

# **Low-Carbon Society Modeling and Scenario Making Process**



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# 1. A brief introduction of AIM

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- AIM(Asian Pacific Integrated Model) is a group of computer models developed by a team composed of NIES(National Institute for Environmental Studies), Kyoto University, and several research institutes in the Asian-Pacific region.
- The objective of AIM is to design and assess policy options for stabilizing the global climate, particularly in the Asian-Pacific region.
- Internationally, AIM has been used as a core tool for developing IPCC, GEO and Millennium Ecosystem Assessment scenarios conducted by UN. Many members of AIM team have been deeply involved to IPCC process, as CLA or LAs.
- Also, the assessments conducted by AIM gave influential impacts on the real actual processes;
  - 1) to determine national GHG reduction targets and in the implementation process, in Japan,
  - 2) to assess national and regional feasible reduction potential of GHG emissions in China, India, and several local regions in Asian countries

## 2. What we are now doing, ...

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### **In order to realize Asian Low Carbon Societies,**

1. We are focusing on domestic and international factors which control the realization of LCS,
2. Describing the development, accumulation, and deepening of factors which control LCS with multi-layered, spatial, and integrated quantification models/tools,
3. Applying quantification models/tools to various Asian regions,
4. Taking account of regional distinctive diversified characteristics,
5. And designing positive Asian low carbon societies and roadmaps towards the LC societies, in each region with a back-casting methodology.

### **3. What are the Asian Low Carbon Societies, we target ?**

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By the middle of this century (2050), the target societies will satisfy the followings;

1. Harmonized with drastically changing future Asian society and economy,
2. Complying with national development targets, under the global, national and regional constraints on fossil and renewal energy resources, land resource, as well as GHG emission
3. Promoting LCS policies based on each region's characteristics ,
4. Also utilizing effectively co-benefits of LCS policies and neighboring policies.

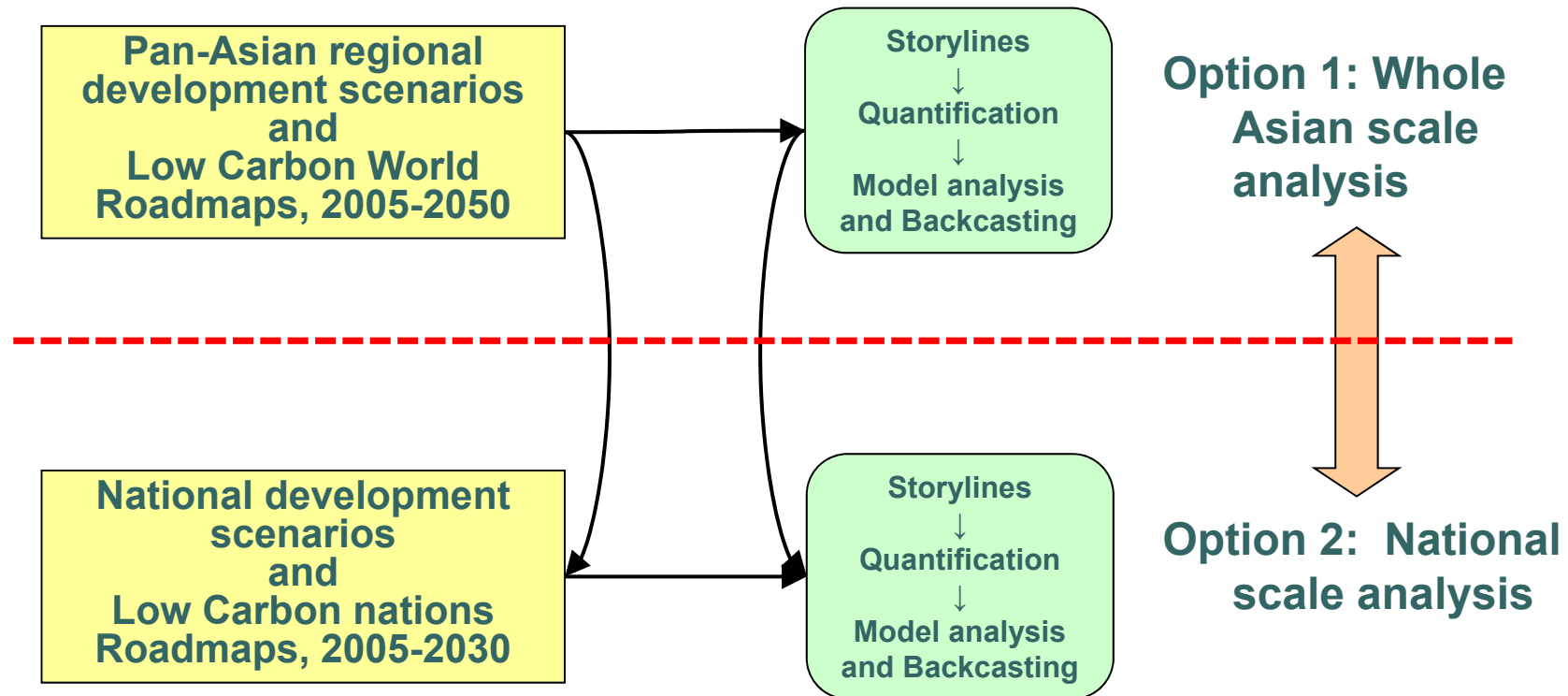
**Also, in order to taking account of multilayered characteristics of Asian LCS issue and not to loose perspective and reality of LCS, we are adopting**

### **Two approaches in regional and time scales**

1. Pan Asian-Pacific approach : Put more emphasis on comprehensiveness and compatibility among global and pan Asian-Pacific regions
2. National or Local region specific study : Country/local region specific approach collaborating with domestic research institutions, and putting more focus on regional initiative and acceptability

## Two regional/time scales of concern

To both scales, our methodology has been applied, and they are inter-connected each other.

