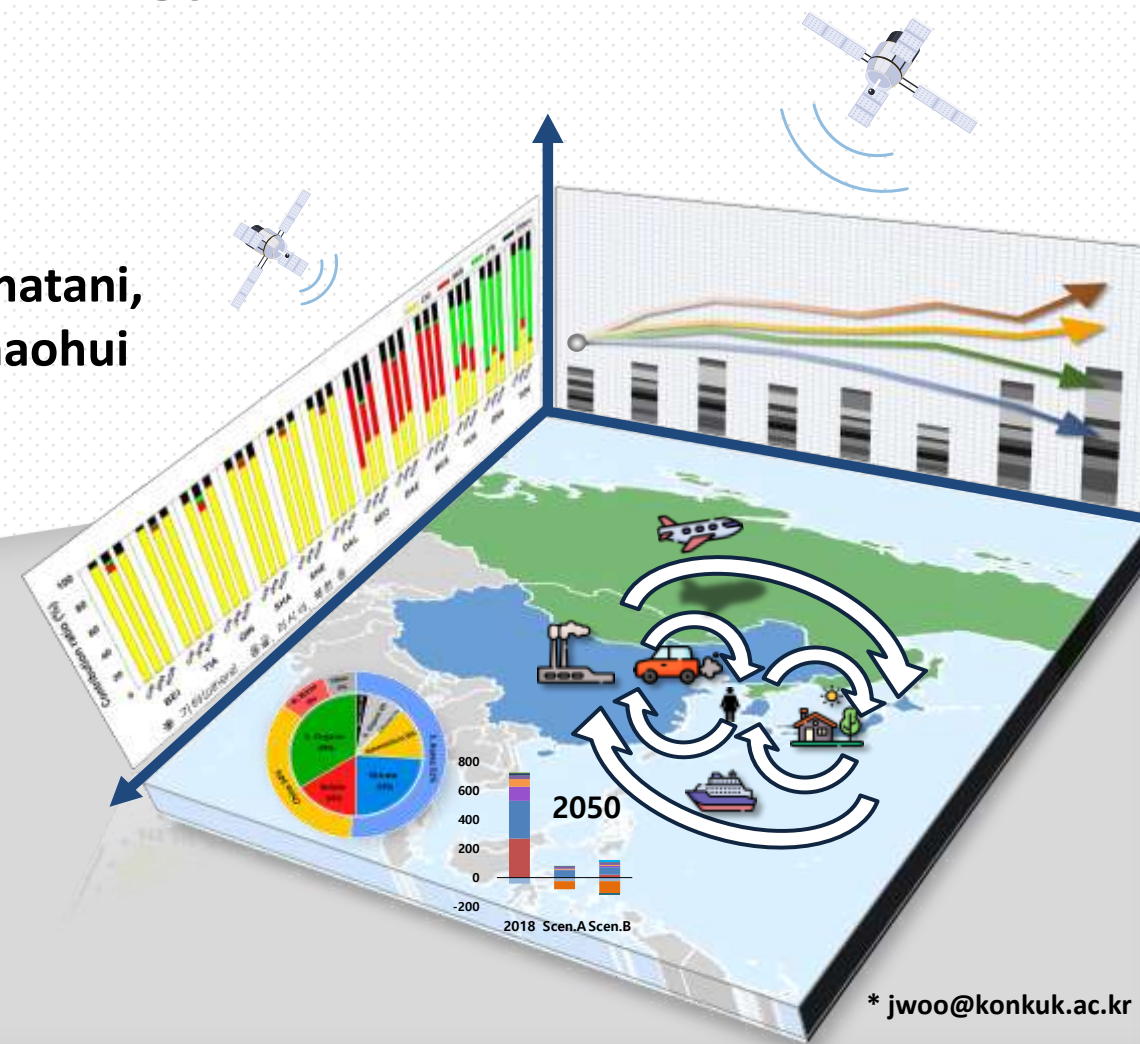


A New Research Framework on Future Climate-Air quality Management Strategy in Northeast Asia

Jung-Hun Woo, Zbigniew Klimont, Younha Kim, Satoru Chatani, Shuxiao Wang, Young Hwan Ahn, Shinichiro Fujimori, Shaohui Zhang, Guo Fei, Jia Xing

