The 5th Workshop on GHG Inventories in Asia (WGIA5)
Kuala Lumpur, Malaysia
6-8, September, 2007

Mitigation Scenario Analysis - Asia-Pacific Integrated Models -

Tatsuya HANAOKA, Mikiko KAINUMA, Toshihiko MASUI, Junichi FUJINO, Shuichi ASHINA, Yuko KANAMORI, Takeshi IKEGAMI

National Institute for Environmental Studies

Yuzuru MATSUOKA

Kyoto University

Frequently Asked General Questions

- **Is there any simple method to assess future mitigation scenarios?**
- **What kinds of approaches / steps / methods / datasets should be considered and prepared for mitigation analysis?**

Outline of presentation

1. Overview of AIM model family

2. Approaches of mitigation scenario analysis

- ✓ Top-down approach: AIM/CGE model
- ✓ Bottom-up approach: AIM/Enduse model
  AIM/Energy Snapshot tool

3. Examples of mitigation scenario analysis

- ✓ Application of AIM/Energy-snapshot tool
- ✓ Approached of scenario analysis
- ✓ Example results

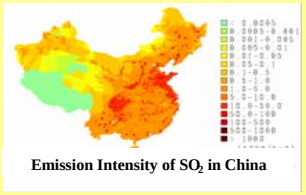
AIM team activities

AIM = Asia-Pacific Integrated Model

AIM Model Development

AIM/ Energy/Technology/Country

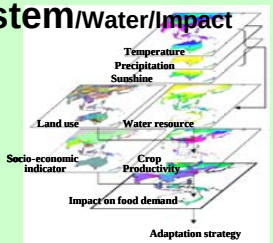
A bottom-up technology selection model of energy use and emissions at country and local level



Emission Intensity of SO_2 in China

AIM/ Ecosystem/Water/Impact

A set of ecosystem models, including a vegetation dynamics model, a water resource model, an agricultural productivity model and a health impact model



AIM/Bottom-up

A bottom-up technology & land use model for Asia-Pacific region

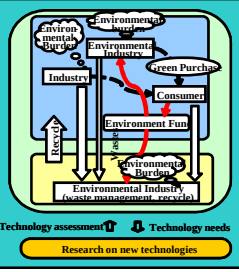
AIM Family

AIM/Top-down

A general-equilibrium-type world economic model

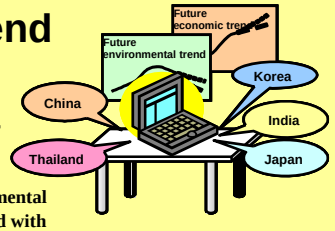
AIM/Material

An environment-economy interacted model with material balance and recycling process modules



AIM/Trend

Developed as a **communication** platform in order **to construct** **Asia**-pacific regional environmental outlook supported with **multi**-regional environment-economic CGE model



Strategic Database

Institution, Management, Technology, Adaptation Database

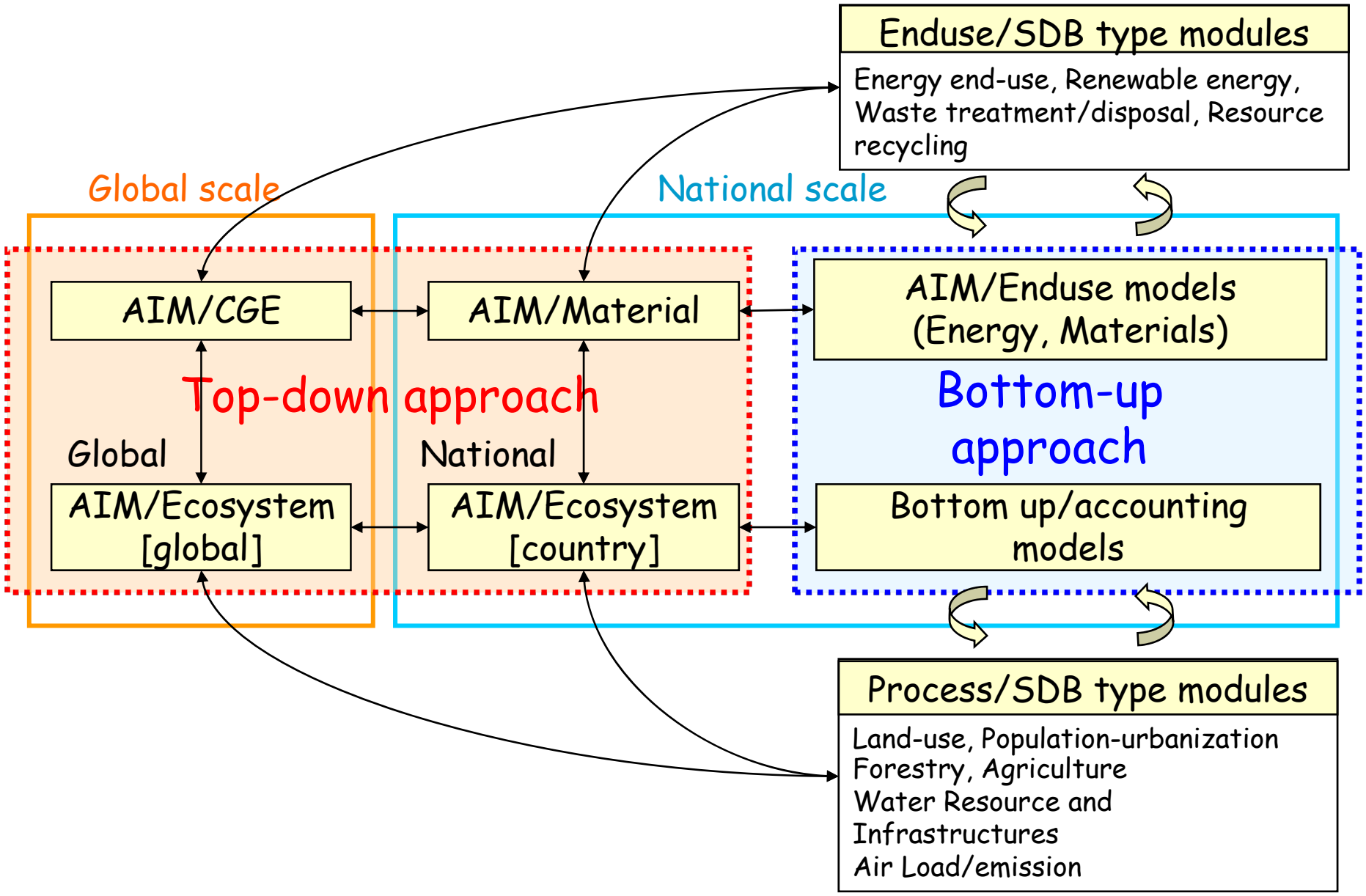
Scenario Assessment

Model Base

Strategy Option Base

Index Base

AIM family for mitigation analysis



Top-down and bottom-up approach

Bottom-up approach

AIM/Enduse model

- This model can assess individual technologies under the detail technology selection framework
- This model is partial equilibrium model on energy

AIM/Energy-Snapshot tool

- This tool can assess energy balance and CO2 emissions among sectors simultaneously.
- This is a snapshot tool at a certain point (but not optimization model).

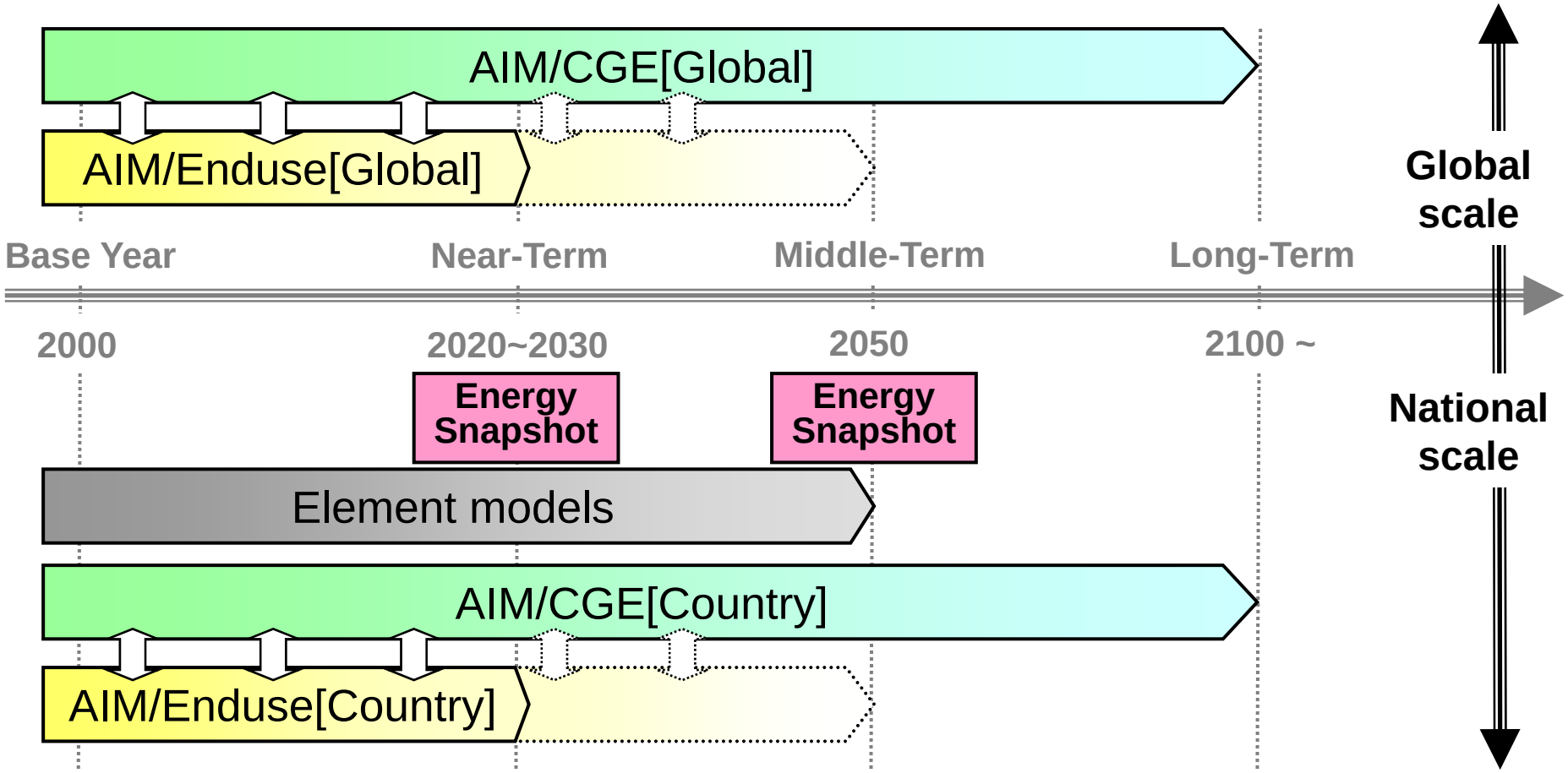
Top-down approach

AIM/CGE model

- This model draws the balanced macro economy, based on social conditions such as population, technology and preference, countermeasures.
- This model is a general equilibrium model.