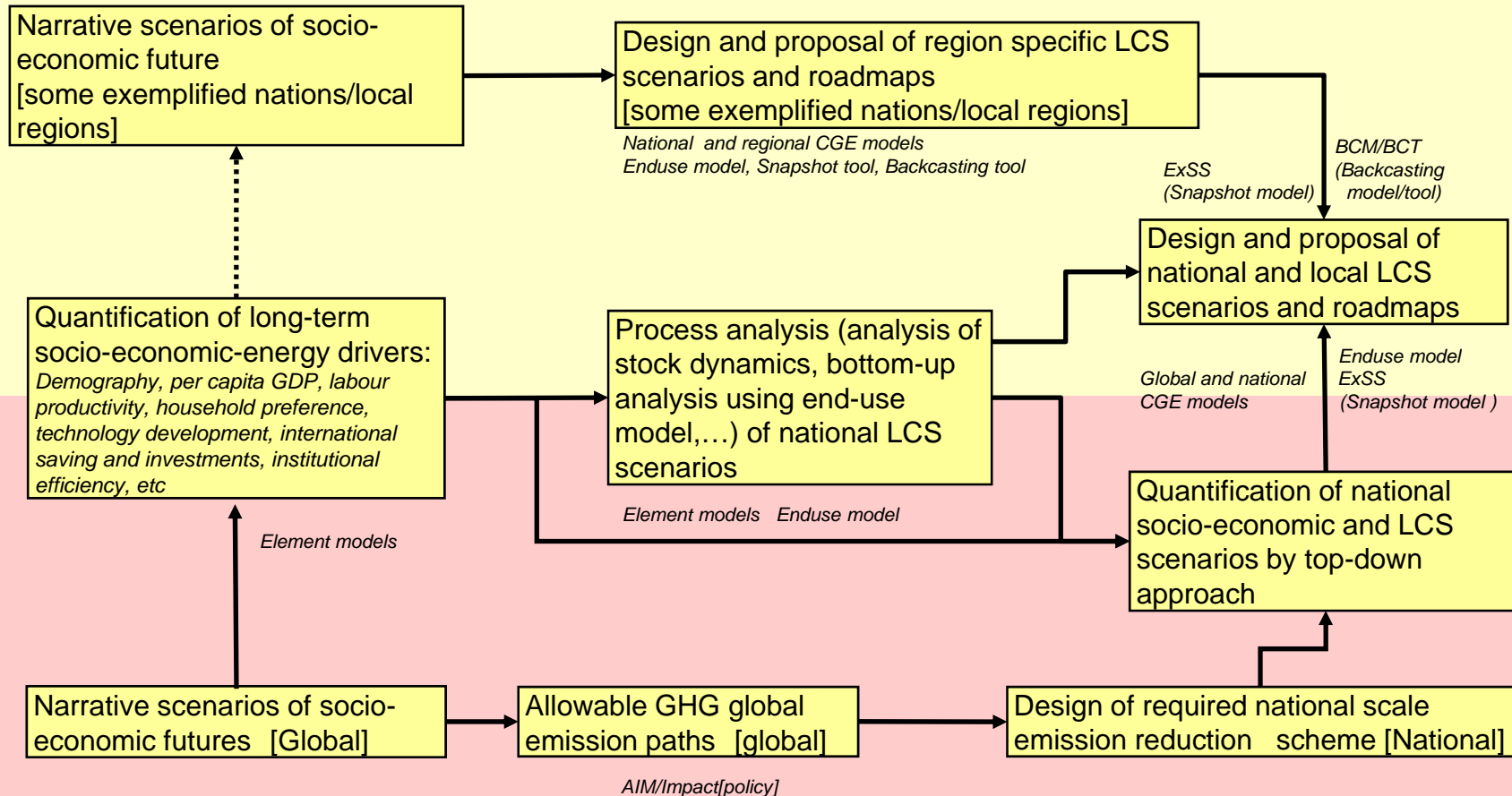


# How do we implement these approaches?

## Flow diagram of the study

### Country specific study

*National and Local regional LCS study collaborated with domestic institutes [some exemplified regions]*



### Pan-Asian Pacific study



## **4. Modeling**

**Development, maintenance and application of multi-layered modeling system**

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**Two groups of models and tools have been developed.**

- (1) Quantification tools encompassing various spatial scales and disciplines, operated complementary e.g. global, country, and regional (city) scales, economical, demographical, industrial, building, transportation systems, etc.**
- (2) Integration models/tools which link the above models towards low carbon society visions and roadmaps.**

Manual of these models is available from <http://www-cger.nies.go.jp/publication/I072/I072.html>

#### 4. Modeling

**Up to now, we developed nine national/local scale models for quantifying national development processes related with energy consumption, landuse change their management etc. (*Element models*)**

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1. ***AIM/enduse***: National and local level bottom-up engineering type model for energy supply/consumption
2. ***Macro-economy model (EME)***: Supply-side type mid-term econometric model
3. ***Population/Household dynamics model (PHM)***: to describe each country's demographic dynamics
4. ***House and building dynamics model (BDM)***: to describe transition and renovation dynamics towards modern and highly insulated buildings.
5. ***Traffic demand model (TDM)***: to describe passenger and freight transports coupled with economic activity and urban structure
6. ***Material stocks and flow model (MSFM)***: to describe material metabolism towards low material societies
7. ***Energy supply model (ESM)***: to describe scenarios of biomass production, power infrastructure development
8. ***Household production and lifestyle model (HPLM)***: to describe the transition of household consumption, lifestyle etc.
9. ***LULC transition model (LDM)***: to describe GHG emissions caused by landuse change.

#### 4. Modeling

### **Three integrated models/tools for full coupling of LCS scenarios with national developing process**

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- ***AIM/cge***: One/multi-regional multi-sectoral static CGE model. Integration platform with which element models are soft-linked according to analytical objects.
- ***Extended snapshot tool (ExSS)***: A tool to designing social accounting matrices, energy balance tables, landuse transition matrix, GHG emission and reduction tables of the target societies. Multi-regional static model.
- ***Back-casting model /Tool (BCM/BCT)***: A model for designing roadmaps towards low carbon societies. Dynamic optimization model.

# Model Implementation

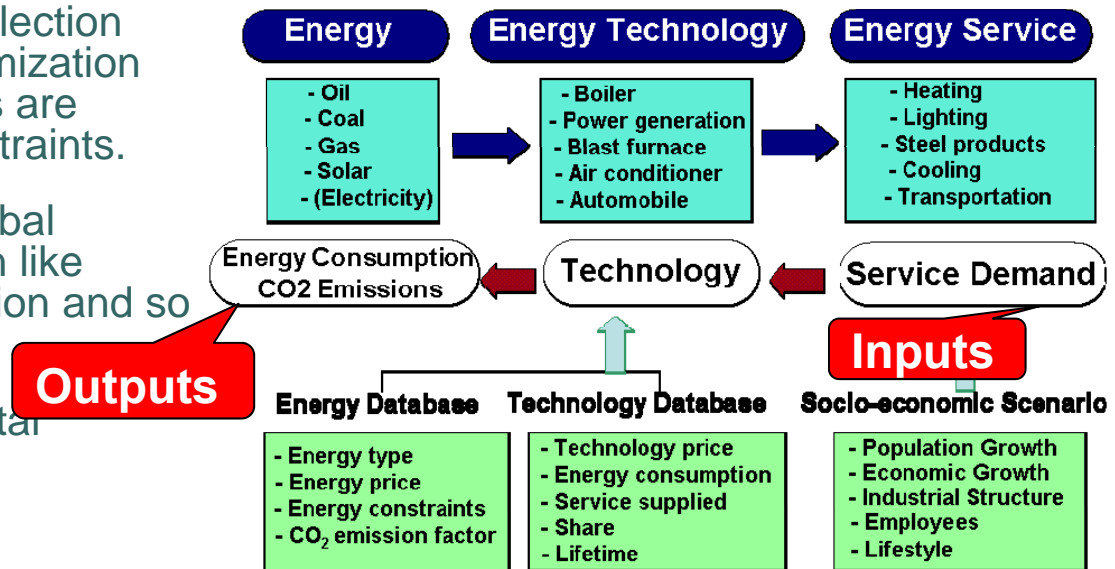
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- All models are on MS-Windows XP or later,
- Most models are implemented with,
  - 1) GAMS (Mathematical programming Language),
  - 2) MS Office,
  - 3) Gnu tools in GnuWin
- And some models use,
  - 4) Fortran/C
  - 5) ArcGIS

# An example of Element models: AIM/enduse Model

**A model for describing the engineering mechanism of GHG emissions and their reduction**

- Bottom-up type technology selection model, based on a linear optimization framework in which total costs are minimized under several constraints.
- Analyze policies related to global warming and local air pollution like emission tax, subsidy, regulation and so on
- Considering local environmental constraints
- Simplified Structure
- Flexible model structure to cope with various practical situation in different regions

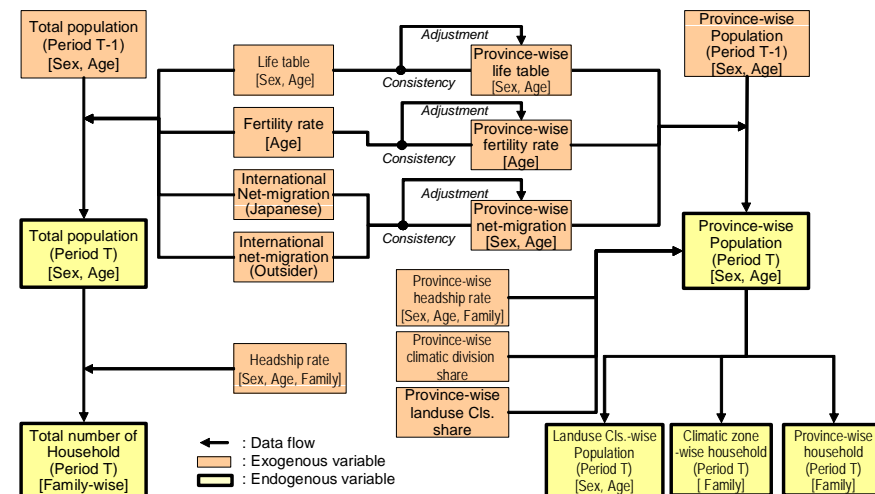


Structure of the AIM/End-Use Model

- “Energy technology” refers to a device that provides a useful service by consuming energy
- “Energy service” refers to a measurable need that must be satisfied.

