AIM activities for assessing emissions of Long-Lived GHGs and Short-Lived Climate Pollutants by AIM/Enduse[Global] model

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1. Overview of AIM activities for assessing emissions of Short-lived climate pollutants (SLCPs) and Long-Lived GHGs (LLGHG)

2. Overview of AIM/Enduse[Global] and its scenarios

3. Comparison between GAINS & AIM/Enduse

4. Example results by AIM/Enduse – what we can analyze & what we cannot analyze
AIM models for mitigation analysis
- role of the AIM/Enduse model -

Top-down approach
- AIM/Material
- AIM/Extended Snapshot

Hybrid approach
- AIM/Backcast
- AIM/Energy Snapshot

Bottom-up approach
- AIM/Enduse[Country]

Global scale
- AIM/Impact[Policy]

National scale
- AIM/CGE[Country]

- AIM/CGE[Global]

Model Output

- Global emission paths to climate stabilization
- Mitigation potentials and costs curves
- Macro-economic driving forces
- Industrial production, transportation volume, etc

Element / transition (service demand)
MOEJ-S12: Promotion of climate policies by assessing environmental impacts of SLCP and seeking LLGHG emissions pathways (FY2014-FY2018)

Goal: To develop an integrated evaluation system for LLGHG and SLCP mitigation policy, by interconnecting emission inventory, integrated assessment models, and climate models.

**Theme 1: Air quality change event analysis**
- Analysis on regional AQ change
- Development of emission inventory
- Inversion algorithms of emission estimation

**Theme 2: Integrated model and future scenarios**
- Global socio-economic scenarios
- National & regional emissions scenarios
- Urban & household emissions AQ assessment

**Theme 3: SLCP impacts on climate & environment**
- Impact assessment of aerosols & GHG
- Assessment of health, agriculture, water cycle, sea level rise

**Theme 4: Integrated operation system (Toolkits, data archive)**
- CCAC, UNFCC, IPCC, EANET
- Proposal and assessment of climate and air pollution policies
- MDG, SDG, Future Earth

**Integrated Assessment Model (AIM)**
- Improved emission inventory
- SLCP emissions scenarios
- Climate and Environment Model
- Assessment of activities/policies
- Feedback of impacts

**Chemical transfer model and emission inventory in Asia**
- AIM/Enduse model
  - Socio-economical & emissions scenario
- Climate model, earth system model
  - Climate change impact & adaptation
1. - To indicate socio-economic scenarios considering climate change and environmental impacts and
   - To present emissions scenarios of Long-lived GHG (LLGHG) and Short lived Climate Pollutant (SLCP).
     【global/national/local scales】

2. - To evaluate co-benefits of LLGHG mitigation measures and SLCP reduction measures and
   - To analyze regional characteristics in Asia, in a manner consistent with long-term global scenarios such as achieving 2°C global temperature change limit target and halving global GHG emissions by 2050.
     【national/regional scales in Asia】
S-12 Theme 2: Improvement of Integrated Assessment Model and Quantification of Future Scenarios

Sub-theme (1)
- Socio-economic scenario considering climate & Env. Impact
- Global model AIM/CGE
- Assessment of mitigation costs & climate change impacts

Sub-theme (2)
- Future socio-economic scenarios
- Global model AIM/Enduse
- Improvement of Enduse (Local activities & Pollution Management Technologies)
- National emissions scenarios on LLGHG • SLCP

Sub-theme (3)
- Local emissions scenarios on LLGHG • SLCP
- Household Model
- Local Air pollution model

Key:
- Green: Relation to other Theme
- Orange: Relation to Env. policies

- Env. & Climate Impacts
- Theme 3: Env. & Climate Impacts
- Theme 4: Synthesis system
- Emission inventory
- Improved inventory
- Env. & climate Policy in Japan

- Future Scenarios
- Research goals

- AIM models
Overview of AIM/Enduse model

- Bottom-up type model with detailed technology selection framework with optimization
- Recursive dynamic model
- Assessing technological transition over time
- Analyzing effect of policies such as carbon/energy tax, subsidy, regulation and so on.

