AIM approach on regional low carbon development in Asian region, 2015

The 21th AIM International Workshop

November 14, 2015

Ohyama Memorial Hall, NIES

Tsukuba, Japan

Speaker: Yuzuru Matsuoka, Kyoto University, Japan

Three important aspects of Low Carbon Development (LCD) study

1. **Planning of Low Carbon Society and its realization cannot be conducted without multi-disciplinary, integrated and quantification methodologies.**
2. **Not only the planning of LCD Actions, but also the monitoring and improvement of the plans are crucial to realize LCSs. Integrated and quantification methodologies are also useful to these stages.**
3. **Establishing the methodologies and apply them to the target regions, taking account of regional distinctive diversified characteristics, is indispensable.**

Three special characteristics of LCS policies

Long-term | **Relate to whole socio-economic activities** | **Relate to many policies**

Characteristics		Note
1.	**Long-term** horizon, 5 to 50 years from now, the world of totally different from historical trends	Drastic changes expected in the regional economy, demography, transportation system, technology, and lifestyle. Difficult to project with simple extrapolation of historical trends
2	**Strong and complex relations to** nearly whole **socio-economic activities**	Macro-economy, Industry, Agriculture and Forestry, Transportation, Energy Supply and Consumption, Land use, and people's Lifestyle
3	**Strong relations to** many **policies**. In other words, a large rooms of enhancing co-benefits	Environment policies, Waste policy, Water policy, Transportation management, Economic and Industrial policies, and so on

Necessity of integrated quantitative scenario approach

The previous characteristics restrict the methodology within the following:

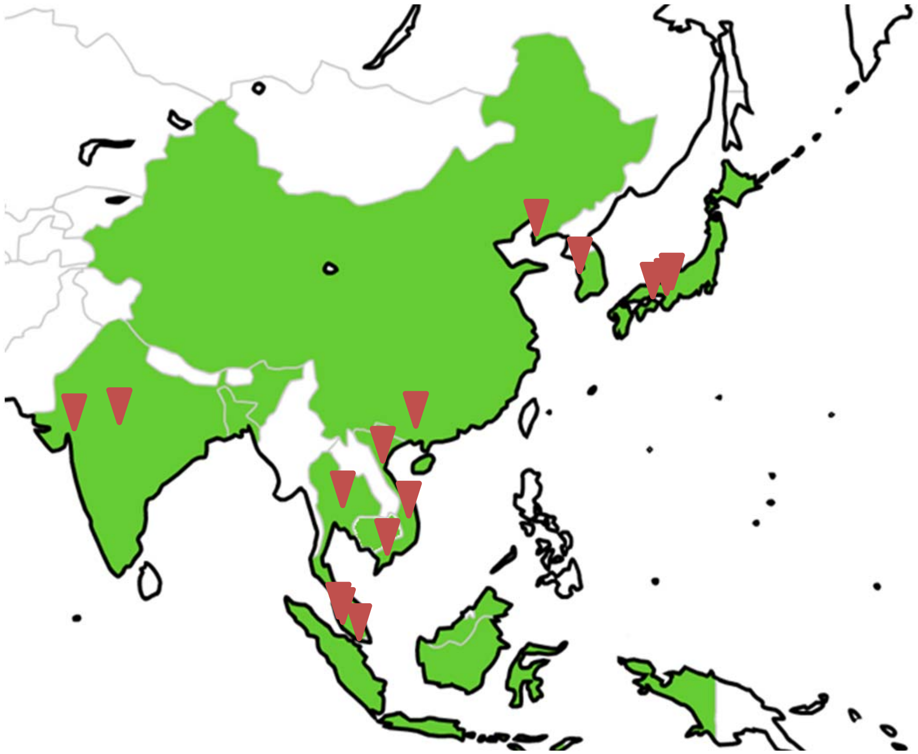
	Characteristics	How to deal with it ?
1.	Drastically different socio-economies in future and hard to extrapolate from historical trends	Based on sound and scientific principles with quantitative expressions, such as balances of demand and supply in monetary term (**Social Accounting Matrix**), energy flow (**Energy Balance Table**), and so on
2.	Strong and complex relations to nearly whole socio-economic activities	Cross sector analysis, such as **input-output analysis**, **integration of sector specific modules**, and so on
3.	Strong relations to many policies	Consideration of a bundle of **quantitative targets, policies, and their interactions**, not only the direct reduction policies, but also related ones.

On top of the above, the methodology should be **transparent, easy to operate and understand**.

These are the necessity of integrated quantitative scenario approach, which we are now adopting.

Up to now, we have applied and are applying our methodology to 8 nations and 14 regions in Asia regions

- Malaysia
  - Putrajaya
  - Cyberjaya
  - Iskandar Malaysia
- India
  - Bhopal
  - Ahmedabad
- Vietnam
  - Hồ Chí Minh
  - Đà Nẵng
  - Hải Phòng
- Bangladesh
- Indonesia
- Cambodia



- Japan
  - Kyoto
  - Shiga
- China
  - Guan Zhou
  - Dalian
- Thailand
  - KhonKaen
- S. Korea
  - Kyonggi-do

Stage of Study

Preparing study → Scenario making → Scenario study finished → Policy Implementation and Monitoring → Ex-post evaluation

Progress of Asian regional studies after last AIM workshop (Jan. 2015-Nov.2015)

region	country	stage	note
Iskandar Malaysia	Malaysia	Scenario study is finished	• Project sponsored by JICA/JST is over by June 2016 • Refinement to five local authorities • Conducting detailed documentation
Hồ Chí Minh	Vietnam	Scenario making is in the last stage	• Qualitative design of the cities' Climate Change Action Plan (CCAP) • Report to the city government in November, 2015
Đà Nẵng	Vietnam	Preparing stage	• Preliminary analysis using ExSS and it's discussion with city government • Finish within this FY
Hải Phòng	Vietnam	Preparing stage	• Institutional arrangement for the collaborative study • Finish within this FY
Cambodia	Cambodia	Scenario making is in the last stage	• Finish the improvement of analysis of energy related sector's scenario • Extensions to AFOLU and waste sectors
Kyoto	Japan	Interim evaluation is finished	• Interim evaluation of on-going LCS policies • Reanalysis of present emission reduction target's feasibility

Final evaluation of Iskandar Malaysia (IM) project conducted by JICA Terminal Evaluation Team, October 15, 2015

- **Project name: Development of Low Carbon Society Scenarios for Asia Regions (SATREPS*)**
- **Research Team: Kyoto University (KU), National Institute for Environmental Studies (NIES), Okayama University (OU), University Technology Malaysia, Iskandar Regional Development Authority (IRDA), etc.**
- **Objectives: Establish and utilize LCS scenarios for policy development in Iskandar Malaysia, and disseminate the approach to Asian region**
- **Evaluation by 5 criteria:**
  1) Relevance: Very High, 2) Effectiveness: Very High, 3) Efficiency: High,
  4) Impact: Very High, 5) Sustainability: High
- **Conclusion of evaluation:**
  All indicators of the project purpose have been achieved. Moreover, various and many positive impacts such as creation of LCS scenarios in other regions based on this project have been expanding from IM to other areas in Malaysia, and other Asian countries. <u>This project is identified as one of the best projects in the history of SATREPS</u>.