# An example of Element models: Population and Household Model

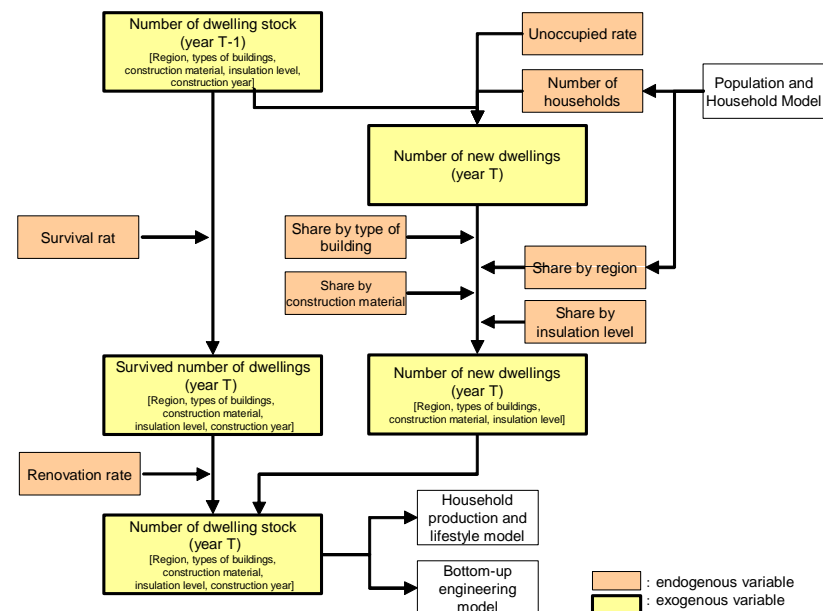
- A cohort component model for population, a household headship rate model for household types, with spatial resolution of provinces, land-use types and climate zones and five family types was developed, and is used to analyze effects of depopulation and changes in family composition on the realization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



Flowchart of PHM

# An example of Element models: House and Building Dynamics Model (BDM)

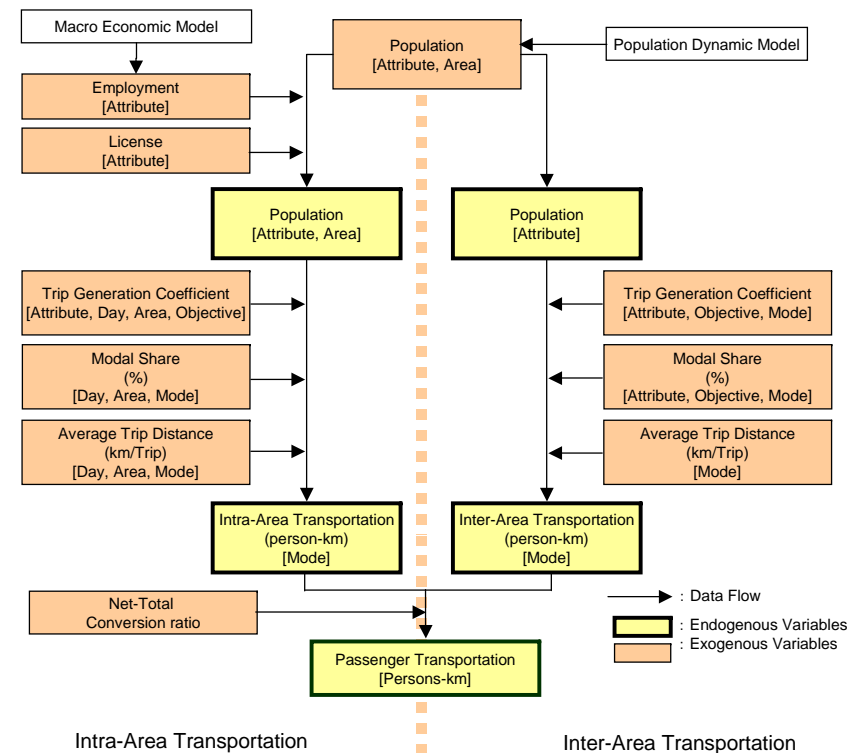
- Enhancement of building insulation is an effective countermeasures. For example, in Japan, 60% of the heating demand from the residential sector can be cut down, if appropriate insulation systems are installed. Future dynamics of building construction and rebuilding, besides configuration of buildings in urban and rural area affects total 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.
- Outputs: Future type/age/insulation of buildings



Flowchart of BDM (residential)

# An example of Element models: Passenger Transportation Demand Model (PTDM, a part of TDM)

- 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 tele-working and virtual communication systems and so on.
- Passenger Transportation Demand Model (PTDM) can simulate transportation demand associated with changes in population distribution, people's activity patterns, modal shares and average trip distances.
- The traffic demands in this model 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 with keeping mutual dependency
- Outputs: Future transport volume/modal structure of passenger travel





