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

The 21th AIM International Workshop
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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

### Characteristics

1. **Long-term** horizon, 5 to 50 years from now, the world of totally different from historical trends
   - **Note**: 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
   - **Note**: 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
   - **Note**: 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:

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>How to deal with it?</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Drastically different socio-economies in future and hard to extrapolate from historical trends</td>
<td>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</td>
</tr>
<tr>
<td>2. Strong and complex relations to nearly whole socio-economic activities</td>
<td>Cross sector analysis, such as input-output analysis, integration of sector specific modules, and so on</td>
</tr>
<tr>
<td>3. Strong relations to many policies</td>
<td>Consideration of a bundle of quantitative targets, policies, and their interactions, not only the direct reduction policies, but also related ones.</td>
</tr>
</tbody>
</table>

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

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

* 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

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

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

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

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

- Authorize task force
- Human resource, budget plan of research
- Existing policies, plans, and studies, national and regional circumstances etc.
- Timeframe, scope and boundary
- Related statistics, reports and preliminary surveys
- Adjusting of methodologies, tools and software
- Demography, macro economy, industrial structures etc.
- Define the “baseline”
- Identify parameters and indicators on GHG and non-GHG effects
- 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”.

The 21th AIM International Workshop, 2015
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.
**Strategic Level PDCA**

**LCS Action**
Every 5 to several ten year’s cycle

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

**Managerial/Tactical Level PDCA**

**LCS Program/Measure**
Every year’s cycle

- **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

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

Exogenous variables describing counter measure (action/measure)'s intensity: \( \overline{RX} = \{RX_{pm} | pm \in PM\} \)

Endogenous variables describing system behavior, including emissions and quantified targets: \( \overline{SX} = \{SX_{st} | st \in ST\} \)

Endogenous variables connecting counter measure structure and emission structure (Direct Measure), which are a part of \( \overline{SX} \): \( \overline{MX_{DM}} = \{MX_{dm} | dm \in DM\} \)

Two sets of system equations

Equation of counter measure structure: \( \overline{MX_{DM}} = GDM(\overline{ZX}, \overline{RX}) \)

Equation of emission structure: \( \overline{SX} = GSM(\overline{ZX}, \overline{MX_{DM}}) \)
A model of emission structure (1)

Simple emission model “S-model”

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

\[ G_{g,c} = A_c \cdot \sum_{s \in S(c)} \left[ i_{s,c} \cdot \left\{ \sum_{d \in D2(s)} (id_{2,d,s} \cdot sd_{2,d,s}) \right\} \cdot \left\{ \sum_{d \in D1(s)} id_{1,d,s} \cdot sd_{1,d,s} \cdot \left( \sum_{e} (ie_{e,d} \cdot i_{ge,e,c}) \right) \right\} \right] \]

where:

- \( G_{g,c} \): Emission of Gas g in sector c
- \( A_c \): Activity of sector c. Depending to ZX
- \( i_{s,c} \): Service demand intensity of service s in sector c
- \( id_{1,d,s} \): Production rate of service s by d (∈D1)
- \( sd_{1,d,s} \): Share ratio of service production device d (∈D1) in service s
- \( id_{2,d,s} \): Changing rate of service s by d (∈D2)
- \( sd_{2,d,s} \): 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), \( ie_{ne,d} = 1 \)
- \( ig_{g,d} \): Direct gas emission intensity of gas g by operating d. In this formulation, it is replaced by \( ig_{g,ne,d} \)
- \( ig_{ge,e,d} \): Emission coefficient of gas g from d and energy e. In case of e='ne'(non-energy), it is same as \( ig_{g,d} \)

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

\[ \left\{ SX_{ive \in IVE_{g,e,d1,d2}} \right\} = \left\{ A_c, i_{s,c}, id_{1,d1,s}, sd_{1,d1,s}, id_{2,d2,s}, sd_{2,d2,s}, ie_{e,d1}, ig_{ge,e,d1} \right\} \]