There are advantages/disadvantages in each approach, so target of analysis will be different depending on approaches.

Temporal scale of mitigation analysis



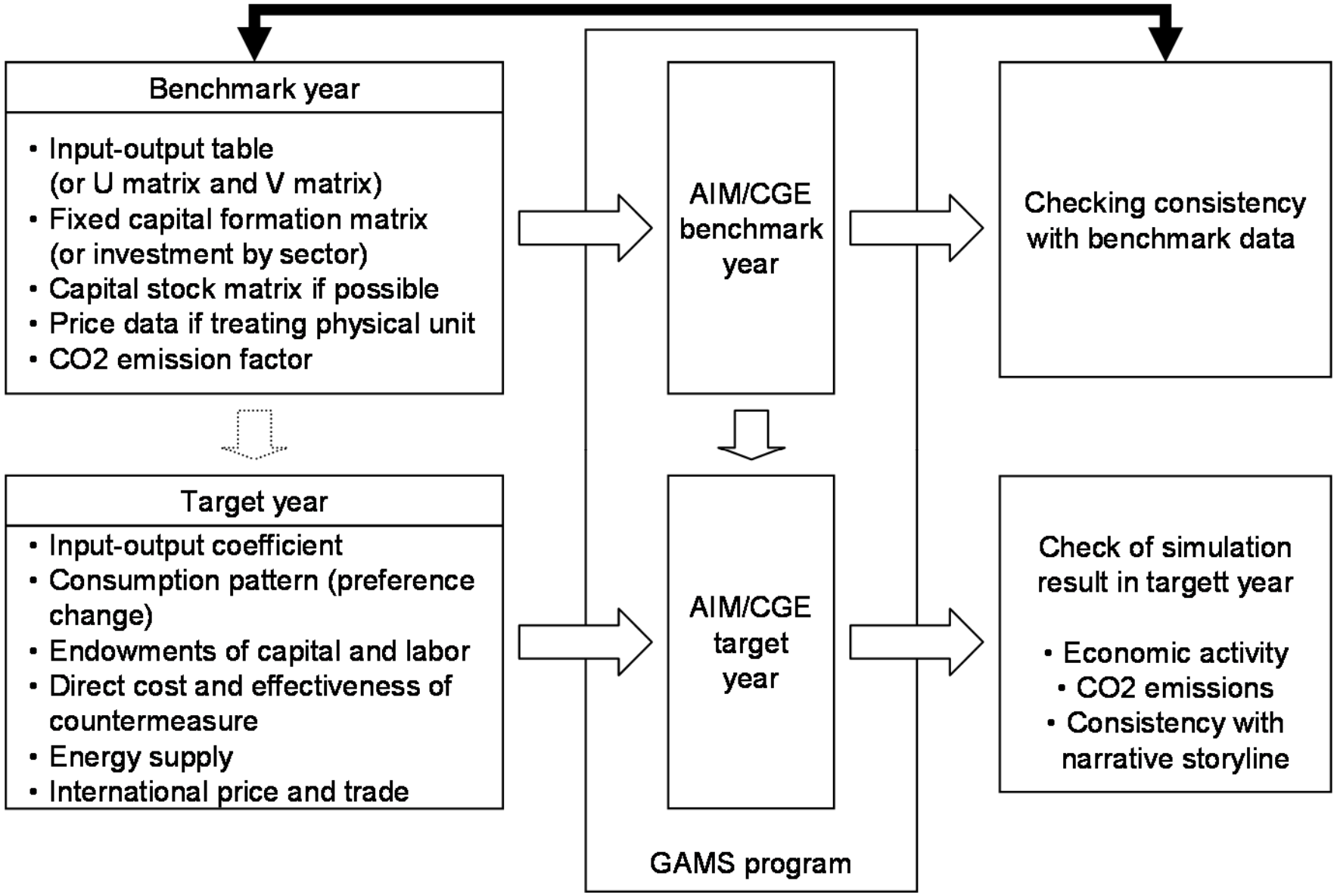
- **Due to data constraints of future technology information, Enduse model analyzes scenarios with horizons of 2020~2030, and up to 2050 at most.**
- **CGE model deal with long-term analyses, but it needs to set assumptions on energy efficiency improvements, and macro economic parameters, etc.**

Framework in AIM/CGE model

- Type : a recursive dynamics general equilibrium model
- Target Gas :CO2, non-CO2(CH4, N2O etc)
- Commodities and activities :

- primary energy
  - coal, crude oil, natural gas, nuclear, hydro, other renewable (solar, wind, waste, biomass, ...)
- final energy
  - coal products, oil products, town gas, electricity, heat, hydrogen, biomass (solid, liquid, gas)
- non-energy
  - agriculture, forestry, fishery, foods, textile, paper, chemical, cement, other ceramic, steel, non-steel metal, machinery, other production, construction, water, whole sale & retail trade, finance & insurance, real estate, transport (passenger, freight), communication, public service, other service.

