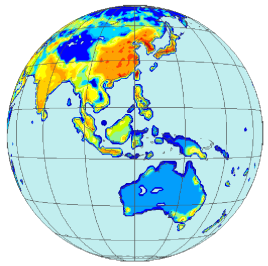
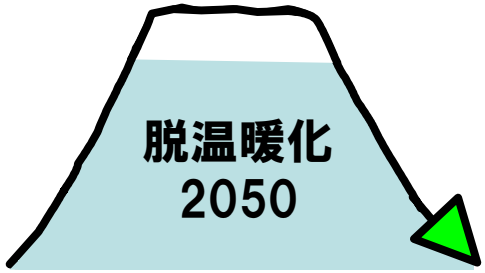
Japan – UK Joint Research Project, The first workshop on
"Developing Visions for a Low-Carbon Society through Sustainable Development"
Mita Kaigisho, Tokyo, Japan



Modeling Activity to support Japan "LCS toward 2050" project

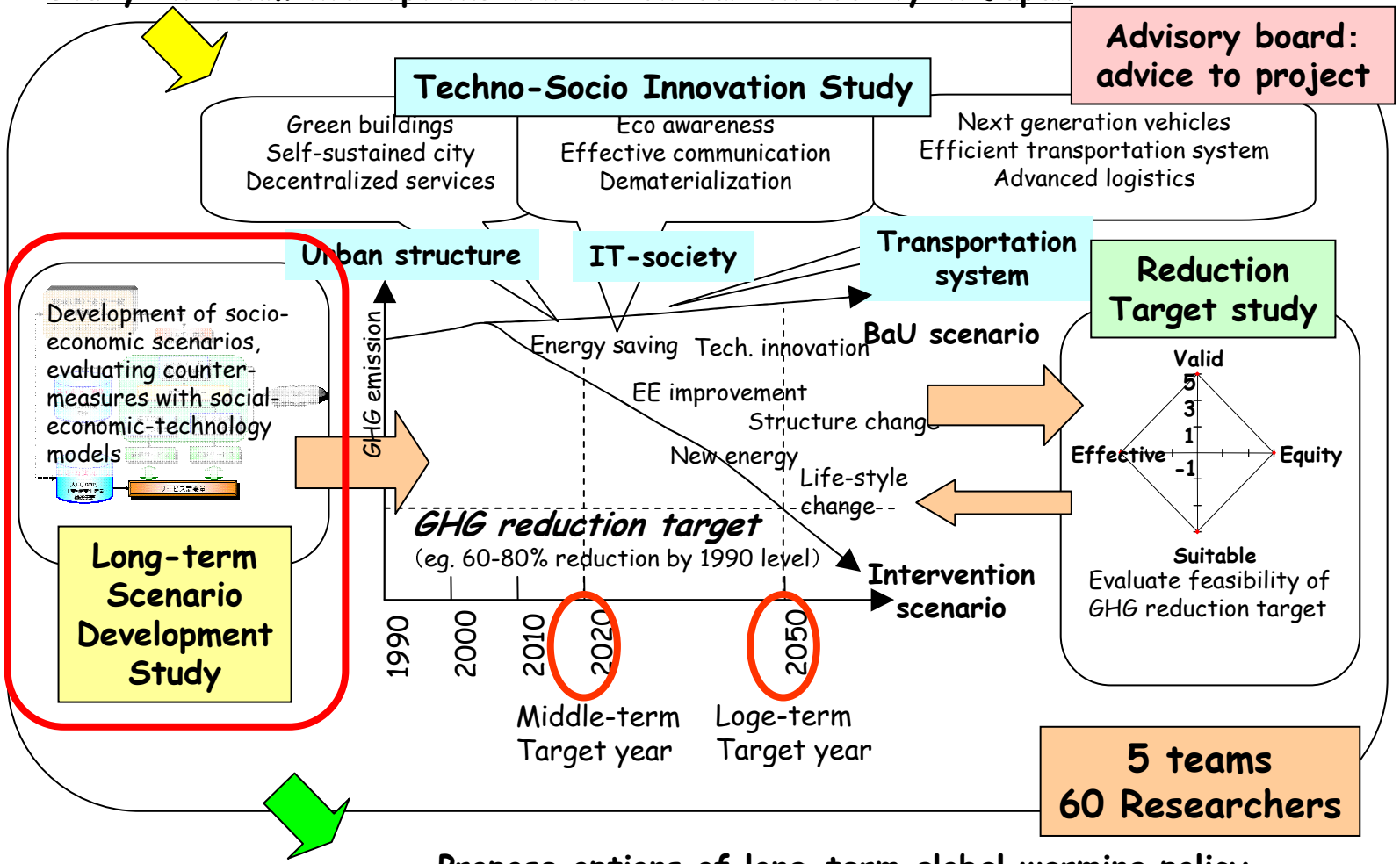
Yuzuru Matsuoka
Kyoto University



Japan Low Carbon Society Scenarios toward 2050

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

Study environmental options toward low carbon society in Japan



Propose options of long-term global warming policy

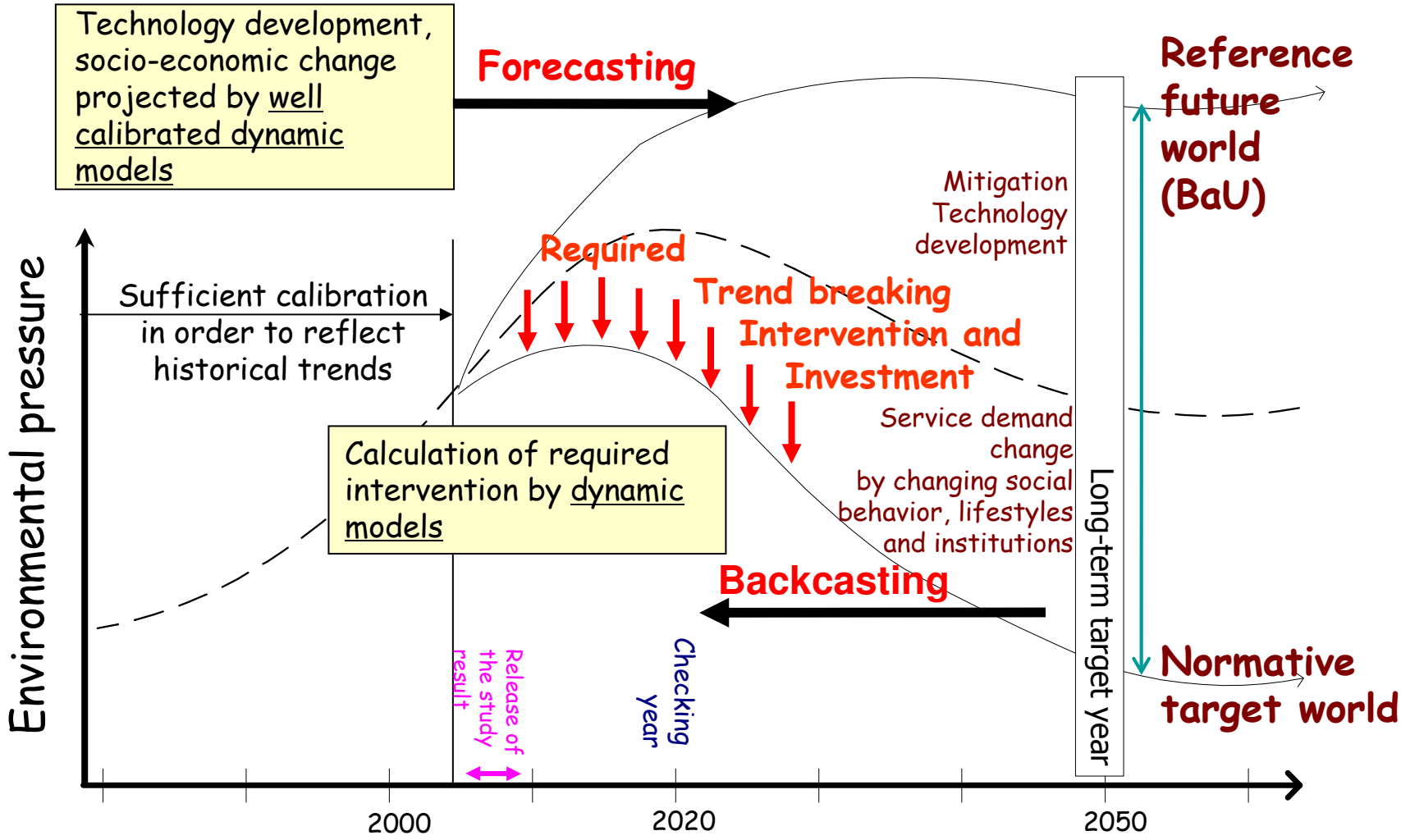
Objectives of LCS scenario study

1. Developing LCS scenarios which satisfy the prescribed emission targets as well as the related environmental, economical and social targets.
2. The scenarios are concrete, plausible, quantitative and consistent with technology, economy and sociality.
3. However, the LCS may be far from the BaU pathway (current trend), and in order to reach them, we must identify groups of "Trend Breaking Interventions"
4. To identify, and evaluate the "Trend Breaking Interventions" from the viewpoint of technological, environmental, and economical aspects are required.

In order to describe the plausible, feasible, and consistent future, we are proceeding the study in the following steps

1. Description of narrative scenarios and storylines, supported by project members, the advisory board, interviews to experts.
2. Construction of world visions in 2020 as the extrapolation of historical trends with likely counter-measures.
3. Construction of world visions in 2050 as the realization of Low Carbon Society (LCS) which satisfy global GHG emission constraints.
4. Identification and evaluation of required interventions (Trend Breaking Interventions) that induce the society to LCS.