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

\[ G_{g,e,d1,d2} = \prod_{ive \in IVE_{g,e,d1,d2}} SX_{ive} \quad (S1) \]
A model of emission structure (2)

Simple emission model “S-model”

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

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

Where 

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

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

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

(S2)

Where, $DG_{(g,e,d1,d2),ive}$ are coefficients describing a first order dependency of $\Delta G_{g,e,d1,d2}$ to $(A_c - A_c^{(B)})$ 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 modeldifferentiates 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 (\( CM \)) : 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 \( PMs \).
A model of counter measure structure (2)

Simple counter measure model: “M-model”

Direct measures: \( DM = \{dm_{g,e,d1,d2}\} \)

Interventions corresponding to the elements of IVE except \( A_c \) in S-model, or

\[ \{dm_{g,e,d1,d2}\} = \{ive(\in IVE_{g,e,d1,d2} \setminus A_c)\} \]

7 types of \( DM \) are identified. They are:

<table>
<thead>
<tr>
<th>Intervention type</th>
<th>Explanation</th>
<th>Elements related</th>
</tr>
</thead>
<tbody>
<tr>
<td>mis</td>
<td>Intervention to service demand intensity. Increase of using efficiency of goods and material, more energy efficient lifestyle, decrease of transportation volume, are the examples.</td>
<td>( s ): service</td>
</tr>
<tr>
<td>msd 1 and msd 2</td>
<td>Promotion or Depromotion of the technology (type 1 or type 2) in order to change the device's diffusion rates.</td>
<td>( d ): device/technology</td>
</tr>
<tr>
<td>mid 1 and mid 2</td>
<td>Intervention to service production/reduction efficiency of technology (type 1 or type 2), for example, by operation and maintenance</td>
<td>( d ): device/technology</td>
</tr>
<tr>
<td>mie</td>
<td>Intervention to energy efficiency, for example, operation and maintenance improvements</td>
<td>( d ): device/technology and ( e ): energy</td>
</tr>
<tr>
<td>mige</td>
<td>Intervention to emission coefficient of energy, such as a change of electricity ( \text{CO}_2 ) emission coefficient. Also, includes intervention to direct gas emission intensity</td>
<td>( g ): gas, ( e ): energy and ( d ): technology/device</td>
</tr>
</tbody>
</table>
A model of counter measure structure (3)

Simple counter measure model: “M-model”

**Program measures**: $PM = \{pm\}$, directly reflect of implementation programs. From a viewpoint 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

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

\[
\overline{MX}_{DM} \triangleq ^{t} \left( \text{mis}_{s,c}, \text{mid}_{1_{1,s}}, \text{msd}_{1_{1,s}}, \text{mid}_{2_{2,s}}, \text{msd}_{2_{2,s}}, \text{mie}_{e,d1}, \text{mige}_{g,e,d1} \right)
\]

\[
= \left( \text{AD3} \cdot \text{I} \left[ \overline{RX}_{PM3} \right] \cdot \text{ACPM2} \cdot \overline{RX}_{PM2} + \text{AD1} \cdot \overline{RX}_{PM1} + \overline{AD0} \right) \quad (M1)
\]

where AD3, ACPM2, AD1 and AD0 are constant parameter matrix/vector, and

\[
\text{I} \left[ x \right] = \begin{pmatrix}
x_1 & 0 & 0 & 0 \\
0 & x_2 & 0 & 0 \\
0 & 0 & \cdot & 0 \\
0 & 0 & 0 & x_\cdot
\end{pmatrix}
\]

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

- **Technology selection**
  - Bottom up type engineering model for technology selection
  - *e.g.* AIM/enduse, AFOLUB

- **Projection of driving forces**
  - Top down type socio-economic-energy model for projecting driving forces
  - *e.g.* ExSS, AIM/CGE

- **M-model**
  - Simple counter measure structure model, which connects policy actions to direct interventions on emission structure

- **S-model**
  - Simple emission structure model, which connects interventions to emission structure

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

- **Programs of LCS actions and measures: RX**
  - Policy intervention: RX
  - Feedback, evaluation of actions, etc.