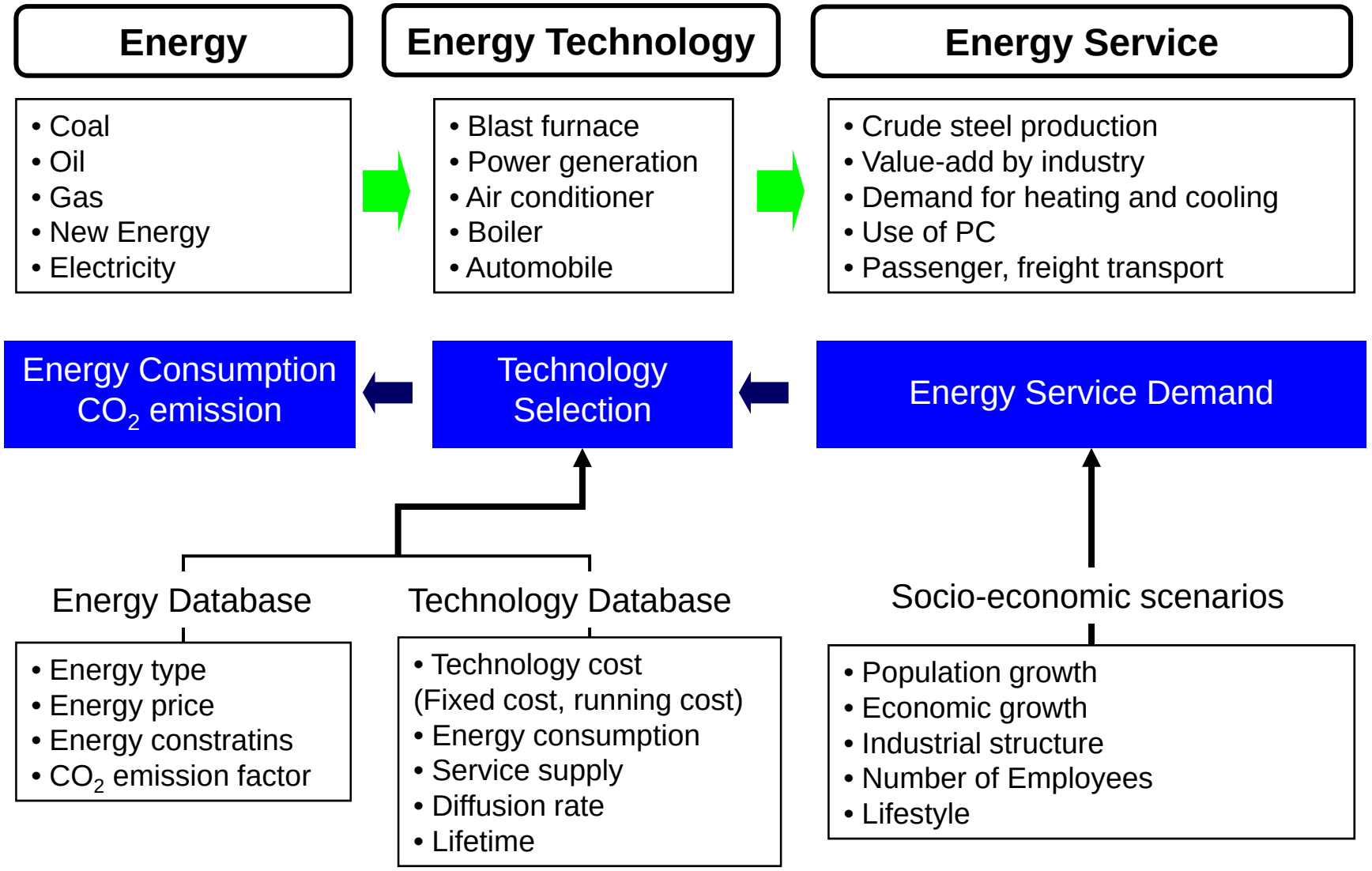
Process of model development



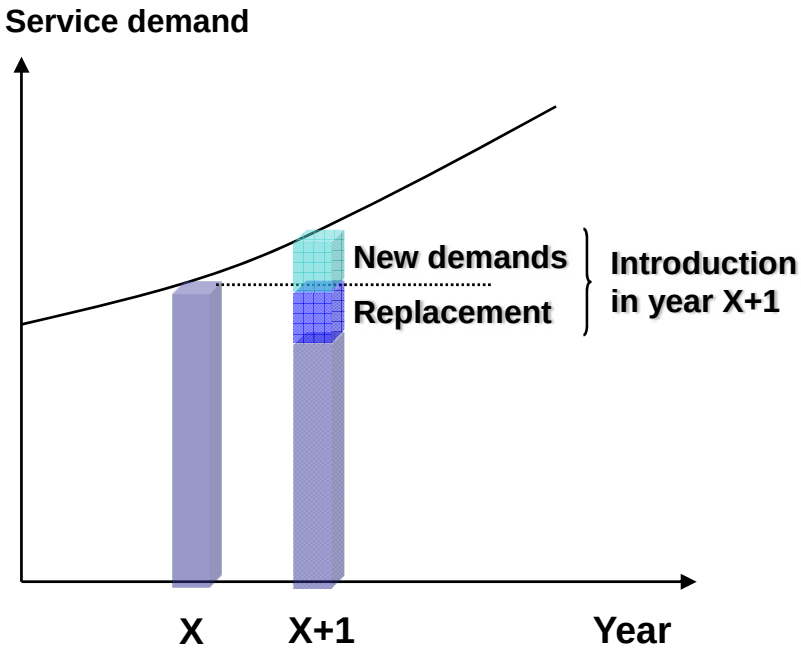
Framework of AIM/Enduse model

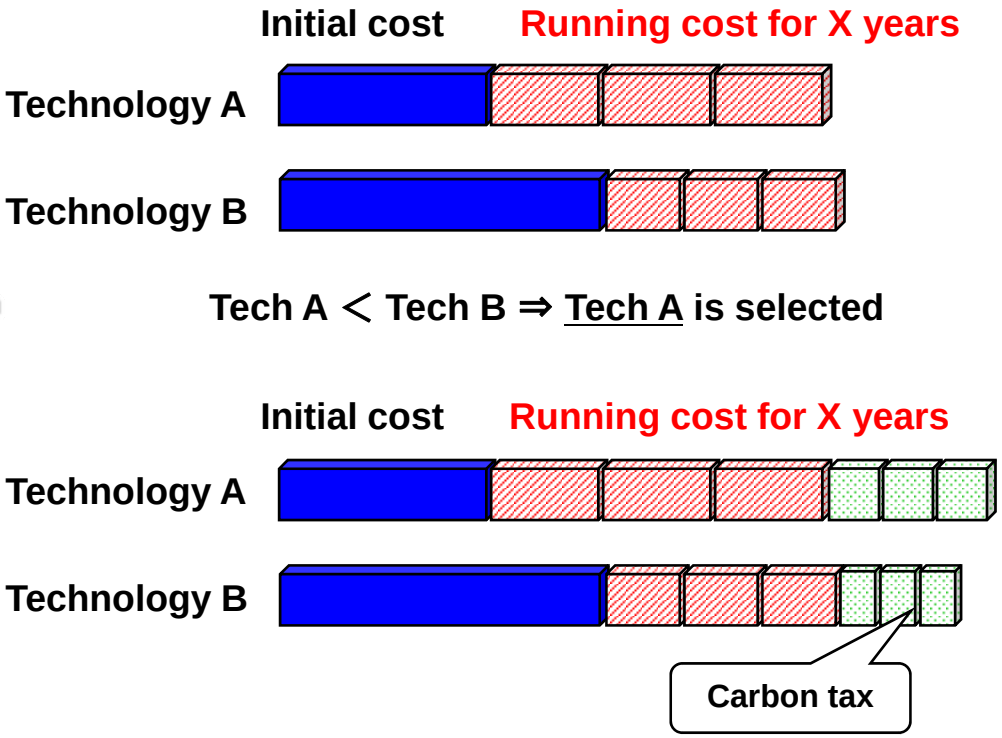
- **Type : a Bottom-up optimization model with detail technology selection framework**
  - **by giving energy service demand exogenously, mitigation options are selected under various carbon emission constraints**
- **Target Gas :CO2, non-CO2(SO2, NOx, N2O, CH4,etc)**
- **Target Sectors : multiple sectors**
  - **power generation sector, industry sector, residential sector, commercial sector, transport sector, agriculture sector, waste sector, other CH4 emissions sector, F-gas emissions sector**

Outline of AIM/Enduse model



Logic of technology selection



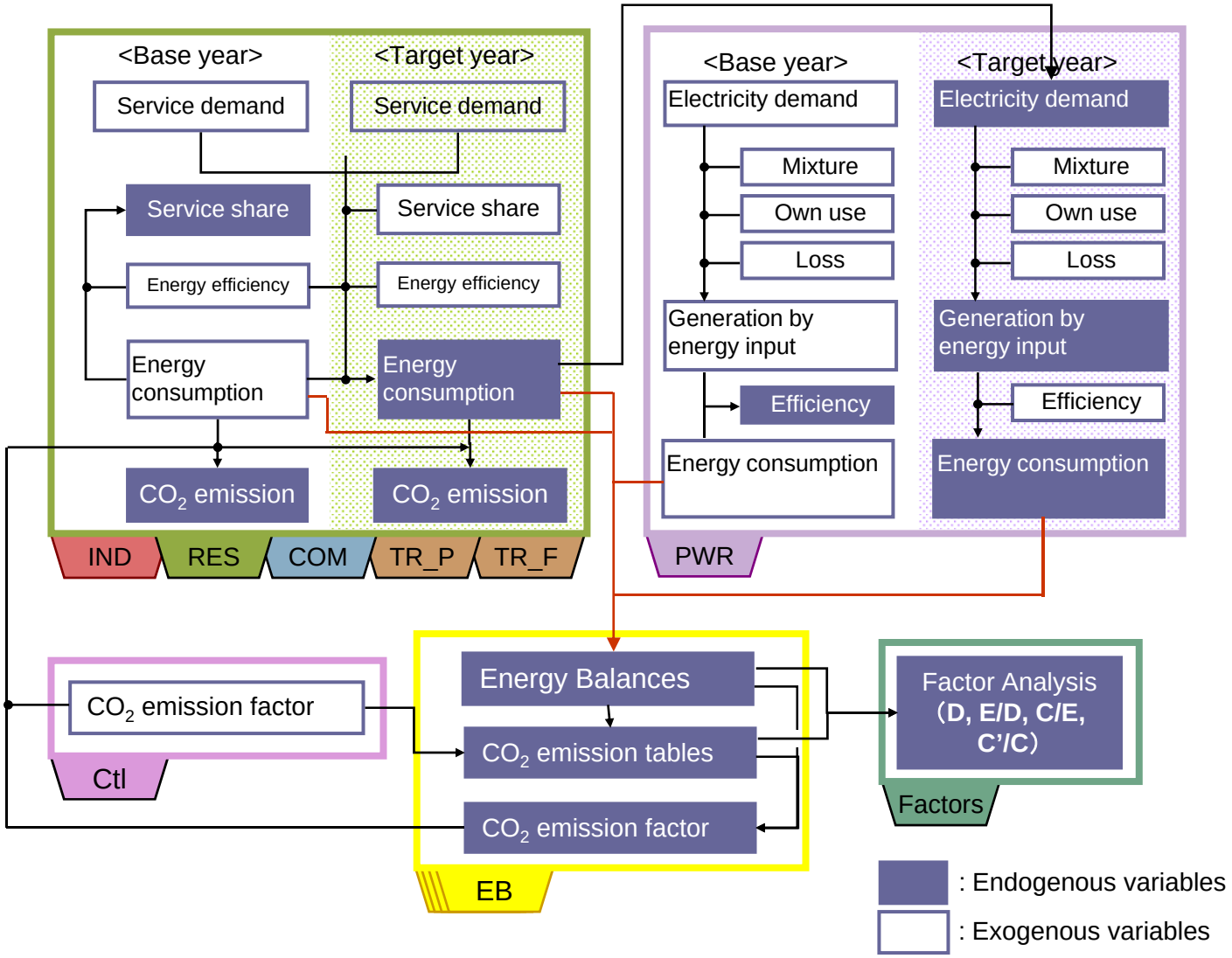


As private industries take into account high investment risk for energy conserving technologies, **a payback period of 3-years** is assumed.