Forecasting from now and Backcasting from future prescribed/normative world



Two types of models were required to support scenario development

(1) Snapshot model

The first group focuses on describing LCS in a certain future (e.g. year 2050), concretely, quantitatively, and consistently with physical, economical, technological laws.
We call the models, "Snapshot models". Examples are;

- Household Production and Lifestyle model
- Passenger and Freight transportation demand model
- Energy supply and demand balance model
- Energy technology bottom-up model
- Inter-sectoral economic model

Two types of models were required to support scenario development

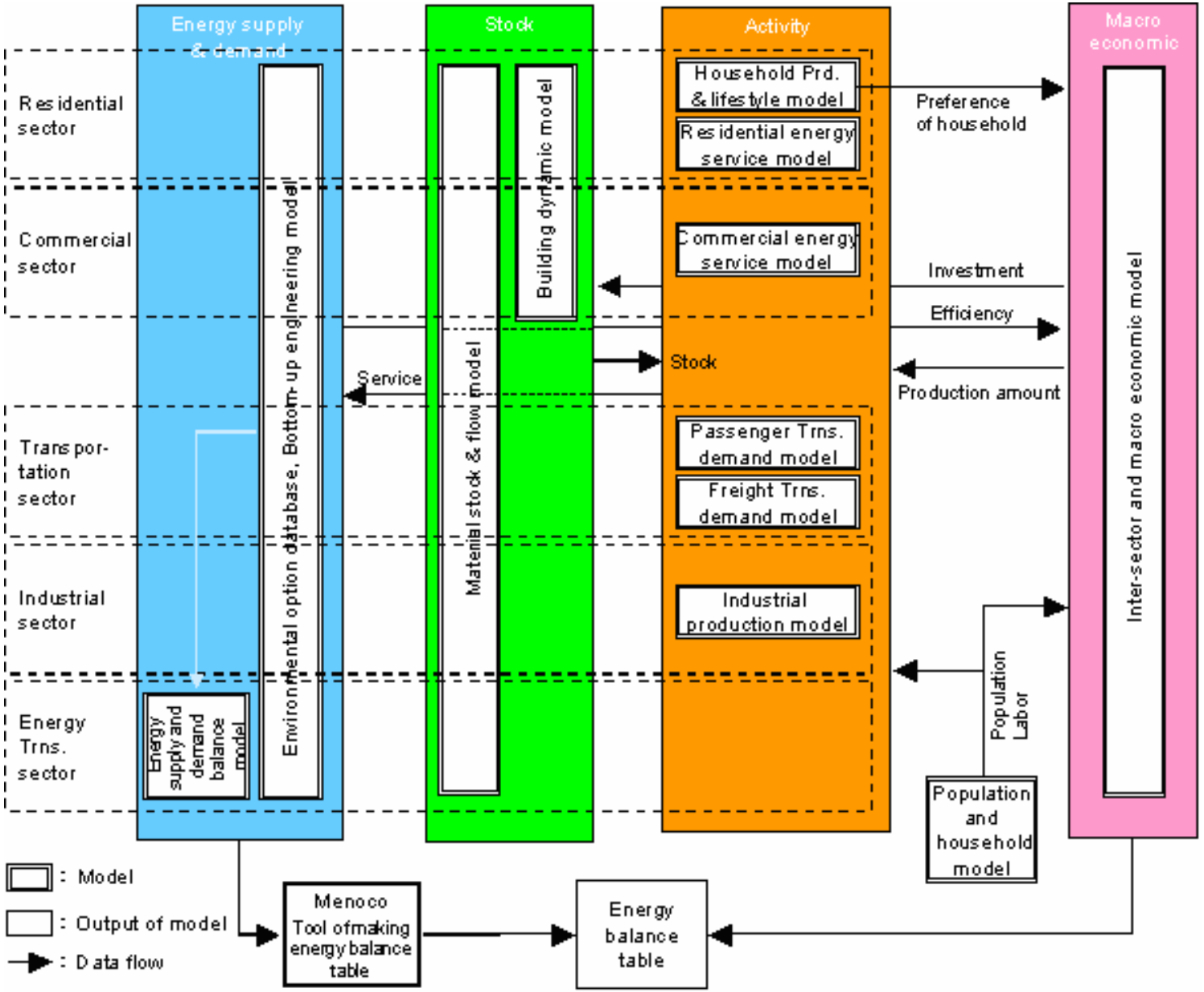
(2) Transition model

The second group focuses on the dynamics and trend transition of the society, economic system, and the technological system. We call models of the group, "Transition models". Examples are;

- Population and household dynamics model
- Material stock and flow dynamics model
- Building Dynamics model
- Microeconomic model

We link the "Snapshot models" and the "Transition models" to construct LCS scenarios, and to identify/evaluate required interventions for realizing LCS.

Relationship among element models



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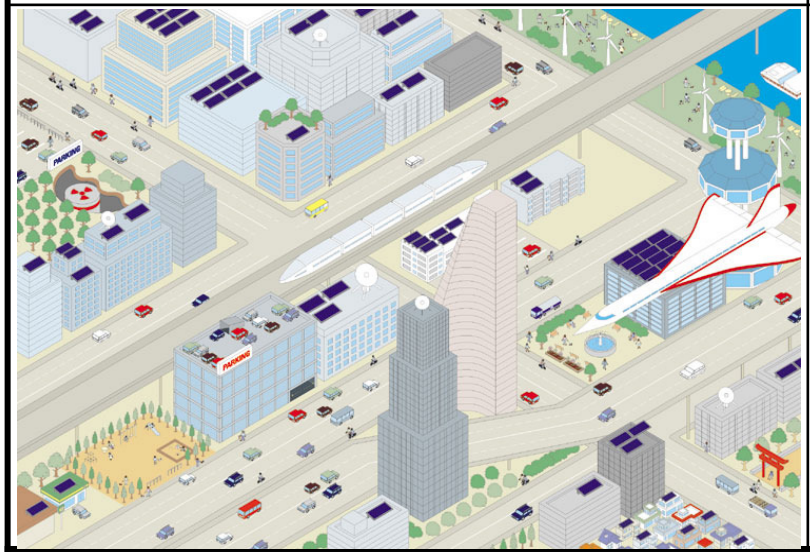
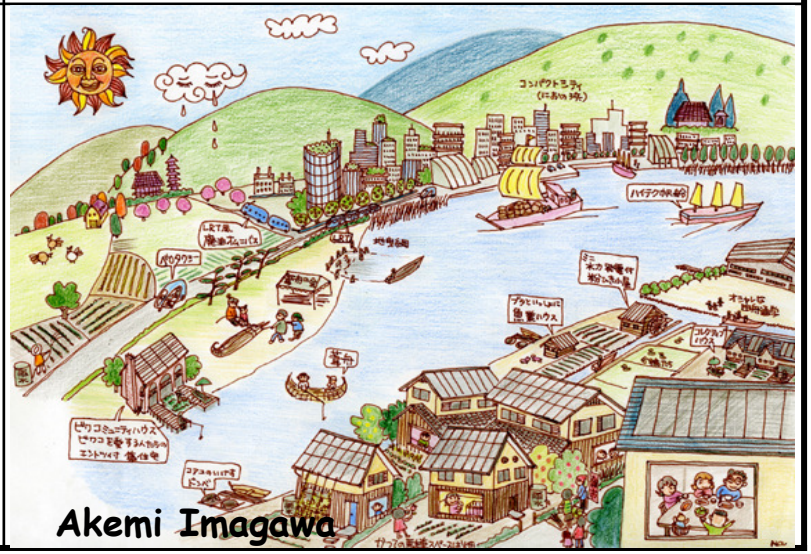
As for LCS visions, we prepared two different but likely future societies

Scenario A	Scenario B
Bustling, Technology-driven	Slow, Natural-oriented
Urban concentrated/ Individualistic	Decentralized, Community-oriented, Self-sufficient
Centralized production /recycle	Produce locally, consume locally,
Convenient and Beneficial	Social and Cultural Values
	

Key concepts of 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	· Downslide	· 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

Key concepts of two scenarios (2)

Keywords		Scenario A	Scenario B
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

On these two scenarios, we allocate possible trend-breaking options

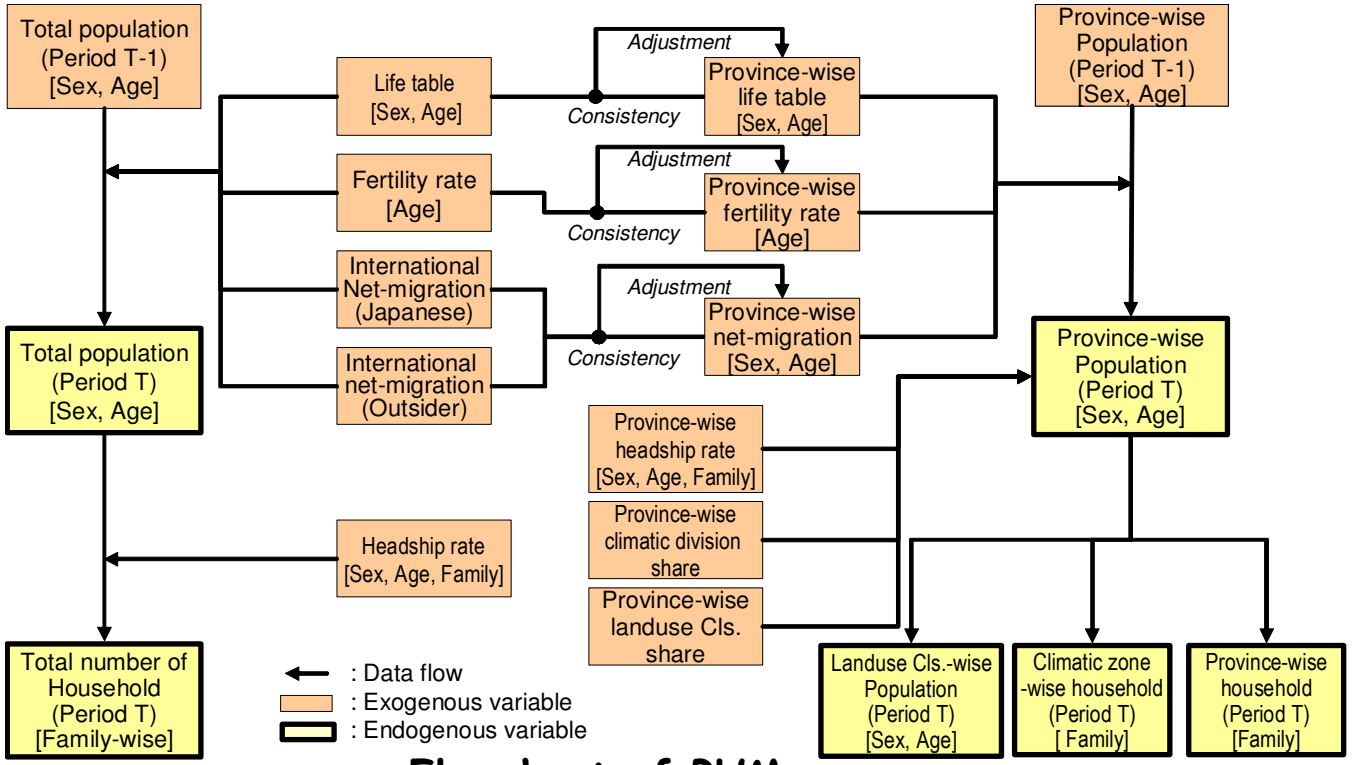
Sector	Scenario A	Scenario B
Industry	· Energy efficient production technology	· Energy efficient production technology
Residential and Commercial	· Insulation of the building · Diffusion of all-electric home · Diffusion of high efficiency heat pump air conditioner and water heater · Development and diffusion of fuel cells · Optimal energy control by HEMS	· 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