- **Emissions and their reductions: G, ΔG**
  - Emission reduction: AG
  - Share rate of technology d
  - Driving force of sector c

The 21th AIM International Workshop, 2015
Clarification of various emission projections for evaluating the performance of Action's and measures

Baseline, planned and adjusted emissions

<table>
<thead>
<tr>
<th>Situation</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>B</td>
<td>Baseline</td>
</tr>
<tr>
<td>BR</td>
<td>Updated baseline, or Projected situation based on planned RX and realized ZX</td>
</tr>
<tr>
<td>RB</td>
<td>Imaginary status with realized intervention and assumed environment situation, or projected situation based on planned RX and realized ZX</td>
</tr>
<tr>
<td>R</td>
<td>Realized</td>
</tr>
<tr>
<td>P</td>
<td>Planned</td>
</tr>
</tbody>
</table>

Various definitions of emission reduction

<table>
<thead>
<tr>
<th>Formula of emission reduction</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>$SX^{(B)} - SX^{(P)}$</td>
<td>Planned reduction</td>
</tr>
<tr>
<td>$SX^{(B)} - SX^{(RB)}$</td>
<td>Adjusted realized reduction with ex-ante external conditions</td>
</tr>
<tr>
<td>$SX^{(RB)} - SX^{(R)}$</td>
<td>Adjusted realized reduction with realized external conditions</td>
</tr>
<tr>
<td>$SX^{(B)} - SX^{(R)}$</td>
<td>Realized reduction based on baseline emission</td>
</tr>
</tbody>
</table>

Combinations of Environmental variables and counter measures for calculation

<table>
<thead>
<tr>
<th>Environmental variables $ZX$</th>
</tr>
</thead>
<tbody>
<tr>
<td>E.g. Economic growth rate, Grid power emission coefficient, etc</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Actions and measures $RX$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Offline (B) $SX^{(B)}$</td>
</tr>
<tr>
<td>Offline (P) $SX^{(P)}$</td>
</tr>
</tbody>
</table>

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

Chronicle of our Kyoto study

<table>
<thead>
<tr>
<th>Year</th>
<th>Nation</th>
<th>Kyoto City</th>
<th>Research activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>2004</td>
<td></td>
<td>Establishment of Ordinance on &quot;Measures against global warming in Kyoto City&quot;, the first climate change ordinance in Japan</td>
<td></td>
</tr>
<tr>
<td>2006</td>
<td></td>
<td>Construction and implementation of the first round of &quot;Actions for Combating Global Warming in Kyoto&quot;</td>
<td>Start of a study on &quot;Kyoto LCS Scenario&quot; with ExSS, and proposed 40% emission reduction target by year 2030</td>
</tr>
<tr>
<td>2007</td>
<td></td>
<td>(continue)</td>
<td></td>
</tr>
<tr>
<td>2009</td>
<td></td>
<td>Selected as &quot;Environmental Model City&quot; by the cabinet office</td>
<td>Proposal of &quot;A roadmap towards Low Carbon Kyoto&quot; with WBS methodology and &quot;Backcasting tool&quot;</td>
</tr>
<tr>
<td>2010</td>
<td>National GHG emission reduction target: 25% from year 1990</td>
<td>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</td>
<td></td>
</tr>
<tr>
<td>2011</td>
<td>Shutdown of all nuclear power plants in Japan</td>
<td>The second round of &quot;Actions for Combating Global Warming in Kyoto&quot; was started</td>
<td></td>
</tr>
<tr>
<td>2013</td>
<td>National GHG emission reduction target: 3.5% from year 2005</td>
<td>Start review study of the actions and targets, considering recent socio-economic environment</td>
<td></td>
</tr>
<tr>
<td>2015</td>
<td></td>
<td>Review and performance evaluation of the actions considering recent national, social, and economic circumstance</td>
<td></td>
</tr>
</tbody>
</table>
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 CO₂ emissions by ex-post analysis