- Target Gas: Multiple gases
  \( \text{CO}_2, \text{CH}_4, \text{N}_2\text{O}, \text{HFCs}, \text{PFCs}, \text{SF}_6, \text{SO}_2, \text{NOx}, \text{CFCs}, \text{HCFCs}, \text{etc} \)

- Target Sectors: multiple sectors
  - power generation sector, industry sector, residential sector, commercial sector, transport sector, agriculture sector, municipal solid waste sector, fugitive emissions sector, F-gas emissions sector
  - (each of these can be further disaggregated into sub-sectors)
AIM/Enduse [Global]
- Regional Classification -

E.g.) Comparison to GAINS 25 Regions

<table>
<thead>
<tr>
<th>AIM/Enduse</th>
<th>GAINS</th>
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</thead>
<tbody>
<tr>
<td>ASIA</td>
<td>Japan, China+, India, Indonesia+, Korea, SE Asia, Rest S Asia, Asia-STAN</td>
</tr>
<tr>
<td>ASEAN</td>
<td>Indonesia, SE Asia</td>
</tr>
<tr>
<td>Annex I</td>
<td>Japan, Oceania, USA, Canada, Western EU, Central EU, Turky, Ukraina+, Russia +</td>
</tr>
</tbody>
</table>

World
32 regions

Annex I (exact)

- OECD (approx)
  - KOR (Korea)
  - MEX (Mexico)
  - BRA (Brazil)
  - ARG (Argentina)
  - XLM (Other Latin America)
  - ZAF (South Africa)
  - XAF (Other Africa)
  - XME (Middle East)

- ASEAN (exact)
  - JPN (Japan)
  - AUS (Australia)
  - NZL (New Zealand)
  - RUS (Russia)
  - CHN (China)
  - IND (India)
  - IDN (Indonesia)
  - THA (Thailand)

- USA (United States)
- XE15 (Western EU-15)
- XE10 (Eastern EU-10)
- XE2 (Other EU-2)
- XSA (Other South Asia)
- XEA (Other East Asia)
- XSE (Other South-East Asia)
- MYS (Malaysia)
- VNM (Viet Nam)
- CAN (Canada)
- TUR (Turkey)
- XEI (Other South-East Asia)
- XENI (Other EU)
- XCS (Central Asia)
- XOC (Other Oceania)
# AIM/Enduse[Global]
## - Target Gases and Sectors -

<table>
<thead>
<tr>
<th>GHG</th>
<th>Sector</th>
<th>Sub sectors whose mitigation actions are considered in Enduse model (other subsectors are treated as scenario)</th>
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<tbody>
<tr>
<td>CO₂</td>
<td>Power generation</td>
<td>Coal power plant, Oil power plant, Gas power plant, Renewable (Wind, Biomass, PV)</td>
</tr>
<tr>
<td>CH₄</td>
<td>Industry</td>
<td>Iron and steel, Cement Other industries (Boiler, motor etc)</td>
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<tr>
<td>N₂O</td>
<td>Transportation</td>
<td>Passenger vehicle, Truck, Bus, Ship, Aircraft, Passenger train, Freight train (except for pipeline transport and international transport)</td>
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<tr>
<td>SO₂</td>
<td>Residential and &amp; Commercial</td>
<td>Cooling, Heating, Hot-water, Cooking, Lighting, Refrigerator, TV</td>
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<tr>
<td>NOₓ</td>
<td>CH₄</td>
<td>Agriculture</td>
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<tr>
<td>BC</td>
<td>N₂O</td>
<td>MSW</td>
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<td>PM</td>
<td>CH₄</td>
<td>Fugitive</td>
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<tr>
<td>ODSs, HFCs, PFCs, SF₆</td>
<td>Fgases emissions</td>
<td>By-product of HCFC-22, Refrigerant, Aerosol, Foams, Solvent, Etching, Aluminum production, Insulation gas, others.</td>
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<tr>
<th>CO₂</th>
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<th>N₂O</th>
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Emission factors can be set by energy, by sector and by region over time. Settings on technology options are the same, too.