To analyze the feasibility and impacts of interventions with the 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)
	c. Changes of the share of detached and multidwelling houses	-	Household Production and Lifestyle Model (f)
	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)
	h. Changes in social environment and human activities	-	Freight Transportation Demand Model (j-m)
	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)
	u. Impacts of future technological choices on social energy efficiency	-	EDB (u)
	v. Ensuring economical consistency of LCS	-	Inter-sector and Macro Economic Model (v)

Population and Household Model

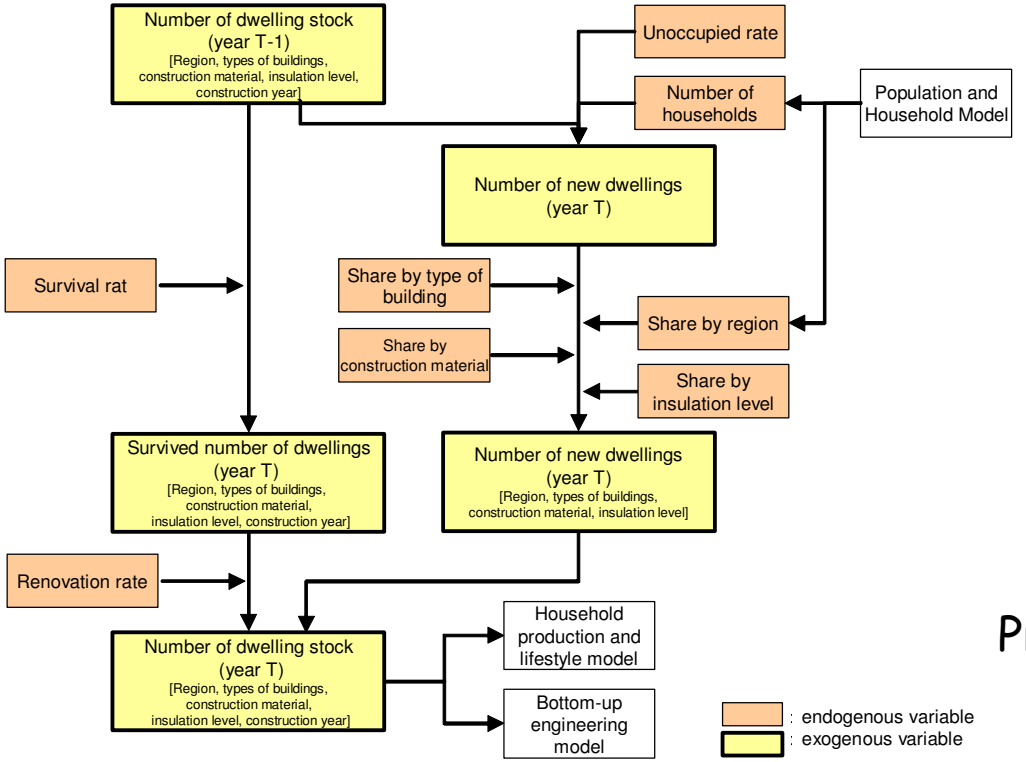
- Drastic change in Japan's society by 2050 is on the population structure. Downturn in birthrate, depopulation and aging will continue until 2050, and they affect greatly the future vision.
- A cohort component model for population, a household headship rate model for household types, with spatial resolution of provinces, land-use types and climate zones and five family types was developed, and is used to analyze effects of depopulation and changes in family composition on the realization of LCS.



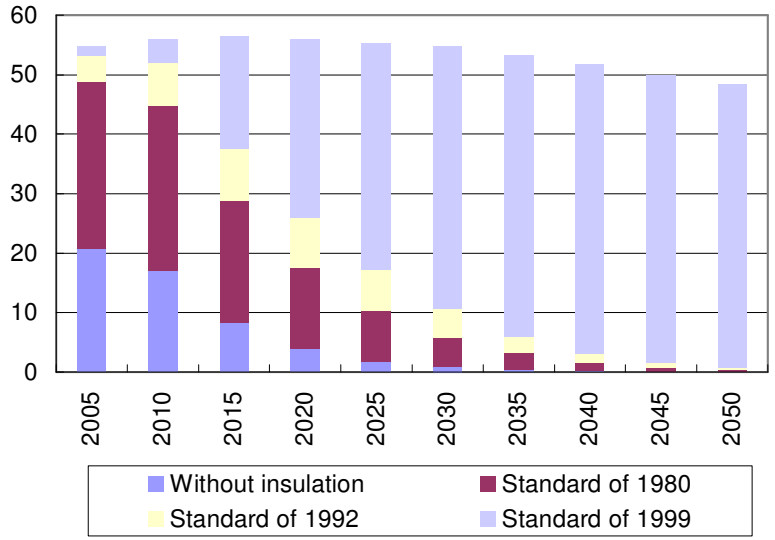
Flowchart of PHM

Building Dynamics Model

- Enhancement of building insulation is very effective countermeasures. 60% of the heating demand from the residential sector can be cut down, if appropriate insulation systems are installed. Besides, configuration of buildings in urban and rural area affects social energy efficiency greatly.
- In order to take account these factors, a model of building dynamics (BDM) was developed.
- It is a cohort model with a spatial resolution of climate zones, four heat insulation levels, four residential building types, and six commercial building types.



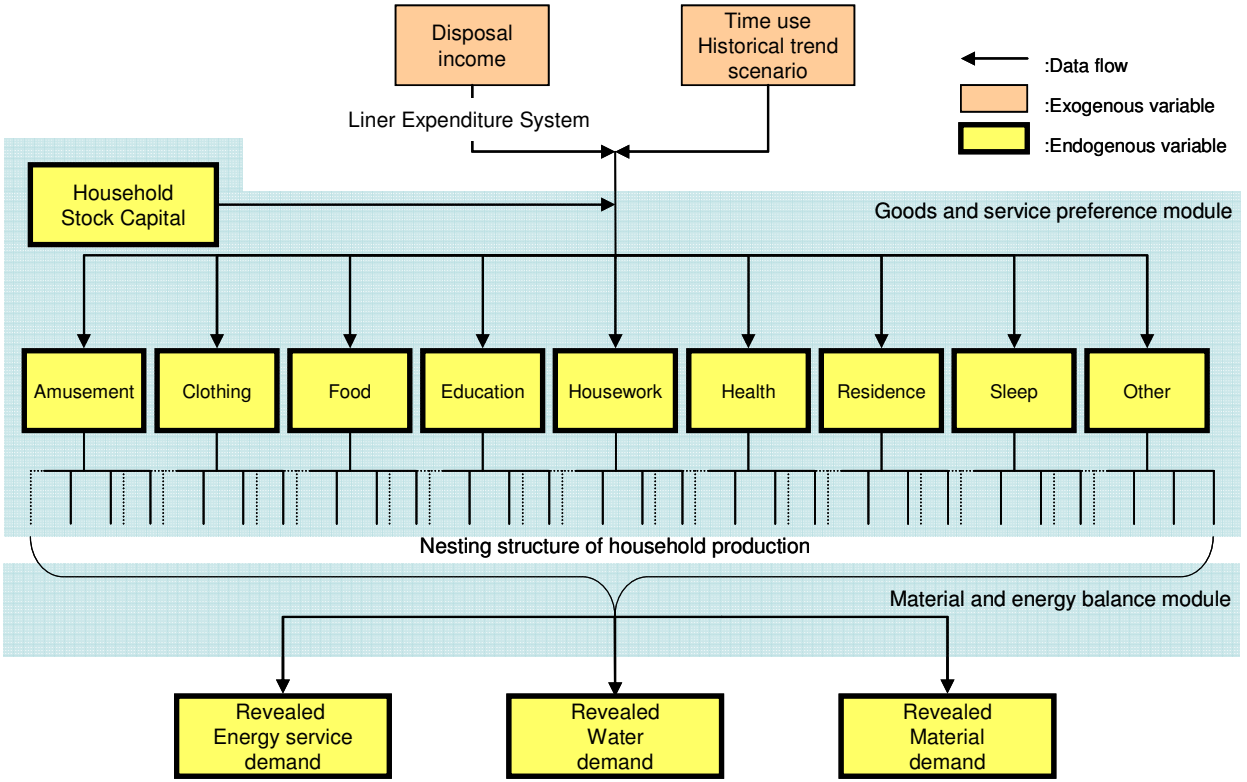
Flowchart of BDM (residential)



Projection of residential dwelling stock by insulation level (number in million)

Household Production and Lifestyle Model

- 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.
- People's preference of goods and service, the efficiency improvements of household production are greatly affects the realization of the LCS.
- 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 type composition, age composition, income budget, and time budget in the future.

