage the people to conduct "creative destructions" and step forward towards a sustainable and brighter future.

Appendix

A. Population and Household Model

A.1 Model Characteristics

- The population and household model (PHM) simulates the future province-wise population by age and sex, given exogenous data on national and province-wise base year's population, expected survivorship rate, expected fertility rate, and expected migration rate. The number of households by family type is also calculated with the headship rate method as described in section A.2.
- Moreover, it simulates population and households by climate zone and land-use classification with the detailed assumption of population distribution.

A.2 Model flow chart

Fig. A.1 shows the flow chart used for estimating future population and households. The cohort component method is used here. Each birth cohort is calculated with fertility rate, survivorship rate, and migration rate. It states that the population at the next time interval ("t + 1") is the population at the beginning time interval ("t") plus the net natural increase (or decrease) plus the net migration. Base year's population, expected survivorship rate, expected fertility rate, and expected migration rate are given exogenously. When there are inconsistencies between national parameters and provincial parameters, we modify the provincial parameters in order to be consistent with the national ones.

The headship rate method is used for projecting the number of households. The headship rate in a given category based on age, sex and family type is defined as the ratio of the number of heads of households to the total number of members in that type. We use the historical trend of change in headship rate as the basis for calculation and modify the parameter to reflect the assumed social change in order to estimate the number of households in the future.

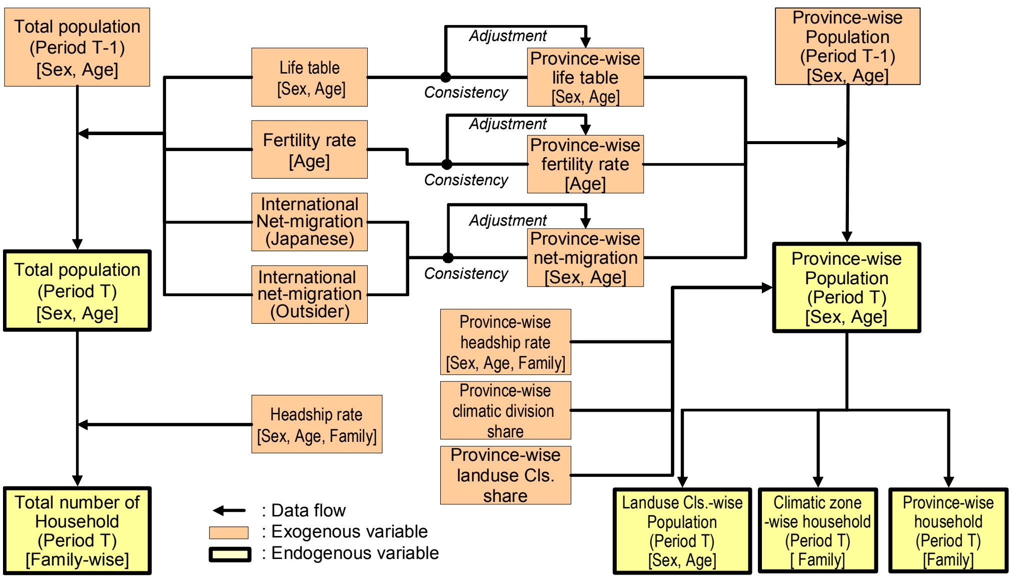


Fig. A.1 Flow chart for projecting population and number of households

Number of households by climate zone and population by land-use class are estimated with the assumption of current population distribution in a prefecture.

The indices of the PHM are listed in Table A.1.

Table A.1 Indices of Japan's Population and Household Model (PHM)

Indices	Classification	Elements
Age	19	Birth, 0-4, 5-9, 10-14, 15-19, 20-24, 25-29, 30-34, 35-39, 40-44, 45-49, 50-54, 55-59, 60-64, 65-69, 70-74, 75-79, 80-84, 85-
Sex	2	Male, Female
Family	5	One-person, Couple-only, Couple-Children, Parent-Children, Others
Province	47	(all prefectures)
Climate	6	I (Hokkai), II (Aomori, Iwate, Akita), III (Miyagi, Yamagata, Fukushima, Tochigi, Nagano, Niigata), IV (except I-III,V,VI), V (Miyazaki, Kagoshima), VI (Okinawa)
Land-use	10	i. Three largest metropolitan area: i-1. Cities, i-2 Lowland farming, i-3 Intermediate & mountainous area ii. Hub cities: ii-1.Cities, ii-2.Lowland farming, ii-3.Intermediate & mountainous area iii. Prefectural hub cities iv. Others: iv-1.Cities, iv-2.Lowland farming, iv-3.Intermediate & mountainous area

A.3 Example of Simulation Result

Fig. A.2 shows an example of simulation output. Japan's future population will decrease by about 20% compared to the current level. Population will tend to concentrate in Tokyo metropolitan area. As for households, the share of "one person" family will increase.

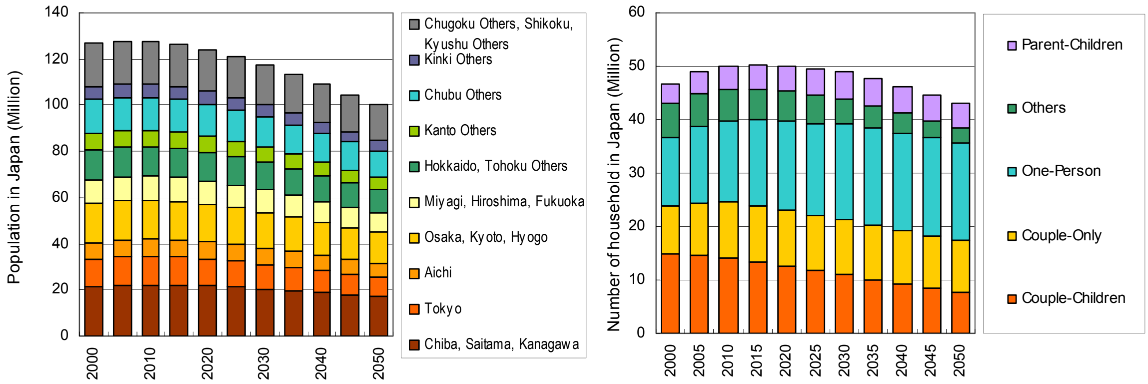


Fig. A.2 Example of output from the PHM
(Left: Region-wise population, Right: Number of households by family type)

B. Material Stock and Flow Model

B.1 Model Characteristics

- Material Stock and Flow Model (MSFM) estimates the change of material stocks and flow in the society. The factors considered in the model are final consumption and investments which are affected by capital stocks, material densities of goods, physical input output coefficients of production sectors, and recycling rate of wastes.
- The input data of this model is the final demand calculated by an economic model (Macroeconomic model). The outputs are material flow among sectors, the flow between economic activities and the environment, and material stocks accumulated as production capital, waste accumulation, and so on.
- The MSFM analyzes the mechanism of changes in material stocks and flow, and the effect of recycling materials in the future society, and looks for the measures towards the LCS in connection with material consumption.