Framework of AIM/Energy snapshot tool

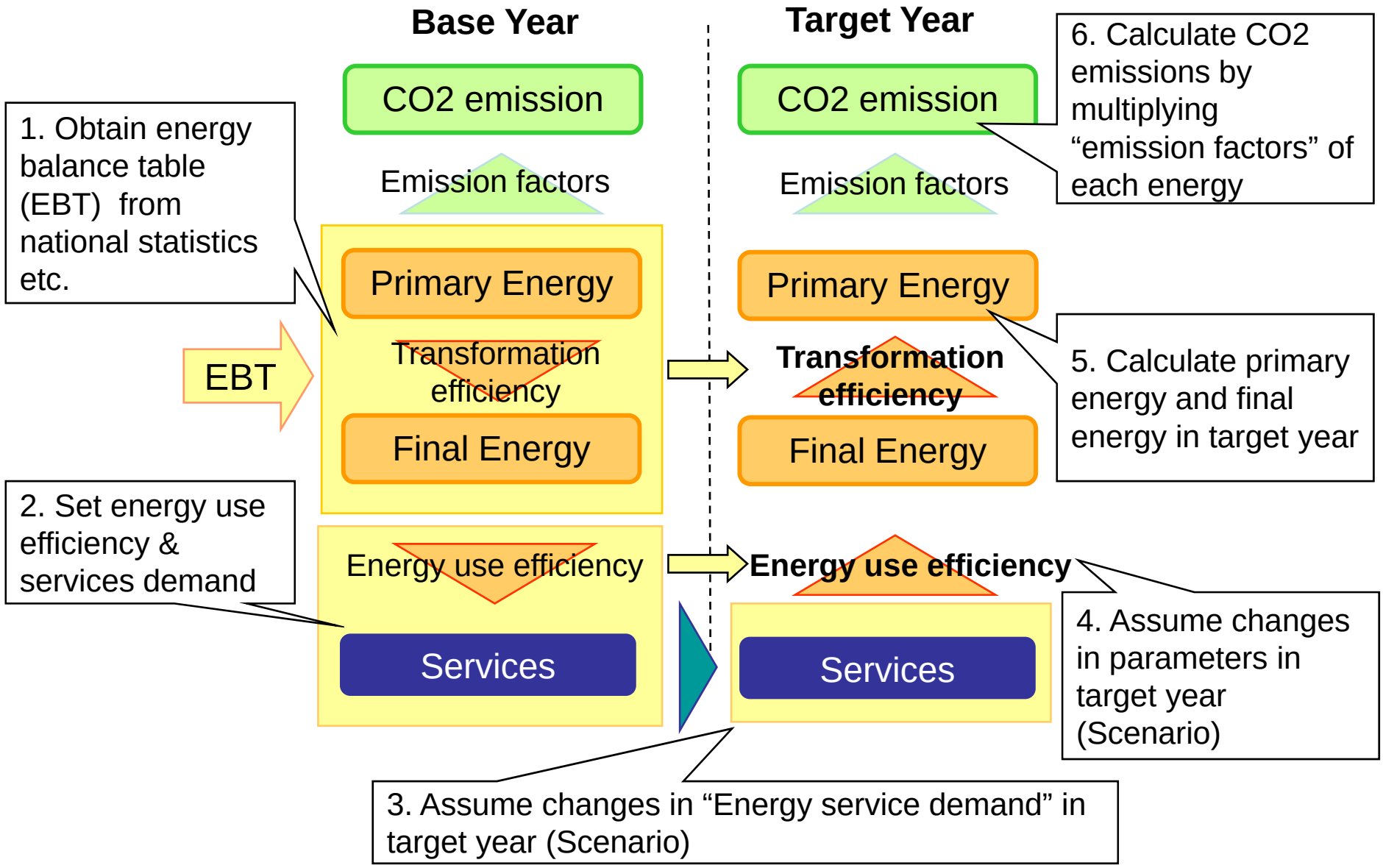
- Type : an accounting tool to calculate the energy balance table and the CO2 emission table immediately with keeping consistency among sectors.
  - by giving service demand, share of energy and energy improvement by classification of service and energy in the base year and the target year
- Target Gas :CO2
- Target Sectors : multiple sectors
  - power generation sector, industry sector, residential sector, commercial sector, transport sector

Outline of Energy Snapshot (ESS) tool



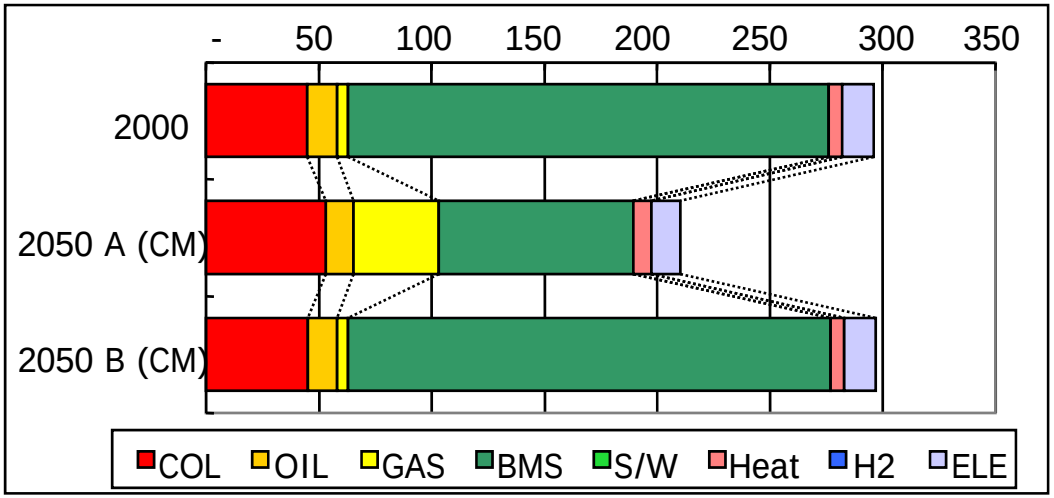
Energy Snapshot : Manual, Excel file
http://www-iam.nies.go.jp/aim/datalibrary.htm

Calculation process of ESS

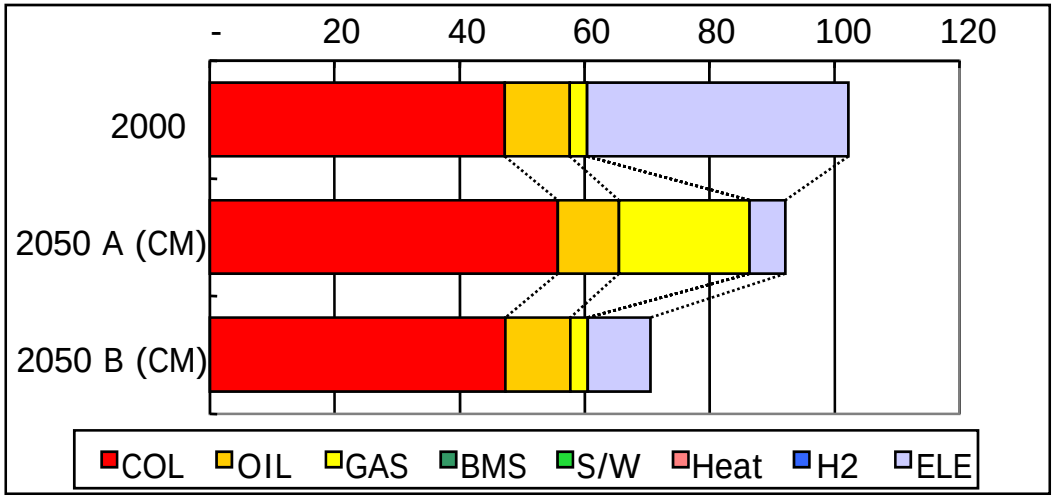


Example of result figures by ESS

Energy Consumption



CO2 Emission



Example of factor analysis by ESS

- Extended Kaya Identity

$$C = D \times \frac{E}{D} \times \frac{C'}{E} \times \frac{C}{C'}$$

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

D: Driving forces (service demand)

E: Energy Consumption

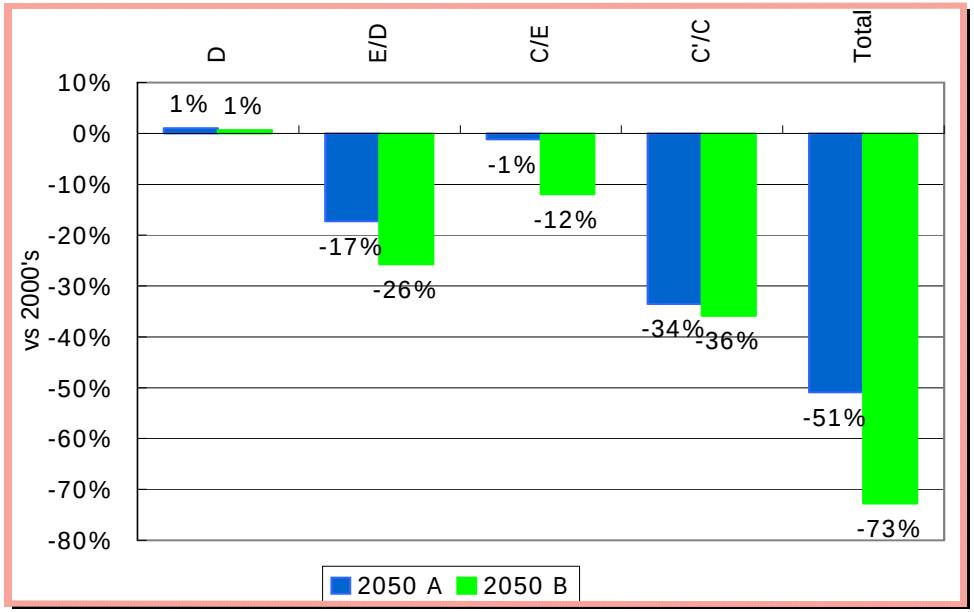
C': CO_2 emission without measures in transformation ector

C: CO_2 emission with measures in transformation sector

E/D: Energy Intensity

C'/E: CO_2 intensity in end-use sector (without measures in transformation sector)

C/C': Change of CO_2 intensity by measures in transformation sector



Scenario of 2050 in China

	CM(A)	CM(B)
GDP	National planning before 2050, 7.5% from 2000 to 2010, 5.1% from 2010 to 2050.	National planning before 2050, 7.5% from 2000 to 2010, 5.1% from 2010 to 2050.
Population	National control plan, reach peak between 2040 to 2050 by around 1.6billion	National control plan, reach peak between 2040 to 2050 by around 1.6billion
Per capita GDP	11 thousand US$ by 2050(1990 price),	11 thousand US$ by 2050(1990 price),
Energy use technology progress	Fully diffusion of advanced energy use technology by 2050, technology efficiency is 30% higher than that in 2000, fuel cell vehical will be widely used by 2030	Fully diffusion of advanced energy use technology by 2050, technology efficiency is 40% higher than that in 2000, fuel cell vehical will be widely used by 2030

Note) China's GDP average annual growth rate shown as 7.5% from 2000 to 2010 is the national planning data.