- ✔️: Updated & elaborating
- *: On-going updating
AIM/Enduse[Global] and element models

Service demand models
- Transportation Demand Model
- Household Lifestyle Model
- Municipal Solid Waste Model
- Agricultural Prod & Trade model
- Fluorocarbon Emission Model

Energy Resource DB
- Coal
- Oil
- Gas
- Nuclear
- Hydro
- Geothermal
- Solar
- Wind
- Biomass

Energy Supply sector
- Electricity
- Solid fuel
- Liquid fuel
- Gas fuel
- Heat
- Hydrogen

Energy mining sector

Emissions

Macro-economic model
- Socio-economic scenario
- Population & Household number
- GDP & Sector value added

Socio-economic scenario
- Energy Supply sector
- Energy mining sector

Database
- Variable
- Model
- Database

Energy Resource DB
- Energy price
- Emission factor

Technology DB
- Cost
- Efficiency
- Lifetime
- Diffusion rate
Future Socio-economic settings

e.g.) GDP growth per capita in each country

- China
- India
- ASEAN

Considering various features of different socio-economic scenarios
Modeling future service demands

E.g.) Passenger transport volume estimation mode

Considering socio-economic features to future service demand estimations in each sector and country (i.e. POP, GDP, are consistent across sectors and countries)
By energy, sector and country, we can set various constraints such as
- Technology settings in the base year
- Energy balance in the base year
- Technology diffusion rate
- Speed of technology diffusion rate
- Technology constraints
- Energy constraints
- Speed of energy efficiency improvement
- Technology cost
- Technology costs improvement etc

Selecting technologies to satisfy future service demands and to balance supply and demand, by sector, by country under various constraints & under minimizing total system costs.
Future Scenario settings

Case 1) Reference scenario (GHG mitigations under BaU & no pollution control measures)
Case 2) Technological mitigation measures under emissions pathways constraints at 2 °C, 2.5°C, and 3°C reported by UNEP Emission Gap Report
Case 3) Technological mitigation measures under carbon pricing scenarios, considering the current useful references of carbon pricing such as
   - EU-ETS carbon prices fluctuated due to global economic change, and varied around 15-30 EURO/tCO₂.
   - The price of CER for CDM projects also fluctuated around 10-20 EURO/tCO₂.
   - Due to the economic recession, the carbon price decreased, around 1 - 5 EURO/tCO₂.
   - Upper limits of carbon price of EU-ETS penalty price is 100 EURO/tCO₂.
   - IEA (2010) reported carbon price is at 175 US$/tCO₂ in the 450 ppmv scenario.

Future global economy-wide carbon prices scenarios (US$/tCO₂)

<table>
<thead>
<tr>
<th>Scenario name</th>
<th>2013</th>
<th>2020</th>
<th>2030</th>
<th>2040</th>
<th>2050</th>
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<tbody>
<tr>
<td>Reference</td>
<td>0</td>
<td>0</td>
<td>0</td>
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<tr>
<td>50 US$/tCO₂</td>
<td>3.75</td>
<td>12.5</td>
<td>25</td>
<td>37.5</td>
<td>50</td>
</tr>
<tr>
<td>100 US$/tCO₂</td>
<td>7.5</td>
<td>25</td>
<td>50</td>
<td>75</td>
<td>100</td>
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<tr>
<td>200 US$/tCO₂</td>
<td>15</td>
<td>50</td>
<td>100</td>
<td>150</td>
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<tr>
<td>400 US$/tCO₂</td>
<td>30</td>
<td>100</td>
<td>200</td>
<td>300</td>
<td>400</td>
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</table>

- Increase from the range of current carbon price up to 50US$/tCO₂
- Increase from the range of current carbon price up to EUETS penalty price
- Increase from the carbon price before economic recession, up to IEA assumption
AIM/Enduse[Global] in global 32 regions
Baseline emissions from fuel combustion & industry in Asia

- **CO₂**
  - Asia
  - China
  - India
  - ASEAN

- **SO₂**
  - Asia
  - ASEAN

- **NOₓ**
  - Asia
  - ASEAN
Comparison with GAINS results
- Reference CH4 emissions -

- Major emission sources of CH4 are not from fuel combustion. Thus, we need to carefully see sectors such as agriculture, waste and fugitive emissions.
- Another major difference is that AIM/Enduse includes “no regret” in this reference scenario.
Example of CH₄ emission estimation
How to estimate MSW generation in Asia?