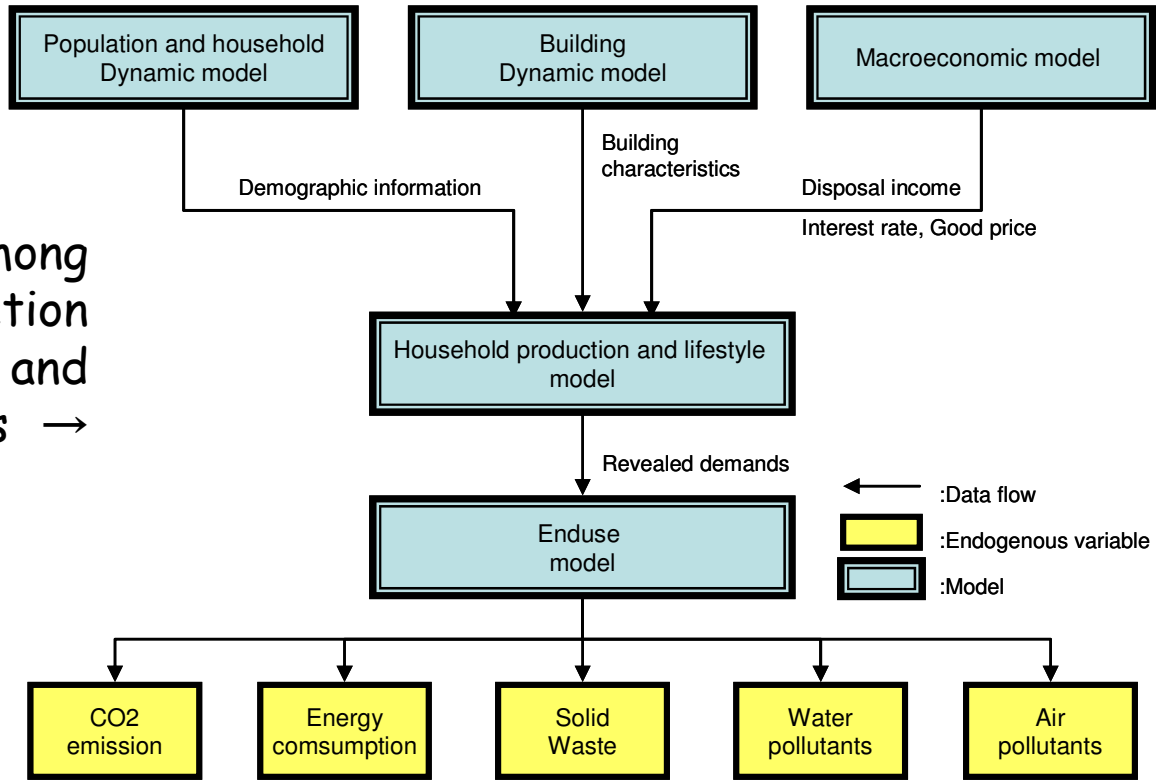


Flowchart of HPLM

Household Production and Lifestyle Model(2)

- 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.

Linking among Household production and lifestyle model and related models →

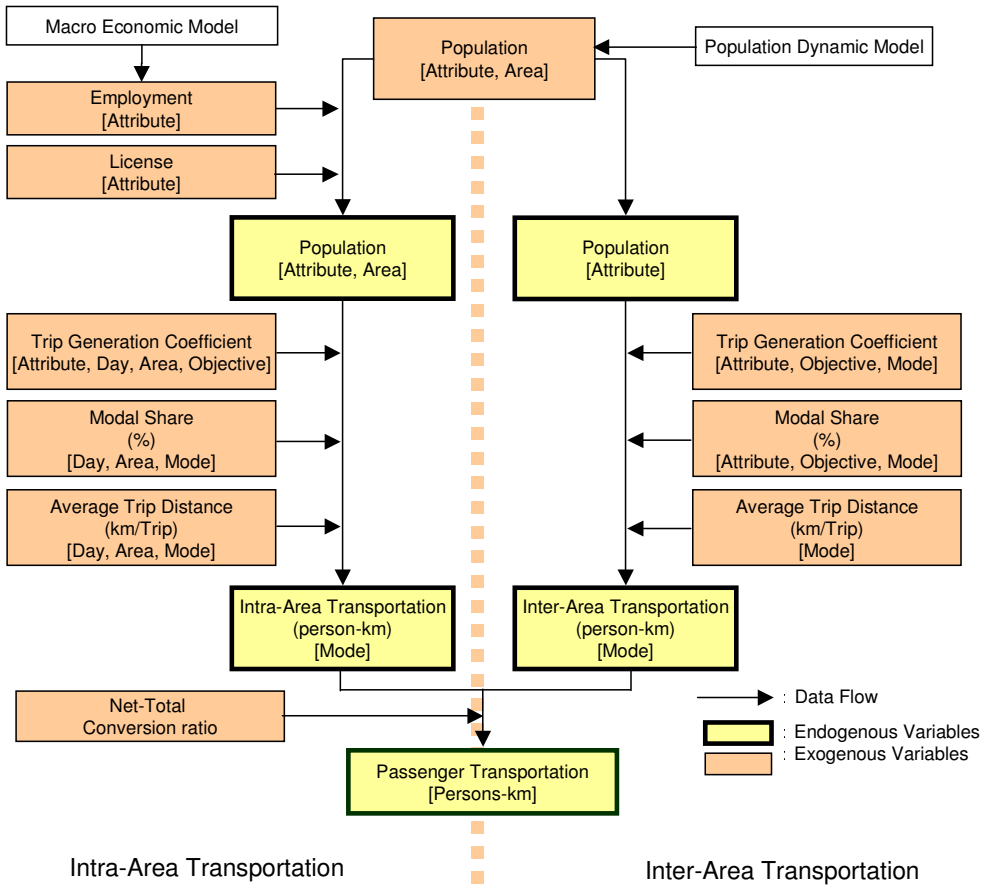


Passenger Transportation Demand Model

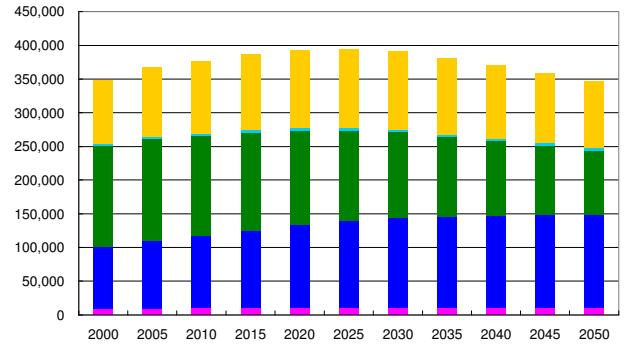
- Many effective countermeasures exist related with transportation. Modal shift from private motor vehicles to mass transit systems, urban planning towards compact cities, transportation substitution with diffusions of teleworking and virtual communication systems and so on.
- Passenger Transportation Demand Model (PTDM) can simulate transportation demand associated with changes in population distribution, social environment, people's activity patterns, modal shares and average trip distances.
- The demands are divided into two types,

  1)Intra-regional transportation (within the daily living area),
  2)Inter-region transportation (between the daily living areas),

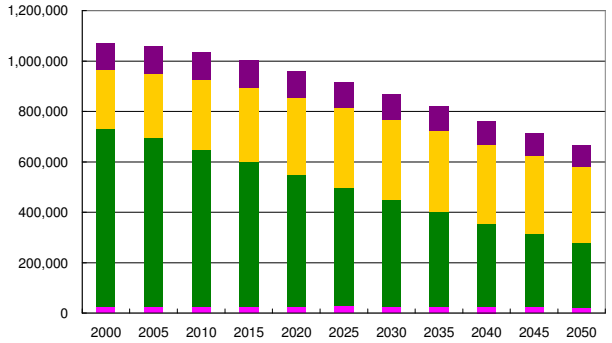
  and they are calculated separately.



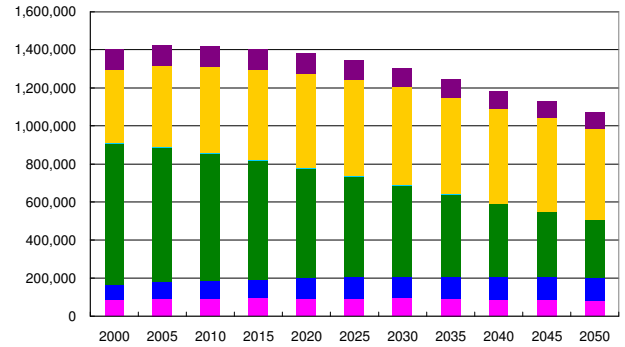
Passenger Transportation Demand Model (2)



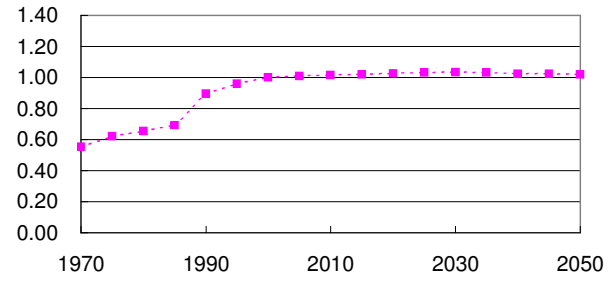
Inter-region transportation demand by mode of transportation (mil. person-km)



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



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



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

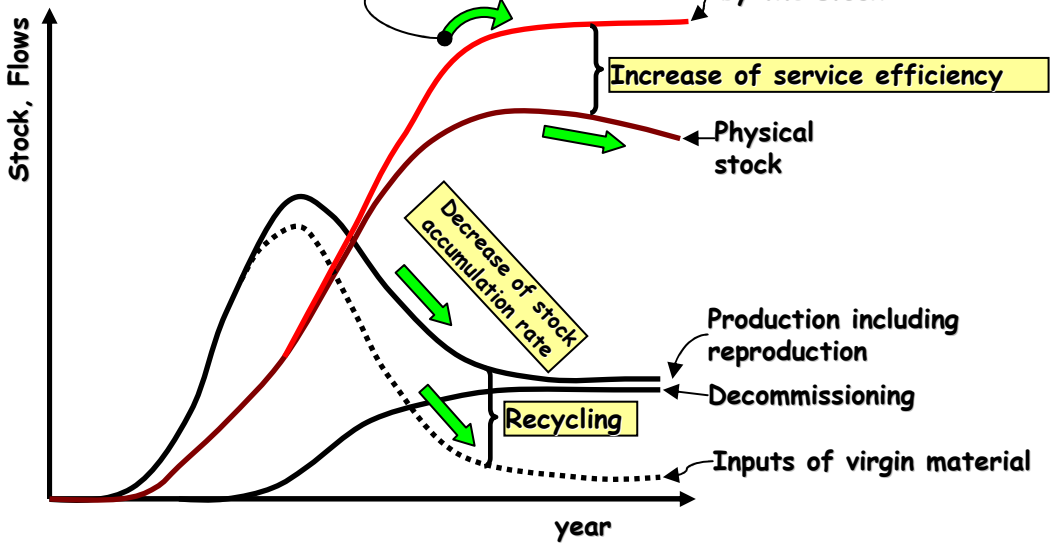
Buses Aviation Pass.cars Maritime Railways Walk&Bike

- In this example, the spreading of compact cities is assumed. This change causes a decrease in average trip distance and also a low growth rate of per capita transportation demand.
- In addition, the share of railways transportation will increase rapidly due to the promotion of modal shift from car to train.