Konkuk University

2023 International Conference on CMAS-Asia-Pacific
6 July. 2023, Saitama, Japan



AQNEA* :

A New Research Framework on Future Climate-Air quality Management Strategy in Northeast Asia

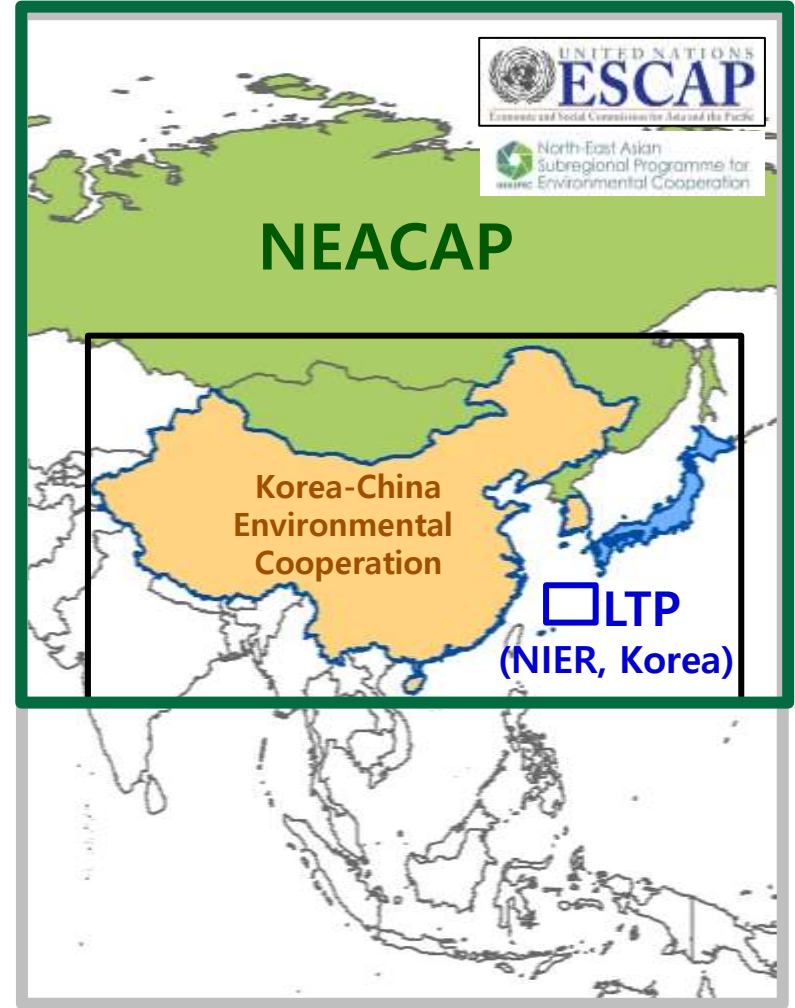
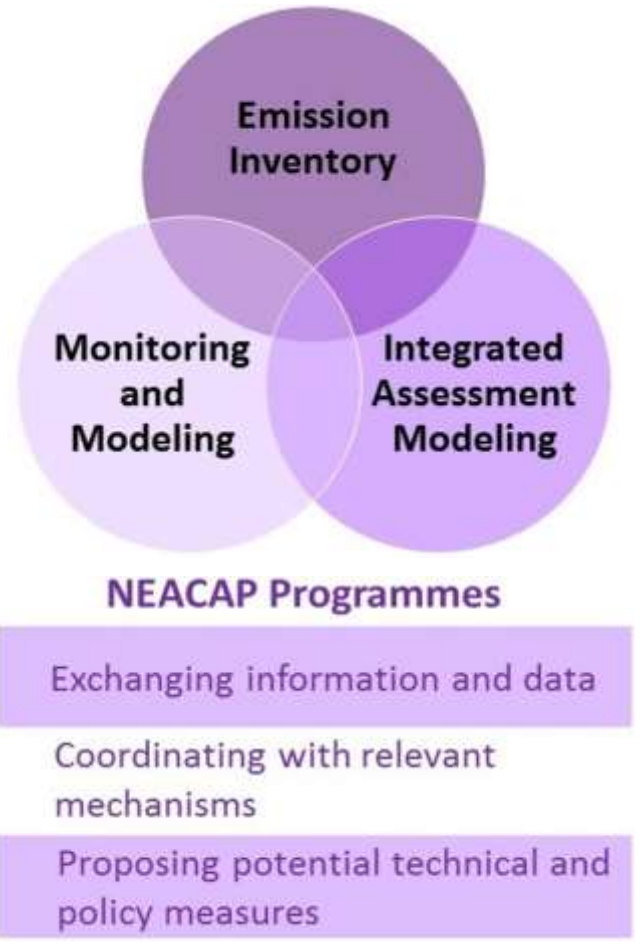
*Air Quality in NE Asia