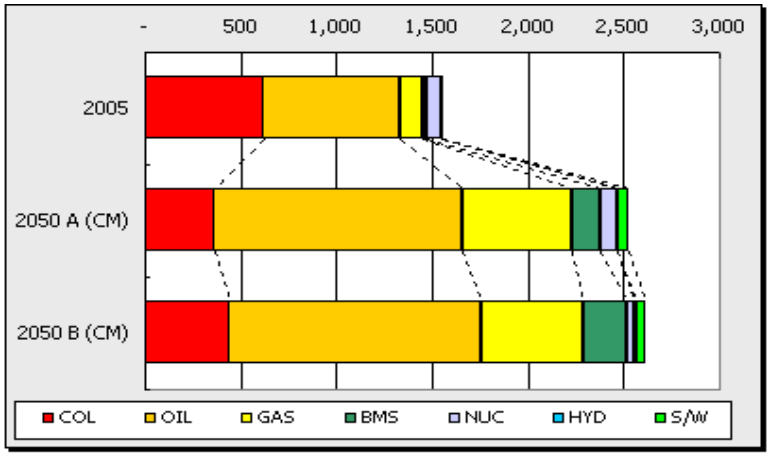
Source: Prof.Hu, Dr.Jiang (tentative results)

Scenario of 2050 in China

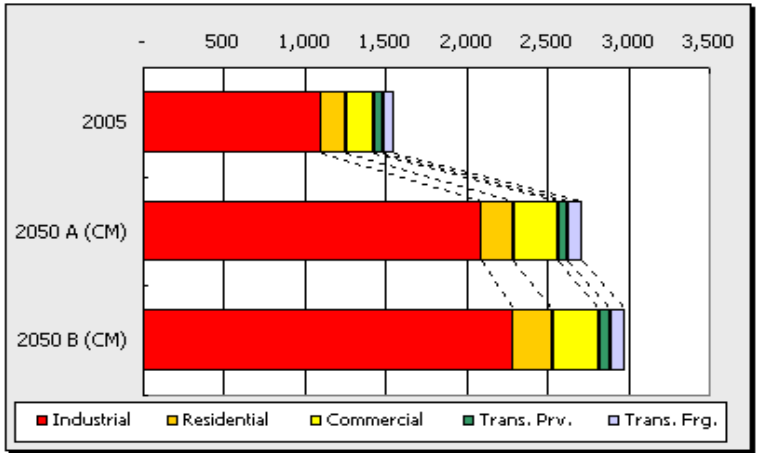
	CM(A)	CM(B)
Annual average marginal cost improvement of energy exploitation technology	Coal: 0.4% Oil: 0.8% Natural gas: 0.3%	Coal: 0.5% Oil: 0.8% Natural gas: 0.8%
Non-Conventional energy use	Non-Conventional gas is needed after 2040, small demand for non-conventional oil	Non-Conventional gas is needed after 2040, small demand for non-conventional oil
Modern renewable energy such as solar	Cost will be 0.36yuan/kWh by 2050	0.18yuan/kWh by 2050
Modern biomass utilization technology	More than 70mtce biomass is available at cost lower than US$44/tce	More than 70mtce biomass is available at cost lower than US$50/tce

Source: Prof.Hu, Dr.Jiang (tentative results)

Energy Snapshot in China in 2050

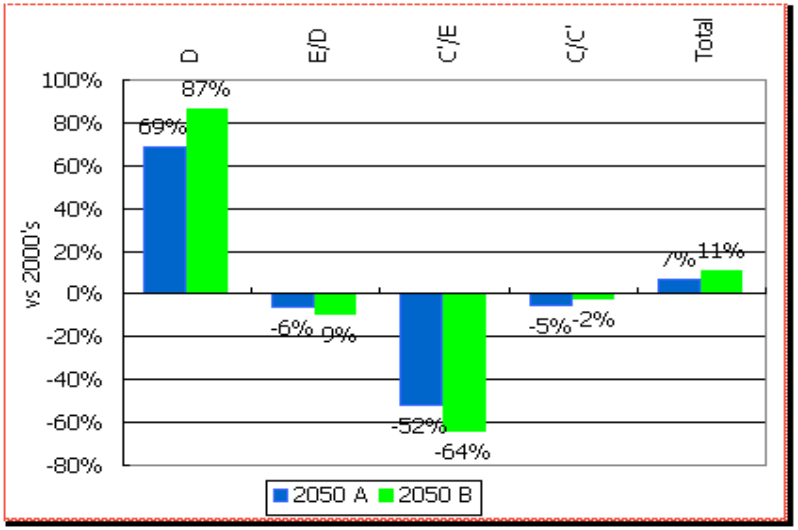


Primary Energy Consumption



Energy Consumption by Sector

Note) the primary energy consumption does not include the fuel uses for generating electricity



Factor analysis of CO2 Emission by Industrial sector

Source: Prof.Hu, Dr.Jiang (tentative results)

Low Carbon Scenario (LCS) Study in Japan - Application of AIM/Energy-snapshot tool -

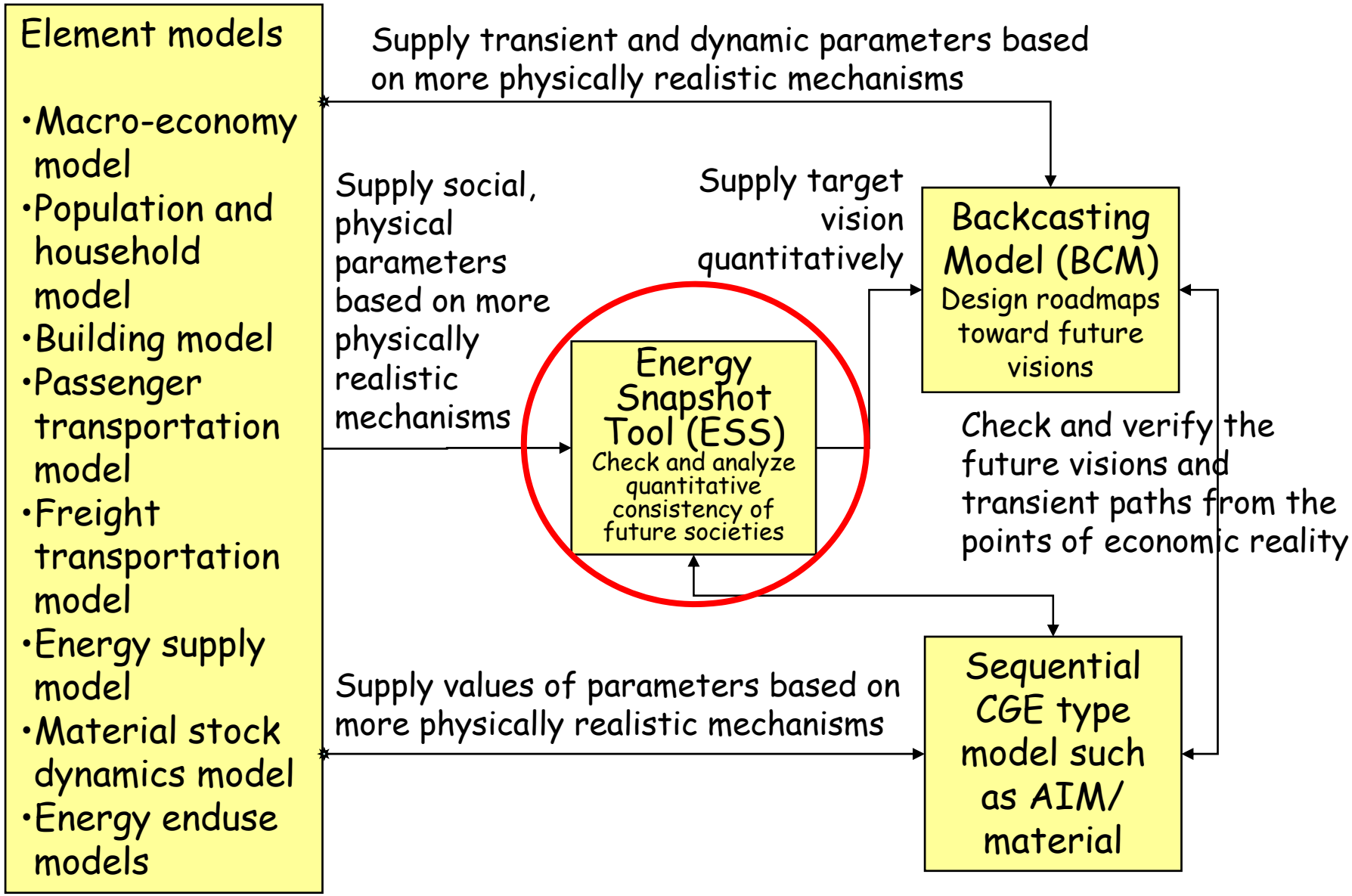
Motivation of the study:

This study assesses the possibility of achieving the Low-Carbon Society in Japan by targeting at 70% CO2 emission reduction by 2050 compared to the 1990 level, while satisfying the expected demand for energy services in 2050.