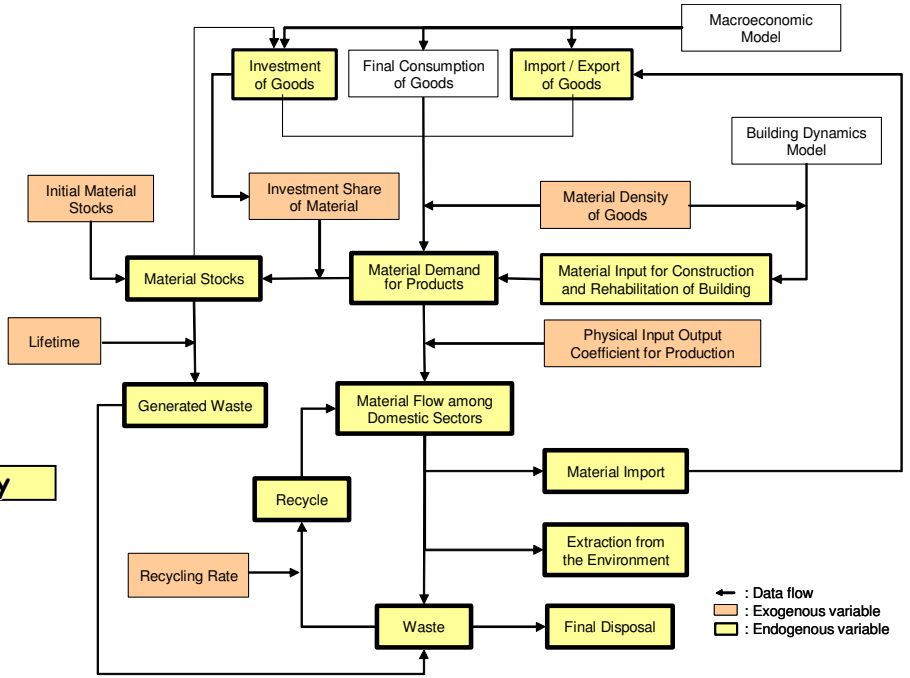
Material Stock and Flow Model

Material Stock and Flow Model (MSFM) estimates the change of material stocks and flow in the society. 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.

Stock dynamics greatly affects social energy/material efficiency



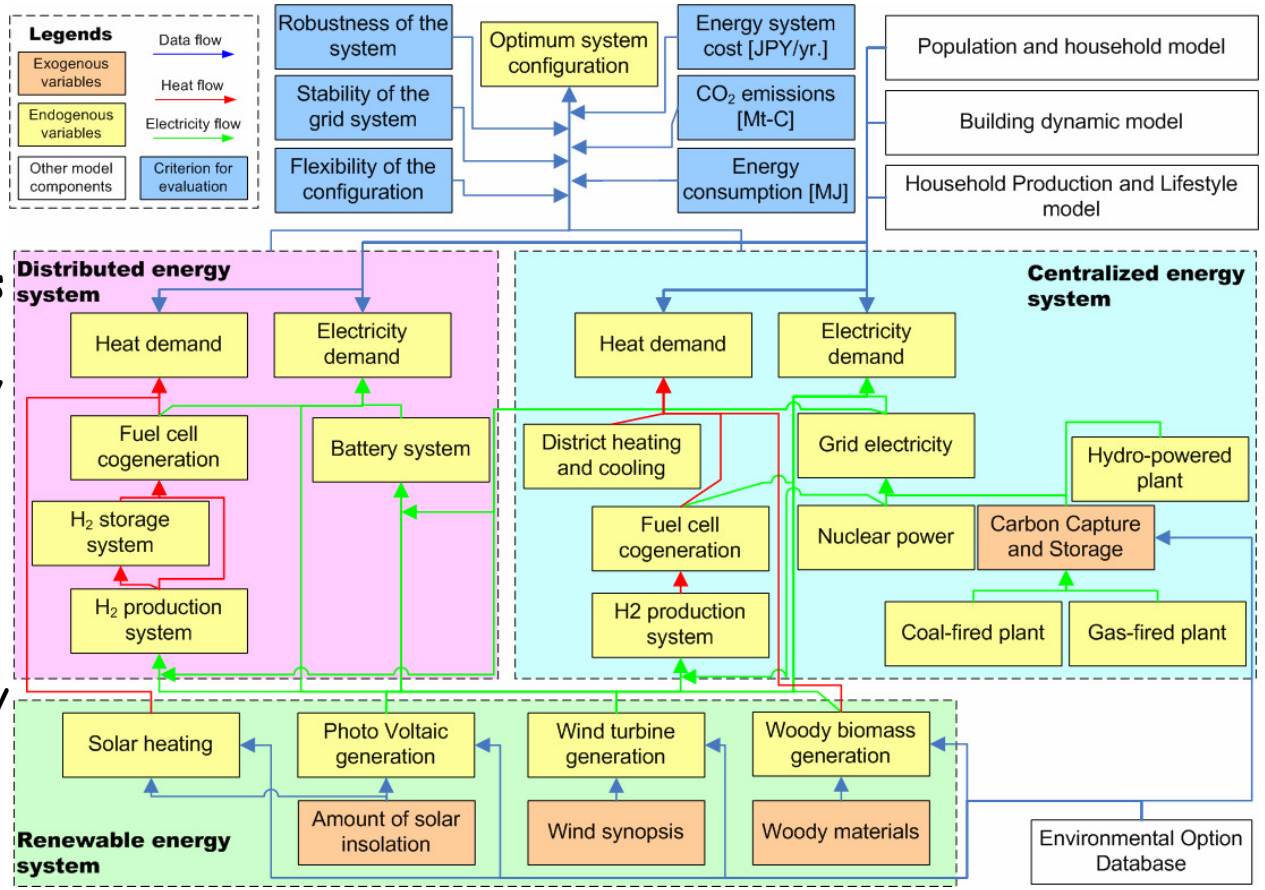
These factors affect energy consumption, greatly



Flowchart of MSFM

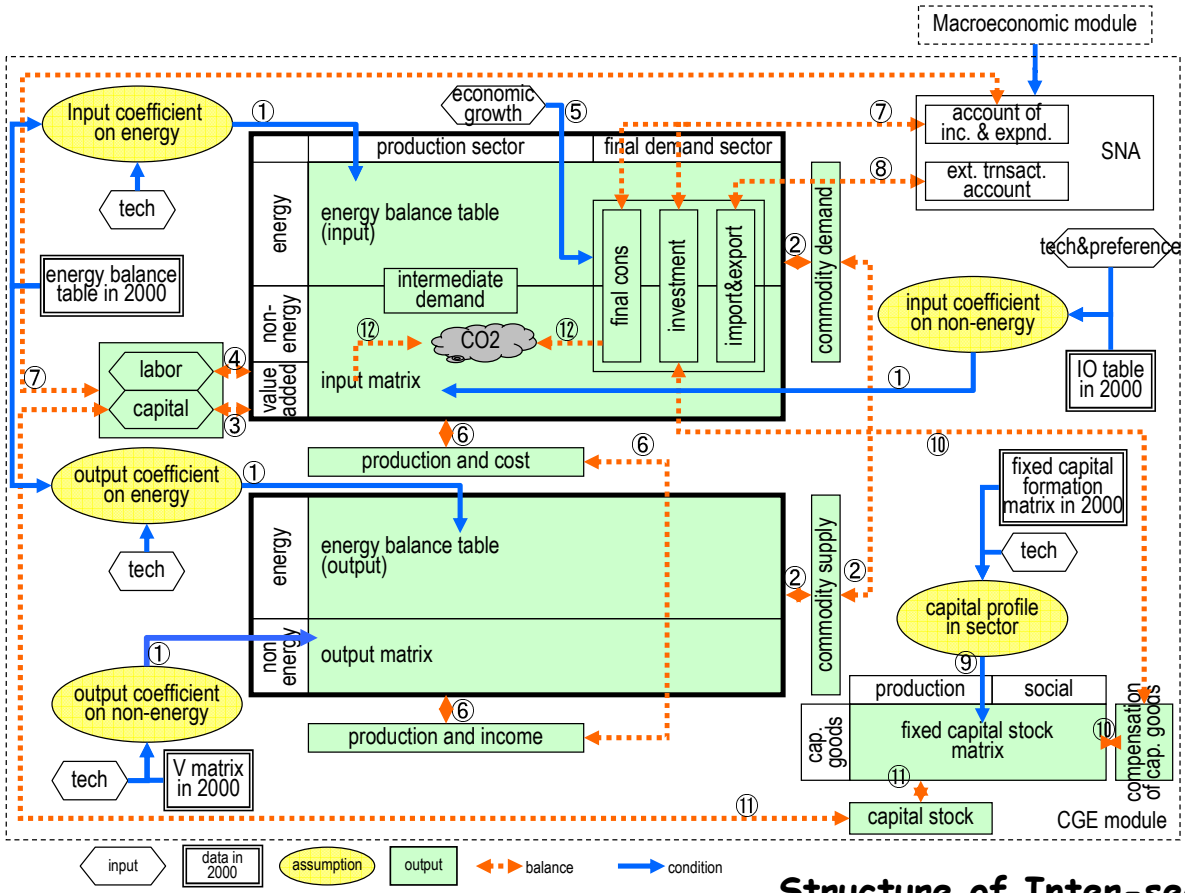
Energy Supply and Demand Balance Model

- To supply CO_2 free electricity, electricity from fossil fuels would be coupled with carbon capture and storage (CCS). The other way is to use nuclear, renewable and hydrogen. Current hydrogen production processes of on-site fossil fuel reforming need to be changed, since it is economically difficult to capture the CO_2 from widely dispersed facilities.
- As for heat sources, fossil fuel use is replaced by renewable, heat from fuel cell cogeneration systems and heat pumps. As a transportation fuel, biofuels would be a possible option besides CO_2 free electricity and hydrogen.
- Energy Supply and Demand Balance Model (ESDBM) seeks optimum configurations of the energy system based on the energy balance between supply and demand, especially with detailed description of renewables.



Inter-sector and Macro Economic Model

- Taking into account the countermeasures proposed in the individual models, Inter-sector and Macro Economic Model (IMEM) consists of a sequential dynamic general equilibrium module for a single country coupled with a macroeconomic module.
- The model can be used to analyze the impacts of energy efficient and dematerialization technologies in industrial sectors, progress in informatization, and increase of service sectors.



