Scenarios of Energy and Air quality in Northeast Asia: data linkage and harmonization

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A process of converting energy IAM data to GAINS and further

- **Activity projections**
  - IAMs
  - Energy
  - Transport
  - Industry
  - Agriculture
  - Waste

- **Emission scenarios**
- **GAINS**
  - EmisFactors
  - CostFactors
  - Controls
  - Policies
  - 0.1° x 0.1°
  - Urban vs. rural
  - Low vs. high

- **Spatial distribution & Transfer-coefficients**
  - GAINS
  - IERs (GBD)
  - Demography

- **Concentrations & Health impacts**
  - GAINS
## AQNEA: A set of scenarios by countries and the source IAM

<table>
<thead>
<tr>
<th>Country</th>
<th>IAM; Integrated Assessment Model Framework</th>
<th>Scenario group</th>
<th>Scenario in IAM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Korea</td>
<td>GUIDE-METER</td>
<td>Baseline</td>
<td>BAU</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Middle scenario</td>
<td>Stated Policies (Outdated NDC)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Net-Zero</td>
<td>Net Zero</td>
</tr>
<tr>
<td>Japan</td>
<td>AIM/Hub-Japan 2.4</td>
<td>Baseline</td>
<td>Baseline</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Middle scenario</td>
<td>26% by 30 + 80% by 50</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Net-Zero</td>
<td>46% by 30 + 100% by 50</td>
</tr>
<tr>
<td>China</td>
<td>MESSAGEix-GLOBIOM 1.1-M-R12</td>
<td>Baseline</td>
<td>Baseline</td>
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<tr>
<td></td>
<td></td>
<td>Middle scenario</td>
<td>2-degree</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Net-Zero</td>
<td>Carbon neutrality</td>
</tr>
<tr>
<td>Rest of NE Asia</td>
<td>IIASA GAINS</td>
<td>Baseline</td>
<td>Baseline+Stated Policies</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Middle scenario</td>
<td>Proposed Pledges</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Net-Zero</td>
<td>Net Zero</td>
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</table>
Matrix system to set-up GAINS scenarios

<table>
<thead>
<tr>
<th></th>
<th>SSP1-1.9</th>
<th>SSP1-2.6</th>
<th>SSP2-4.5</th>
<th>SSP3-7.0</th>
<th>SSP3-LowNTCF</th>
<th>SSP3-LowNTCF-CH4</th>
<th>SSP5-8.5</th>
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</thead>
<tbody>
<tr>
<td><strong>Air pollution strategy</strong></td>
<td>MFR</td>
<td>MFR</td>
<td>CLE</td>
<td>CLE</td>
<td>MFR</td>
<td>MFR</td>
<td>CLE</td>
</tr>
<tr>
<td><strong>VOC pathway</strong></td>
<td>Baseline</td>
<td>Baseline</td>
<td>Baseline</td>
<td>Baseline</td>
<td>Baseline</td>
<td>Baseline</td>
<td>Baseline</td>
</tr>
<tr>
<td><strong>Agriculture pathway</strong></td>
<td>Healthy diet</td>
<td>Efficient N-use</td>
<td>Baseline</td>
<td>Baseline</td>
<td>Baseline</td>
<td>Mitigation</td>
<td>Baseline</td>
</tr>
<tr>
<td><strong>Forest fires</strong></td>
<td>Mitigation</td>
<td>Mitigation</td>
<td>Baseline</td>
<td>Baseline</td>
<td>Mitigation</td>
<td>Mitigation</td>
<td>Baseline</td>
</tr>
<tr>
<td><strong>Shipping pathway/controls</strong></td>
<td>MFR</td>
<td>MFR</td>
<td>CLE</td>
<td>CLE</td>
<td>MFR</td>
<td>MFR</td>
<td>CLE</td>
</tr>
<tr>
<td><strong>Emission factors</strong></td>
<td>LowN</td>
<td>LowN</td>
<td>Base</td>
<td>Base</td>
<td>Low</td>
<td>Low</td>
<td>Base</td>
</tr>
</tbody>
</table>
GAINS Explorer

: Infrastructure to process global, regional, and national scenarios for further analysis and intercomparison in the GAINS model

**Data Sources**
- KOREA
  - GUIDE_METER
- JAPAN
  - AIM_Japan
- CHINA
  - MESSAGEix_China
  - GCAM

**ETL**
- Extracted Data

**GAINS**
- Pollutant Management
  - Multi sectoral pathway data
  - Emission factors
  - Control Strategies
  - Costs
  - Impacts
  - Geotiff Map services

**Web App. And Services**
- DATA EXPORT API

**Extracted Data**
- Activity
- Emissions
- Costs
- Impacts

**ETL Scenario definition metadata and importing scripts**

**ETL**
- Extract, Transform, Load
Processing of scenario data into the GAINS model structure for China, Japan, and S. Korea

- **IAMs**
  IAM_Japan (national)
  MESSAGE_China (national)
  GUIDE_Korea (17 subregions)