* SATREPS: "Science and Technology Research Partnership for Sustainable Development", a project funding scheme by JICA and the Japan Science and Technology Agency (JST)

Documentation efforts of AIM regional LCS scenario approach

1. Start of the Story
- 1-1 Formulation of the region's top initiative
- 1-2 Construction of Task force
- 1-3 Resource allocation

- Authorize task force
- Human resource, budget plan of research

2. Framework setting
- 2-1 Background research
- 2-2 Framework setting

- Existing policies, plans, and studies, national and regional circumstances etc.
- Timeframe, scope and boundary

3. Construction of LCS visions
- 3-1 Data collection and estimation
- 3-2 Localization of the methods
- 3-3 Design and quantification of LC Society visions

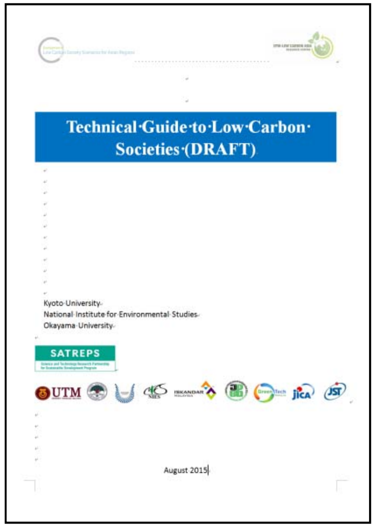
- Related statistics, reports and preliminary surveys
- Adjusting of methodologies, tools and software
- Demography, macro economy, industrial structures etc.

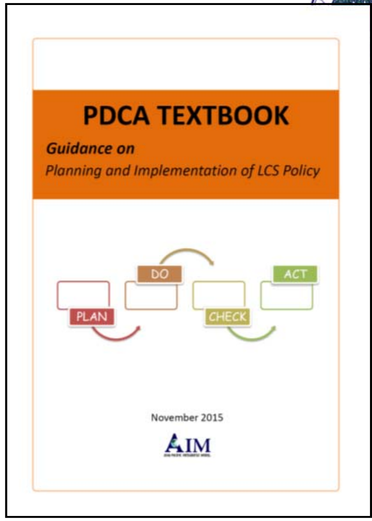
4. Design of LCS policies and assessment of GHG and non-GHG effects of the policies
- 4-1 Design of feasible and likely LCS policies
- 4-2 Projection of Baseline emissions and policy scenario emissions
- 4-3 Assessment of GHG and non-GHG effects of LCS policies

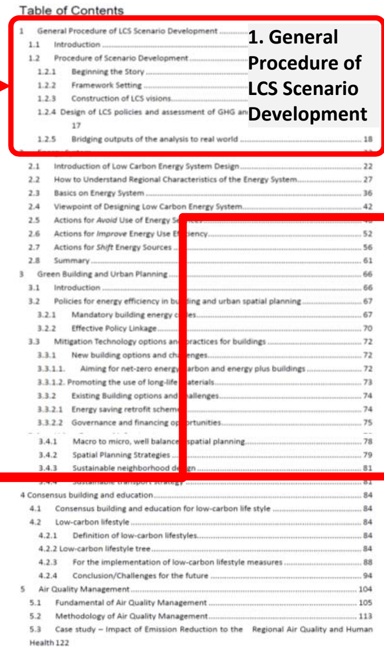
- Define the "baseline"
- Identify parameters and indicators on GHG and non-GHG effects

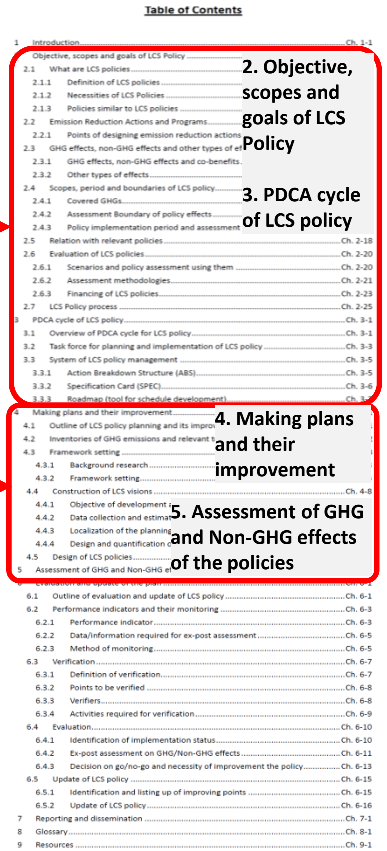
5. Bridging outputs of the analysis to real world
- 5-1 Formulation of Actions and Programs for implementation
- 5-2 Demonstration and reporting the results to policy makers

- Make priority list of actions and policies based on the analysis and construct WBS and roadmap for realizing LCS









The details of 5 step approach and supporting tools will be explained in two forthcoming textbooks, *i.e.*
- ***"Technical Guide to Low Carbon Societies"* and**
- ***"PDCA Textbook: Guidance on Planning and Implementation of LCS Policy".***

PDCA cycle of LCS policy (1)

PDCA process of LCS policy: an iterative management procedure with continuous improvement of the planning and implementation process of LCS policy.

1) "Planning and pledge" phase by regional authorities,
2) Implementation phase ("Do"),
3) Evaluation phase ("Check"),
4) Improving phase based on the results of evaluation ("Act").

Three levels of PDCA: In order to utilize the PDCA process of LCS policy, hierarchical characteristics by the difference in level of implementation entities and the implemented. Three levels of PDCA are existed from a view point of the lengths of cycling and levels of detail.

1) **"Strategic"** level, with a time frame of five to several ten years, may be vague, and the main entities related are organizational, board, or executive level.
2) **"Managerial/tactical"** level, with a year time frame, have a high level of detail, and are managed by the unit or department level.
3) **"Operational"** level, more short term and more detailed level.