#### 4. Modeling

### **Three integrated models/tools for full coupling of LCS scenarios with national developing process**

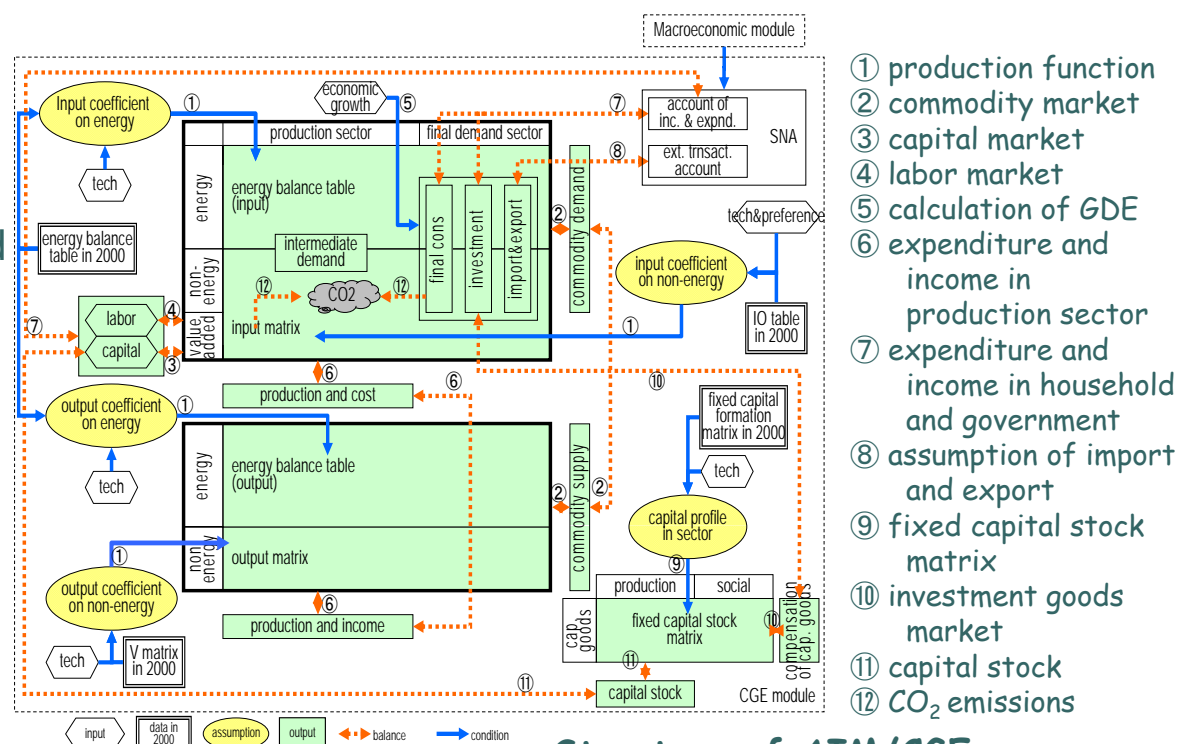
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- ***AIM/cge***: One/multi-regional multi-sectoral static CGE model. Integration platform with which element models are soft-linked according to analytical objects.
- ***Extended snapshot tool (ExSS)***: A tool to designing social accounting matrices, energy balance tables, landuse transition matrix, GHG emission and reduction tables of the target societies. Multi-regional static model.
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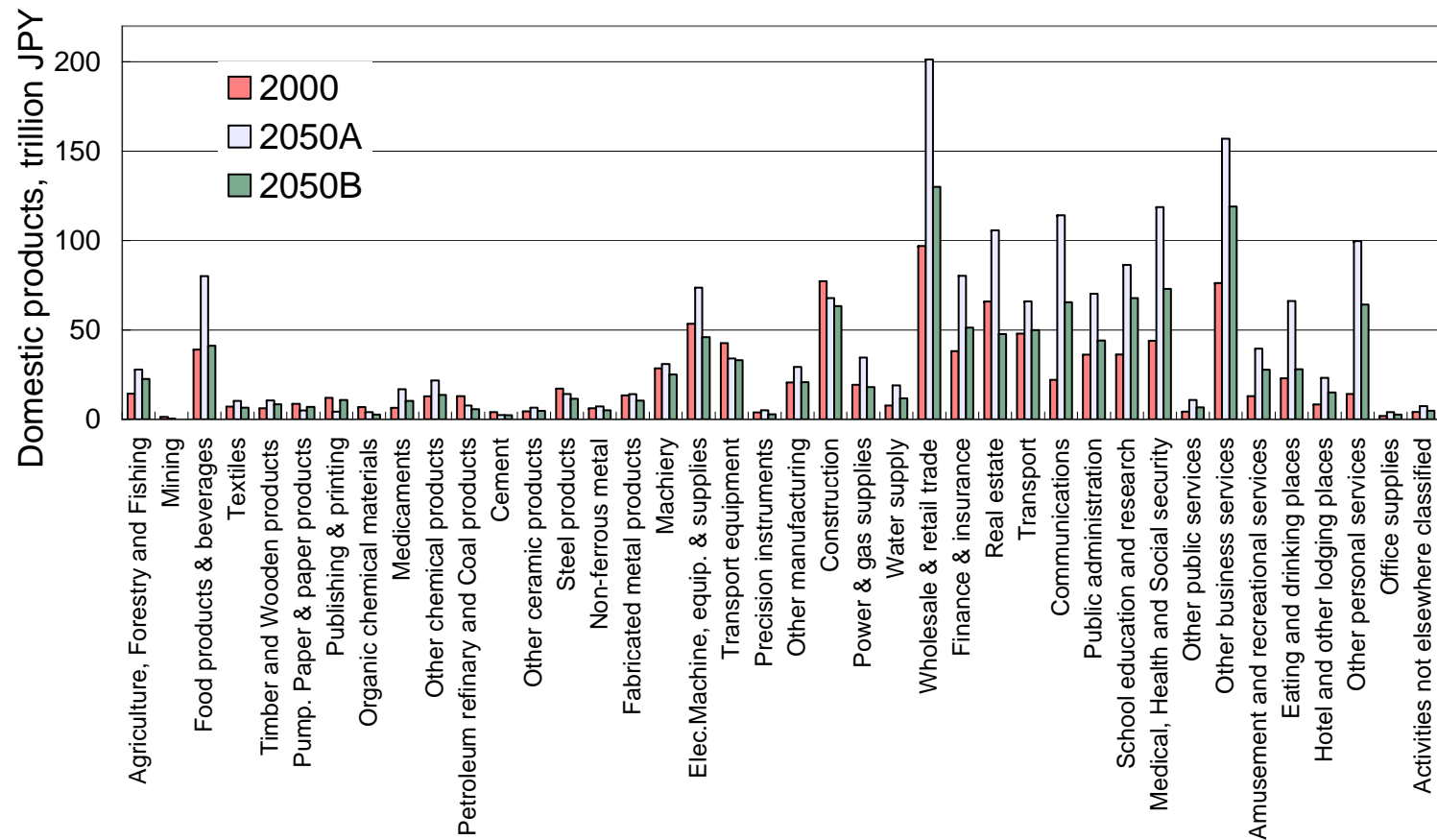
# An example of Integrated models: Computable General Equilibrium model (AIM/CGE)

- AIM/CGE consists of a GE (general equilibrium) module, detailed energy balancing module and several satellite modules. This model is used to project macro economic activity, sector production, based on descriptive future economic scenarios.

- Also the model can be used to estimate the economic effect of diffusion of energy efficient technologies and dematerialization technologies in industrial sectors, development of ICT, increase of service sectors, change of people's goods and service preference.



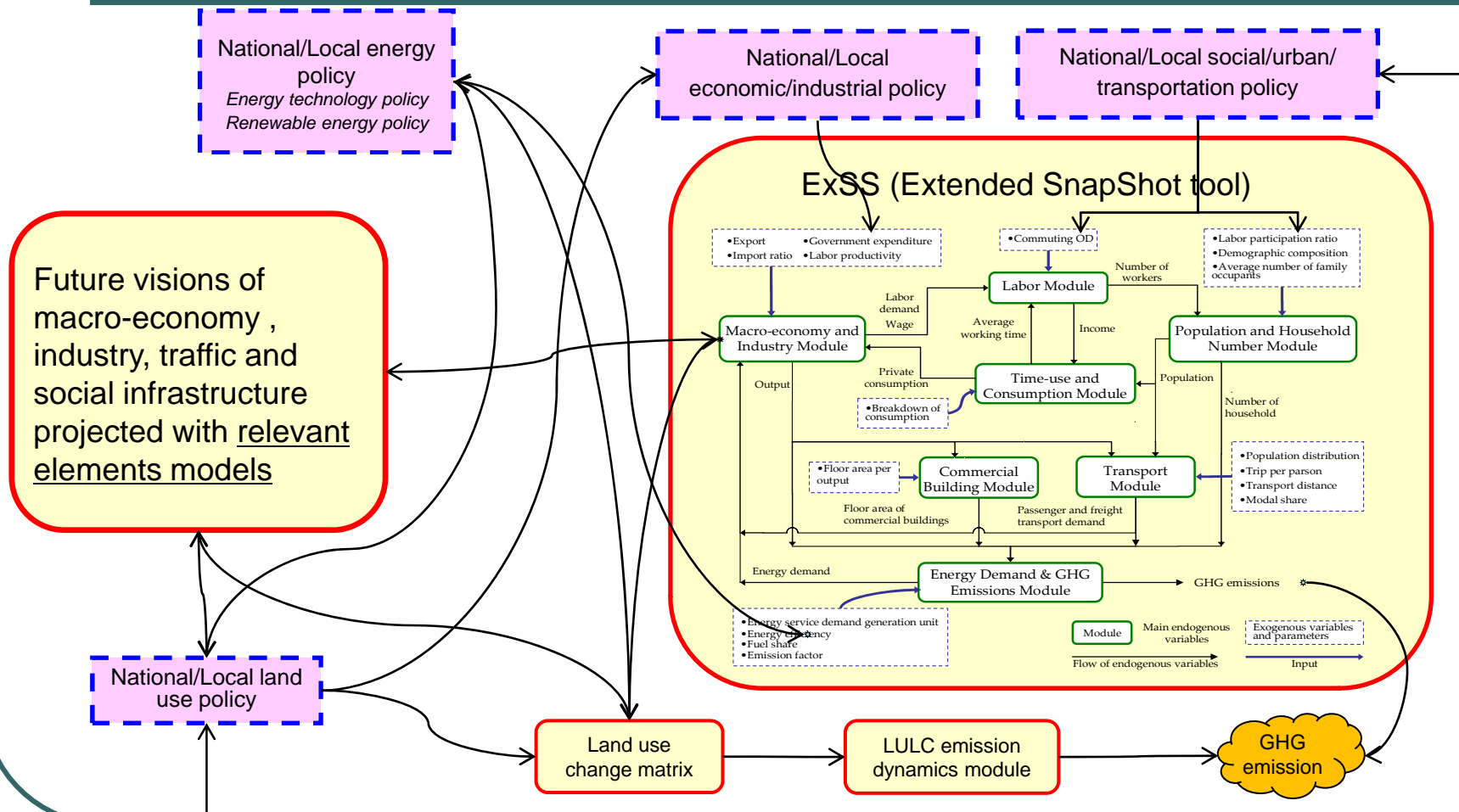
# An example of AIM/CGE outputs in the Japan 2050 LCS study



## 4. Modeling

### Extended Snapshot Tool (ExSS)

- A tool to integrate social accounting matrices, energy balance tables, landuse transition matrix, GHG emission and reduction tables of the target societies -