Highlights

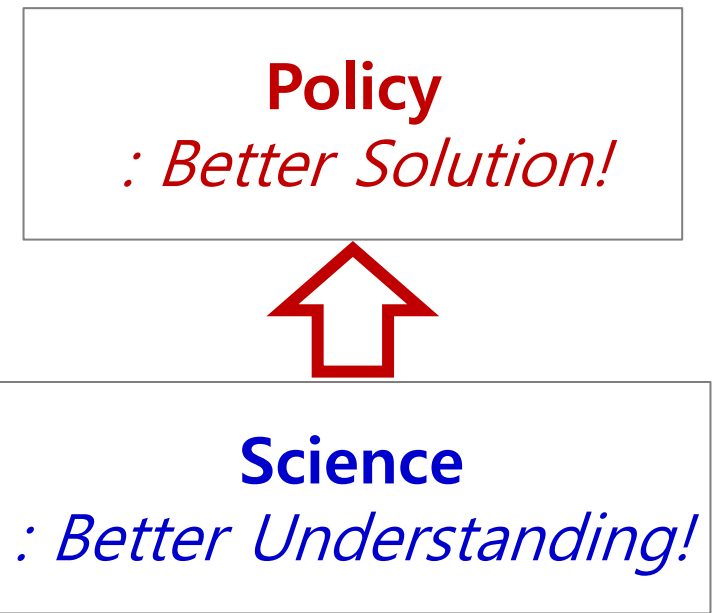
- The AQNEA (Air Quality in Northeast Asia) project was launched with the aim of finding a better future air quality management strategy in Northeast Asia
- Three future energy scenarios: BAU, old-NDC, and NetZero, and two air quality scenarios were set: NFC and MFR
- National energy IAM studies revealed a significant transition from fossil fuel-based energy to renewable energy in China, South Korea, and Japan, as part of their efforts to achieve carbon neutrality.
- The transition to renewable energy had a high co-control effect on combustion-driven air pollutants. However, it emphasized that air pollution controls, especially for pollutants like Volatile Organic Compounds (VOCs), were crucial
- By the year 2060, most regions in China would attain the WHO's new guideline of $5 \mu\text{g}/\text{m}^3$ for PM_{2.5}. The co-benefit effect of the NetZero scenario would lead to a decrease of 360,000 premature deaths per year, while additional air pollution control measures would result in a further decrease of 24,000 premature deaths per year.
- In the NetZero scenario for Korea, both CO₂ and air pollutant emissions were significantly reduced, leading to improved PM_{2.5} concentrations. However, consideration of transboundary pollution inputs in IAM analysis is still necessary, especially in Korea
- These outcomes would support domestic and international research collaboration frameworks, such as NEACAP (NE Asia Clean Air Partnership) of UN ESCAP

Air Pollution : Domestic Policy in Korea and International Cooperation in NE Asia

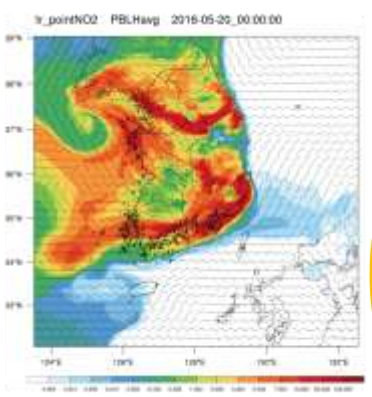
North-East Asia Clean Air Partnership (NEACAP by UN ESCAP)