PDCA cycle of LCS policy (2)

Strategic and Managerial levels

Strategic Level PDCA	Managerial/Tactical Level PDCA
LCS Action Every 5 to several ten year's cycle	LCS Program/Measure Every year's cycle

Strategic Level PDCA

Plan

- Design of the Actions
  > Set overarching target and each Action's target
  > List-up and disposition of programs (ABS)
  > Conceptual design of programs and Roadmaps
- Ex-ante evaluation of Actions/Programs
- Dissemination of the plan

Do

- Management and adjustment of Programs implementation

Check

- Integration of tracking indexes
- Ex-post evaluation of Actions/Programs
- List up problems on the Action management

Act (Re-Plan)

- Amendment the Actions
  > Modification of targets
  > Improvement of Action-Program scheme
  > Re-design of programs and Roadmaps

Do

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Managerial/Tactical Level PDCA

Plan

- Detailed design of programs
- Creating the enabling environment
- Development of implementation/ monitoring plans

Do

- Implementation and operation of programs

Check

- Tracking of performance indexes
- Review of program performance
- List up problems on operation

Act (Re-Plan)

- Improvement, modification or suspension of programs

Do

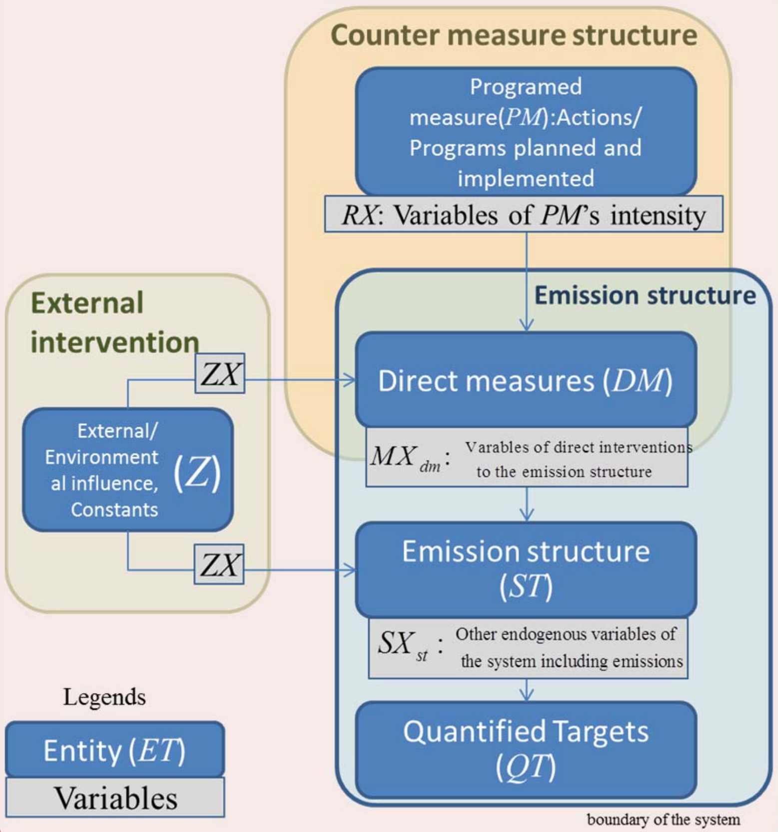
Quantification tools supporting PDCA process of LCS policy

Stage	Task	Tools and their role of supporting PDCA process
Planning	Design of the Actions	
	Organize/Construct Action scheme	
	Set overarching target and each Action's target	
	List-up and disposition of programs	Organize and construct Action scheme with "Action Breakdown Structure" (ABS)
	Preliminary design of programs	
	Ex-ante evaluation of Actions	Analysis of action and program structure with "Action Design Structure Matrix" (ADSM, DSM of actors, measures and emission mechanisms)
		Quantitative assessment of target feasibility, and contribution of each program (ExSS)
		Cost-Effectiveness-Resource affordability analysis of actions and programs
	Rough design of action roadmap	Quantitative feasibility assessment of the action roadmap with "BackCasting Tool" (BCT)
	Dissemination of the plan	
Doing	Programs implementation, management and adjustment of operation	
	Monitoring and reporting of operational indexes	
Check	Monitoring and integration of tracking indexes	Improvement of quantification tools, recalibration of system parameters, and external factors
	Ex-post assessment of Actions/Programs	Quantification of action's progress
Act (Re-Plan)	Listing up of problems on action management, progress and their quantitative assessment	Attribution of the discrepancies between plans and real progresses, to programs and implementers
	Feasibility check/Modification of targets	Reassessment of target feasibility
	Improvement/Re-design of Action-Program scheme	Re-analysis of cost-effectiveness-resource affordability of actions and programs
	Reallocation of resources for actions	
	Re-design of Roadmaps	Revision of the action roadmap with "BackCasting Tool" (BCT)

Modeling of “Emission structure” and “Counter measure structure”

In order to analyze the PDCA process, quantitatively and transparently, we need to have operational models of “Emission structure” and “Counter measure structure” of the LCS system

Schematic diagram of “Counter measure structure” and “Emission structure” models



Generic equations of “Counter measure structure model” and “Emission structure model”

Four sets of variables

Exogenous variables discribing environment and constraints	: $\overrightarrow{ZX} = \{ZX_z \mid z \in Z\}$
Exogenous variables discribing counter measure (action/measure)'s intensity	: $\overrightarrow{RX} = \{RX_{pm} \mid pm \in PM\}$
Endogenous variables describing system behavior, including emissions and quantified targets	: $\overrightarrow{SX} = \{SX_{st} \mid st \in ST\}$
Endogenous variables connecting counter measure structure and emission structure (Direct Measure), which are a part of $\overrightarrow{SX}$	: $\overrightarrow{MX_{DM}} = \{MX_{dm} \mid dm \in DM\}$

Two sets of system equations

Equation of counter measure structure	: $\overrightarrow{MX_{DM}} = \overrightarrow{GDM}\left(\overrightarrow{ZX}, \overrightarrow{RX}\right)$
Equation of emission structure	: $\overrightarrow{SX} = \overrightarrow{GSM}(\overrightarrow{ZX}, \overrightarrow{MX_{DM}})$

A model of emission structure (1)

Simple emission model “S-model”

Consider a typical emission structure of gas g emission from sector c :

$$G_{g,c} = A_c \cdot \sum_{s \in S(c)} \left[is_{s,c} \cdot \left\{ \sum_{d \in D2(s)} \left(id2_{d,s} \cdot sd2_{d,s} \right) \right\} \cdot \left\{ \sum_{d \in D1(s)} id1_{d,s} \cdot sd1_{d,s} \cdot \left(\sum_e \left(ie_{e,d} \cdot ige_{g,e} \right) \right) \right\} \right]$$

where:

$G_{g,c}$	:	Emission of Gas g in sector c
A_c	:	Activity of sector c. Depending to ZX
$is_{s,c}$	:	Service demand intensity of service s in sector c
$id1_{d,s}$	:	Production rate of service s by d (∈D1)
$sd1_{d,s}$	:	Share ratio of service production device d (∈D1) in service s
$id2_{d,s}$	:	Changing rate of service s by d (∈D2)
$sd2_{d,s}$	:	Share ratio of service economizing device d (∈D2) in service s
$ie_{e,d}$	:	Energy intensity of d for energy e. In case of e='ne' (non-energy), $ie_{'ne',d}=1$
$igd_{g,d}$	:	Direct gas emission intensity of gas g by operating d. In this formulation, it is replaced by $ige_{g,'ne',d}$
$ige_{g,e,d}$	:	Emission coefficient of gas g from d and energy e. In case of e='ne'(non-energy), it is same as $igd_{g,d}$

Also, aliasing a set of variables with $IVE_{g,e,d1,d2}$ as:

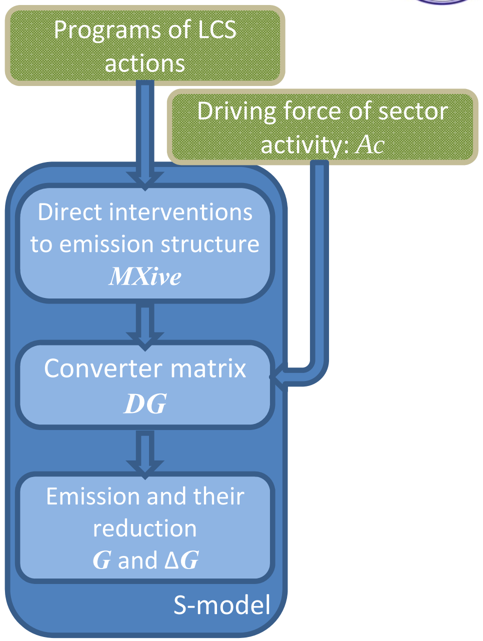
$$\left\{ SX_{ive \in IVE_{g,e,d1,d2}} \right\} = \left\{ A_c, is_{s,c}, id1_{d1,s}, sd1_{d1,s}, id2_{d2,s}, sd2_{d2,s}, ie_{e,d1}, ige_{g,e,d1} \right\}$$

Considering s and c are specified by $d1$ or $d2$, **gas g emission from energy e, technology $d1$ coupled with $d2$ is:**

$$G_{g,e,d1,d2} = \prod_{ive \in IVE_{g,e,d1,d2}} SX_{ive} \qquad \text{(S1)}$$

A model of emission structure (2)

Simple emission model "S-model"



A Schematic diagram of S-model

Denoting the divergence of SX_{ive} from baseline B by MX_{ive}, with a exception of A_c,;

$$MX_{ive} = SX_{ive} - SX_{ive}^{(B)}, \qquad ive \in IVE_{g,e,d1,d2} \setminus A_c$$

Where

$$\left\{ MX_{ive \in IVE_{g,e,d1,d2} \setminus A_c} \right\} = \left\{ mis_{s,c}, mid1_{d1,s}, msd1_{d1,s}, mid2_{d2,s}, msd2_{d2,s}, mie_{e,d1}, mige_{g,e,d1} \right\}$$

Corresponding to these MX_{ive}, the $\Delta G_{g,e,d1,d2}$: divergence of $G_{g,e,d1,d2}$ from $G_{g,e,d1,d2}^{(B)}$, is decomposed using a decomposing formula (see appendix);

$$\Delta G_{g,e,d1,d2} \triangleq G_{g,e,d1,d2} - G_{g,e,d1,d2}^{(B)} = DG_{(g,e,d1,d2),A_c} \cdot \left(A_c - A_c^{(B)} \right) + \sum_{ive \in IVE_{g,e,d1,d2} \setminus A_c} DG_{(g,e,d1,d2),ive} \cdot MX_{ive} \qquad \text{(S2)}$$

Where, $DG_{(g,e,d1,d2),ive}$ are coefficients describing a first order dependency of $\Delta G_{g,e,d1,d2}$ to $\left(A_c - A_c^{(B)} \right)$ and MX_{ive}, which are analytically derived from equation (S1)

We name this emission model **"S-model"**

A model of counter measure structure (1)

Simple counter measure model: “M-model”

The model differentiates counter measures into the following three types

- ✓ A measure is an intended intervention to reduce GHG emissions originally controlled by actors outside of the system. A set of measures is written by “*M*”, and the element of the set is written by “*m*”.

- ✓ *M* is divided into three groups (sets), **Direct Measures (*DM*)**, **Consolidated Measures (*CM*)** and **Program measures (*PM*)**.

$$M = DM \cup CM \cup PM$$

- ✓ **Direct measure (*DM*) :** Directly intervene emission mechanisms (*e.g.* improvement of energy efficiency or service efficiency) and reduce GHG emissions.
  Program measures (*PM*) : measures planned/programed by policies.
  Consolidated measure (C*M*) : a combined measure convenient to connect *DM* and *PM* from a view point of intervention mechanisms.

  DM and *CM* are consequences of one or multiple *PM*s.

A model of counter measure structure (2)

Simple counter measure model: "M-model"

Direct measures : $DM = \left\{ dm_{g,e,d1,d2} \right\}$

Interventions corresponding to the elements of *IVE* except A_c in S-model, or

$$\left\{ dm_{g,e,d1,d2} \right\} = \left\{ ive\left(\in IVE_{g,e,d1,d2} \setminus A_c \right) \right\}.$$

7 types of *DM* are identified. They are;

Intervention type	Explanation	Elements related
mis	Intervention to service demand intensity. Increase of using efficiency of goods and material, more energy efficient lifestyle, decrease of transportation volume, are the examples.	*s* : service
msd 1 and *msd* 2	Promotion or Depromotion of the technology (type 1 or type 2) in order to change the device's diffusion rates.	*d* :device/technology
mid 1 and *mid* 2	Intervention to service production/reduction efficiency of technology (type1 or type 2), for example, by operation and maintenance	*d* :device/technology
mie	Intervention to energy efficiency, for example, operation and maintenance improvements	*d* :device/technology and *e:* energy
mige	Intervention to emission coefficient of energy, such as a change of electricity CO_2 emission coefficient. Also, includes intervention to direct gas emission intensity	*g* : gas, *e* :energy and *d* : technology/device

A model of counter measure structure (3)

Simple counter measure model: "M-model"

Program measures : $PM = \{pm\}$, directly reflect of implementation programs. From a view point of interventions to gas emission mechanism, often duplicating, reflecting territories of implementation agencies, confusing, and difficult to set straight

Example of Program measures : Climate Change Action Programs proposed in the HCMC study

Sector code	Project code	Sector	Content	Status	Effort
	(151027)				(151027)
I	I-1	Land-use planning	Development of Land Use Regulations and its Operation	Current	Internal
I	I-1	Land-use planning	Urban Development in Model Region (in a integrated manner of the 10 important sectors)	Planned	External
I	I-2	Land-use planning	Afforestation and greening (parks, roads, pedestrian spaces, riparian and coastal areas)	Planned	Internal
I		Land-use planning	Appropriate Site Allocation of Venous Industry Infrastructure	Potential	
I		Land-use planning	Appropriate Management of Large-scale Green Lands	Potential	
I	I-2	Land-use planning	Build wind channels (green corridors)	Potential	External
II	II-1	Energy	Energy efficiency technology applied to buildings	Current	Internal
II	II-1	Energy	ESCO (Energy Saving COmpany) Project	Current	External
II	II-1	Energy	ESCO (Energy Saving COmpany) Project for commercial buildings	Current	External
II	II-1	Energy	ESCO (Energy Saving COmpany) Project for industries	Current	External
II	II-3	Energy	High Efficiency Lighting	Current	Internal
II	II-3	Energy	High Efficiency Lighting in public lighting	Planned	Internal
II	II-3	Energy	High Efficiency Lighting in commercial buildings	Current	Internal
II	II-3	Energy	High Efficiency Lighting in households	Current	Internal
II	II-7	Energy	High Efficiency Air Conditioners (such as Air Conditioners with Inverter Controllers)	Current	Internal
II	II-7	Energy	High Efficiency Air Conditioners (such as Air Conditioners with Inverter Controllers) in commercial buildings	Current	Internal
II	II-7	Energy	High Efficiency Air Conditioners (such as Air Conditioners with Inverter Controllers) in households	Current	Internal
IX		Agriculture	Reduction of Agricultural Chemicals and Fertilizers Usage	Potential	External
IX		Agriculture	Photovoltaic Power Generation at Agricultural Communities	Potential	External
X	X-1	Tourism	Improvement of Water Traffic Network	Current	Internal