① production function
② commodity market
③ capital market
④ labor 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 CO_2 emissions

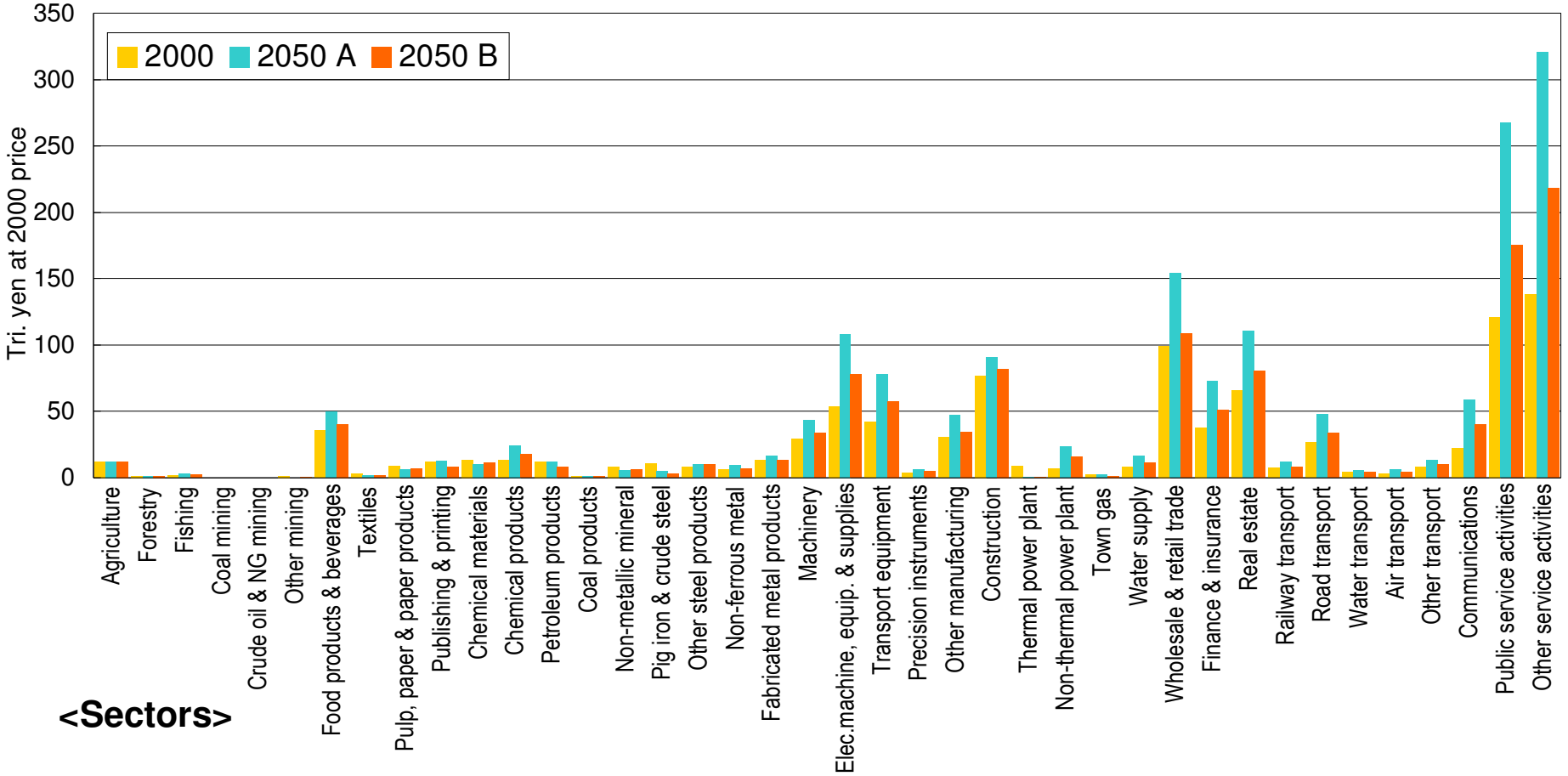
Structure of Inter-sector Module

Modeled production sectors and commodities in the inter-sector 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

Examples of the projected sector productions in year 2050



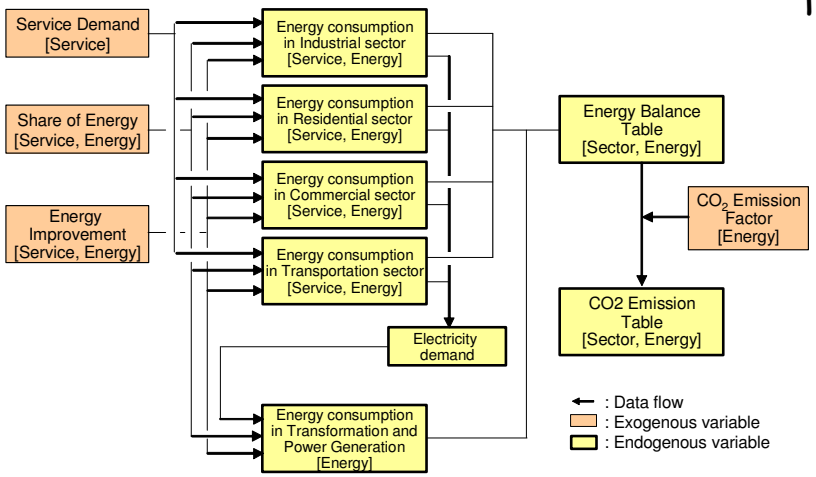
Besides these models, we prepared

Menoco Tool

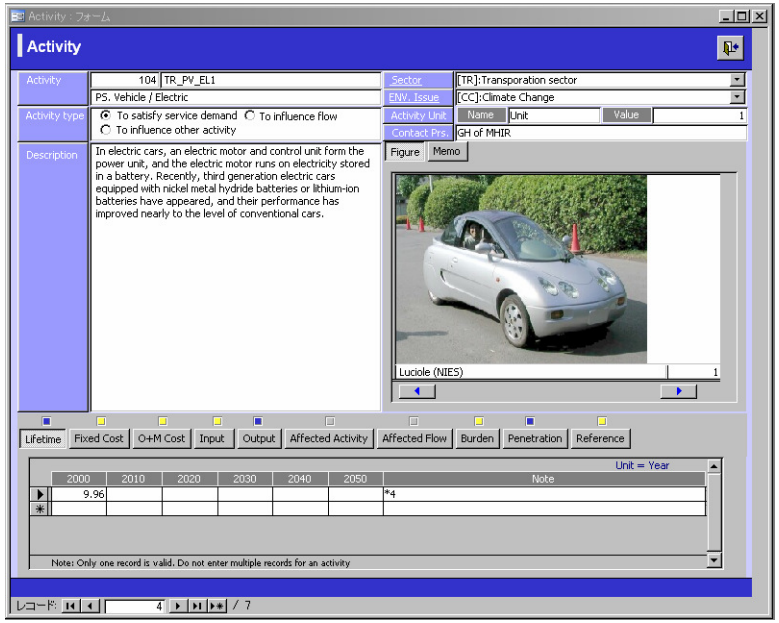
- "Menoco" means "back of the envelope" type calculation in Japanese. It was developed on MS Excel, and calculates an energy balance table, a CO_2 emission table It is suitable for communication among stakeholders to design LCS.

Environmental Options Database (EDB)

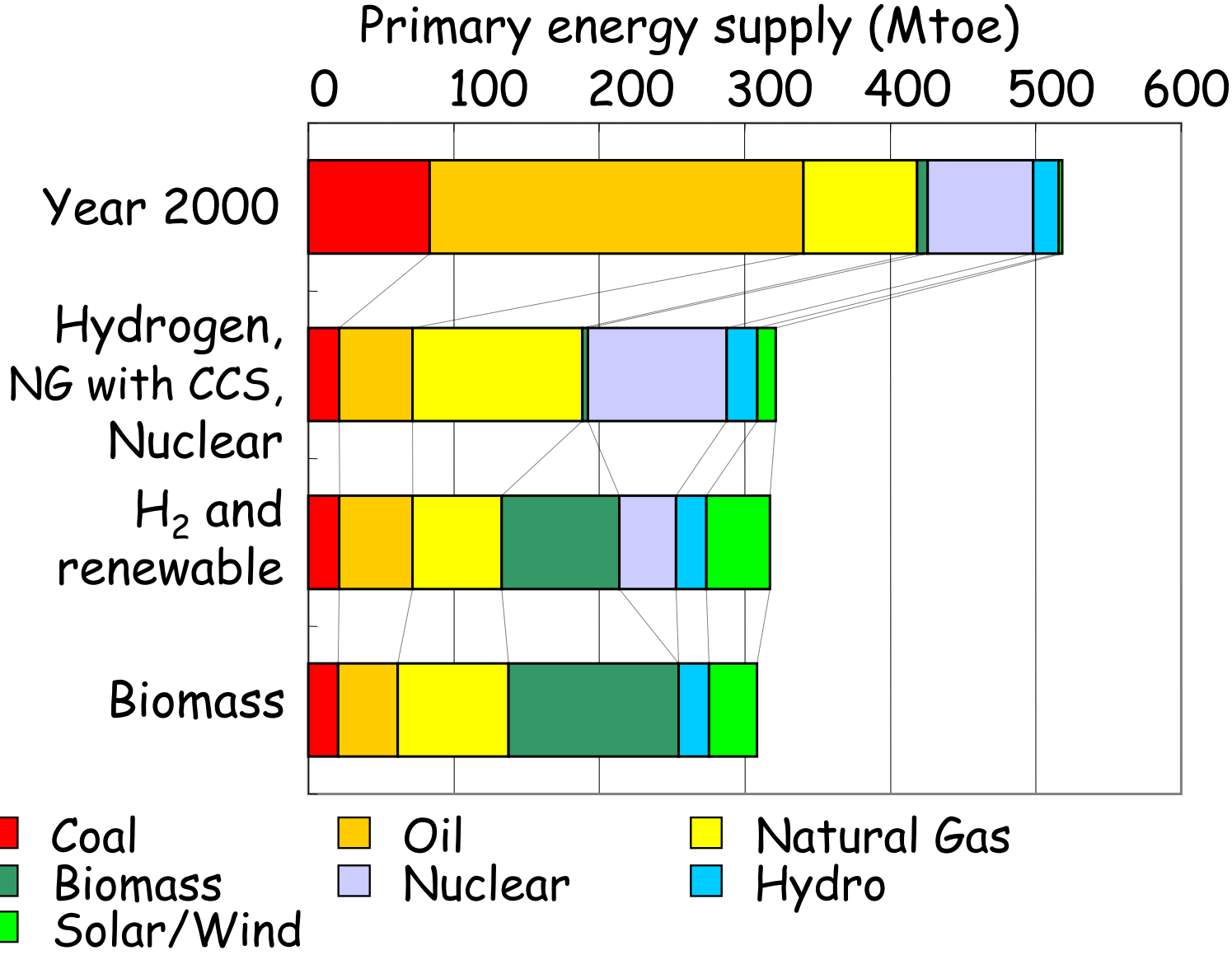
- A database system which stores information of related activities.
- Activity includes energy technology, institution, infrastructure, lifestyle, and other aspects, and narrative description and quantitative value are entered in the database.
- An engineering bottom-up type energy and emission calculator is attached to this database.
- The EDB serves as an exchange platform between the each sectors experts and the scenario team.