How to estimate future MSW generations in Asia? Asia will follow historical US trend? Japan trend or the average trend of developed countries?

Note) Data include Japan, China, Thailand, USA, EU27 & Chinese provinces.
Comparison with GAINS results
- Reference SO2 emissions -

- Major differences are how to estimate future energy service demands, how to set emission factors by fuel and by country, and how to consider fuel policies and air pollution control policies in the future scenario.

- The results in the AIM/Enduse[Global] model does include neither fuel policies nor air pollution control policies in the reference scenario.
Comparison with GAINS results
- Reference NOx emissions -

- Major differences are how to estimate future energy service demands, how to set emission factors by fuel and by country, and how to consider fuel policies and air pollution control policies in the future scenario.
- The results in the AIM/Enduse[Global] model does include neither fuel policies nor air pollution control policies in the reference scenario.
Comparison with GAINS results
- Reference PM & BC emissions -

Large uncertainties & large gaps maybe due to settings of EF and pollution control measures?
6 GHGs emissions pathways in Asia and comparison with 2 °C target pathways

- Emissions constraints of achieving 2°C-3°C were calculated based on UNEP Gap Report
- Future global economy-wide carbon prices scenarios (US$/tCO₂)

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</table>

Source) modified from Hanaoka et al, Environmental Pollution (2014)
There are large reduction potentials of air pollutants and SLCPs, due to GHG mitigation actions such as drastic fuel shifts and energy efficiency improvement. (e.g. 60～90% reductions compared to baseline in 2050)

Source) modified from Hanaoka et al, Environmental Pollution (2014)
SLCP & Air pollutants reduction potentials in Asia - Cobenefits of implementing CO2 mitigation policies -

Features of reduction potentials are different by energy type, by gas type and by sector, e.g.)
- Sox: Power & industry
- Nox: transport and power
- BC: power and transport

There is a limitation of large reductions only by fuel shifts and energy efficiency improvements

--- Reference scenario
- 2°C scenario
- Industry
- Transport
- Residential & Commercial
- Energy supply
- Others

Source) modified from Hanaoka et al, Environmental Pollution (2014)
What AIM/Enduse can & cannot do for Global Emissions Scenarios Comparison

AIM/Enduse can discuss
- Estimating future emissions scenarios both LLGHGs, SLCPs and air pollutants, quantitatively up to 2050.
- Analysing abatement actions by technology, by sector and by country under carbon tax, energy tax, subsidies, etc
- Analysing technology selections under various constraints such as emissions pathways constraint, energy supply constraint, technology diffusions, etc
- Discussing mitigation costs and required initial investments

AIM/Enduse cannot discuss
- Considering “spill-over effects” and “rebound effects” such as changes in the industrial structure, changes of service demands and changes in technology and energy price.
- Considering GDP losses due to GHG mitigation actions and pollutants abetment actions
- Considering land use change and its corresponding open biomass burnings
Conclusion

◆ Mitigation measures of energy efficiency improvement on the demand side and the shift to less-or non-carbon energies on the supply side play important roles in reducing CO₂ emissions as well as increasing cobenefits of SO₂ and NOx emissions reductions.

◆ Energy shift in energy supply sector largely contribute to reducing GHGs as well as SO₂ in Asia. However, NOx are derived from transport as well as energy supply, and there are limitations to shifting from fuel vehicles to Hybrid, plug-in Hybrid, electric vehicles in developing countries.

◆ One caveat in this study is that, to focus on cobenefits of reducing air pollutants by introducing GHG mitigation measures, air pollutant control policies and fuel policies are not considered in this study. It is also possible to include these impacts into the Enduse model analysis in the further study.

◆ There is a limitation of reducing SLCPs and air pollutants only by fuel shifts and energy efficiency improvements from the viewpoint of low carbon measures, thus it is also required to consider policies such as air pollutant control measures and low sulfur content fuel policies.
Timing is important!

Thank you for your attention!

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