B.2 Model flow chart

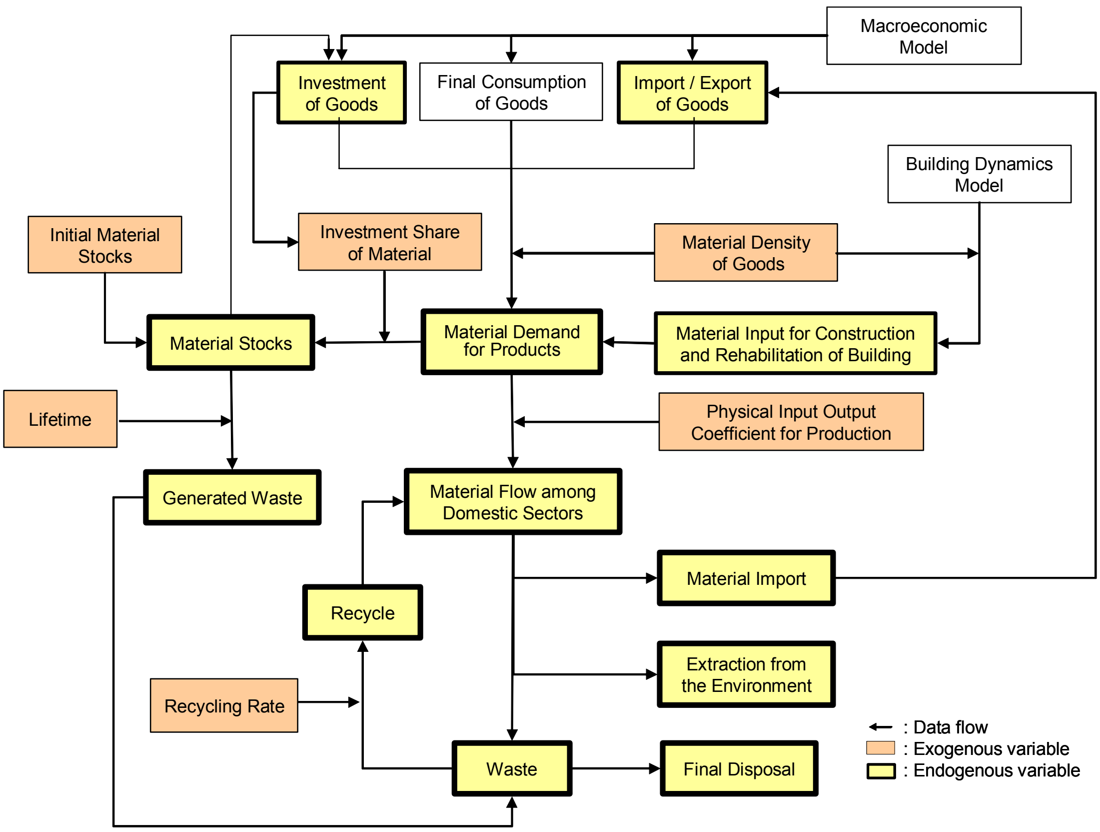


Fig. B.1 Flow chart for projecting future material stocks and flow

The model was calibrated with the past 30 years' socio-economic data, the material stocks data, and production data. As for the socio-economic data, population, the number of households, the amount of investment, GDP, and import and export were considered. As for material stocks and productions, floor area of dwellings, the number of car ownership, steel and cement production, *etc*, and other factors were taken into account. Using these relational expressions and the future estimates of socio-economic indices, demands for future stocks of durable goods in each year are estimated. From the difference between the demand for stocks and the existing stocks, the required investment is calculated. The material demand for products, the driving force of the MSFM, is calculated by multiplying the volume of goods production by their material density. Here, "Material Density" is defined as the weight of material per unit (ton per unit monetary amounts, ton per vehicle, ton per m^2, *etc*). Material input for construction and rehabilitation of buildings which are the output from the Building Dynamics Model, is also the driving force for the MSFM.

The amount of stocks is determined by adding new investments in the previous period and subtracting the depleted portion. Initial material stocks are estimated by accumulating material inputs over the past 100 years.

The material flow among domestic sectors and the flows related to the extraction from the environment and the disposal into the environment are estimated based on the concept of material balance of goods and sectors while considering parameters such as changes in the material density of the goods, changes in physical input-output coefficients of production sectors by technology innovation, and changes in the recycling rate of materials and lifetimes of durable goods. Flows related to the extraction from the environment and the disposal into the environment are also estimated.

Table B.1 Classification of Materials, Goods, Sectors

Material	Iron, Cement, Woods, Aluminum
Goods	Building, Civil engineering structure, Machinery, Others
Sectors	Production sectors, final demand sectors
Production	Primary process (Pig iron), Secondary process (Crude steel), Tertiary production (Final steel products), Final goods production *( ) Example of iron case
Final demand	Households, Government, Investment, Import and Export

C. Building Dynamics Model

C.1 Model characteristics

- Building Dynamics Model (BDM) estimates the future dwelling stock by climate zone, type of building, construction material, insulation level and construction year by using cohort method.
- The inputs of the model are the dwelling stock in the base year, the survival rate of dwelling stock and the number of new dwellings which satisfy the future demand from the households.

C.2 Model flow chart

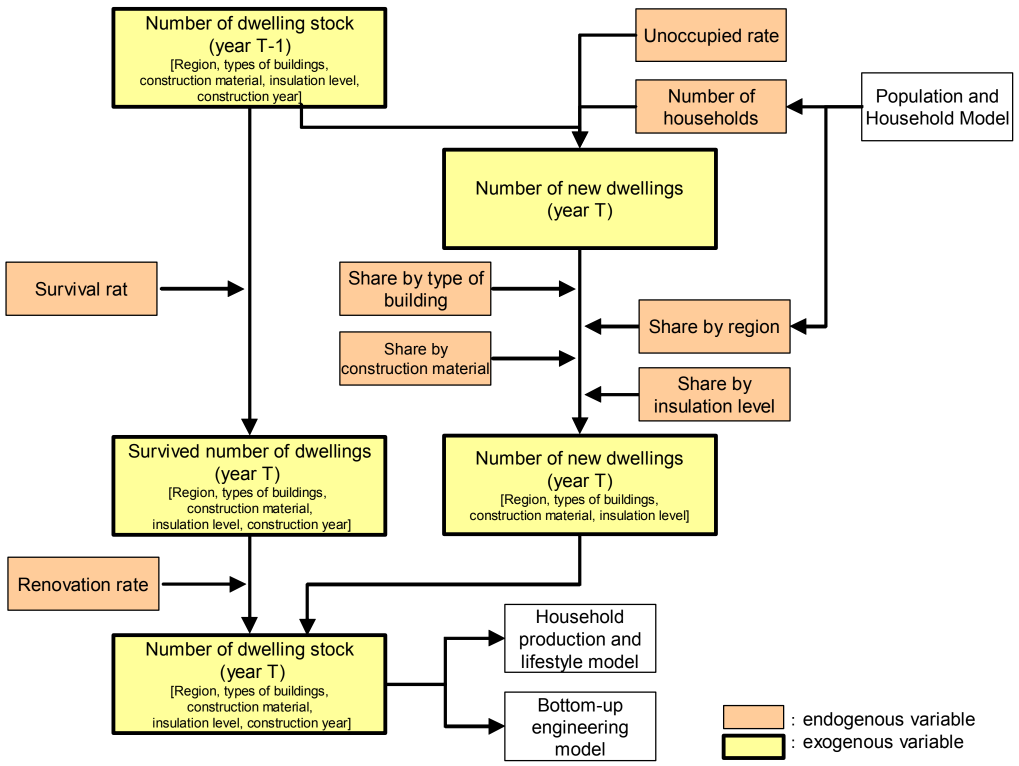


Fig. C.1 BDM Flow Chart

Table C.1 Climate zone, Types of buildings, Construction material, Insulation level

Indices	Elements	
Climate zone	I (Sapporo)	II (Morioka)
	III (Sendai)	IV (Tokyo)
	V(Kagoshima)	VI(Naha)
Type of building	Detached, Apartment	
Construction material	Wooden, Non-wooden	
Insulation level	Without insulation, Standard of 1980, Standard of 1992, Standard of 1999	

The dwelling stock in the base year (2003) is from the 2003 Housing Survey of the Ministry of Internal Affairs and Communications. As for the survival rate of dwelling stock, we estimated it with the Weibull distribution from the Housing Surveys of 1978, 1983, 1988, 1993, 1998 and 2003.

The dwelling stock in a future year is calculated by adding the new number to the surviving stock from the previous year. First, the demand for dwelling stock is determined in proportion to the number of households determined by the Population and Household Model. Next the total number of new dwellings is determined based on the demand for dwelling stock and the surviving stock from the previous year. Then the number of new dwelling by region, type of building, construction material, insulation level is calculated by multiplying the total number of new dwelling with the proportion by region, type of building, construction material, and insulation level. Finally, the dwelling stock is calculated by adding the new dwellings to the surviving dwellings from the previous year.

Renovation of insulation and room expansions could also be taken into account.

C.3 Example of Simulation Results

Examples of simulation outputs are shown below. Fig C.2 shows the estimated future dwelling stock by type of building and construction material. Reflecting the decrease in the future number of households, the dwelling stock would also decrease after peaking in 2015.

Fig C.3 shows the estimated future dwelling stock by insulation level. "Standard of 1999" is the latest insulation level and almost comparable to the strict European insulation levels. Growth of the "Standard of 1999" since 2015 results from renovation of insulation for existing dwellings. About a quarter of the existing dwelling stock is still present in 2050, therefore not only an enhancement of insulation for new dwellings but also renovation of insulation for existing dwellings is essential to make all the dwelling stock meet the "Standard of 1999" in 2050.

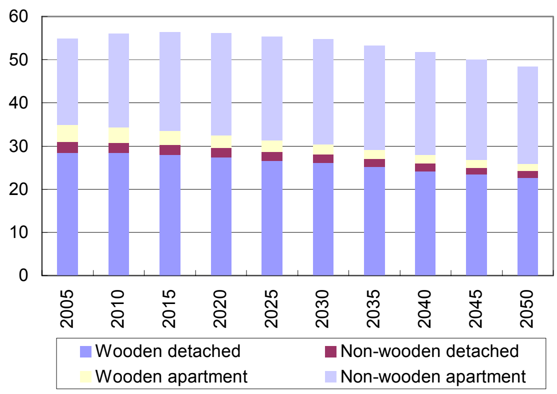


Fig. C.2 Estimated number of dwelling stock (Million)

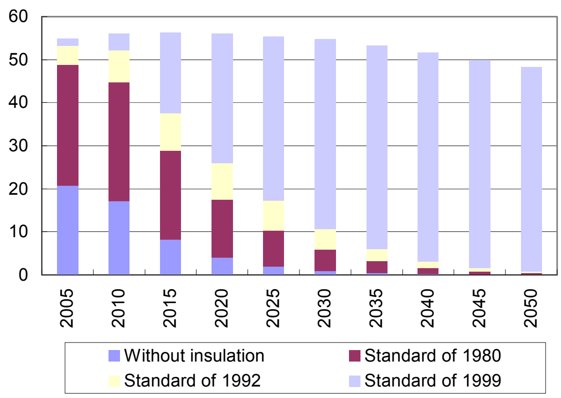


Fig. C.3 Estimated number of dwelling stock by insulation level (Million)

D. Passenger Transportation Demand Model

D.1 Model characteristics

- Passenger Transportation Demand Model (PTDM) can simulate transportation demand associated with changes in population distribution, social environment, people's activity pattern, modal share and average trip distance.
- The model is based on the transportation model developed by the Ministry of Land Infrastructure and Transport (MLIT) in Japan. In this model, the transportation demand within the daily living area (intra-region transportation) and between the daily living areas (inter-region transportation) are calculated separately.