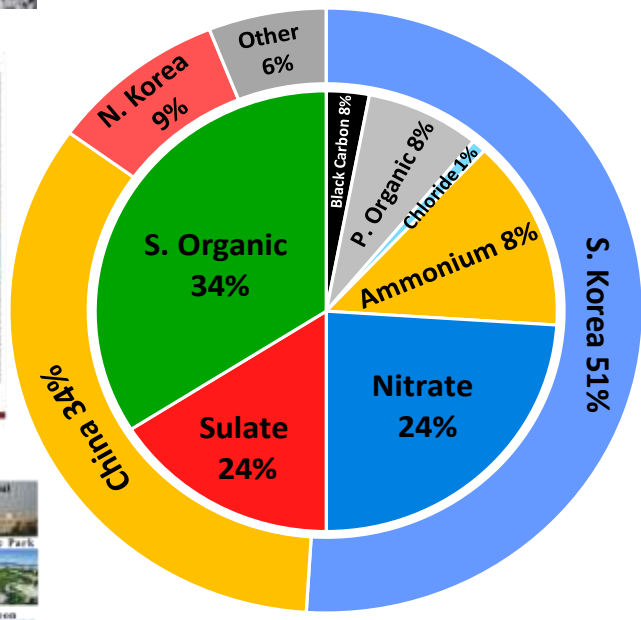
Air Quality Management Policy in Korea



Science : NIER/NASA KORUS-AQ and beyond

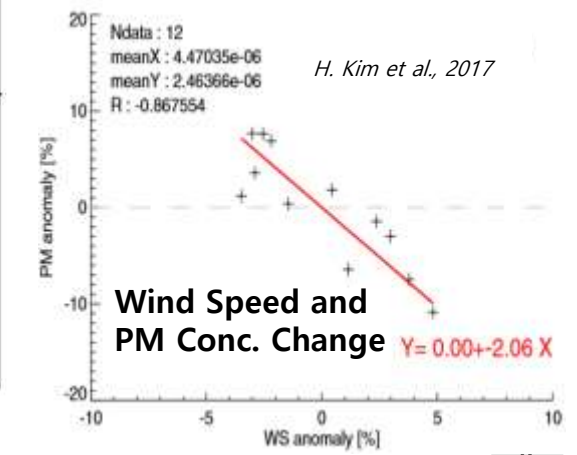
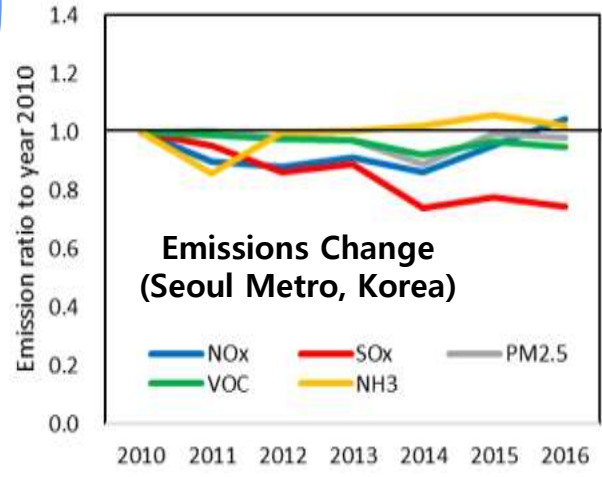
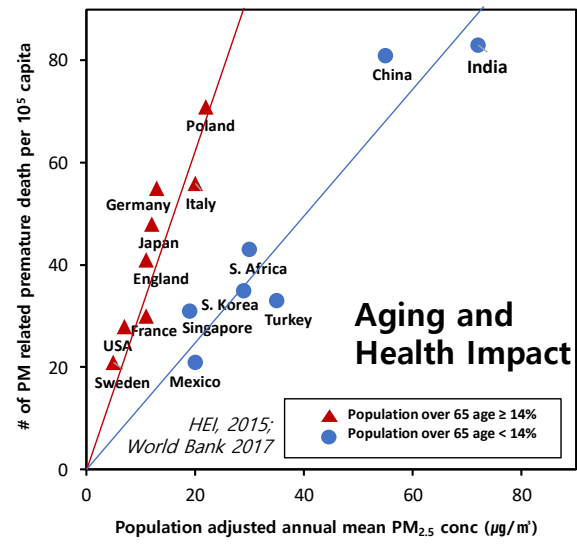
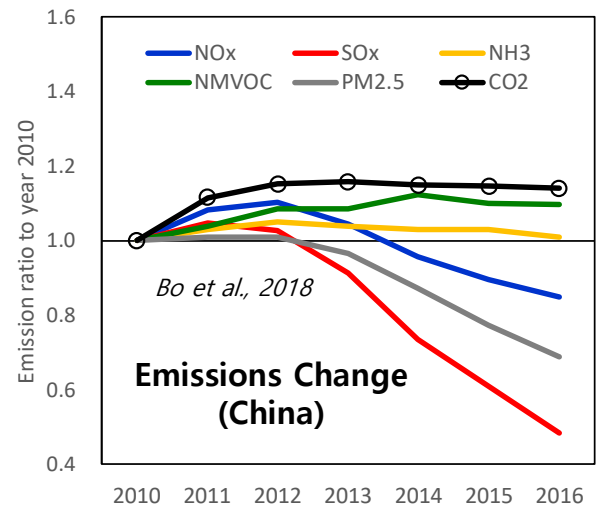