# An example of outputs of ExSS

Macroeconomic frame of the target society

	2005	2030	2030/ 2005
Population (10)	147	140	0.95
No. of households (10)	65	65	0.99
GDP (bill yen)	6124	8305	1.36
GDP per capita (mill yen/capita)	4.15	5.94	1.43
Gross output (bill yen)	9938	13400	1.35
Primary industry	17	19	1.13
Secondary industry	2735	3542	1.30
Tertiary industry	6947	9507	1.37
Passenger transport volume (mill p-km)	9251	8192	0.89
Freight transport volume (mill t-km)	3484	4571	1.31

Input output table of the target society

No.	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	Total intermediate input	Final demand	Export	Import	Total value added		
01 Agriculture, Forestry and Fishing	2	124	1	0	0	2	1	0	0	0	0	4	0	25	0	158	4	0	3	5	150	
02 Food Products and Beverages	1	119	0	0	0	0	0	0	0	0	0	11	0	134	0	267	200	0	668	664	775	
03 Textiles	0	2	15	0	2	1	2	0	8	1	1	5	2	5	1	44	35	172	0	35	172	
04 Pulp, Paper and Printing	0	34	2	88	8	6	3	2	31	16	5	38	42	11	17	304	11	0	207	185	337	
05 Machinery	0	0	0	0	273	5	9	1	3	0	9	16	74	1	2	394	88	514	139	873	1279	
06 Other Manufacturing and Mining	2	67	32	28	136	114	146	11	24	7	53	137	27	36	12	830	78	0	32	345	854	
07 Construction	0	1	1	1	2	2	1	20	1	13	6	15	1	7	0	70	0	440	0	440	70	
08 Utility	0	16	6	6	16	11	4	19	46	10	17	61	8	59	1	282	191	23	0	61	458	991
09 Wholesale and Retail Trade	1	58	7	15	49	17	33	3	27	5	17	51	24	71	10	387	624	0	142	420	1477	2100
10 Finance, Insurance and Real Estate	1	13	6	11	18	7	9	10	192	156	58	34	62	55	17	649	1421	191	0	284	191	2070
11 Transport, Communication and Manufacturing	1	34	4	15	23	14	37	7	150	38	76	61	38	57	7	564	262	0	11	321	263	826
12 Public Service	0	10	1	1	72	13	3	7	9	2	6	16	4	3	149	468	1022	0	237	193	1863	
13 Business Service	0	44	24	18	43	24	43	42	147	120	90	96	84	56	3	815	68	0	93	234	327	883
14 Personal Service	0	0	0	0	0	0	0	0	4	2	5	15	7	32	1	68	684	0	837	300	1280	752
15 Others	0	12	1	4	9	4	3	3	26	19	5	11	8	10	0	115	0	0	0	20	20	96
Total intermediate input	8	532	80	188	651	222	294	124	671	388	349	570	382	563	73	5095	4134	1051	1270	5908	-4058	13400
Total value added	11	244	92	149	627	210	242	275	1430	1947	545	1293	501	717	22	8105	1051	0	284	191	0	9156
Total input (domestic production)	19	775	172	337	1278	431	536	399	2101	2335	895	1863	883	1280	96	13400	1051	0	1554	1554	0	14451

Energy balance table of the target society

	2005						2030 Frozen at current level case						2030 Corrective measures case								
	Coal	Petroleum	Natural gas	Biomass	Solar & Wind	Electricity	Total	Coal	Petroleum	Natural gas	Biomass	Solar & Wind	Electricity	Total	Coal	Petroleum	Natural gas	Biomass	Solar & Wind	Electricity	Total
Residential	0	59	232	0	0	269	560	0	59	230	0	0	267	556	0	24	126	9	27	173	359
Agriculture, Forestry and Fishing	0	7	0	0	0	0	8	0	8	0	0	0	0	9	0	3	4	0	0	0	7
Food Products and Beverages	0	6	22	0	0	6	34	0	7	29	0	0	8	44	0	3	29	0	0	7	39
Textiles	0	69	159	0	0	3	231	0	95	219	0	0	4	317	0	34	247	0	0	3	285
Pulp, Paper and Printing	0	1	22	0	0	6	30	0	2	30	0	0	8	39	0	1	27	0	0	8	35
Machinery	1	3	39	0	0	36	79	1	4	52	0	0	48	106	2	1	44	0	0	47	93
Other Manufacturing and Mining	0	8	43	0	0	18	70	0	11	57	0	0	24	92	0	4	46	0	0	23	73
Construction	0	24	4	0	0	0	28	0	27	5	0	0	0	32	0	8	15	0	0	0	24
Utility	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Wholesale and Retail Trade	0	76	57	0	0	60	194	0	73	55	0	0	58	186	0	9	45	2	7	33	97
Finance, Insurance and Real Estate	0	52	39	0	0	41	132	0	50	38	0	0	39	126	0	6	31	2	5	23	66
Transport, Communication and Broadcasting	0	8	6	0	0	6	19	0	7	5	0	0	6	18	0	1	4	0	1	3	9
Public Service	0	77	58	0	0	61	196	0	92	69	0	0	73	234	0	11	56	3	9	42	121
Business Service	0	26	15	0	0	17	58	0	26	14	0	0	15	55	0	5	15	1	2	9	31
Personal Service	0	46	35	0	0	36	117	0	66	50	0	0	52	168	0	8	41	2	7	30	87
Others	0	3	2	0	0	1	6	0	3	2	0	0	2	8	0	0	2	0	0	1	4
Passenger Transport	0	543	0	0	0	39	582	0	537	0	0	0	36	572	0	251	0	62	0	42	355
Freight Transport	0	202	0	0	0	0	202	0	270	0	0	0	1	270	0	150	0	47	0	1	198
Total	1	1205	735	0	0	601	2546	1	1378	856	0	0	641	2834	2	517	733	128	58	445	1882