D.2 Model flow chart

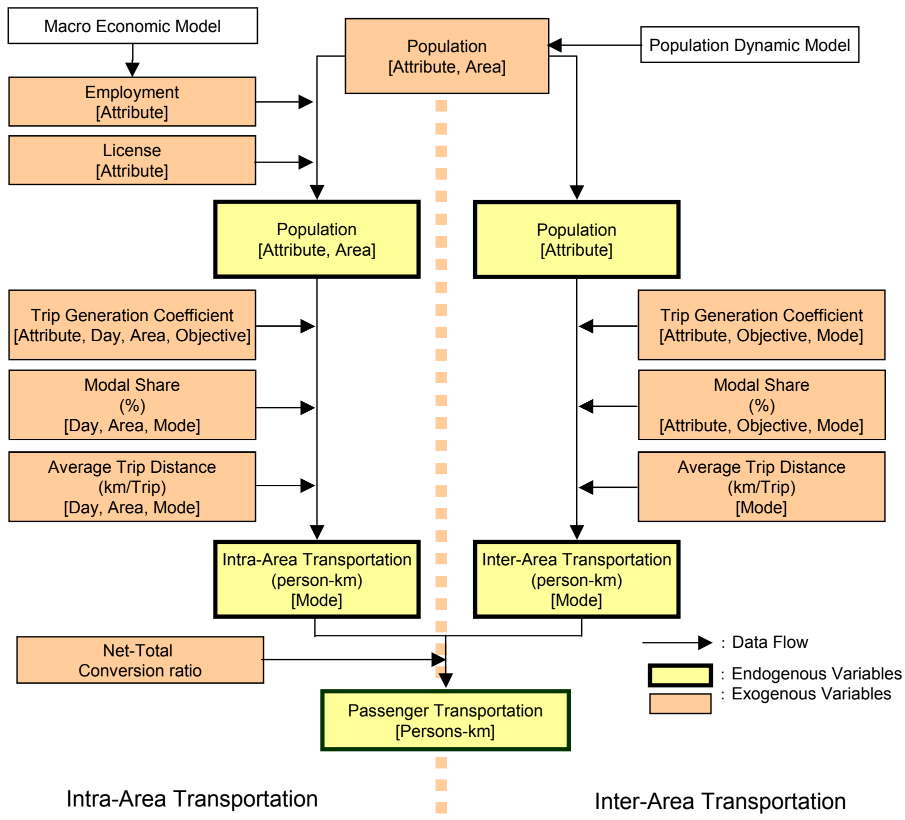


Fig. D.1 Transportation Model Flow Chart

The logic of calculation of intra and inter regional transportation demands are identical. Firstly, classified population data by attribute shown in Table D.1 is calculated by license holding ratio, employment rate and outputs from Population and Household Model. Secondly, trip generation coefficient, modal share, and average trip distances are multiplied to obtain the transportation demands. Exogenous variables used in the models include: trip generation coefficient, modal share, and average trip distance. The following table shows attributes of variables used for the simulation.

Table D.1 Attributes of variables in PTDM

	Intra-Area Transportation	Inter-Area Transportation
Mode	Passenger cars, Buses, Railways, Walk&Bike	Passenger cars, Buses, Railways, Aviation, Maritime
Objective	Commute to work, Commute to school, Return, Business, Private & Shopping, Sighteseeing & Leisure	Business, Sightseeing, Private, Others
Attributes	Sex, Age (3) Licence, Employment	Sex, Age (6)
-Age	Under 14, 15-64, over 65	Under 19, 20's, 30's, 40's, 50's, Over 60
-Area	Metropolitan area (TMUC[1], LCU[2], LCC[3], Others) ×Three land types (Urban, Agricultural, Mountainous)	—

1 TMUC: Three Major Urban Commuting Area, which includes Tokyo, Osaka and Nagoya urban area
2 LCU: Local Central Urban Area
3 LCC: Local Core City

D.3 Example of Simulation Results

The following figures show sample outputs of the simulation. As shown in Fig D.4 and Fig. D.5, though total transportation demand is decreasing, per capita transportation demand stays constant. The reasons for such a low growth rate in per capita transportation demand are explained by the effect of urban structures becoming increasingly compact and decrease in average trip distance. In addition, the share of railways transportation will increase rapidly due to the promotion of modal shift from car to train.

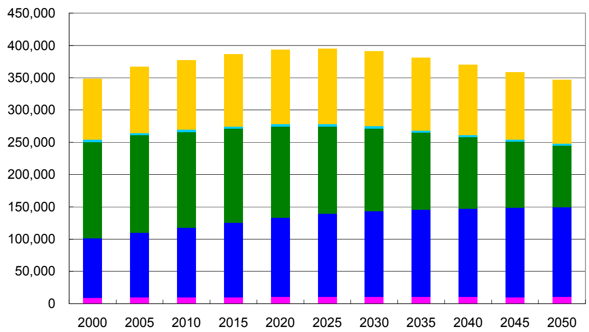


Fig. D.2 Inter-region transportation demand by mode of transportation (mil. person-km)

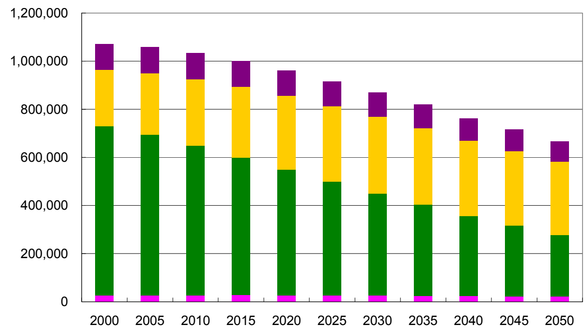


Fig. D.3 Intra-region transportation demand by mode of transportation (mil. person-km)

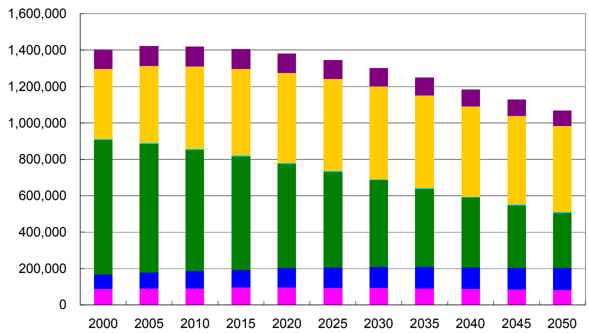


Fig. D.4 Total transportation demand by mode of transportation (mil. person-km)

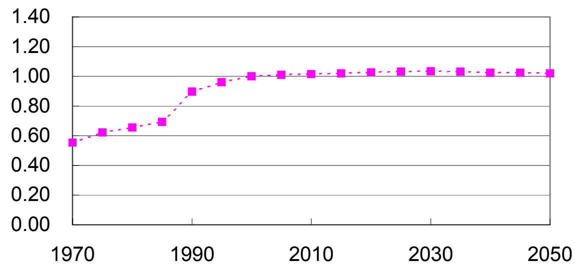


Fig. D.5 Total transportation demand per capita (mil.person-km/cap)

Buses Aviation Pass.cars Maritime Railways Walk&Bike

E. Freight Transportation Demand Model

E.1 Model characteristics

- Freight Transportation Demand Model (FTDM) simulates freight transportation volume associated with changes in industrial structure, material density, transportation distance, and modal share.
- The inputs of the model are production and imports calculated in the Inter-sector and Macroeconomic Model.
- The outputs are freight transportation volumes in terms of tonne-km by mode.

E.2 Model flow chart

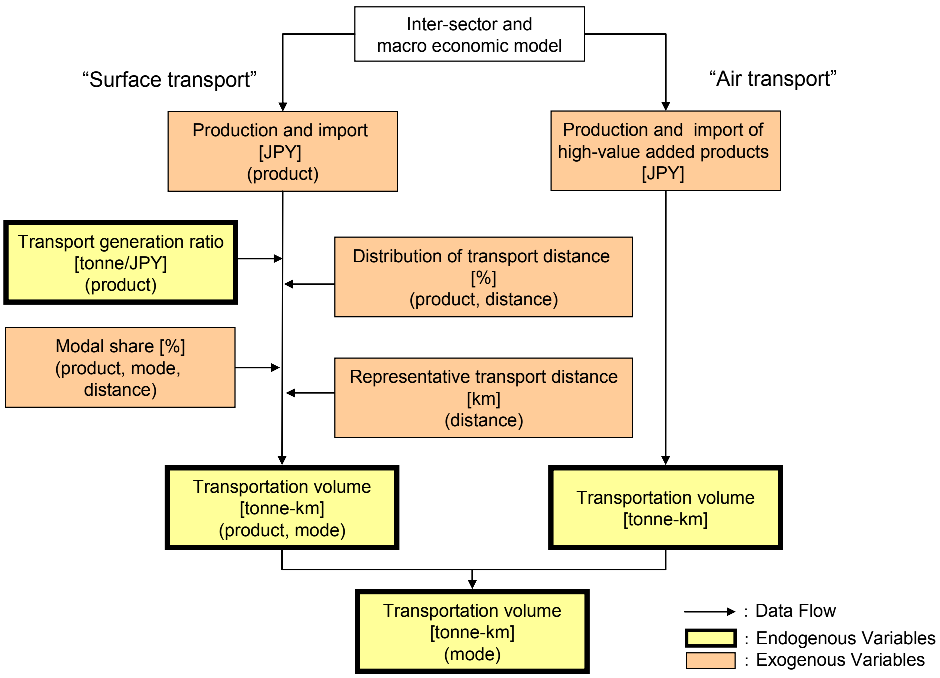


Fig. E.1 FTDM flow chart

Different flows are used for surface transport and air transport. For surface transport, firstly, transportation volume in terms of tonne is calculated by multiplying gross production (domestic production + imports) by transport generation ratios. Secondly, transportation volume in tonnes in each transport distance is calculated by using distribution of transport distance. Thirdly, transportation volume of each mode of transport in tonnes is calculated by using modal share in each transport distance band. Finally, transportation volume in terms of tonne-km is calculated by using the representative transport distance of each distance band. Transport generation ratios are estimated endogenously using regression equations identified from historical data. Distribution of transport distance, modal share, and representative transport distance of each distance band are given exogenously.