- **Sectoral mapping**
  - IAMs variables to the GAINS sectors & fuels
  - limited to energy projections
  - one mapping matrix for all models

- **Regional mapping**
  - IAMs (sub)regions / provinces to the GAINS regions
  - model-specific regional matrixes

- **Proportional downscaling**
  - based on existing patterns in GAINS
  - missing projections derived from macroeconomic parameters
  - or defaults are used (non-energy sectors)

- **Data exchange**
  - a common format for all models
  - compatible with the AR6/IAMC reporting protocol (template)
  - completeness check
### Mapping of IAMC format to the GAINS structure

<table>
<thead>
<tr>
<th>IAM_SOURCE_VARIABLE</th>
<th>SOURCE_UNIT</th>
<th>GAINS_SECTOR</th>
<th>GAINS_ACTIVITY</th>
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</thead>
<tbody>
<tr>
<td>Primary Energy</td>
<td>Gas</td>
<td>Electricity</td>
<td>w/ CCS</td>
</tr>
<tr>
<td>Primary Energy</td>
<td>Gas</td>
<td>Electricity</td>
<td>w/o CCS</td>
</tr>
<tr>
<td>Primary Energy</td>
<td>Oil</td>
<td>Electricity</td>
<td>w/ CCS</td>
</tr>
<tr>
<td>Primary Energy</td>
<td>Oil</td>
<td>Electricity</td>
<td>w/o CCS</td>
</tr>
<tr>
<td>Primary Energy</td>
<td>Biomass</td>
<td>Electricity</td>
<td>w/ CCS</td>
</tr>
<tr>
<td>Primary Energy</td>
<td>Biomass</td>
<td>Electricity</td>
<td>w/o CCS</td>
</tr>
<tr>
<td>Primary Energy</td>
<td>Coal</td>
<td>Electricity</td>
<td>w/ CCS</td>
</tr>
<tr>
<td>Primary Energy</td>
<td>Coal</td>
<td>Electricity</td>
<td>w/o CCS</td>
</tr>
<tr>
<td>Primary Energy</td>
<td>Nuclear</td>
<td></td>
<td></td>
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<tr>
<td>Primary Energy</td>
<td>Geothermal</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Primary Energy</td>
<td>Hydro</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Primary Energy</td>
<td>Solar</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Primary Energy</td>
<td>Wind</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Power sector**

| Final Energy | Industry | Gases | EJ/yr | IN_ISTE, IN_CHEM, IN_NMMI, IN_PAP, IN_OTH | GAS |
| Final Energy | Industry | Liquids | EJ/yr | IN_ISTE, IN_CHEM, IN_NMMI, IN_PAP, IN_OTH | MD, HF, LPG, GSL |
| Final Energy | Industry | Solids | Biomass | EJ/yr | IN_ISTE, IN_CHEM, IN_NMMI, IN_PAP, IN_OTH | FWD, ARD, CHCO, WST |
| Final Energy | Industry | Solids | Coal | EJ/yr | IN_ISTE, IN_CHEM, IN_NMMI, IN_PAP, IN_OTH | ELE |
| Final Energy | Industry | Heat | EJ/yr | IN_ISTE, IN_CHEM, IN_NMMI, IN_PAP, IN_OTH | HT |
| Final Energy | Industry | Hydrogen | EJ/yr | IN_ISTE, IN_CHEM, IN_NMMI, IN_PAP, IN_OTH | H2 |
| Final Energy | Industry | Other | EJ/yr | IN_ISTE, IN_CHEM, IN_NMMI, IN_PAP, IN_OTH | GTH, SPV, STH |

**Domestic**

| Final Energy | Residential and Commercial | Gases | EJ/yr | DOM_URB, DOM_RUR, DOM_COM, DOM_OTH | GAS |
| Final Energy | Residential and Commercial | Liquids | EJ/yr | DOM_URB, DOM_RUR, DOM_COM, DOM_OTH | MD, HF, LPG, GSL |
| Final Energy | Residential and Commercial | Solids | Biomass | EJ/yr | DOM_URB, DOM_RUR, DOM_COM, DOM_OTH | FWD, ARD, CHCO, WST |
| Final Energy | Residential and Commercial | Solids | Coal | EJ/yr | DOM_URB, DOM_RUR, DOM_COM, DOM_OTH | ELE |
| Final Energy | Residential and Commercial | Electricity | EJ/yr | DOM_URB, DOM_RUR, DOM_COM, DOM_OTH | HT |
| Final Energy | Residential and Commercial | Heat | EJ/yr | DOM_URB, DOM_RUR, DOM_COM, DOM_OTH | H2 |
| Final Energy | Residential and Commercial | Hydrogen | EJ/yr | DOM_URB, DOM_RUR, DOM_COM, DOM_OTH | GTH, SPV, STH |