GHG emission reduction by measures

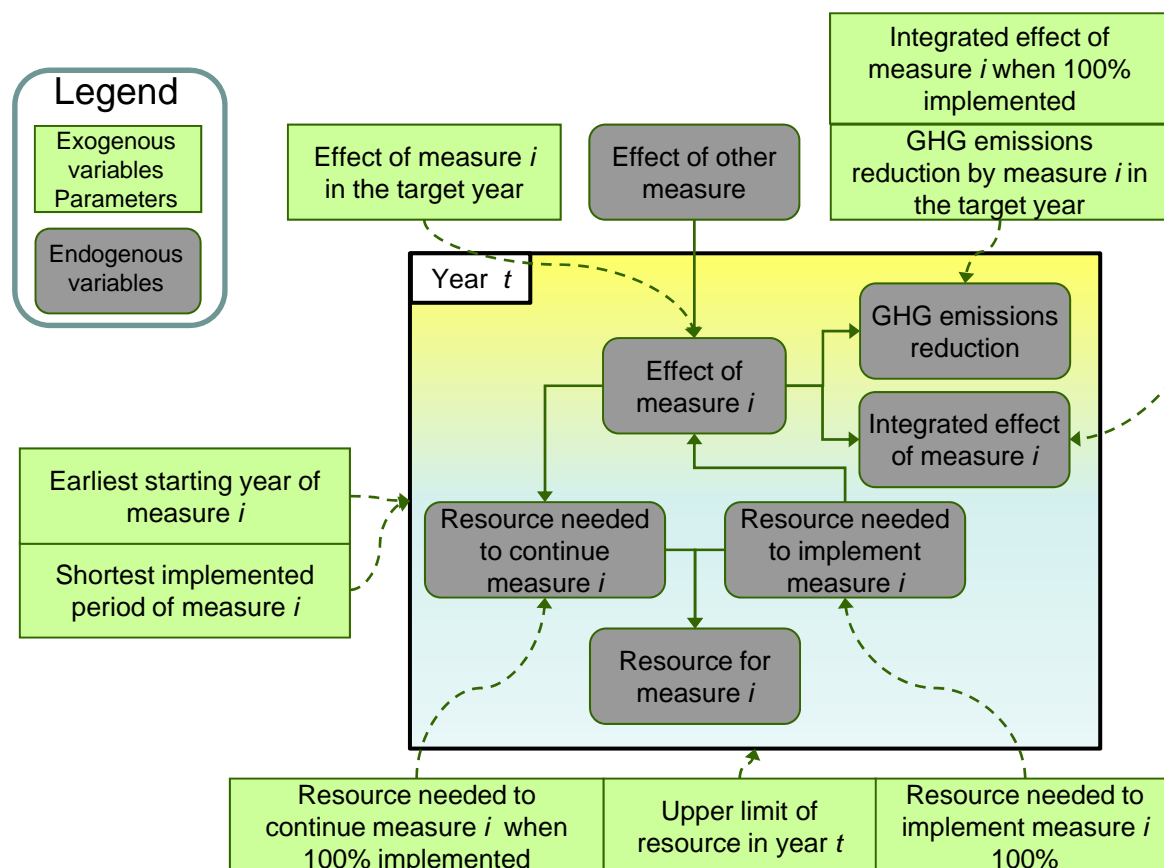
Sector	Low-carbon countermeasure	Data	Source	Category (*)	Identified implementation intensity	Emissions reduction (kt-CO <sub>2</sub> e)	Action (**)	
Household sector	Air conditioner	COP	6.60	2	E	Diffusion ratio (cooling and heating)	50%	
	Highest energy efficiency air conditioner	COP	2.54	1	E	Diffusion ratio (cooling and heating)	50%	
	High energy efficiency kerosene heating	COP	0.88	1	E	Diffusion ratio (heating: kerosene)	80%	
	High energy efficiency gas heating	COP	0.88	1	E	Diffusion ratio (heating: gas)	80%	
	High energy efficiency oil water heater	COP	0.83	1	E	Diffusion ratio (hot water: oil)	70%	
	Gas water heater	COP	0.83	1	E	Diffusion ratio (hot water: gas)	50%	
	Latent heat recovery-type water heater	COP	0.83	1	E	Diffusion ratio (hot water: gas)	50%	
	High energy efficiency gas water heater	COP	4.50	3	E	Diffusion ratio (hot water: electricity)	70%	
	Heat pump water heater	COP	0.55	1	E	Diffusion ratio (cooking: gas)	70%	
	High energy efficiency gas cooker	Thermal efficiency (base year=1)	0.86	1	E	Diffusion ratio (cooking: electricity)	70%	
	High energy efficiency BI cooker	Thermal efficiency (base year=1)	0.86	1	E	Diffusion ratio (cooking: electricity)	70%	
	Fluorescent light	Electricity consumption (conventional type=1)	2.67	1	E	Diffusion ratio	50%	
	LED (substitute fluorescent light)	Electricity consumption (conventional type=1)	1.33	1	E	Diffusion ratio	50%	
	Incandescent light	Electricity consumption (conventional type=1)	8.70	1	E	Diffusion ratio	50%	
	LED (substitute incandescent light)	Electricity consumption (conventional type=1)	4.35	1	E	Diffusion ratio	50%	
	Bulb-type fluorescent light	Electricity consumption (conventional type=1)	2.92	1	E	Diffusion ratio	50%	
	Refrigerator	Electricity consumption (conventional type=1)	2.33	1	E	Diffusion ratio	50%	
	Super high energy efficiency refrigerator	Electricity consumption (conventional type=1)	2.27	1	E	Diffusion ratio	50%	
	Highest energy efficiency refrigerator	Electricity consumption (conventional type=1)	1.54	1	E	Diffusion ratio	50%	
	LCD TV	Thermal loss (base year=1)	0.36	4	E	Diffusion ratio	40%	
	Highest energy efficiency TV	Thermal loss (base year=1)	0.43	7	E	Diffusion ratio	40%	
	House insulation	Energy service demand reduction ratio	10%	5	B	Diffusion ratio	25%	
	New generation level	Potential(ktoe)	295	6	S	Diffusion ratio	10%	
	Photovoltaic generation	Potential(ktoe)	1037	6	S	Diffusion ratio (hot water: all)	5%	
	Solar water heating	Potential(ktoe)	0.2	3	S	Diffusion ratio	27.3	
	Other energy efficiency improvement	Potential(ktoe)	625.1	4	S	Diffusion ratio	41.3	
	Other fuel shifting	Potential(ktoe)	4.07	1	E	Diffusion ratio (cooling: electricity)	50%	
	Total						19.1	4
	Commercial sector	Air conditioner (cooling only)	COP	7.40	2	E	Diffusion ratio (cooling: electricity)	90%
		Super high energy efficiency air conditioner (cooling only)/COP	COP	4.44	1	E	Diffusion ratio (cooling: electricity)	10%
Highest energy efficiency air conditioner (cooling only)		COP	0.87	1	E	Diffusion ratio (hot water: oil)	70%	
Cooling (gas)		COP	0.87	1	E	Diffusion ratio (hot water: gas)	50%	
High energy efficiency gas heat pump		COP	0.85	1	E	Diffusion ratio (hot water: gas)	50%	
High energy efficiency absorption tiller (gas)		COP	3.00	1	E	Diffusion ratio (hot water: electricity)	100%	
High energy efficiency absorption tiller (oil)		COP	0.55	1	E	Diffusion ratio (cooking: gas)	70%	
High energy efficiency boiler (oil)		COP	0.86	1	E	Diffusion ratio (cooking: electricity)	70%	
High energy efficiency boiler (gas)		COP	0.86	1	E	Diffusion ratio (cooking: electricity)	70%	
Air conditioner (heating only)		COP	3.95	1	E	Diffusion ratio	50%	
Super high energy efficiency air conditioner (heating only)/COP		COP	3.36	1	E	Diffusion ratio	50%	
Highest energy efficiency air conditioner (heating only)		COP	4.55	1	E	Diffusion ratio	50%	
High energy efficiency gas heat pump		COP	4.55	1	E	Diffusion ratio	50%	
High energy efficiency absorption tiller (gas)		COP	4.18	1	E	Diffusion ratio	70%	
High energy efficiency absorption tiller (oil)		COP	1.18	1	E	Diffusion ratio	70%	
High energy efficiency boiler (oil)		COP	2.47	1	E	Diffusion ratio	70%	
High energy efficiency boiler (gas)		COP	1.45	1	E	Diffusion ratio	70%	
High energy efficiency boiler (gas)		COP	1.45	1	E	Diffusion ratio	70%	
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High energy efficiency boiler (gas)	COP	1.45	1	E	Diffusion ratio	70%		
High energy efficiency boiler (gas								

# An example of Integrated models: Back-Casting Tool (BCT)

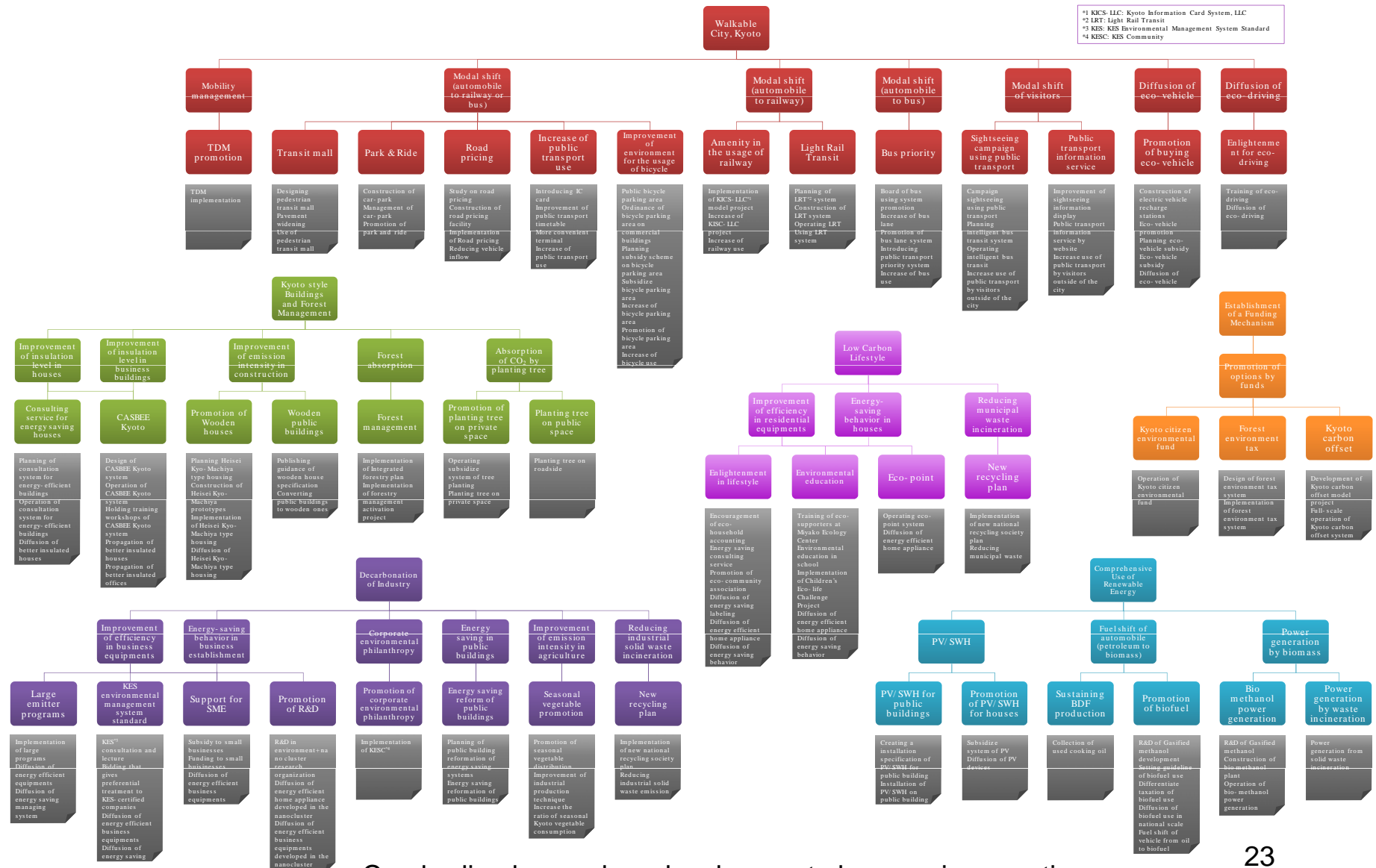
## Designing tool of implementation schedule(roadmap) of policy measures