For air transport, transportation volume in tonne-km is directly calculated with production and imports of high-value added products.

Table E.1 Indices of FTDM

Indices	Elements
Mode	Small Freight Vehicle, Large Freight Vehicle, Railway, Maritime, Aviation
Product	Agricultural Products(AG), Minerals(MI), Metals and Machineries(ME), Chemicals(CH), Light Industries Products(IL), Miscellaneous Industries Products(IM), Specialty Products(SP), Others(OT)
Transport distance band	~100km, 100~300km, 300~500km, 500~750km, 750~1000km, 1000km~

E.3 Example of Simulation Results

The following figures show sample outputs of the simulation. It is assumed that the sum of production and imports for the primary and secondary sectors in 2050 in scenarios A and B is 1.43 and 1.10 times that of year 2000 respectively. It is estimated that total transportation volume in tonne-km in A and B scenario is only 0.91 and 0.79 times that of year 2000 (Fig. E.5). This is partly because the proportion of fundamental materials in production and imports decreases. Moreover, reduction of weight of each unit of product plays a role. Those effects can be seen in the weight reduction of transportation volume (Fig. E.2). As for the transportation volume by transport distance, short distance transport maintains a large share (Fig. E.4). This results in the large modal share of freight vehicle (Fig. E.3) because of the advantage of freight vehicle over other modes for short distance transportation.

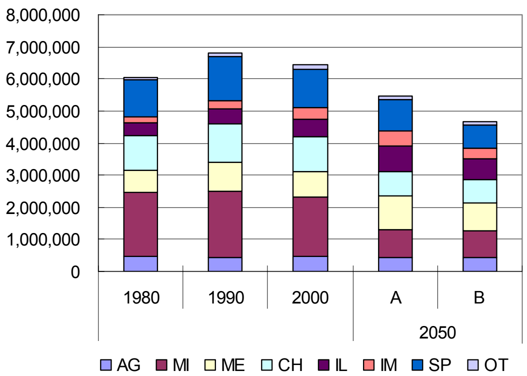


Fig. E.2 Transportation volume in tonnes by product (1000 tonne)

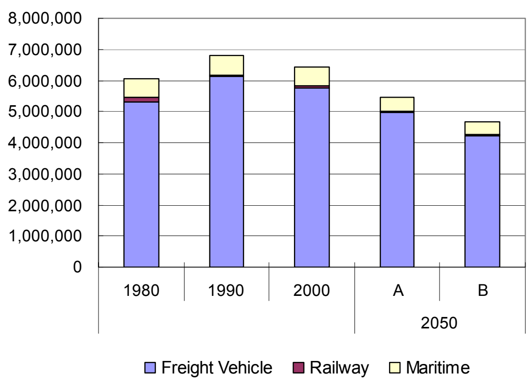


Fig. E.3 Transportation volume in tonnes by mode (1000 tonne)

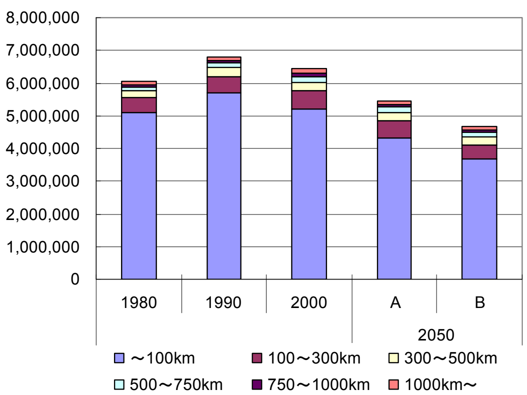


Fig. E.4 Transportion volume in tonnes by transport distance (1000 tonne)

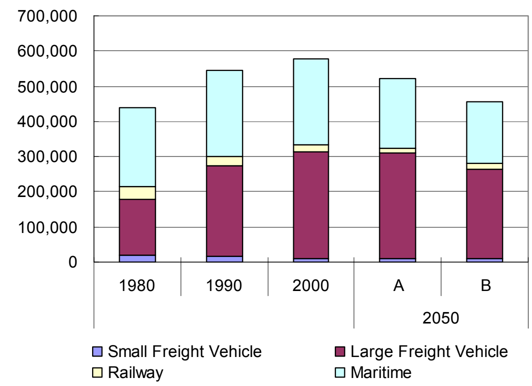


Fig. E.5 Transportion volume in tonne-km by mode (mil. tonne-km)

F. Household Production and Lifestyle Model

F.1 Model characteristics

- The Household Production and Lifestyle Model (HPLM) simulates energy service demand, waste generation, and water consumption for household production by four household types, under prescribed scenarios of household composition, age composition, income budget, and time budget in the future.
- The model can consider demographic and socioeconomic trends with consistency, together with Population and Household Dynamics Model, Building Dynamics Model, and Inter-sector and Macro Economic Model.

F.2 Model flow chart

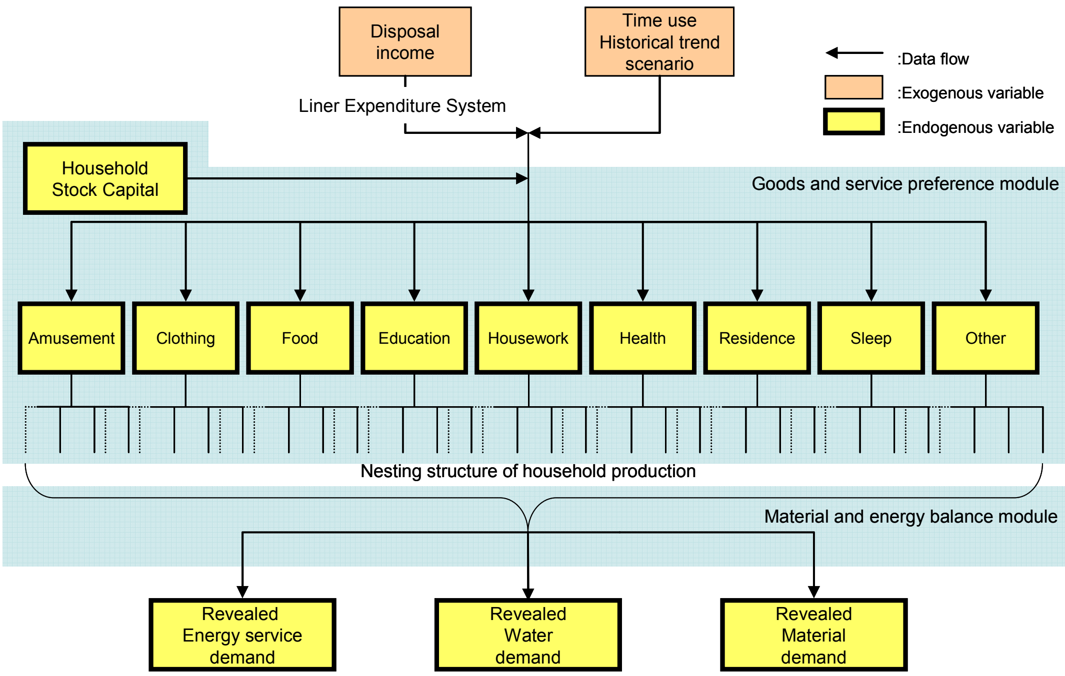


Fig. F.1 Flow chart of HPLM

Fig. F.1 shows the flow chart of HPLM. This model consists of two modules; "goods and service preference module" and "material and energy balance module". "Goods and service preference module" estimates the final consumption expenditure from disposal income, household stock, and time use; it also estimates production of household service with the final consumption expenditure. "Material and energy balance module" estimates environmental load generations by the household service production.

In the model, disposal income is divided between final consumption expenditure and saving. Final consumption expenditures are spent on goods and services which are required for the household production. Preferences of goods are estimated with the historical household survey. The same is done for the time use budget. Produced household benefits are classified into nine categories, and about 400 kinds of goods, time use, and household capital stock are modeled as the inputs for the production in a nested structure.

Furthermore, required energy service demand, water demand, and material demand for household production are summed up, considering time delay, conversion waste, and other factors, in order to calculate the generation of environmental loads.