A model of counter measure structure (4)

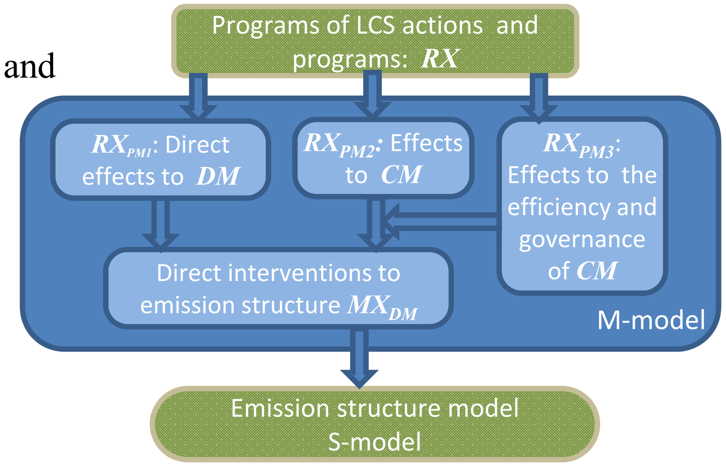
Simple counter measure model: “M-model”

Dividing *PM* (program measure) into three groups, *i.e. PM1*, *PM2*, and *PM3*.
PM1 is a measure directly effecting *DM*, *PM2* to *CM*(consolidated measure). *PM3* is a measure which controls the effectiveness/governance of *CM*.
Using this disaggregation of *PM*, impacts to *DM* by *PM* are modeled by the following formula.

$$\overrightarrow{MX_{DM}} \triangleq {}^{t}\left(mis_{s,c}, mid1_{d1,s}, msd1_{d1,s}, mid2_{d2,s}, msd2_{d2,s}, mie_{e,d1}, mige_{g,e,d1}\right)$$
$$= \left(\mathbf{AD3}\cdot\mathbf{I}\left[\overrightarrow{RX_{PM3}}\right]\cdot\mathbf{ACPM2}\cdot\overrightarrow{RX_{PM2}} + \mathbf{AD1}\cdot\overrightarrow{RX_{PM1}} + \overrightarrow{\mathrm{AD0}}\right) \qquad \text{(M1)}$$

where $\mathbf{AD3}, \mathbf{ACPM2}, \mathbf{AD1}$ and $\overrightarrow{\mathrm{AD0}}$ are constant parameter matrix/vector, and

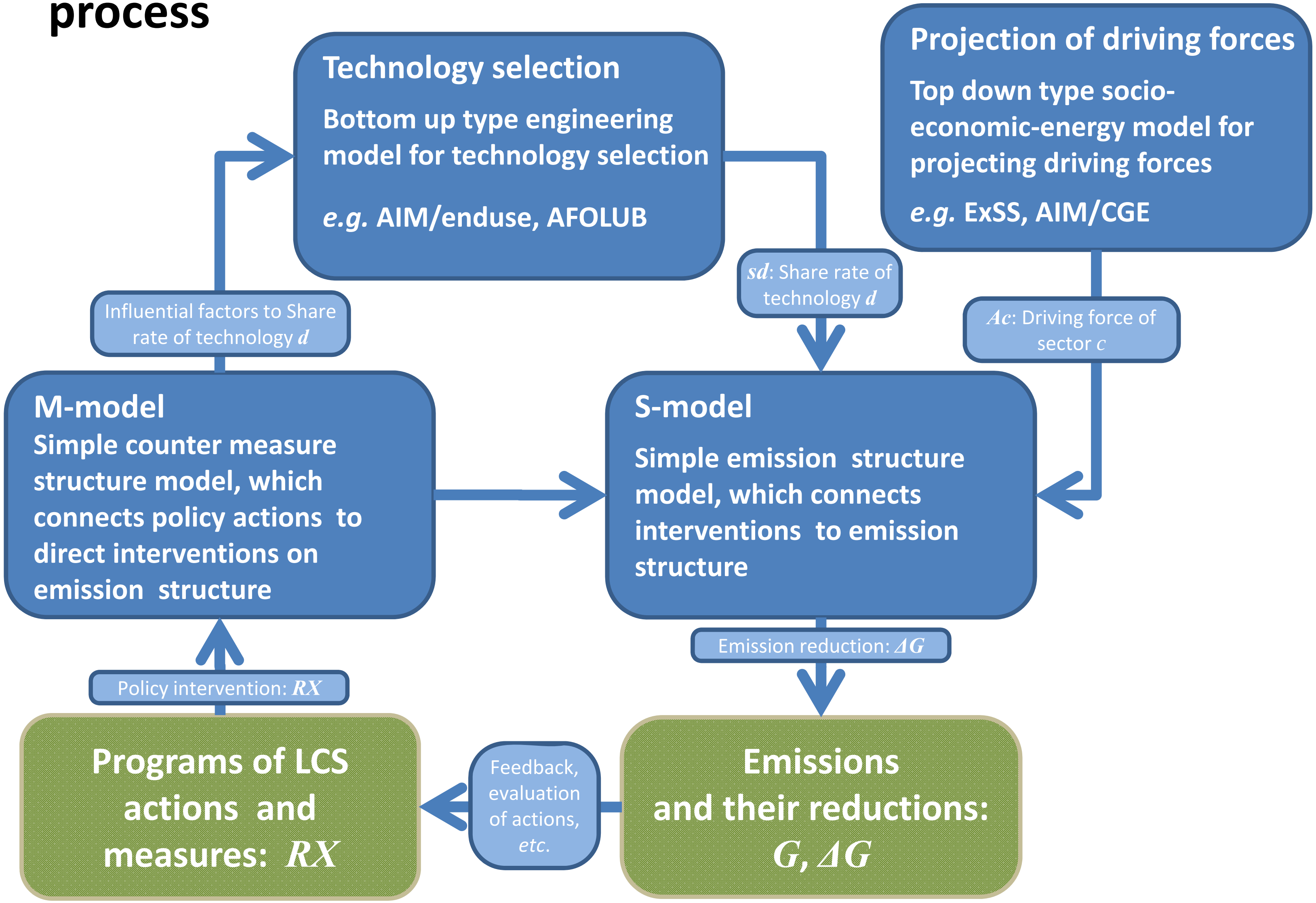
$$\mathbf{I}\left[\vec{x}\right] = \begin{pmatrix} x_1 & 0 & 0 & 0 \\ 0 & x_2 & 0 & 0 \\ 0 & 0 & \cdot & 0 \\ 0 & 0 & 0 & x_{...} \end{pmatrix}$$



A Schematic diagram of M-model

This counter measure structure model is called “**M-model**”, which connects *RX* (variables of program measures) to MX_{DM} (variables of direct measure).