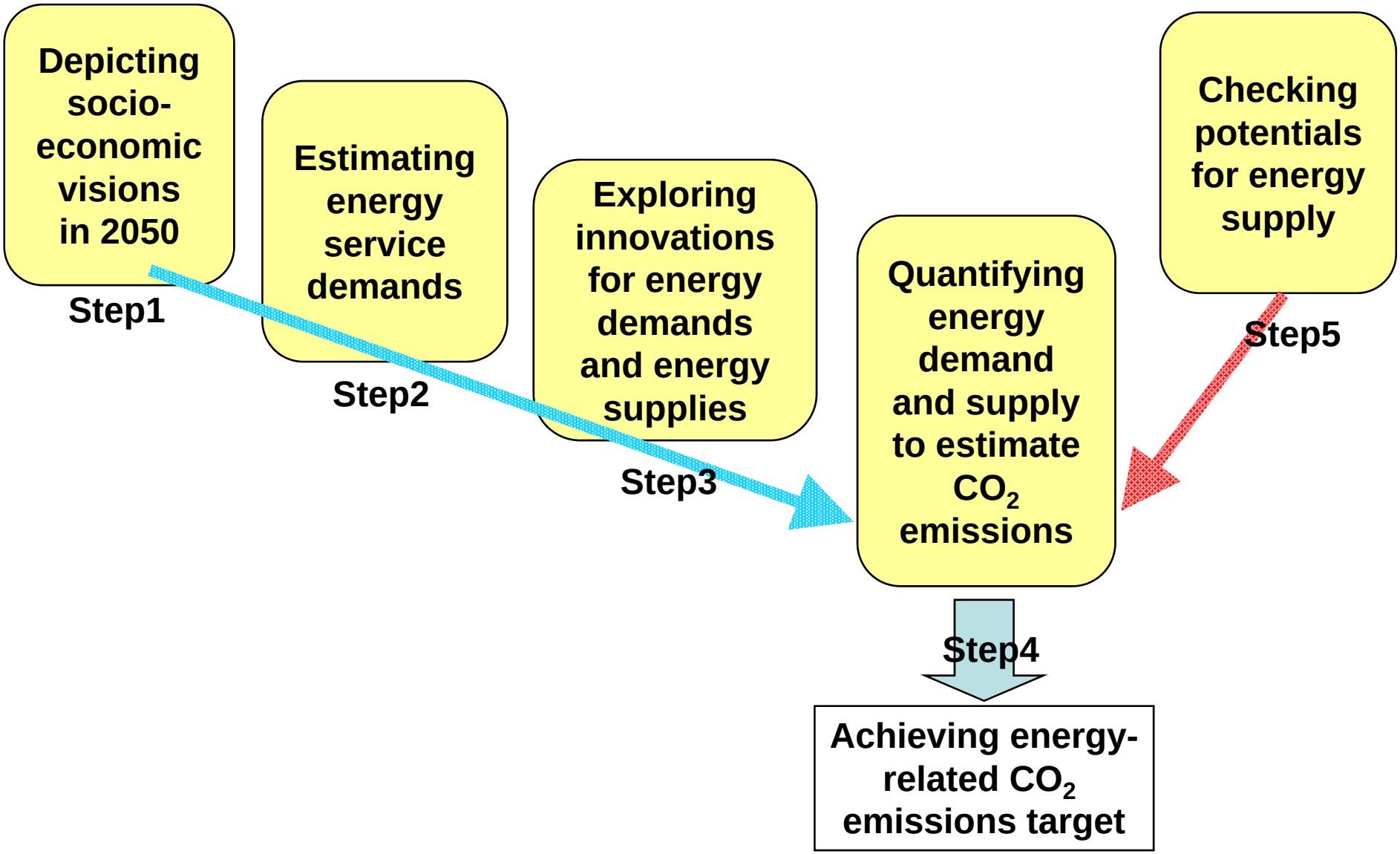
- **How to achieve 70% CO2 emission reduction by 2050?**
- **What kinds of scenarios would be under such a target?**
- **How much energy reduction would be necessary from both demand side and supply side?**

etc…

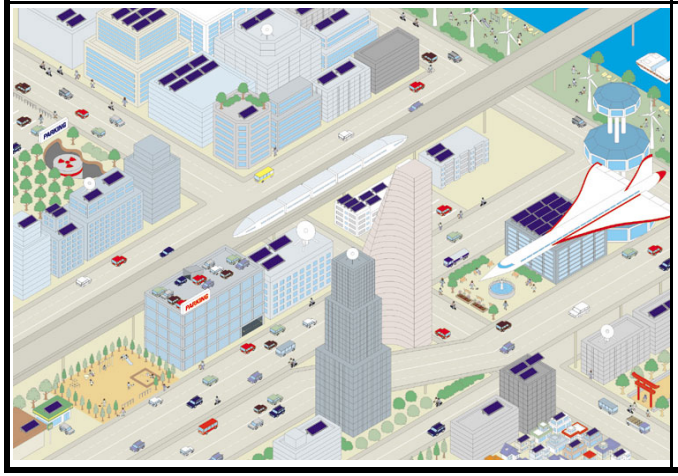
Relations among ESS and element models



Scenario approach toward Low-Carbon Society



Two different visions for societies in 2050 in Japan

Vision A "Doraemon"	Vision B "Satsuki and Mei"
Vivid, Technology-driven	Slow, Natural-oriented
Urban/Personal	Decentralized/Community
Technology breakthrough Centralized production /recycle	Self-sufficient Produce locally, consume locally
Comfortable and Convenient	Social and Cultural Values
	

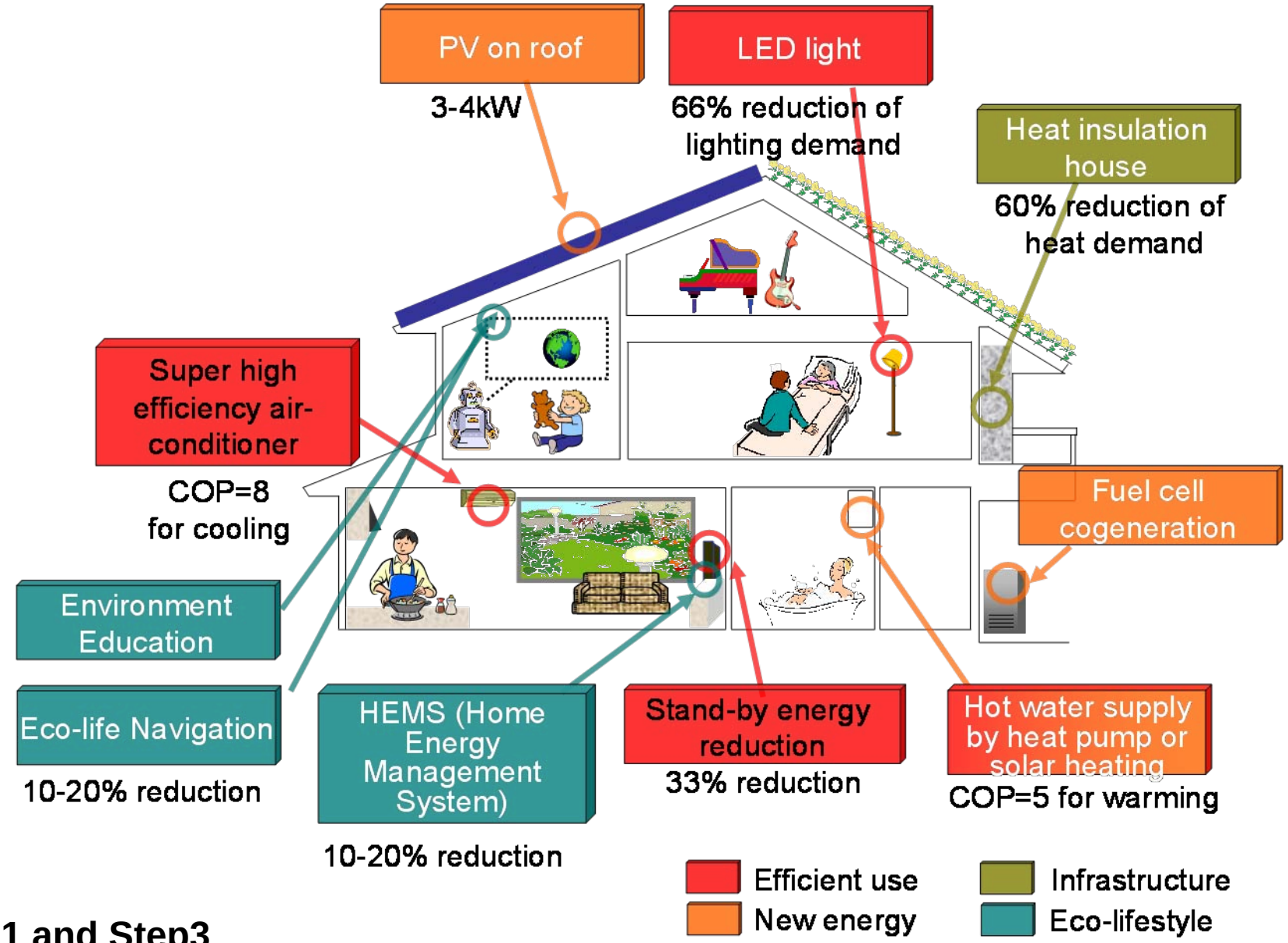
Doraemon is a Japanese comic series created by Fujiko F. Fujio. The series is about a robotic cat named Doraemon, who travels back in time from the 22nd century. He has a pocket, which connects to the fourth dimension and acts like a wormhole.

Satsuki and Mei's House reproduced in the 2005 World Expo. Satsuki and Mei are daughters in the film "My Neighbor Totoro". They lived an old house in rural Japan, near which many curious and magical creatures inhabited.