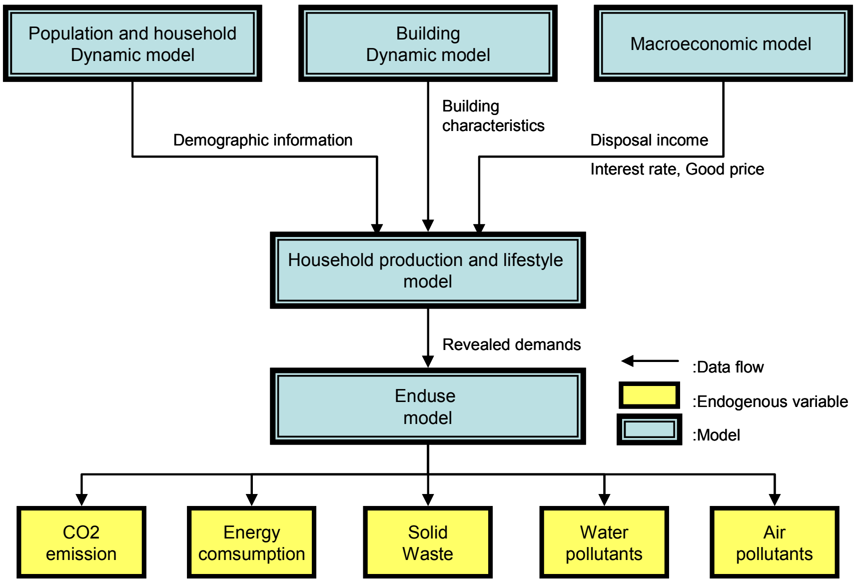
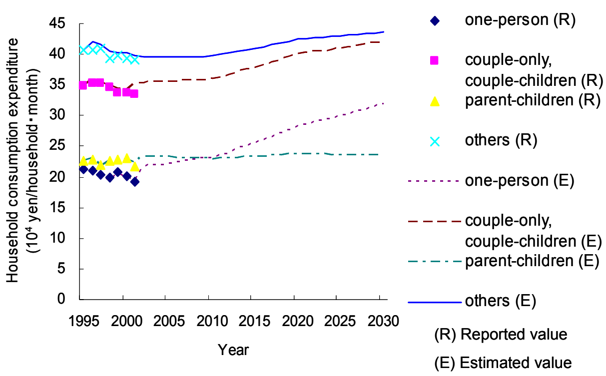


Fig. F.2 Frameworks of HPLM and other models

F.3 Example of Simulation Result

Fig. F.3 shows the growth of the household consumption expenditure by 2030. The growth of "one-person" household consumption expenditure is larger than that of "couple-only, couple-children" or "parent-children" household consumption expenditure. In Fig. F.4, CO_2 emissions by residential energy consumption and by transport activity for household production is shown.



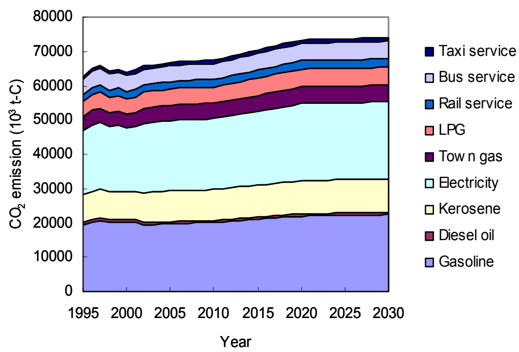


Fig. F.3 Household consumption expenditure

Fig. F.4 CO_2 emission from household activities

G. Energy Supply and Demand Balance Model

G.1 Model characteristics

- Energy Supply and Demand Balance Model (ESDBM) seeks optimum configurations of the energy system based on the energy balance between supply and demand, in order to take full advantage of renewables in specific regions.
- The model requires the following information as exogenous variables: wind synopsis, amount of solar insolation, and stocks of woody materials in regions.
- Major outputs of the model are: optimum capacity of each system, energy supply, total energy system cost, and CO_2 emissions.

G.2 Model flow chart

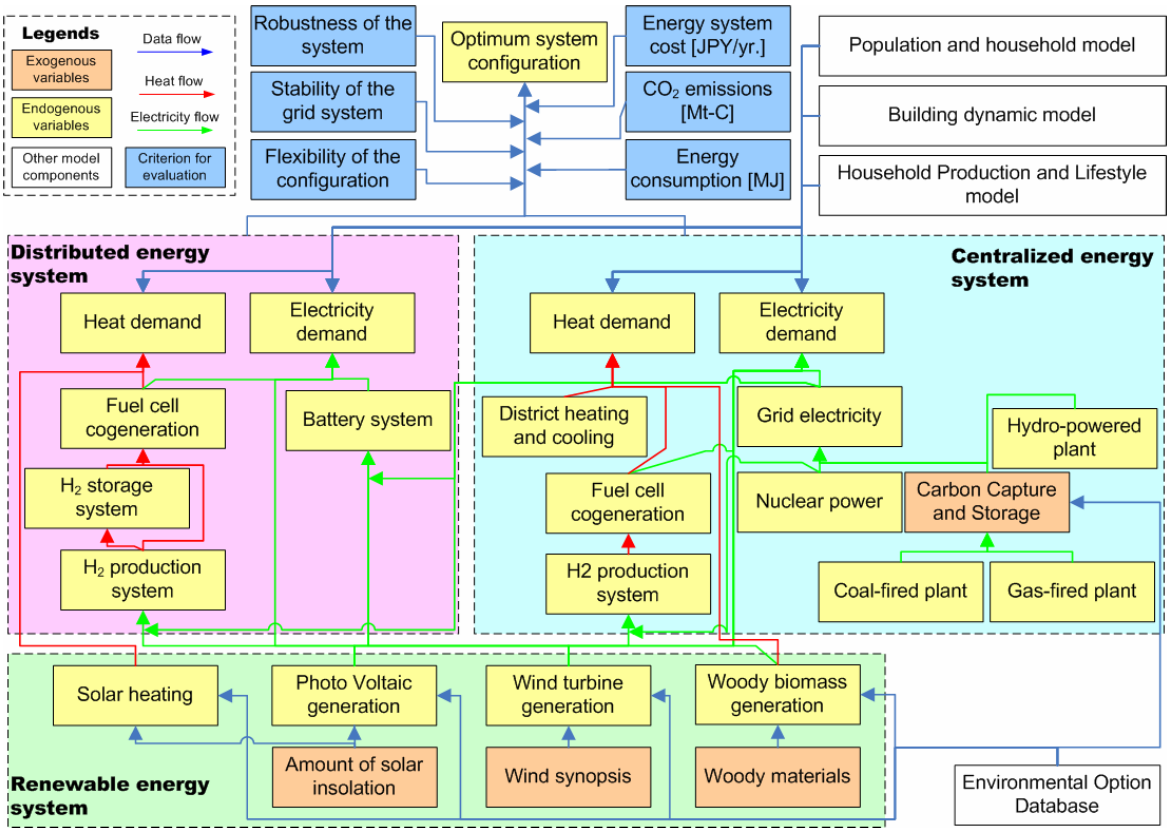


Fig. G.1 ESDBM flow chart

Fig. G.1 shows a scheme of ESDBM. The model configures regional low-carbon energy systems on the basis of regional characteristics of natural resources and energy demands. In the model, Japan is divided into several regions depending on the agricultural structure and climatic conditions. The optimum energy system is configured based on the regional characteristics. The energy demands are determined by other model elements, i.e., Population and Household Model, Building Dynamics Model, Household Production and Lifestyle Model, and so on. Data of natural resources, such as wind synopsis and amount of solar insolation are based on actual observation.

In order to explore future LCS, the model employs two types of energy supply systems: (1) distributed energy system, such as micro-grid and/or 1kW-scale fuel cell combined heat and power system, and (2) centralized energy system, such as grid electricity and district heating system. The model can shed some light on the roles between distributed systems and centralized systems. Renewable energy component includes wind turbine generation, photovoltaic generation, woody biomass cogeneration, and solar heating. In order to analyze the effectiveness of the renewable system, the model considers energy storing capacities, such as batteries or hydrogen storage. Furthermore, the following technological mitigation options are taken into account: CO2 reduction options in the electricity sector, advancing nuclear power, and installation of carbon capture and storage (CCS).

H. Menoco Model

H.1 Model Characteristics

- In Japanese, "Menoco" means "back of the envelope" type calculation. The menoco model is developed on the spreadsheet as shown in Fig. H.1. Given the data on service demand, share of energy. and energy improvement by type of service and energy in 2000/2050, the model calculates the energy balance table and the CO2 emission table while keeping consistency among sectors.
- Since users can conduct sensitivity analysis with different parameters promptly, the model is suitable for communication among stakeholders to design LCS. Besides, the model can be used as a simple assessment tool of output from various models.