Coupling of S-model, M-model and related quantification models for supporting PDCA process



Clarification of various emission projections for evaluating the performance of Action's and measures

Combinations of Environmental variables and counter measures for calculation

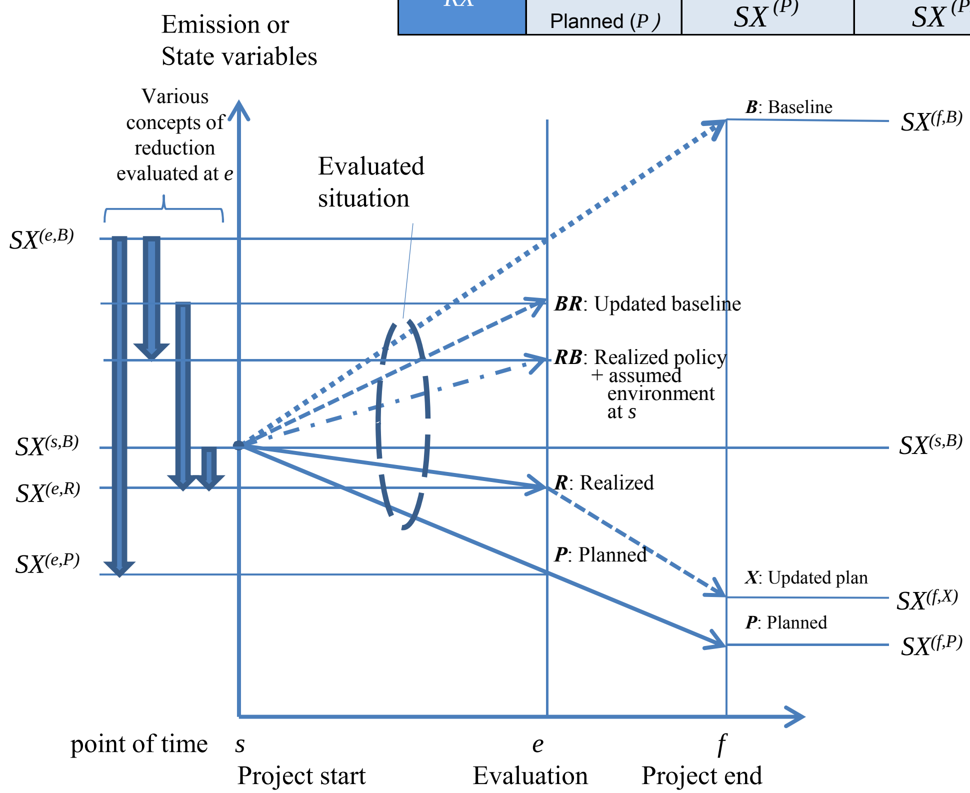
		Environmental variables ZX *e.g.* Economic growth rate, Grid power emission coefficient, etc	
		Baseline (B)	Realized (R)
Actions and measures RX	Baseline (B)	$SX^{(B)}$	$SX^{(BR)}$
	Realized (R)	$SX^{(RB)}$	$SX^{(R)}$
	Planned (P)	$SX^{(P)}$	$SX^{(PR)}$

Baseline, planned and adjusted emissions

Situation	Explanation
B	Baseline
BR	Updated baseline, or Projected situation based on planned RX and realized ZX
RB	Imaginary status with realized intervention and assumed environment situation, or projected situation based on planned RX and realized ZX
R	Realized
P	Planned

Various definitions of emission reduction

Formula of emission reduction	Explanation
$SX^{(B)}-SX^{(P)}$	: Planned reduction
$SX^{(B)}-SX^{(RB)}$	: Adjusted realized reduction with ex-ante external conditions
$SX^{(BR)}-SX^{(R)}$	: Adjusted realized reduction with realized external conditions
$SX^{(B)}-SX^{(R)}$	: Realized reduction based on baseline emission



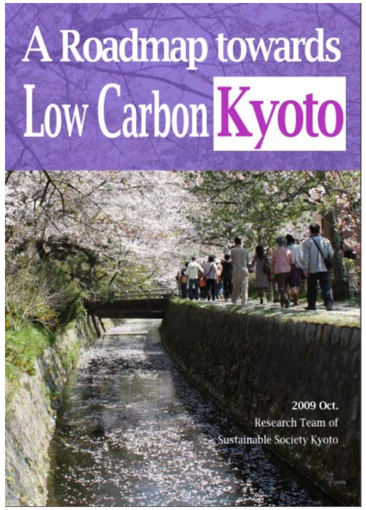
Various emission projections

Case study on ex-post evaluation of a reduction action plan

Chronicle of our Kyoto study

Year	Nation	Kyoto City	Research activity
2004		Establishment of Ordinance on " Measures against global warming in Kyoto City", the first climate change ordinance in Japan	
2006		Construction and implementation of the first round of "Actions for Combating Global Warming in Kyoto"	Start of a study on "Kyoto LCS Scenario" with ExSS, and proposed 40% emission reduction target by year 2030
2007			(continue)
2009		Selected as "Environmental Model City" by the cabinet office	Proposal of "A roadmap towards Low Carbon Kyoto" with WBS methodology and "Backcasting tool"
2010	National GHG emission reduction target: 25% from year 1990	Revision of the global warming ordinance, and set city mitigation targets as 25% emission reduction by year 2020, 40% reduction by year 2030, from year 1990	
2011	Shutdown of all nuclear power plants in Japan	The second round of "Actions for Combating Global Warming in Kyoto" was started	
2013	National GHG emission reduction target: 3.5% from year 2005		
2014			Start review study of the actions and targets, considering recent socio-economic environment
2015		Review and performance evaluation of the actions considering recent national, social, and economic circumstance	

An image of "Environmental model city Kyoto" presented by Kyoto city to the selection committee, Cabinet Office



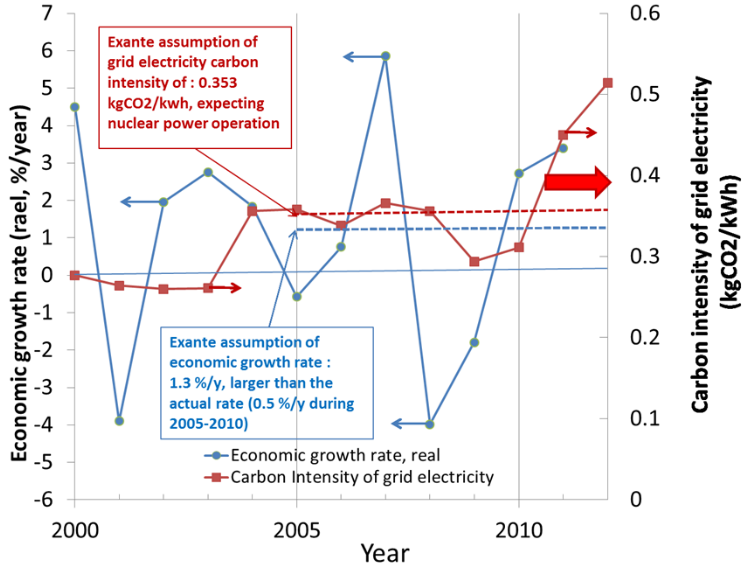
A roadmap proposed to Kyoto city for "Environmental model city Kyoto" and setting mitigation targets"

Review of the Ordinance of "Measures against global warming in Kyoto City" and re-analysis of future reduction targets

- The ordinance was established in year 2004,
  and fully revised in year 2010 which includes the following quantified targets.
- GHG emission reduction targets compared with FY1990:
  FY2010: 10% , FY2020: 25%, FY2030: 40%, FY2050: Realization of Low Carbon Society with a drastic cut of GHG emission

The actions and programs in the current policy was based on our previous study (base year 2005), and after 8 years of implementation, ex-post analysis of performance and re-analysis of future reduction targets are required, especially because of the following drastic changes of external conditions..