Design time schedule and combinations of measures towards the target LCS, which maximizes integrated benefits including co-benefits during planning period, under the following six types of resource constraints.

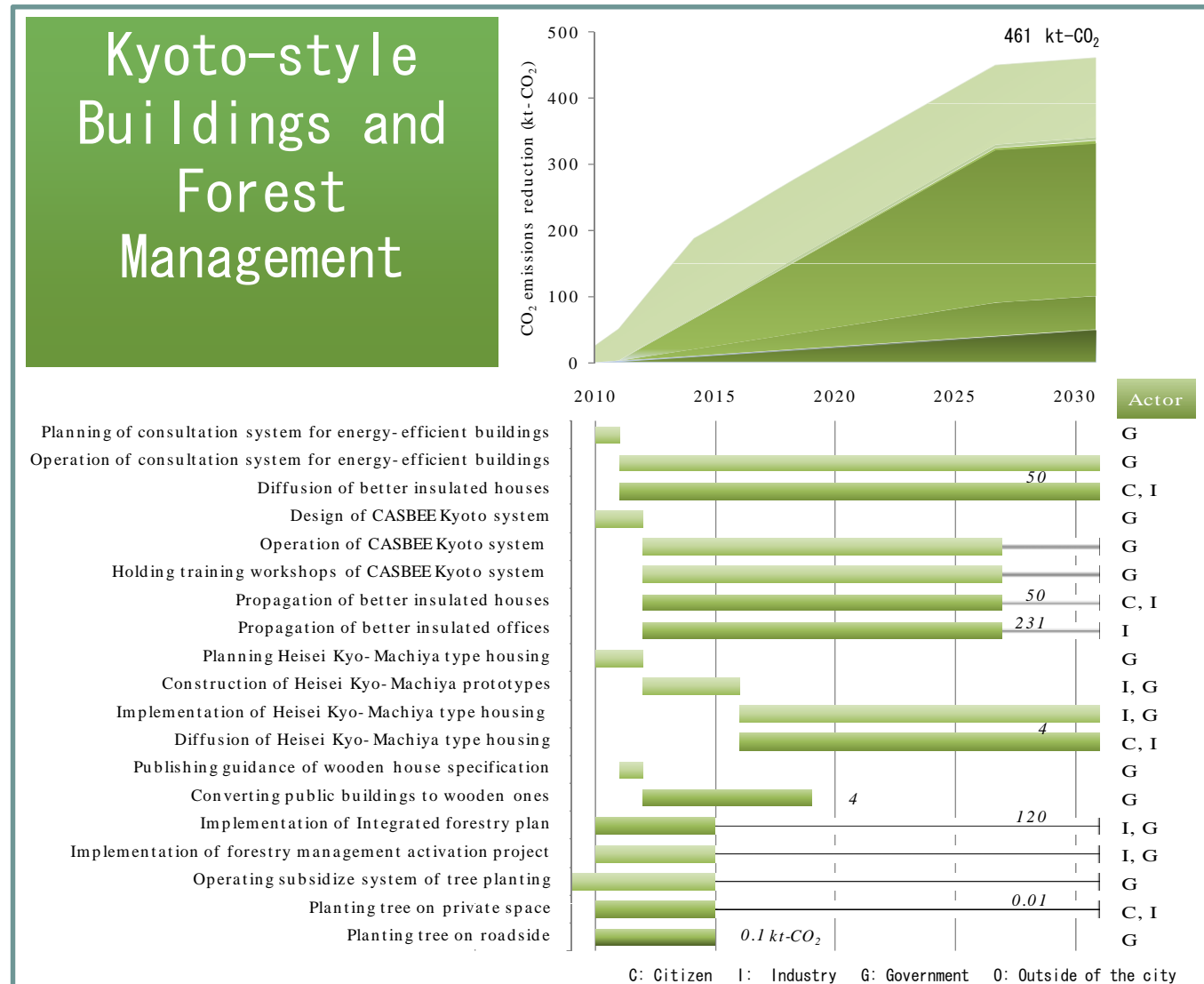
Constraints considered are financial, human and administrative resource (capacity) constraints in private and public sectors.



# An EXAMPLE OF Work Breakdown Structures for LCS derived from ExSS outputs



# An example of the output of the Backcasting Tool —Action roadmap for Kyoto city—





# 5. Application of Model to LCS scenario development

## - Two stages of LCS scenario development -

### Stage 1: Design of a Low Carbon Society

1. Creation of narrative storylines of future Low Carbon Societies
2. Description of sector-wise details of the future LCSs.
3. Quantification of the Macro-economic and social aspects of the LCSs.
4. Identification of effective policy measures and packaging them

### Stage 2: Putting them together and design roadmaps towards LCS

1. Design of policy roadmaps toward the Low Carbon Society
2. Feasibility analysis of the roadmaps considering uncertainties involved in each policy option
3. Analysis of robustness of the roadmap caused by social, economical and institutional acceptability and uncertainties

### **Group 1: Element models;**

- 1) Snapshot models;
  - *CGE[country]*: Quasi steady computable general equilibrium (CGE) model
  - *enduse[country]*: Energy technology bottom-up models
  - *ESM*: Energy supply model
  - *HPLM*: Household production/lifestyle model
  - *TDM*: Transportation demand model
- 2) Transition models;
  - *PHM*: Population and household model
  - *BDM*: Building dynamics model
  - *MSFM*: Material stocks and flow model
  - *EME*: Econometric type macro-economy model
  - *LDM*: Landuse transition model