Residential

Energy service demand

	Unit	2000	2050 BaU		CM		2050 CM	
			A	B	A	B	A	B
Household	Mil.	46.8	43.2	42.1			43.2	42.1
Cool	Mtoe	3	5	3	90%	90%	4	3
Warm	Mtoe	17	15	13	67%	67%	10	9
Hot Water	Mtoe	11	7	12	80%	80%	6	9
Cooking(S)	Mtoe	1	1	1	100%	100%	1	1
Cooking(E)	Mtoe	1	1	1	100%	100%	1	1
Lighting	Mtoe	3	5	3	80%	80%	4	3
Refrigerator	Mtoe	4	3	3	100%	100%	3	3
ICT	Mtoe	2	3	2	100%	100%	3	2
Appliance	Mtoe	10	13	10	100%	100%	13	10

Energy consumption / CO2 Emission

		UMit	COL	OIL	GAS	BMS	S/W	Heat	H2	ELE	Total
Energy Consumption	2000		0	21	9	0	1	0	0	23	54
	2050 A-scenario		0	1	1	0	8	0	4	14	28
	2050 A-scenario		0	2	2	7	18	0	0	8	37
Emission Factor	2000		1.00	0.80	0.55	0.00	0.00		0.00	1.19	
	2050 A-scenario		1.00	0.80	0.55	0.00	0.00		0.53	0.10	
	2050 B-scenario		1.00	0.80	0.55	0.00	0.00		0.00	0.65	
CO2 Emission	2000		0	16	5	0	0	-	0	27	49
	2050 A-scenario		0	1	0	0	0	-	2	1	5
	2050 A-scenario		0	1	1	0	0	-	0	5	7

Service Share

2000	COL	OIL	GAS	BMS	S/W	Heat	H2	ELE	Total
Cool								100%	100%
Warm		59%	15%					26%	100%
Hot Water		55%	33%		7%			5%	100%
Cooking(S)		44%	56%					0%	100%
Cooking(E)								100%	100%
Lighting								100%	100%
Refrigerator								100%	100%
ICT								100%	100%
Appliance								100%	100%

2050 A-scenario	COL	OIL	GAS	BMS	S/W	Heat	H2	ELE	Total
Cool								100%	100%
Warm		5%	5%			10%		80%	100%
Hot Water		5%	5%		10%	10%		70%	100%
Cooking(S)		5%	5%					90%	100%
Cooking(E)								100%	100%
Lighting								100%	100%
Refrigerator								100%	100%
ICT								100%	100%
Appliance								100%	100%

2050 B-scenario	COL	OIL	GAS	BMS	S/W	Heat	H2	ELE	Total
Cool								100%	100%
Warm		5%	5%	50%				40%	100%
Hot Water		10%	10%	20%	30%			30%	100%
Cooking(S)		15%	20%	35%				30%	100%
Cooking(E)								100%	100%
Lighting								100%	100%
Refrigerator								100%	100%
ICT								100%	100%
Appliance								100%	100%

Energy efficiency

2000	COL	OIL	GAS	BMS	S/W	Heat	H2	ELE	Total
Cool								2.84	-
Warm		0.90	0.90	0.90				3.69	-
Hot Water		0.75	0.75	0.75	1.00			0.62	-
Cooking(S)		0.45	0.45	0.45	0.45			0.70	-
Cooking(E)								1.00	-
Lighting								1.00	-
Refrigerator								1.00	-
ICT								1.00	-
Appliance								1.00	-

2050 A-scenario	COL	OIL	GAS	BMS	S/W	Heat	H2	ELE	Total
Cool								8.00	-
Warm		0.90	0.90	0.90		1.00		8.00	-
Hot Water		0.95	0.95	0.95	0.95	1.00		6.00	-
Cooking(S)		0.55	0.55	0.55	0.55			0.80	-
Cooking(E)								1.11	-
Lighting								1.50	-
Refrigerator								1.50	-
ICT								2.00	-
Appliance								1.50	-

2050 B-scenario	COL	OIL	GAS	BMS	S/W	Heat	H2	ELE	Total
Cool								8.00	-
Warm		0.90	0.90	0.90		1.00		8.00	-
Hot Water		0.95	0.95	0.95	0.95	1.00		6.00	-
Cooking(S)		0.55	0.55	0.55	0.55		0.55	0.80	-
Cooking(E)								1.11	-
Lighting								1.50	-
Refrigerator								1.50	-
ICT								2.00	-
Appliance								1.50	-

Fig. H.1 Menoco (only a portion for the Residential sector is shown here)

H.2 Model flow chart

Fig. H.2 shows the flow of estimating energy balance table and CO_2 emission table. The model calculates energy consumption of the end-use sectors, e.g. industrial, residential, commercial, and transportation sector, by energy type and service type, using exogenous data for service demand, mixture of energy, and energy improvement. Then it calculates energy consumption in power generation from the electricity demand in the end-use sector. Energy balance table is created with the energy consumption in end-use sector and power generation sector. Finally CO_2 emission table is created with CO_2 emission factor given exogenously.

Sector, service, energy as indices of Japan's Menoco include the elements shown in Table H.1.

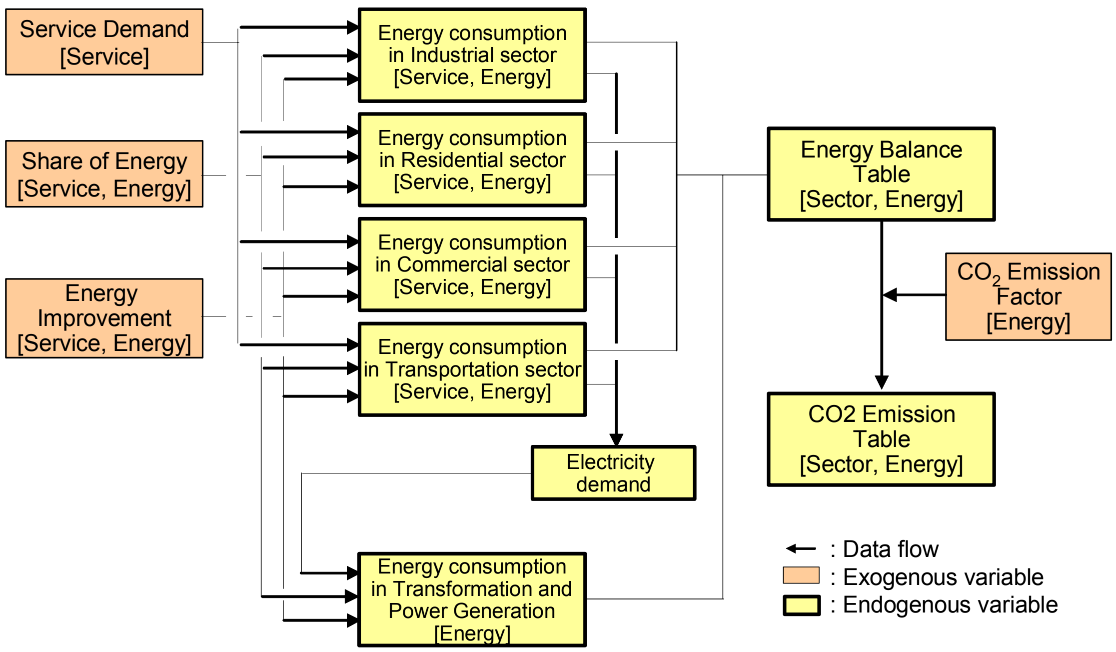


Fig. H.2 Flow chart for Menoco

Table H.1 Indices of Japan's Menoco

Indices	Classification	Elements
Sector	19	Industrial, Residential, Commercial, Transportation
Service	32	Industrial : Crude steel production, Cement production, Ethylene production, Paper production, other production by industrial category Residential : Warming, Cooling, Hot water, Cooking, Lighting, ICT, Other services Commercial : Warming, Cooling, Hot water, Cooking, Lighting, Motor others Transportation, Passenger: Cars(Mini/Small/Medium), Buses, Railways, Maritime, Aviation Transportation, Freight : Cars(Mini/Small/Medium), Railways, Maritime, Aviation Power generation
Energy	10	Coal, Oil, Gas, Biomass, Hydro, Nuclear, Solar/Wind, Hydrogen, Heat, Electricity

H.3 Example of simulation result

See Chapter 2.3

I. Inter-sector and Macro Economic Model

I.1 Model characteristics

- Inter-sector and Macro Economic Model (IMEM) consists of a static general equilibrium module for a single country and a macroeconomic module.
- One of the purposes of this model is to present the consistent pictures to achieve the drastic CO2 emission reduction in 2050 taking into account the countermeasures assessed in the individual models explained above.