- Shutdown of nuclear power plants after the Fukushima accident (National government changed the target from 25% reduction to 18% of 1990 emission
- Stagnation of recent economic growth of the city. In the ex-ante projection for target setting, we used 1.3%/y for real growth rate assumption.



Analysis of CO_2 emissions by ex-post analysis

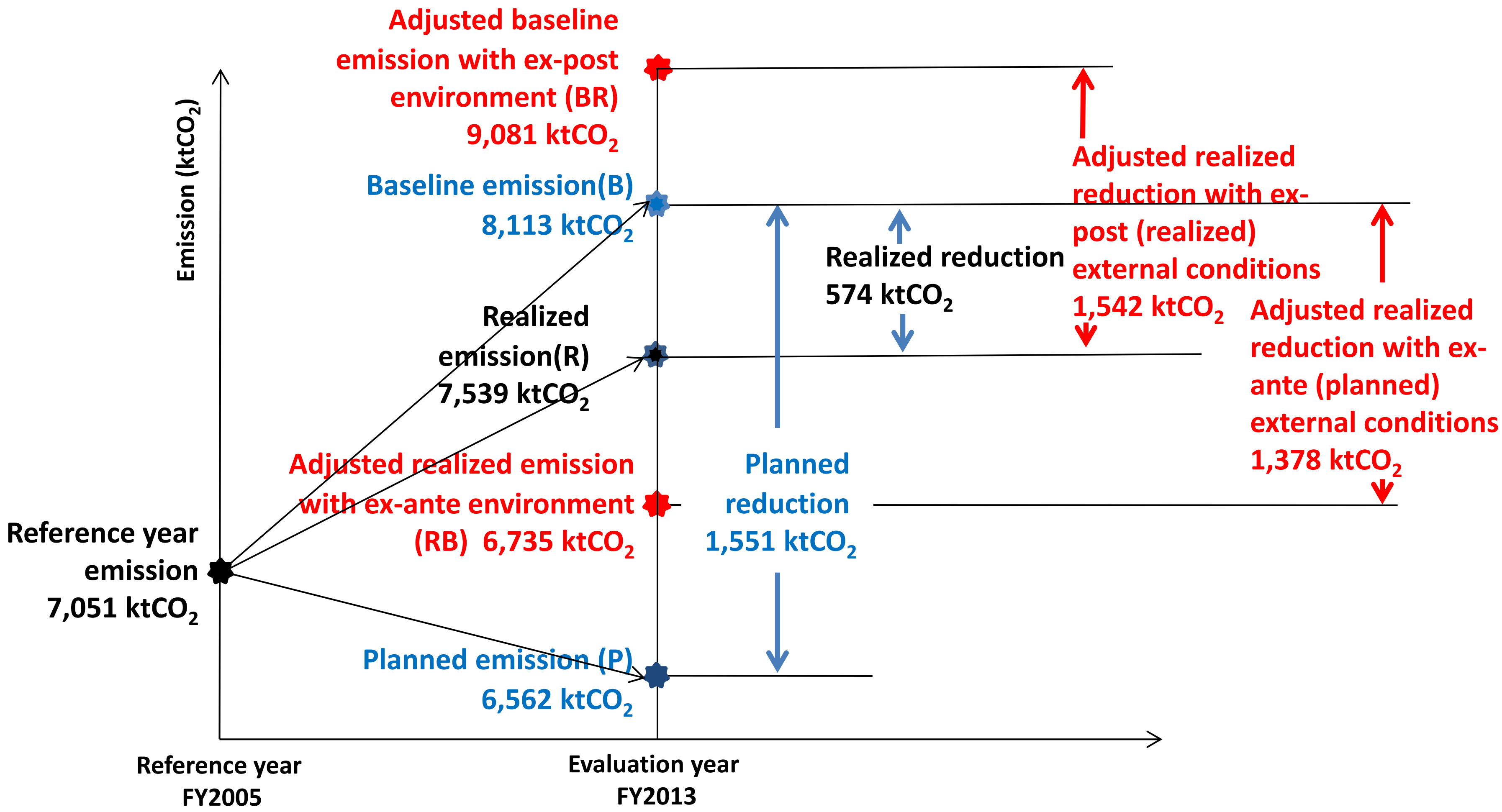
Calculation of CO_2 emissions by ex-ante and ex-post analysis in FY 2013

Year		1990	2005	2010	2013					2030	
					B	*RB*	*P*	*BR*	*R*	*B*	*P*
					Baseline	Realized actions and ex-ante environment situation	Planned	planned actions and realized environmental situation	Realized	Baseline	Planned
CO2 emission (ktCO2)	Reported by city government	7,068	7,051	6,141					7,539		
	Ex-ante analysis in 2008				8,113		6,562			8,897	4,586
	Ex-post analysis in 2015	7,062	7,051	6,141		6,735		9,081	7,539		2,294-5,478
Carbon intensity of grid electricity (kgCO2/kWh)		0.353	0.358	0.316					0.522		0.076-0.398

Calculation of emission reductions by ex-ante and ex-post analysis in FY 2013

Formula of emission reduction	Reduction in FY2013 (ktCO2)	Realized/Planned reduction (%)	Explanation
$SX^{(B)}\text{-}SX^{(P)}$	1,551		Planned reduction
$SX^{(B)}\text{-}SX^{(RB)}$	1,373	88.5%	Adjusted realized reduction with ex-ante external conditions
$SX^{(BR)}\text{-}SX^{(R)}$	1,542	99.4%	Adjusted realized reduction with realized external conditions
$SX^{(B)}\text{-}SX^{(R)}$	574	37.0%	Realized reduction based on baseline emission