LCS Japan scenarios for economy and industry

Economy		Vision A	Vision B
	Growth rate	・Per capita GDP growth rate:2%	・Per capita GDP growth rate:1%
	Technological Development	・High	・Not as high as scenario A
Industry		**Vision A**	**Vision B**
	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

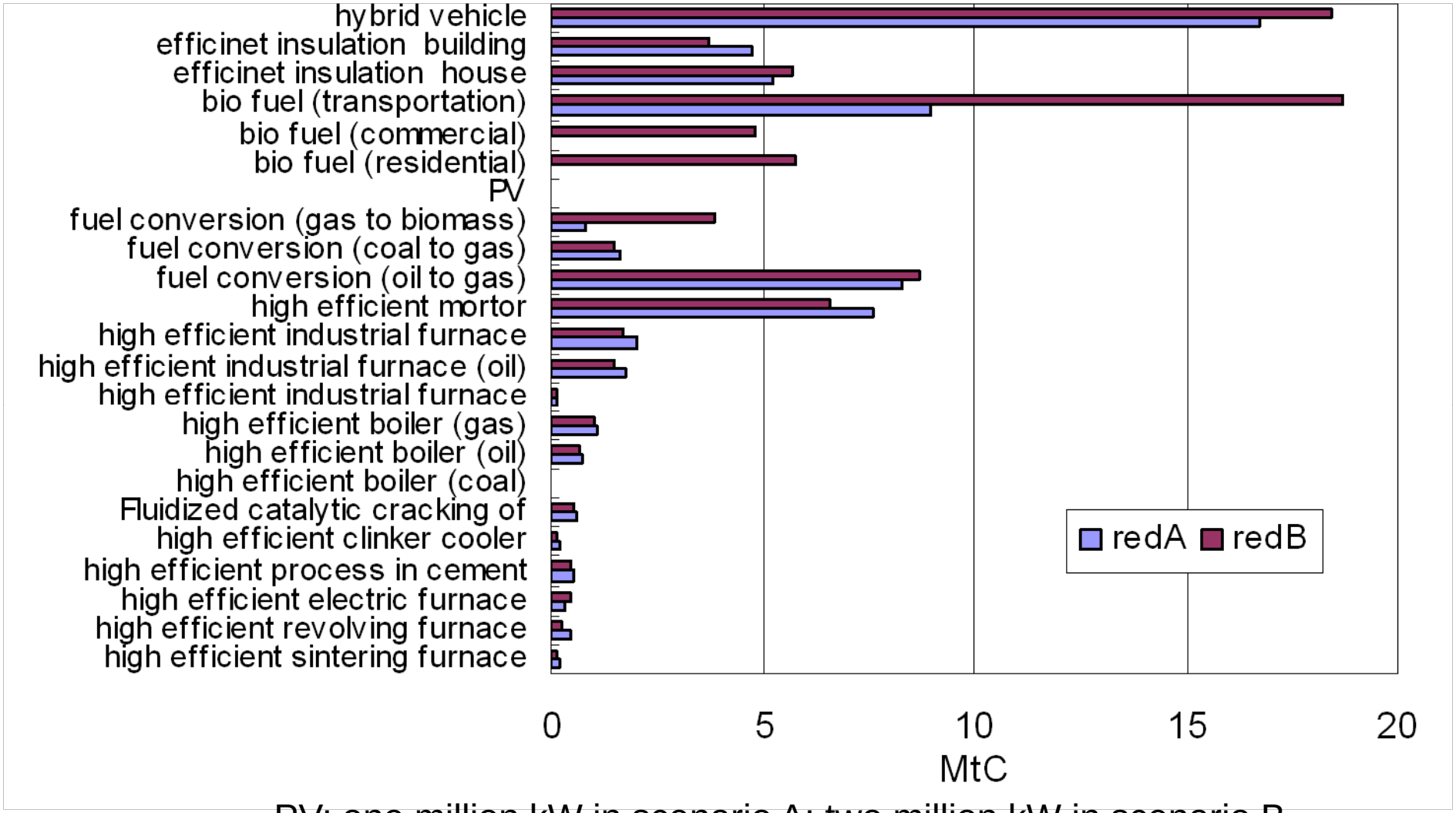
Depiction of future image: Residential sector in 2050



Step1 and Step3

Technology Development and Diffusion in Japan

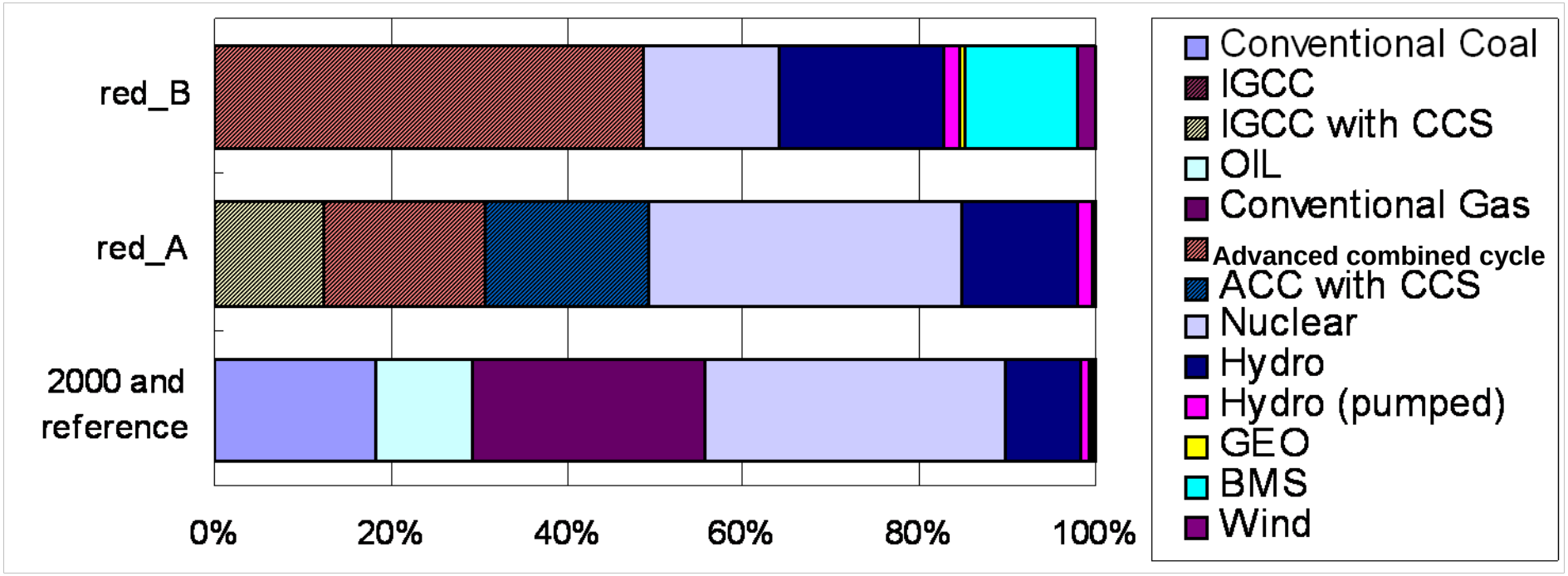
Demand side CO2 reduction by advanced technologies in 2050