I.2 Model flow chart

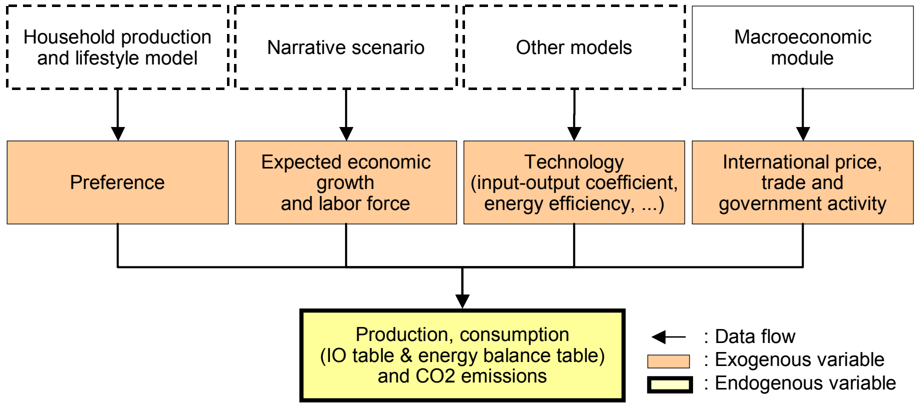
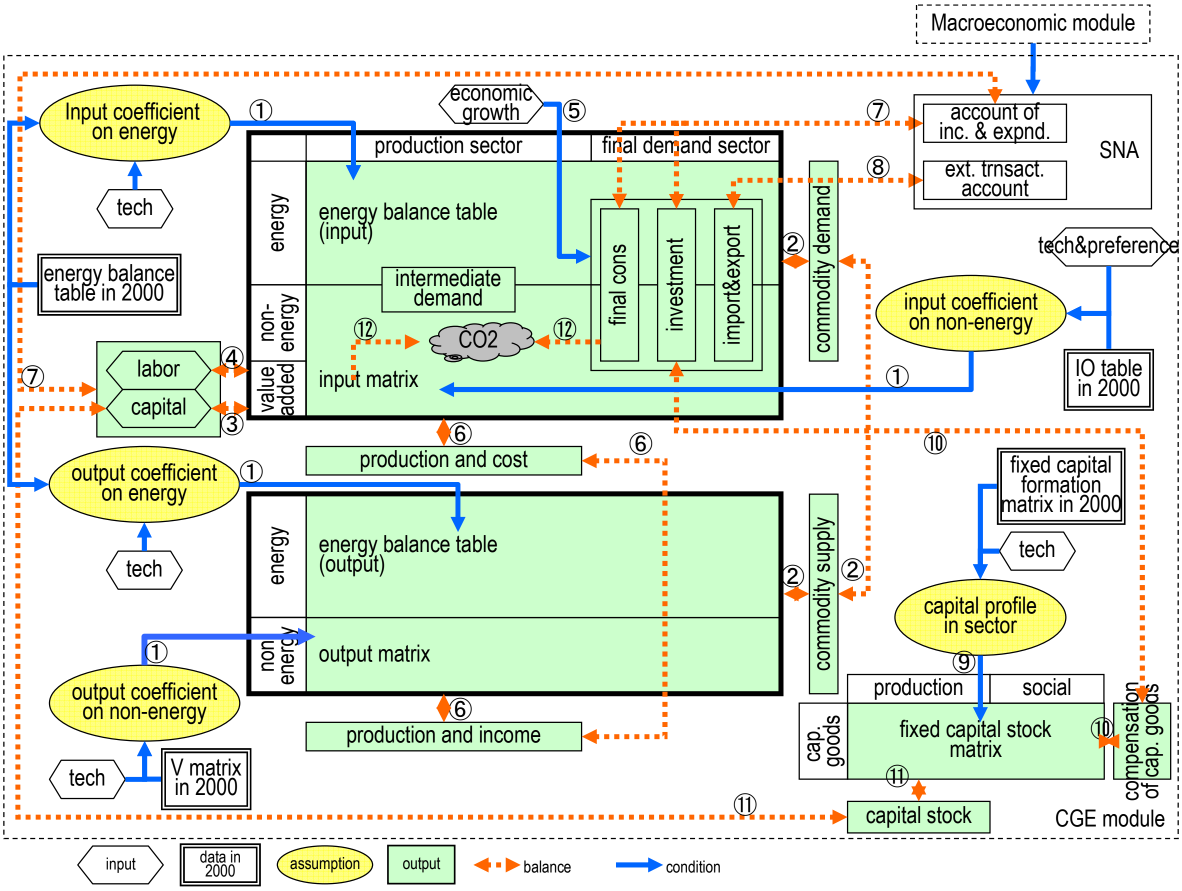


Fig. I.1 IMEM flow chart

The parameters in the CGE module are calibrated from the input-output data in 2000. The input data are updated to assess the future economic activities from the narrative scenario, the models explained in this paper, and the macroeconomic module representing the future values related to the account of macro economy.

Input data include expected economic growth, labour endowment, capital endowment, technology improvement (input-output coefficient and energy efficiency), preference change, ratio of imported goods to domestic goods, international price, etc.

Based on the above input data, the commodity prices and activities are calculated to balance the demand and supply of each commodity. The outputs include the input-output table, energy balance table, and CO2 emissions in the target year.



① production function

② commodity market

③ capital market

④ labour market

⑤ calculation of GDE

⑥ expenditure and income in production sector

⑦ expenditure and income in household and government

⑧ assumption of import and export

⑨ fixed capital stock matrix

⑩ investment goods market

⑪ capital stock

⑫ CO2 emissions

Fig. I.2 Structure of IMEM

Although the number of classifications in the basic data is more than 100, the commodities and sectors are aggregated in order to meet the research objectives. The table I.1 shows the examples of aggregated activities and commodities.

Table I.1 Examples of aggregated activities and commodities in the CGE module

Activities	
Primary industry	Agriculture / Forestry / Fishing
Mining	Coal mining / Crude oil and natural gas mining / Other mining
Manufacturing	Food products and beverages / Textiles / Pulp, paper and paper products / Publishing and printing / Chemical materials / Chemical products / Petroleum products / Coal products / Non-metallic mineral products / Pig iron and crude steel / Other steel products / Non-ferrous metal / Fabricated metal products / Machinery / Electrical machinery, equipment and supplies / Transport equipment / Precision instruments / Other manufacturing
Construction	
Power plant	Nuclear power plant / Thermal power plant / Hydro power plant / Geothermal plant / Photovoltaic generation / Wind power plant / Waste power plant / Biomass power plant
Town gas	
Water supply	
Service	Wholesale and retail trade / Finance and insurance / Real estate / Public service activities / Other service activities
Transport and communications	Railway transport / Road transport / Water transport / Air transport / Other transport / Communications

Commodities	
Primary energy	Coal / Crude oil / Natural gas / Nuclear / Hydro / Geothermal / Photovoltaic / Wind / Waste / Biomass
Secondary energy	Coaks / Other coal products / Gasoline / Naphtha / Jet fuel / Kerosene / Light oil / Heavy oil / LPG / Other petrorium products / Town gas / Electricity / Hydrogen / Heat
Primary industry	Agriculture / Forestry / Fishing
Other mining	
manufacturing	Food products and beverages / Textiles / Pulp, paper and paper products / Publishing and printing / Chemical materials / Chemical products / Non-metallic mineral products / Pig iron and crude steel / Other steel products / Non-ferrous metal / Fabricated metal products / Machinery / Electrical machinery ,equipment and supplies / Transport equipment / Precision instruments / Other manufacturing
Construction	
Water supply	
Service	Wholesale and retail trade / Finance and insurance / Real estate / Public service activities / Other service activities
Transport and communications	Railway transport / Road transport / Water transport / Air transport / Other transport / Communications

I.3 Example of Simulation Results

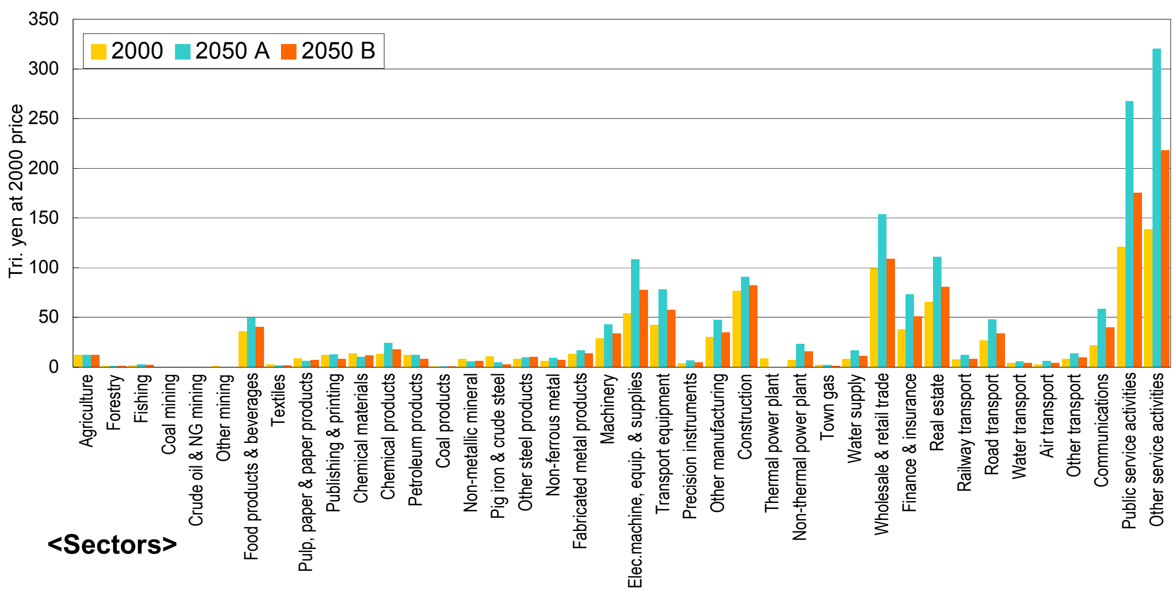


Fig. I.3 Example of the CGE module simulation

J. Environmental Options Database

J.1 Model Characteristics

- Environmental Options Database (EDB) is a database system that stores information of activities which accompany or reduce GHGs emission. Activity includes energy technology, institution, infrastructure, lifestyle, and other aspects. As shown in Fig. J.1, narrative description and quantitative value are entered in the form. All the items in the activity form are shown in Table J1.
- The EDB has a module for estimating future GHGs emission. Given the data on future driving force and penetration of activities, the module calculates energy consumption, GHGs emission, stock of activity, and other outputs. User can analyze the calculated projection using pivot table/graph as shown in Fig. K.2.