Emission reductions by ex-ante and ex-post analysis

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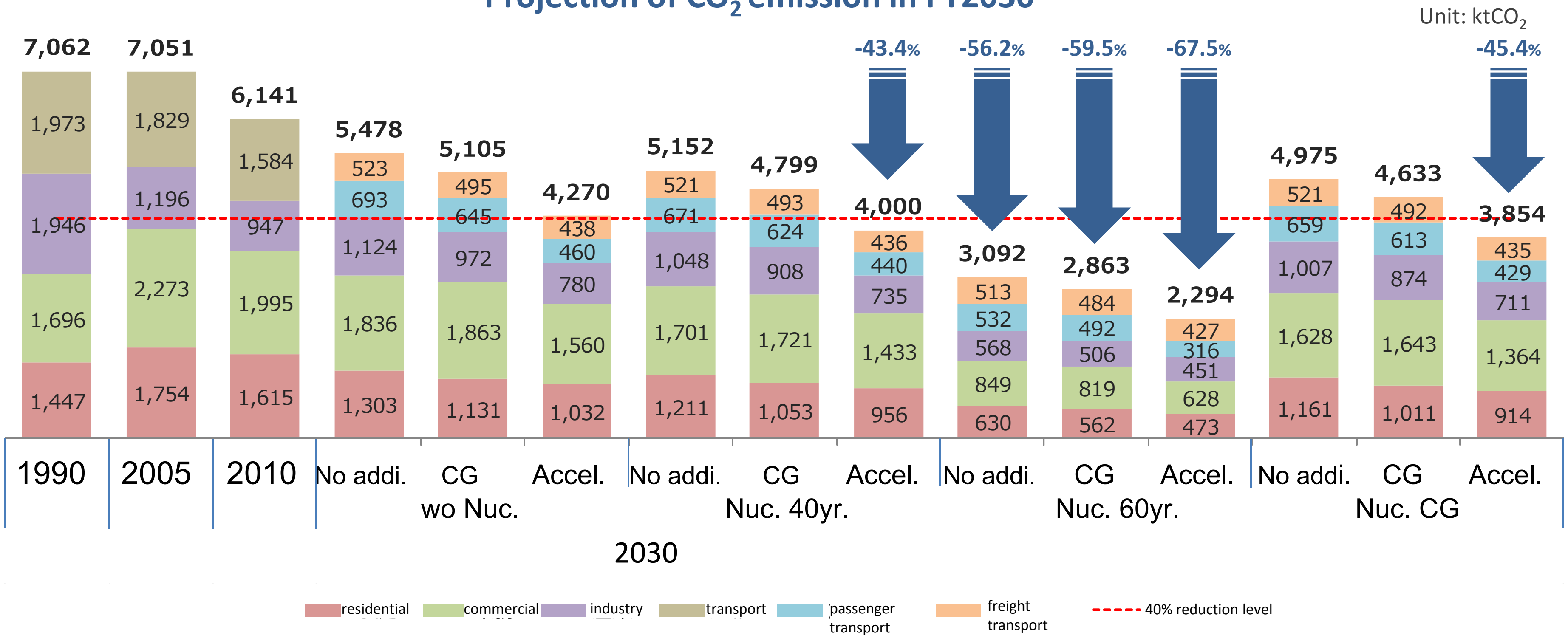
Feasibility analysis of CO_2 emission reduction target

Three scenarios of Nuc. 60yr., one scenario of Nuc. 40yr., and one scenario of Nuc. CG reach the 40% emission reduction target

Scenarios of Nuclear plants and energy demand side measures

Scenario	Content
	Scenarios of Nuclear power plants
wo Nuc.	No nuclear plants operation in year 2030
Nuc.40yr.	No additional construction of nuclear power plants, and operating life span of existing ones is 40 years. 2 plants, 13% of grid power supply in 2030, KEPCO area.
Nuc.60yr.	No additional construction of nuclear power plants, and operating life span of existing ones is 60 years. 9 plants, 50% of grid power supply in 2030, KEPCO
Nuc.CG	Scenario of Agency for Natural Resources and Energy, Central Government (2015). 21% of grid power supply in 2030
	Demand side measures
No.addi.	Introduction of no additional counter measure. Continuation of existing policy.
CG	Interpolation of a scenario based on Agency for Natural Resources and Energy, Central Government (2015).
Accel.	Aggressive introduction of feasible counter measures

Projection of CO_2 emission in FY2030



※ CO_2 from energy consumption

Final remarks

1. In the past 15 years, we have developed and applied our LCD Scenario approach to many Asian nations and local regions. Now, they reached to 8 nations and 14 regions in Asia regions.
2. Related to this, in the past AIM workshops, I reported the followings:
   16th WS: Coupling of AIM/CGE, AIM/enduse and ExSS for Pan-Asian LCS studies
   17th WS: Deployment and its explanation of our Asian regional LCS studies
   18th WS: Introduction of Low Carbon Policy-Action tools for regional LCS study
   19th WS: Overall research procedure of the LC Development Scenario approach
   20th WS: Importance of PDCA process and Ex-ante/Ex-post analysis
3. In this 21st WS, I focused on a PDCA process of regional LCS policy, and propose a methodology of systematic analysis of LCS actions/projects, and their coupling with other quantification tools.
4. Not only planning stage, but also monitoring, auditing and improving the LCS policies are crucial to make the LCS happen in the Asian region. They should be designed and managed with good rationale, efficiency, and transparency. As a next generation study in LCS research, productive and valuable fields exist, here.

Appendix

Decomposition of the change of multiplies

Consider the change of following y caused by small changes of x_is.

$$y = \prod_{i \in I} x_i \tag{1}$$

Denoting the changes of x_i and y by Δx_i and Δy, we describe Δy as a quasi linear function of Δx_i as following.

$$\Delta y = \prod_{i \in I}(x_i + \Delta x_i) - \prod_{i \in I} x_i = \sum_i DY_i \cdot \Delta x_i \tag{2}$$

Expanding the above equation, we can get;

$$\Delta y = \sum_{i \in I} \Delta x_i \cdot \left[\prod_{l \in I \setminus i} x_l + \sum_{n=1,..,\dim(I)-1} \frac{1}{n+1} \left\{ \sum_{J \in C(I \setminus i, n)} \left(\prod_{j1 \in J} \Delta x_{j1} \right) \cdot \left(\prod_{j2 \in I \setminus J \setminus i} x_{j2} \right) \right\} \right] \tag{3}$$

Where $C(I \setminus i, n)$ is a set of any combination of n element sets extracted from $I \setminus i$. For example, in case of $I = \{1,2,3,4,5\}$,

$$C(I \setminus i = 1, n = 3) = \{\{2,3,4\},\{2,3,5\},\{2,4,5\},\{3,4,5\}\}$$

The number of elements in $C(I \setminus i, n)$ is;

$$\dim(C(I \setminus i, n)) = {}_{\dim(I)-1}\mathrm{C}_n = \frac{(\dim(I)-1)!}{n! \cdot (\dim(I)-1-n)!} \tag{4}$$

And in case of $C(I \setminus i, 3), \dim(I) = 5$, it is 4.

By equation (3), DY_i is;

$$DY_i = \prod_{l \in I \setminus i} x_l + \sum_{n=1,..,\dim(I)-1} \frac{1}{n+1} \left\{ \sum_{J \in C(I \setminus i, n)} \left(\prod_{j1 \in J} \Delta x_{j1} \right) \cdot \left(\prod_{j2 \in I \setminus J \setminus i} x_{j2} \right) \right\} \tag{5}$$