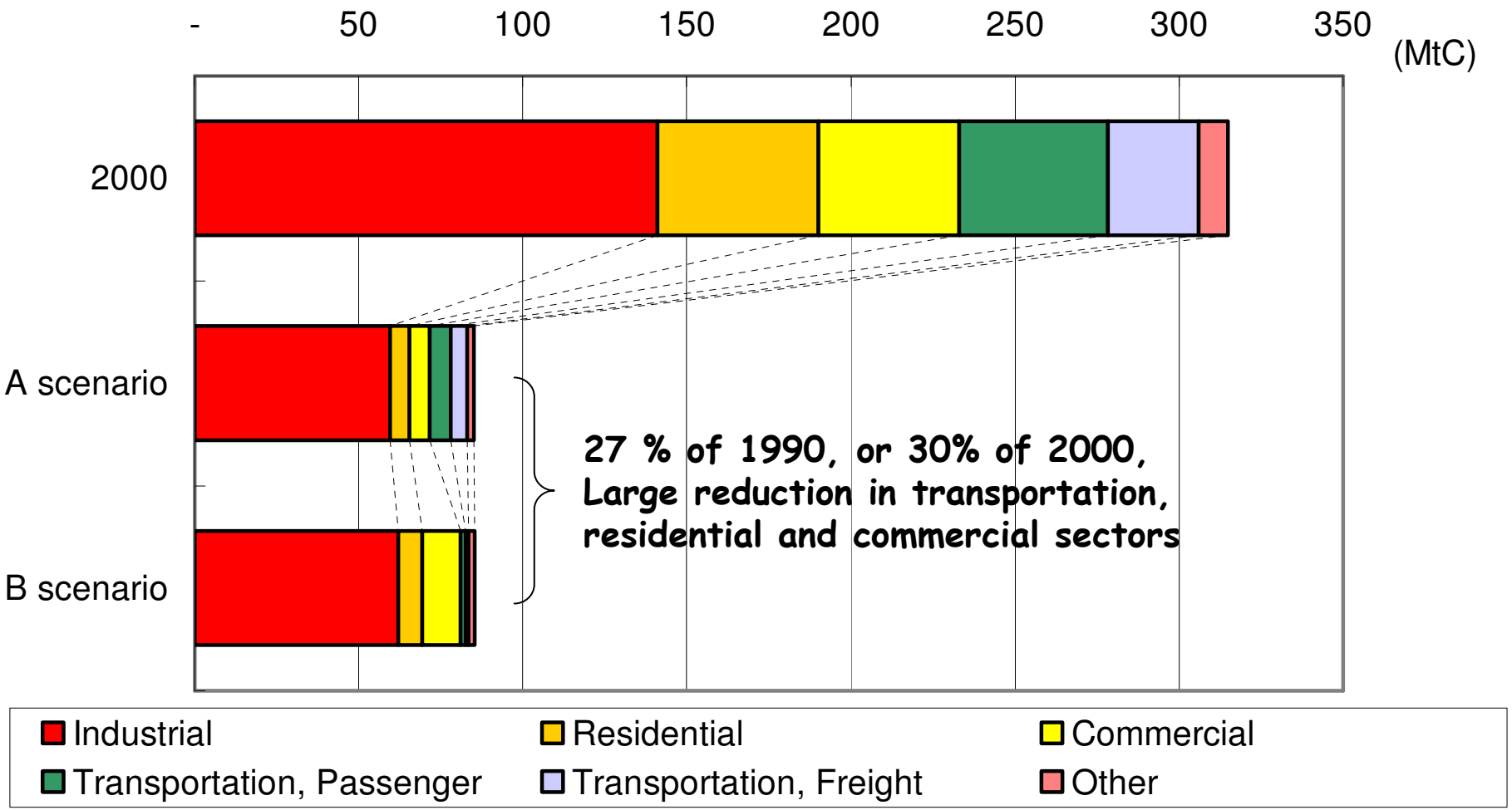
Flowchart of the "Menoco"