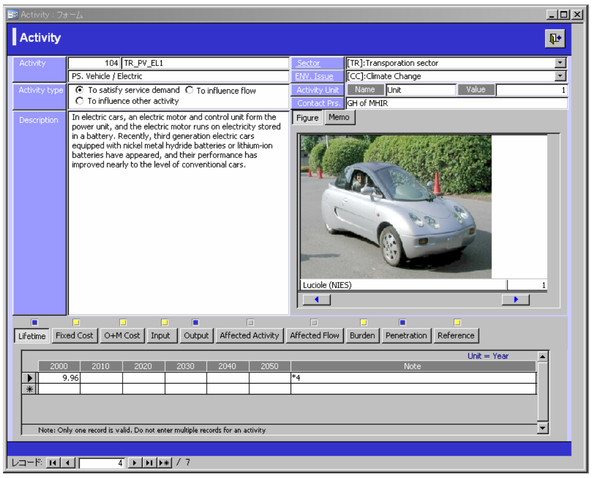


Fig. J.1 Form of Activity in EDB

Table J.1 Items of Activity

Item	Content
Activity type	Type of the activity
Description	Description of the activity
Sector	Sector activity belongs
Activity unit	Unit of activity amount
Figure	Picture or illustration of the activity.
Memo	Data source, estimation method, reference etc.
Lifetime	Lifetime.
Fixed cost	Fixed cost per activity.
O&M cost	Operating and maintenance (O&M) cost per activity. O&M cost here does not include the cost which accompanies inputs.
Input	Input per activity.
Output	Output per activity.
Affected activity	(This item is available when the activity type is "Activity to influence other activity") Increase (+)/decrease (-) rate of affected item of other activity
Affected flow	(This item is available when the activity type is "Activity to influence flow") Increase (+)/decrease (-) rate / quantity of affected flow.
Environmental load	Time-wise value of environmental burden emission per activity. The emission includes the direct emission, not include the emission with input.
Penetration	Penetration rate of the activity
Reference	Reference

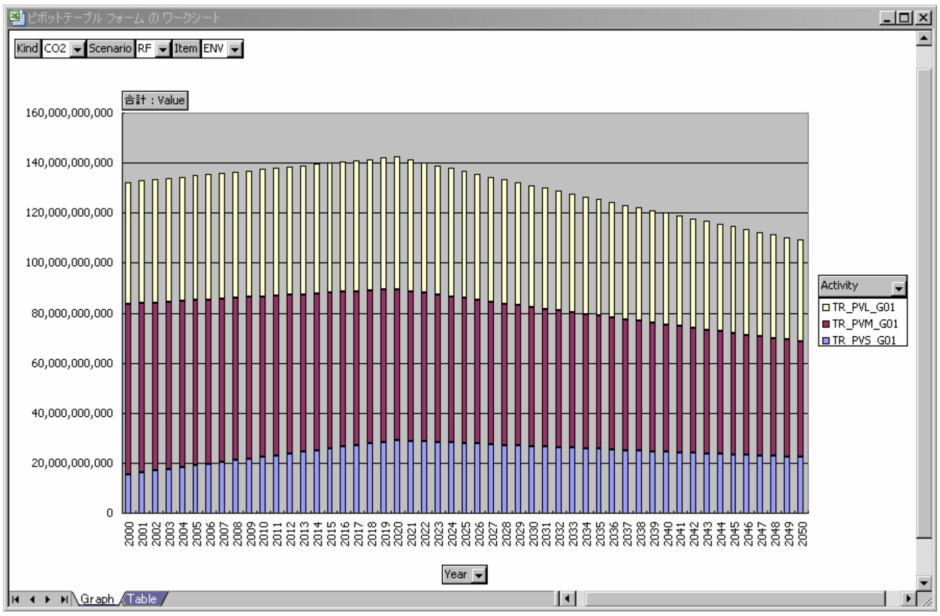


Fig. J.2 An example of simulation output of EDB using pivot function

J.2 Model flow chart

The members of LCS2050 project provide the information on the activities. The database plays the role of information exchange platform for the teams of LCS2050. The estimation module in the EDB calculates future projections under the scenarios of alternative policy. If the share of the activity (among the competing activities) is estimated based on the objective of cost minimization, the bottom-up engineering model is used. Menoco Model and Inter-sector and Macro Economic Model use energy improvement and countermeasure cost from the simulation output of EBD and/or Bottom-up engineering model.

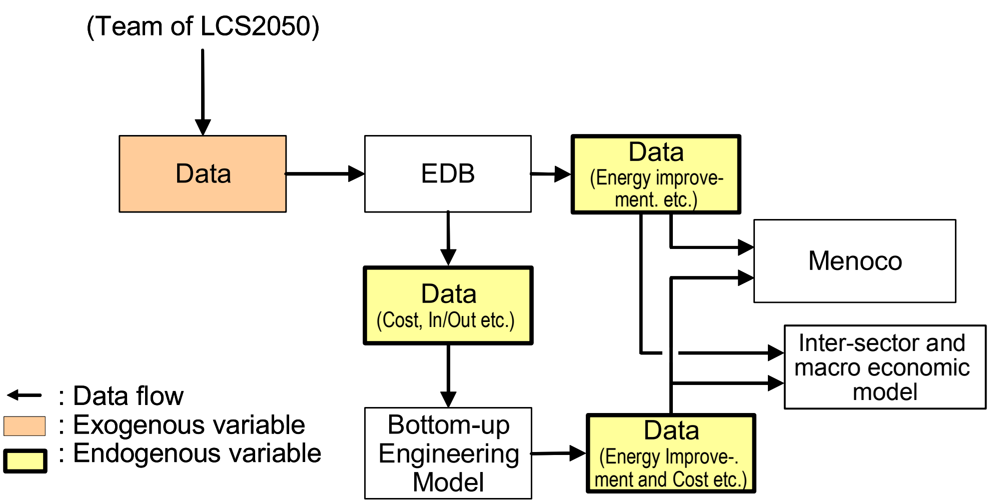


Fig. J.3 Data linkage of models via EDB

"Research Project on Establishing of Methodology to Evaluate Middle to Long term Environmental Policy Options toward Low Carbon Society in Japan (Japan Low Carbon Society Scenarios toward 2050)" (FY2004-2008)

The first great step to prevent global warming was taken by Kyoto Protocol which came into effect on Feb.16, 2005. But it is necessary to reduce GHG (Greenhouse gases) emissions drastically to stabilize climate change. Japan is also required to assess its long-term global warming policy. A large part of social infrastructure is likely to be replaced by 2050. It would be possible to propose concrete policy packages including institutional change, technology development, and lifestyle change toward low carbon society.

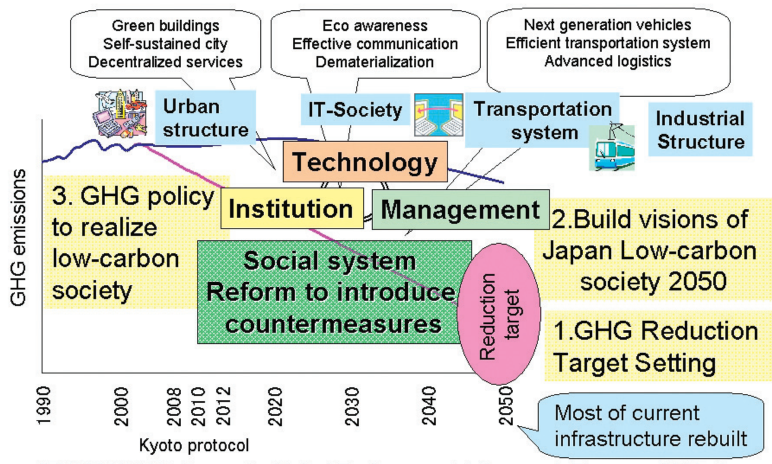
This project focuses on the following issues: 1) long-term scenario development study to integrate environmental options consistently using simulation models, 2) long-term GHG reduction target setting considering effectiveness and validity, and 3) assessment of environmental options considering future socio-economic conditions in a) urban system, b) information technology (IT) society, c) transportation system, and d) industrial change. We have the above 6 sub projects consisting of research experts in those areas and develop social and technically consistent middle and long-term global warming policy. To show probable paths toward a low carbon society in Japan which is compatible with economic development, would enhance public interest and lead to social and lifestyle changes. We propose to offer the latest research findings.

We have simulated the required GHG reduction for Japan. We have investigated the scenarios toward 2050 with back-casting method. The desired Japan 2050 future images with 60-80% GHG reduction will be set and the path considering economic impact, technological possibility, institutional and lifestyle change will be simulated objectively and consistently.

[Researchers]

Project Leader: Shuzo Nishioka (NIES)

Team Leader: Mikiko Kainuma(NIES) for scenario study, Norichika Kanie(TITech) for target setting, Keisuke Hanaki (University of Tokyo: UT) for urban system, Jun Fujimoto(UT) for ICT (Information and Communication Technology) based society, Yuichi Moriguchi(NIES) for transportation system, Yoshifumi Fujii(Bunkyo University) for industrial change, and about 50 other researchers.



[FY2004-2006(+2years), Global Environmental Research Program, MOEJ]

Further information: http://2050.nies.go.jp/

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脱温暖化 2050

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