Composition of Fine Particles (DC-8 Aircraft)



NASA-NIER, Rapid Science Synthesis Report, 2017

Factors Affecting Fine Particle Pollution in Korea

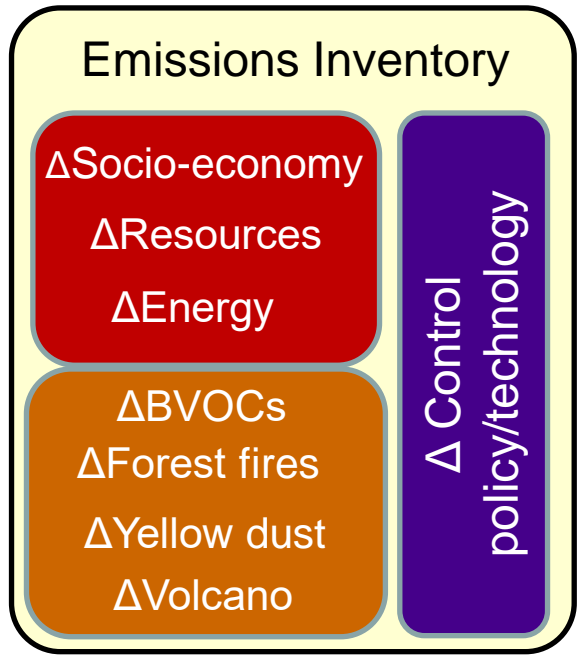


01. BACKGROUND

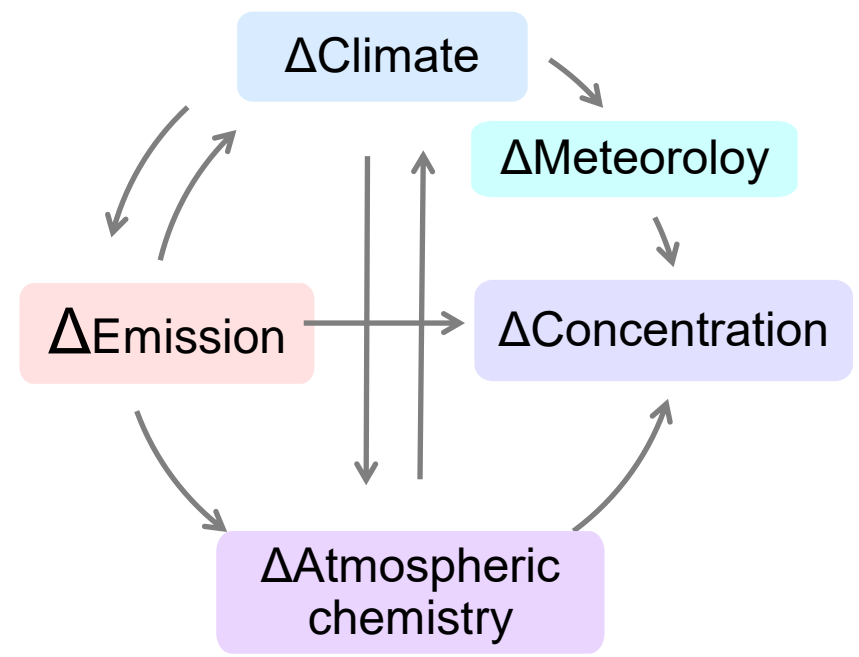
Integrated Assessment : Understanding Processes and Finding Solutions