Calculation of CO₂ emissions by ex-ante and ex-post analysis in FY 2013

<table>
<thead>
<tr>
<th>Year</th>
<th>1990</th>
<th>2005</th>
<th>2010</th>
<th>2013</th>
<th>2030</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>Realized actions and ex-ante environmental situation</td>
<td>Planned</td>
<td>planned actions and realized environmental situation</td>
<td>Realized</td>
<td>Baseline</td>
</tr>
<tr>
<td>SX(B) - SX(P)</td>
<td>7,068</td>
<td>7,051</td>
<td>6,141</td>
<td></td>
<td>7,539</td>
</tr>
<tr>
<td>SX(B) - SX(RB)</td>
<td>8,113</td>
<td>6,562</td>
<td></td>
<td>8,897</td>
<td>4,586</td>
</tr>
<tr>
<td>SX(BR) - SX(R)</td>
<td>7,062</td>
<td>7,051</td>
<td>6,141</td>
<td>6,735</td>
<td>9,081</td>
</tr>
</tbody>
</table>

| 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

<table>
<thead>
<tr>
<th>Formula of emission reduction</th>
<th>Reduction in FY2013 (ktCO₂)</th>
<th>Realized/Planned reduction (%)</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>SX(B) - SX(P)</td>
<td>1,551</td>
<td></td>
<td>Planned reduction</td>
</tr>
<tr>
<td>SX(B) - SX(RB)</td>
<td>1,373</td>
<td>88.5%</td>
<td>Adjusted realized reduction with ex-ante external conditions</td>
</tr>
<tr>
<td>SX(BR) - SX(R)</td>
<td>1,542</td>
<td>99.4%</td>
<td>Adjusted realized reduction with realized external conditions</td>
</tr>
<tr>
<td>SX(B) - SX(R)</td>
<td>574</td>
<td>37.0%</td>
<td>Realized reduction based on baseline emission</td>
</tr>
</tbody>
</table>
Emission reductions by ex-ante and ex-post analysis

Reference year emission
7,051 ktCO₂

Baseline emission (B)
8,113 ktCO₂

Reference year emission with ex-ante environment (RB)
6,735 ktCO₂

Planned emission (P)
6,562 ktCO₂

Realized emission (R)
7,539 ktCO₂

Realized reduction
574 ktCO₂

Planned reduction
1,551 ktCO₂

Adjusted baseline emission with ex-post environment (BR)
9,081 ktCO₂

Adjusted realized reduction with ex-post (realized) external conditions
1,542 ktCO₂

Adjusted realized reduction with ex-ante (planned) external conditions
1,378 ktCO₂

Reference year emission (ktCO₂)

Evaluation year
FY2013

Reference year FY2005

The 21th AIM International Workshop, 2015
Feasibility analysis of CO₂ 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.
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.
Decomposition of the change of multiplies

Consider the change of following $y$ caused by small changes of $x_i$s.

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

Denoting the changes of $x_i$ and $y$ by $\Delta x_i$ and $\Delta y$, we describe $\Delta y$ as a quasi linear function of $\Delta x_i$ as following.

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

Expanding the above equation, we can get;

$$\Delta y = \sum_{i \in I} \Delta x_i \left[ \prod_{j \not\in I} x_j + \sum_{n=1}^{\text{dim}(I) - 1} \frac{1}{n+1} \left( \sum_{J \subset C(I\setminus i,n)} \left( \prod_{j \in J} \Delta x_j \right) \cdot \left( \prod_{j \not\in J} x_j \right) \right) \right]$$ (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;

$$\text{dim}(C(I \setminus i, n)) = C_n = \frac{(\text{dim}(I) - 1)!}{n! \cdot (\text{dim}(I) - 1 - n)!}$$ (4)

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

By equation (3), $DY_i$ is;

$$DY_i = \prod_{j \not\in J} x_j + \sum_{n=1}^{\text{dim}(I) - 1} \frac{1}{n+1} \left( \sum_{J \subset C(I\setminus i,n)} \left( \prod_{j \in J} \Delta x_j \right) \cdot \left( \prod_{j \not\in J} x_j \right) \right)$$ (5)

The 21th AIM International Workshop, 2015