**Transport**

| Final Energy | Transportation | Hydrogen | EJ/yr | TRA_RD_LD, TRA_RD_HD | H2 |
| Final Energy | Transportation | Electricity | EJ/yr | TRA_RD_LD, TRA_RD_HD, TRA_OT | ELE |
| Final Energy | Transportation | Gases | EJ/yr | TRA_RD_LD, TRA_RD_HD, TRA_OT | GAS |
| Final Energy | Transportation | Liquids | Oil | EJ/yr | TRA_RD_LD, TRA_RD_HD, TRA_OT | MD, GSL, LPG, HF |
| Final Energy | Transportation | Liquids | Oil | Shipping | EJ/yr | TRA_OTS | HF, MD |

**Others**

| Primary Energy | Gas | Convert | EJ/yr | CON_COMB, CON_BO, CON_LOSS | GAS |
| Primary Energy | Oil | Convert | EJ/yr | CON_COMB, CON_BO, CON_LOSS | MD, HF, LPG, GSL |
| Primary Energy | Biomass | Convert | EJ/yr | CON_COMB, CON_BO, CON_LOSS | FWD, ARD |
| Primary Energy | Coal | Convert | EJ/yr | CON_COMB, CON_BO, CON_LOSS | HC, BC |
| Final Energy | Non-Energy Use | Coal | EJ/yr | NONEN | GAS |
| Final Energy | Non-Energy Use | Oil | EJ/yr | NONEN | HC, MD, LPG |
| Final Energy | Non-Energy Use | Gas | EJ/yr | NONEN | GAS |
| Final Energy | Non-Energy Use | Biomass | EJ/yr | NONEN | FWD, WST |
| Primary Energy | Oil | Liquids | EJ/yr | PRI_REF | NOF |
| Resource | Extraction | Coal | EJ/yr | MINE_BC, MINE_HC | NOF |
| Resource | Extraction | Gas | EJ/yr | PROD | GAS |
| Resource | Extraction | Oil | EJ/yr | PROD | CRU |
| GDP | MER | | | | MACRO |
| Population | | | | | ANY |

| GDP | MER | | | | MACRO |
| Population | | | | | ANY |
From Energy IAM to GAINS
: Energy and AQ scenario pathways setup

Energy IAM data in GAINS format

Energy activity
1) Baseline
2) NDC(Old)
3) Net-Zero

Energy

2020
2050

Policy-Technology in GAINS

Control Strategy

2020
2050

1) Current Legislation (CLE)
2) Control (MFR)

Data in GAINS

Emission Factor

Future Scenario Pathways

6 Scenario Emissions

Base_CLE
Base_MFR
NDC_CLE
NDC_MFR
NetZero_CLE
NetZero_MFR

Energy activity
Policy-Technology
Data in GAINS
Future Scenario Pathways

Energy IAM data in GAINS format

Energy activity
1) Baseline
2) NDC(Old)
3) Net-Zero

Energy

2020
2050

Policy-Technology in GAINS

Control Strategy

2020
2050

1) Current Legislation (CLE)
2) Control (MFR)

Data in GAINS

Emission Factor

Future Scenario Pathways

6 Scenario Emissions

Base_CLE
Base_MFR
NDC_CLE
NDC_MFR
NetZero_CLE
NetZero_MFR
Result: AQNEA Future Energy Scenario Pathways and CO₂ emissions

China/S.Korea/Japan

Energy
Unit: PJ/yr

Emissions
Unit: Mt CO₂

A: Baseline  B: NDC  C: Net-Zero
Result: AQNEA Future Energy Scenario Pathways and CO₂ emissions

N.Korea / Mongolia / A.Russia

Energy
Unit: PJ/yr

Emissions
Unit: Mt CO₂

A: Baseline  B: NDC  C: Net-Zero
Result: Air Pollutant Abatement in AQNEA Countries

China_PM2.5

S.Korea_NOx

Japan_NOx

N.Korea_SO2

Mongolia_SO2

Unit: kton/yr
AQNEA: Ambient PM2.5 concentrations
 Calculations by the GAINS model

- CLE would not resolve the remaining air quality problems by 2050.
- The remaining elevated concentrations under Net-Zero + MFR (Maximum Feasible Reduction) are largely of natural origin.
AQNEA: Source Contribution of Ambient PM2.5 concentrations: Calculations by the GAINS model

Seoul (Republic of Korea)

Busan (Republic of Korea)

Timestamp: 20230125-140011
Scenario: AQNEA_NDC_CLE
Year: 2020
GAINS Region: KORS_SEOI
Ind road dust resusp (June2019)
Summary

- Energy IAM exported data were converted GAINS activity data format for AQNEA countries
- Integrated analysis in GAINS, such as emissions, air quality, health impact could be conducted
- Stringent air pollution control scenario, MFR, show significant reductions, especially in baseline scenario of a developing country
- Ambient air quality with source contribution analysis show a reasonable agreement with monitoring data and could give some insight of domestic vs transboundary contribution
- Continue to improve harmonization and linkage for AQNEA stage2
• GAINS model

Access to the model:
http://gains.iiasa.ac.at/models/index.html

Tutorial:

• Scenario Explorer

Access to the system:
https://data.ece.iiasa.ac.at/aqnea-internal/#/workspaces
Thank you for your time.