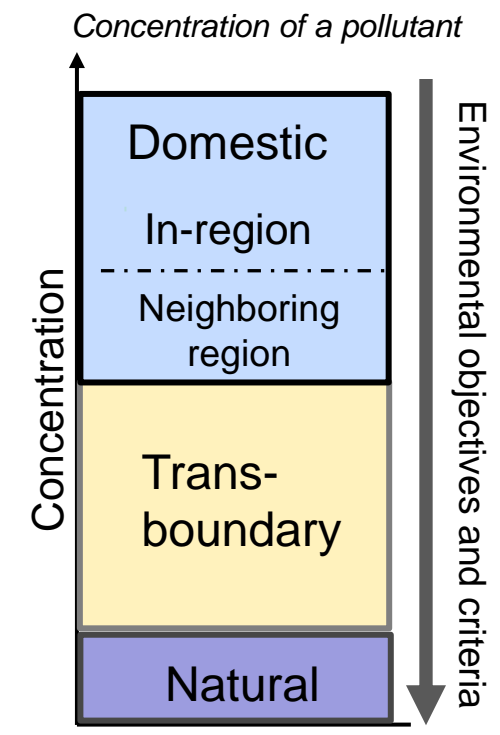
Emission (A)



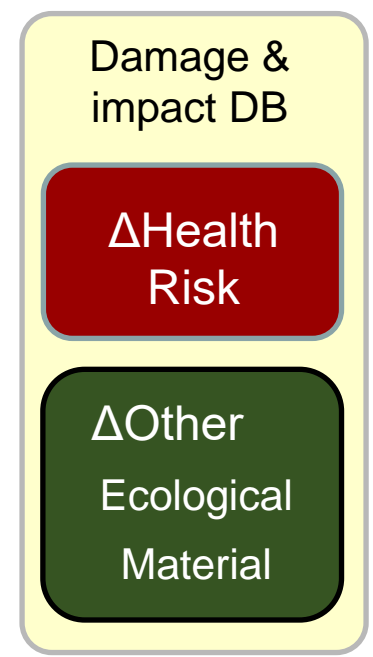
Atmospheric Processes (B)



Concentration (C)



Impact (D)