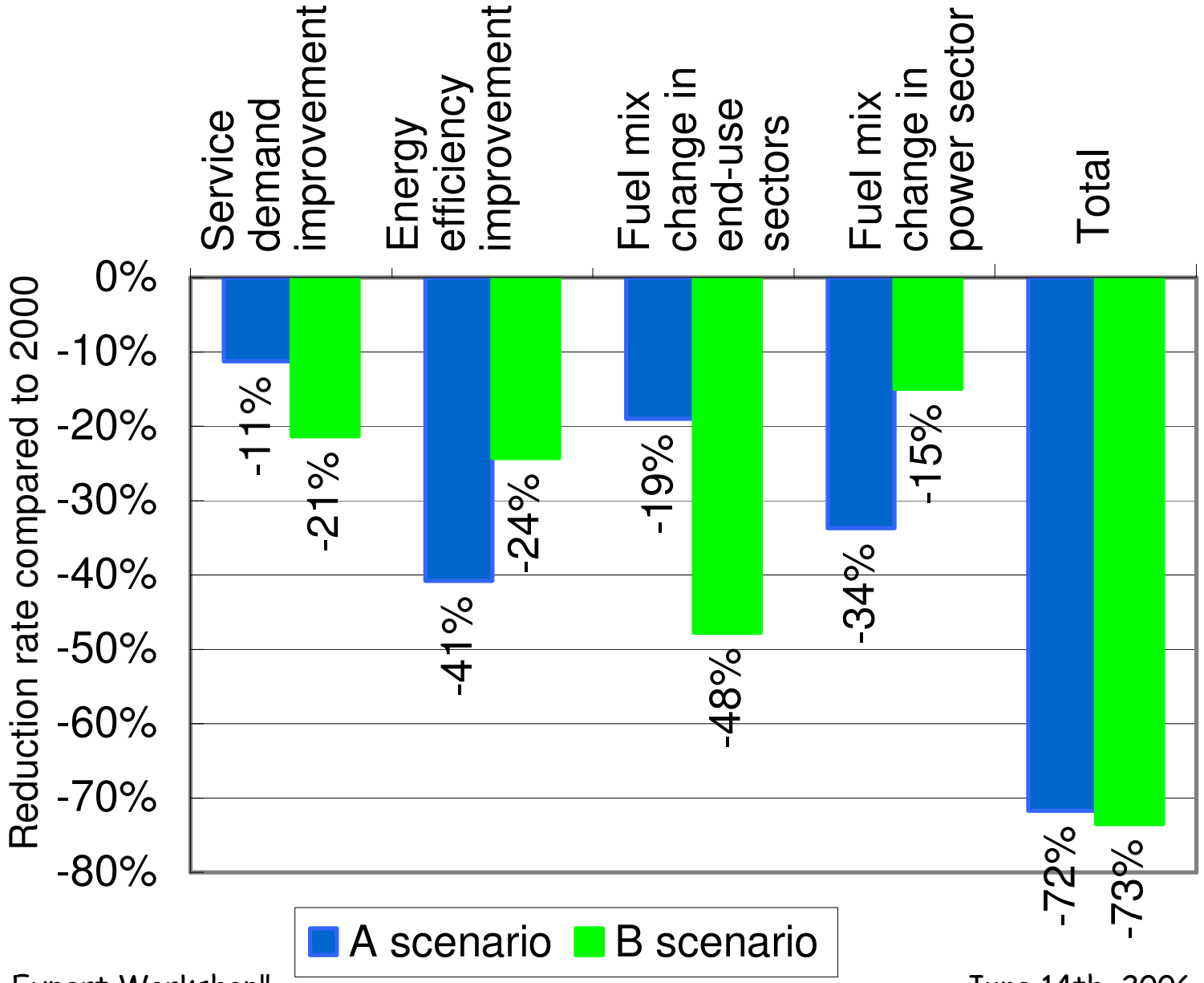
Primary energy supply in scenario B



CO_2 emissions by sector

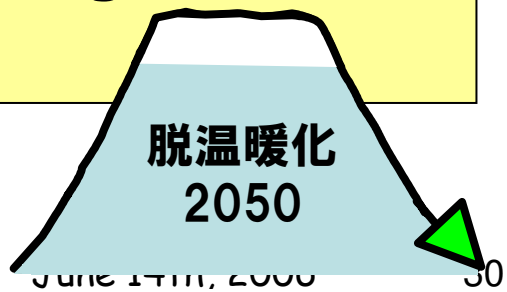


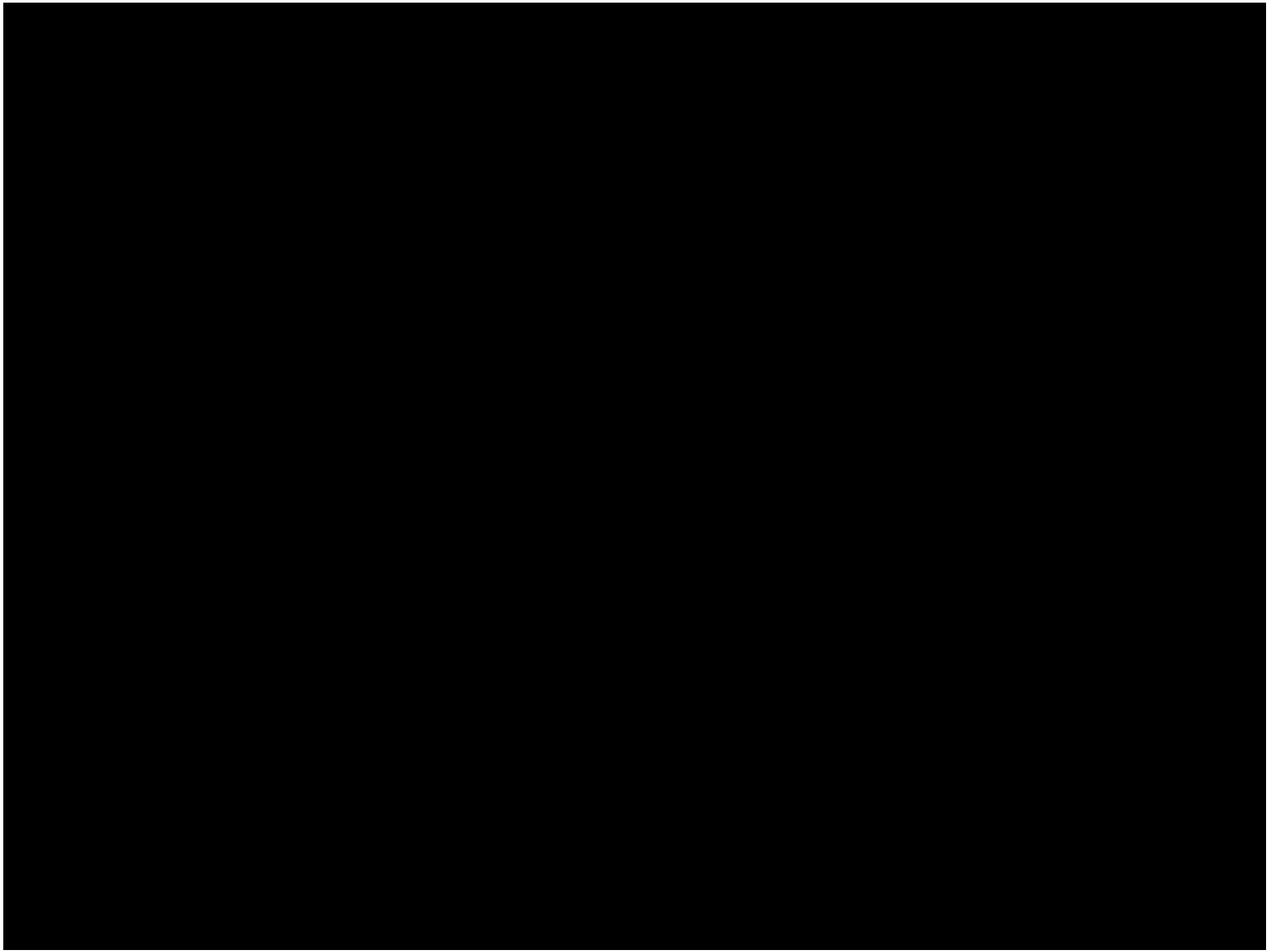
Factor decomposition of CO_2 emission reduction



Expected Outcomes from Japan LCS scenario study

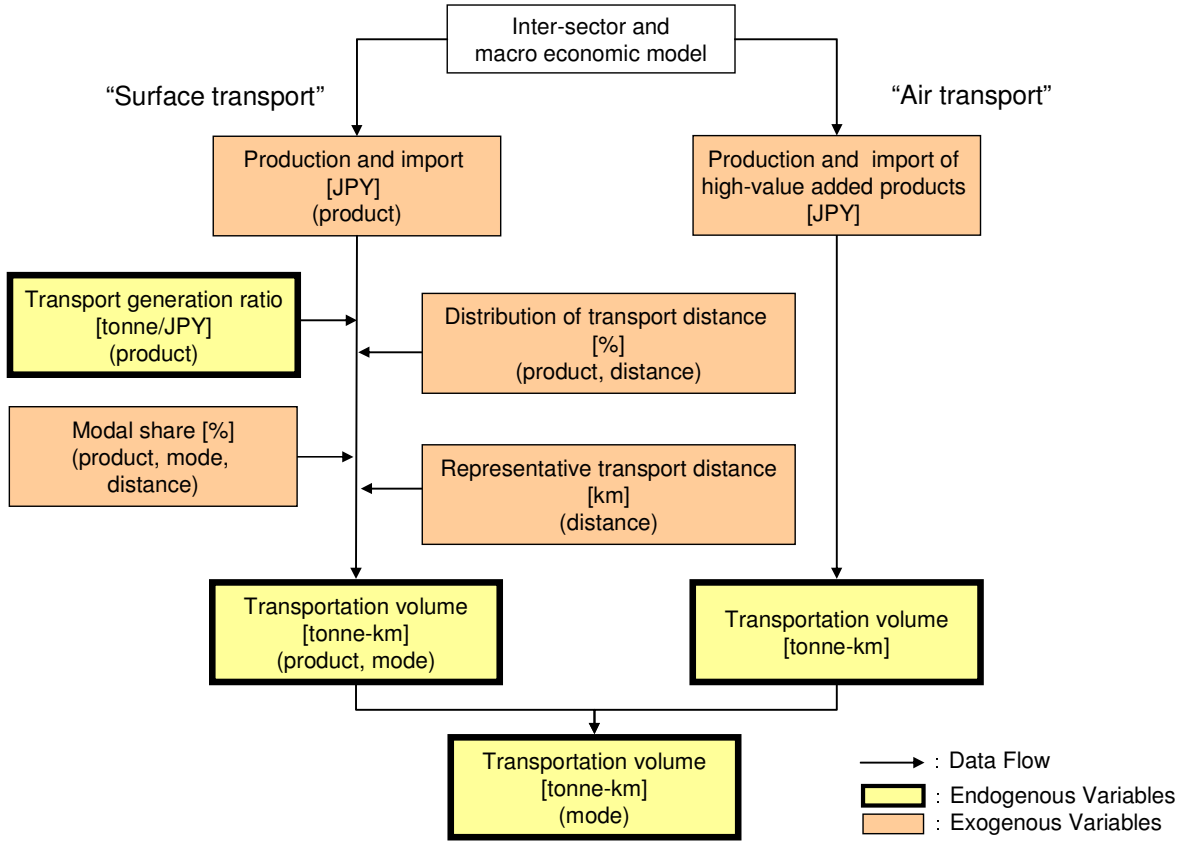
- Feasibility of reduction targets and LCS for Japan
- Identification of countermeasures
- Roadmap toward 2050 considering economic impact and technology feasibility
- Implication of LCS for other environmental issues
- Proposal of policy measures toward long-term sustainable society



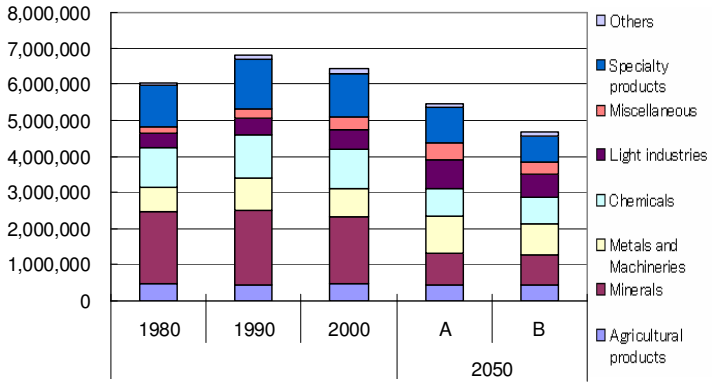


Freight Transportation Demand Model

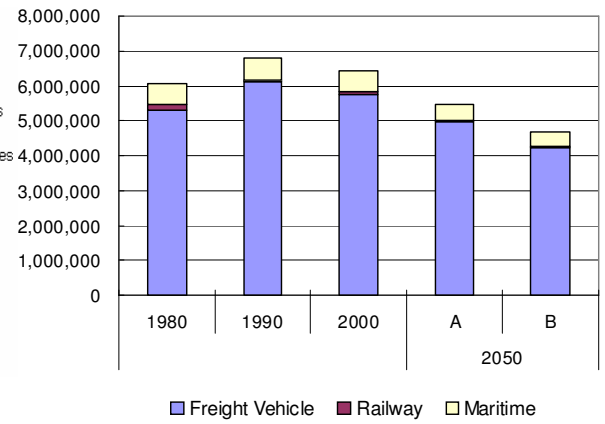
・This model simulates freight transportation volume associated with changes in industrial structure, material density of commodities, transportation distance, and modal share.



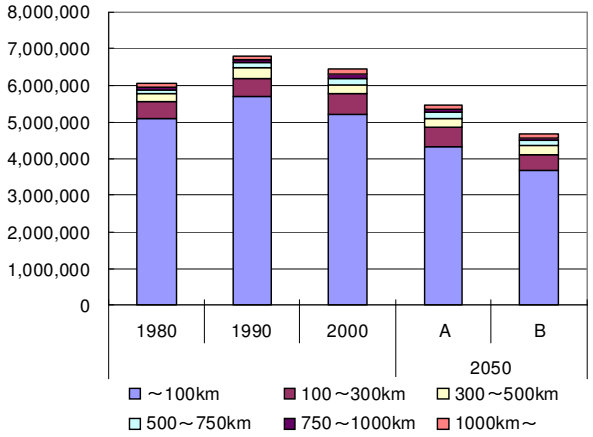
Freight Transportation Demand Model (2)



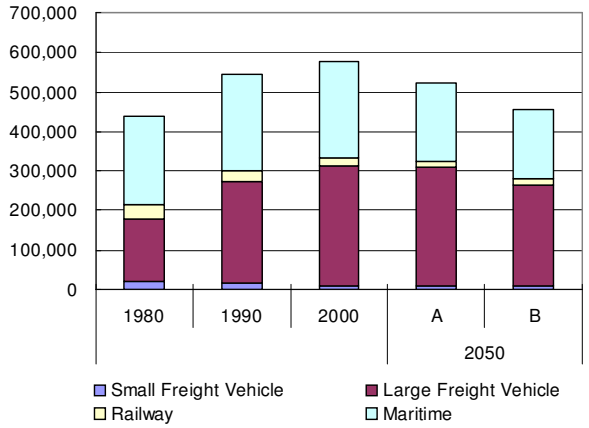
Transportation volume in tonnes by product (1000 tonne)



Transportation volume in tonnes by mode (1000 tonne)



Transportion volume in tonnes by transport distance (1000 tonne)



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

- By year 2050, volumes of freight transport in tonnage become 1.43 and 1.10 times of year 2000, in scenarios A and B.
- In tonne-km, they are 0.91 and 0.79 times, because of the decrease of the ratios of long-distance basic materials.
- On the contrary. short distance transport does not decrease so much.