PV: one million kW in scenario A; two million kW in scenario B

Technology Development and Diffusion in Japan

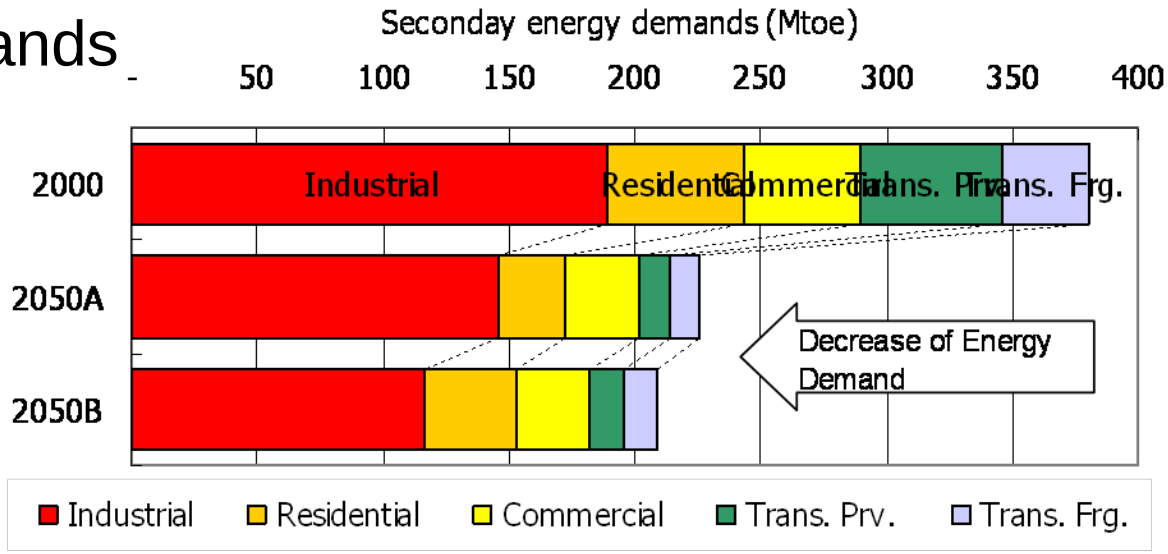
Technologies in power sector in 2050



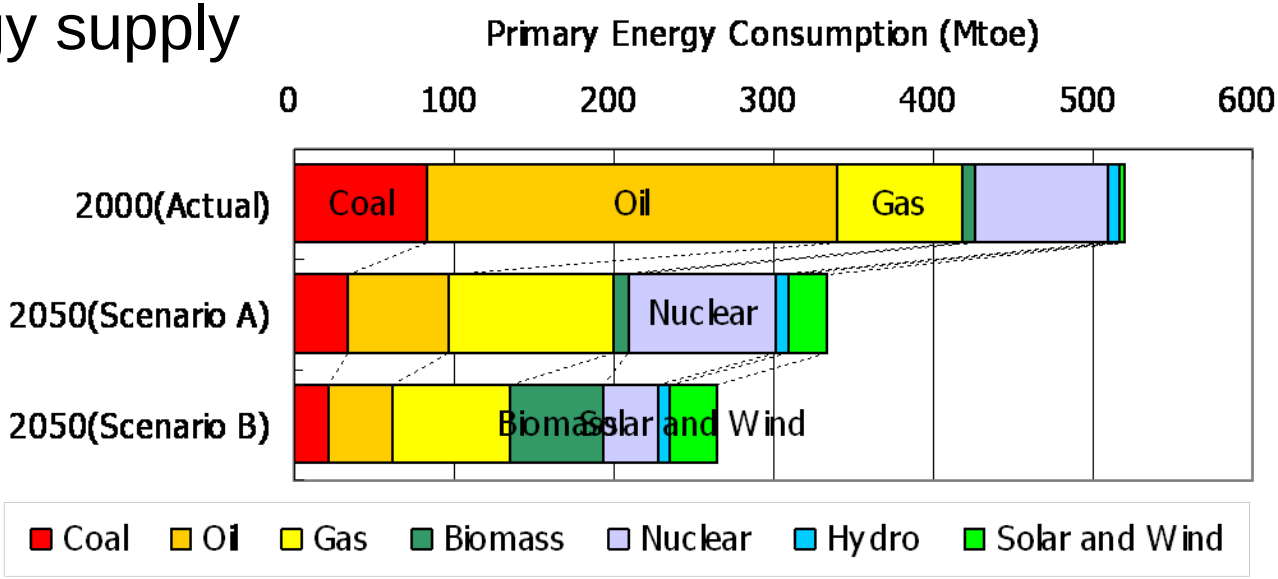
: New technology

70% reduction: combination of demand side energy reduction + low carbon energy

Final energy demands



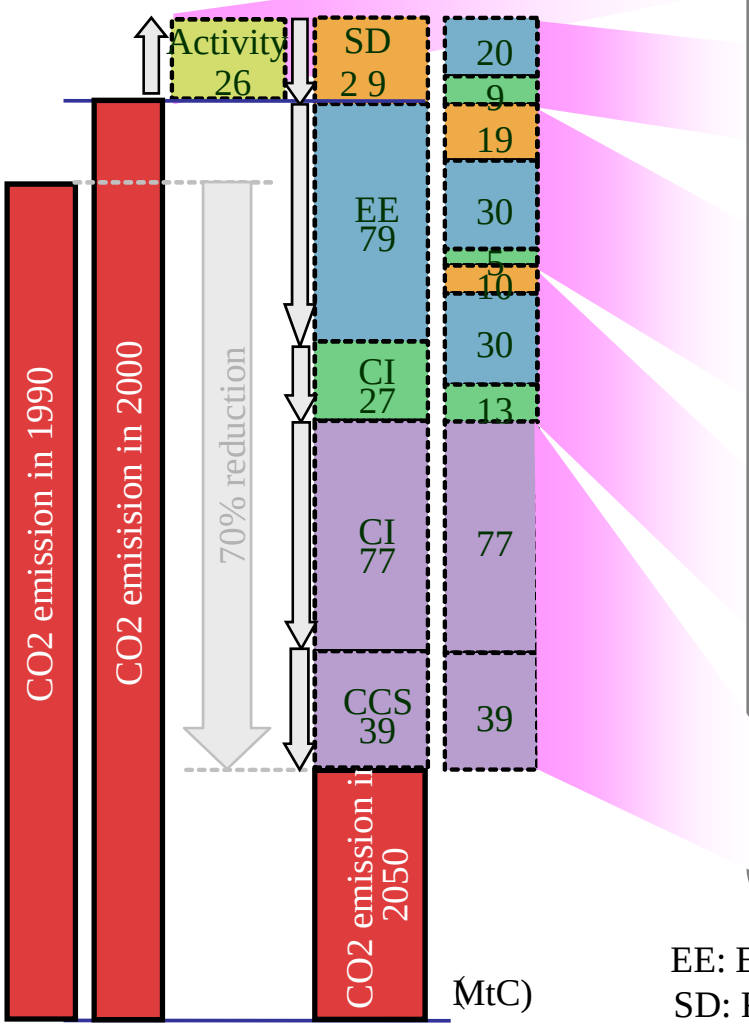
Primary energy supply



Step4 and Step5

70% CO2 emission reduction by 2050

Scenario A :2050



Main factors to reduce CO2 emissions

[Society]

- Activity
  - High economic growth
  - Decrease of population and number of households

[Industrial]

- Energy Intensity Imp.
  - Energy efficient improvement of furnace and motor etc.
- Carbon Intensity Imp.
  - Fuel switching from coal/oil to natural gas

[Residential and commercial]

- Reduction of service demands
  - High insulation dwelling and building
  - Home/Building energy management system
- Energy Intensity Imp.
  - Efficient air conditioner, Efficient water heater, Efficient lighting system
- Carbon Intensity Imp.
  - Fuel cell system
  - Photovoltaic on the roof

[Transportation]

- Reduction of service demands
  - Intensive land-use, Concentrated urban function
  - Public transportation system
- Energy Intensity Imp.
  - Motor-driven mobiles: Electric battery vehicles, Fuel cell battery vehicles
- Carbon Intensity Imp.

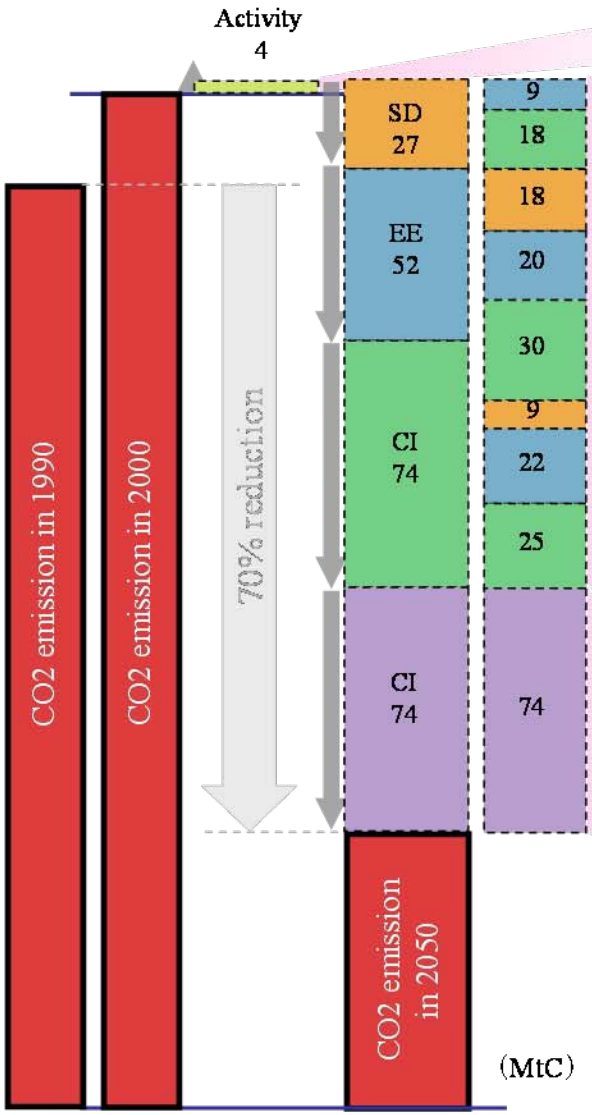
[Energy transformation]

- Carbon Intensity Imp.
  - Nuclear energy
  - Effective use of electricity in night time with storage
  - Hydrogen supply with low carbon energy sources
- CCS
  - Advanced fossil fueled plants + CCS
  - Hydrogen supply using fossil fuel + CCS

EE: Energy Efficiency Improvement, CI: Carbon Intensity Improvement,
SD: Reduction of Service Demands

70% CO2 emission reduction by 2050

Scenario B :2050



Main factors to reduce CO2 emissions

[Society]

- Activity
  - Reduction of final demand by material saturation
  - Reduction of raw material production
  - Decrease of population and number of households

[Industrial]

- Energy Intensity Imp.
  - Energy efficient improvement of furnace and motor etc.
- Carbon Intensity Imp.
  - Increase of Fuel switching from coal/oil to natural gas /biomass

[Residential and commercial]

- Reduction of service demands
  - High insulation dwelling and building
  - Eco-life navigation system
- Energy Intensity Imp.
  - Efficient air-conditioner, Efficient water heater, Efficient lighting system
- Carbon Intensity Imp.
  - Photovoltaic on the roof
  - Expanding biomass energy use in home
  - Diffusion of solar water heating

[Transportation]

- Reduction of service demands
  - Shortening trip distances for commuting through intensive land use
  - Infrastructure for pedestrians and bicycle riders (sidewalk, bikeway, cycle parking)
- Energy Intensity Imp.
- Carbon Intensity Imp.
  - Biomass-hybrid engine vehicle

[Energy transformation]

- Carbon Intensity Imp.
  - Expanding share of both advanced gas combined cycle and biomass generation

EE: Energy Efficiency Improvement, CI: Carbon Intensity Improvement, SD: Reduction of Service Demands

Thank You!

2050 LCS study
http://2050.nies.go.jp/index.html

The Energy Snapshot tool
http://www-iam.nies.go.jp/aim/datalibrary.htm