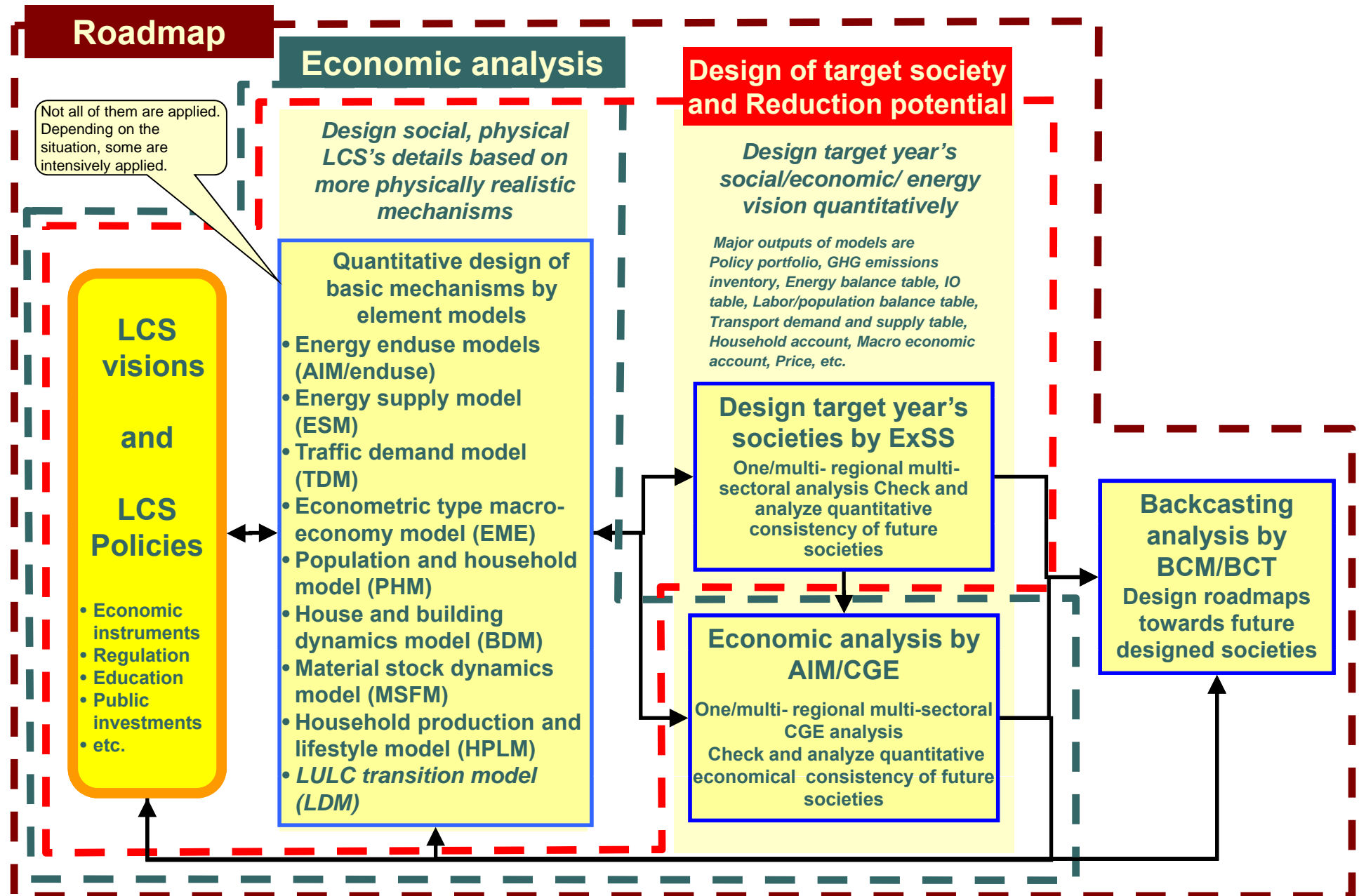
### **Group 2: Extended Snapshot Tool (ExSS) and CGE**

### **Group 3: Backcasting Model for roadmap design and transient control (BCM/BCT)**

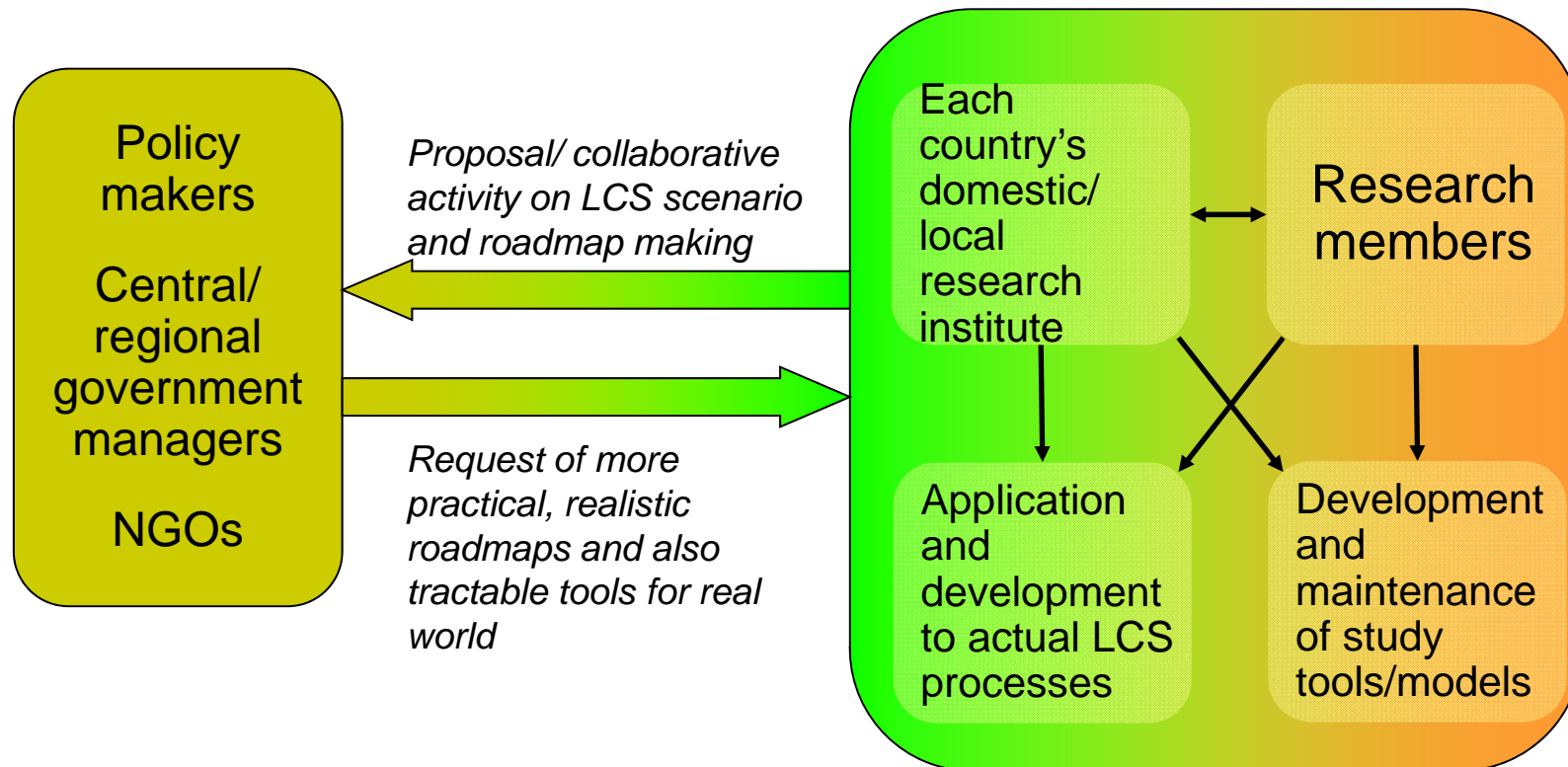
**Several different issues exist corresponding with the audience, and the stage of the study**

Type	Focusing issues
(1) Design of Target Society and Reduction Potential	Analysis of GHG reduction targets and reduction potential
(2) Economic analysis	Economic analysis of LCS policies
(3) Roadmap	Design of policy packages and roadmaps

# Coupling with focusing issues with models



## 6. Collaborating with Asian colleagues



# Region specific studies now we are going on

## Communication and feedbacks of LCS study to real world





# Asia Modeling Network



Asian Modeling Meeting at Tsukuba on 17-18  
September 2009



14<sup>th</sup> AIM International  
Workshop on 14-15  
February 2009



AIM Training Workshop on 2-4  
August 2010

## 7. Final remarks

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1. **“Low Carbon Society (LCS)” issue is not only related with GHG emission activities but also essentially connected with national development planning. Real and quantitative integration is necessary in order to design Low Carbon Society.**
2. **Myopic tactics can not drive us to LCS. In order to realize LCS, policy measures with well calculated strategies and time horizon of more then several decades are necessary.**
3. **From that point of view, we have developed tools in order to design quantitatively the visions of LCS and roadmaps towards LCS. We applied them to the real fields mainly in Japan.**
4. **Collaborating with Asian colleagues, we want to extend our approach to Asia region, acquiring experience, improving and intensifying the applicability to real world.**