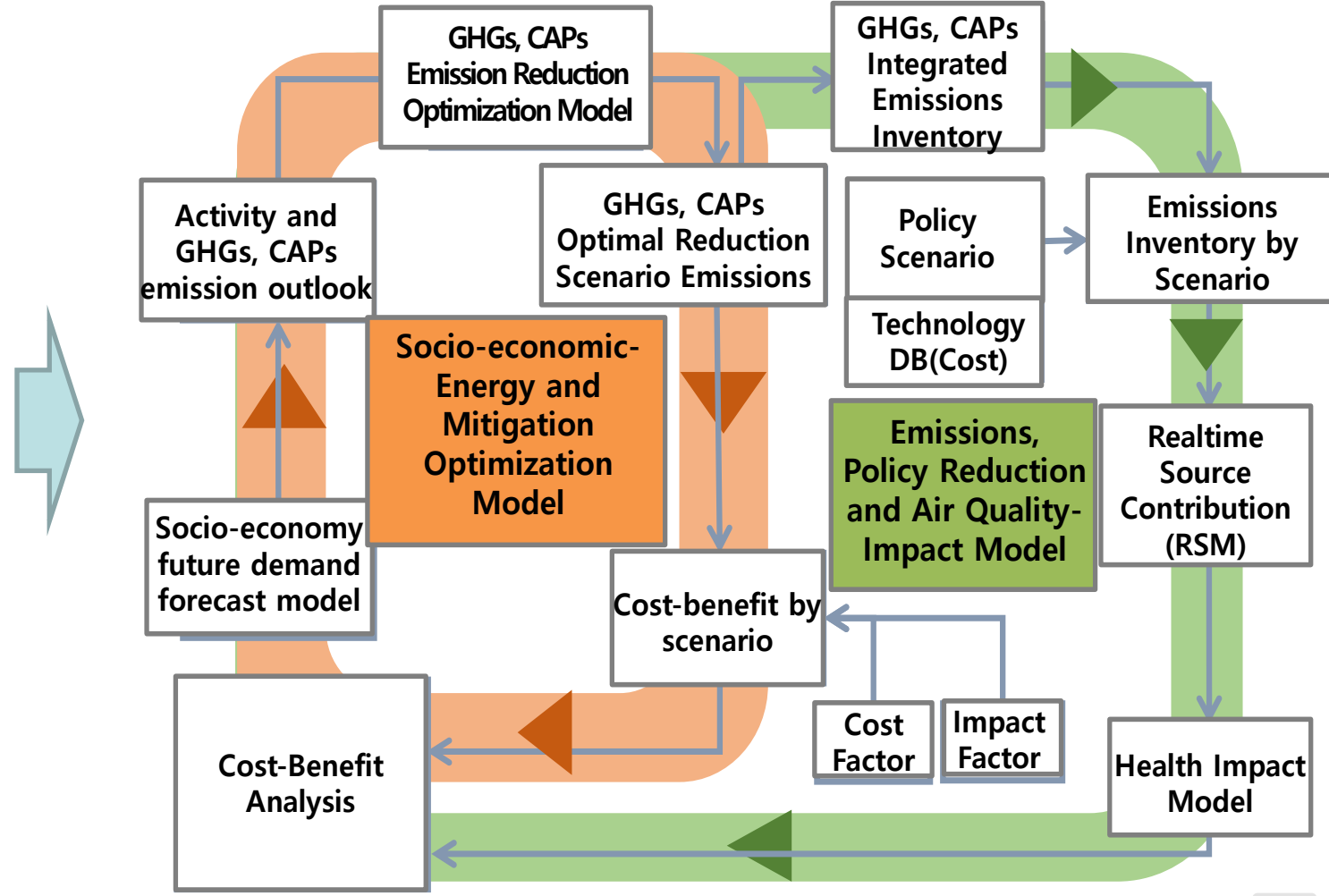
The GUIDE* Integrated Assessment Model (Korea)

*GHGs and air pollutants Unified Information Design system for Environment

+CAPs : Criteria Air Pollutants



*IAM : Integrated Assessment Model



AQNEA : Integrated Management Strategies for Future Air Quality Improvements in NE Asia

Objectives

Establish Network of Experts in Northeast Asia

Develop Integrated AQ Management Strategies

Share Results using Web Service Systems

Support International Cooperation Frameworks

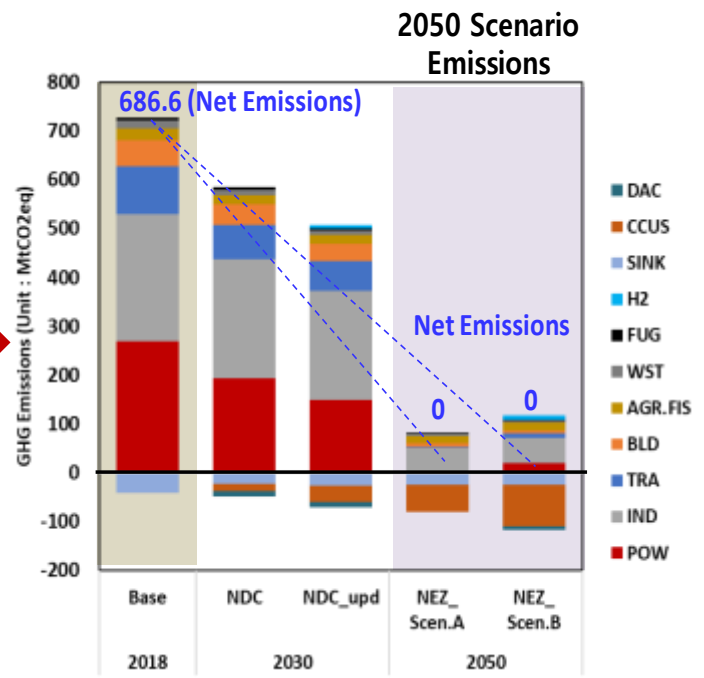
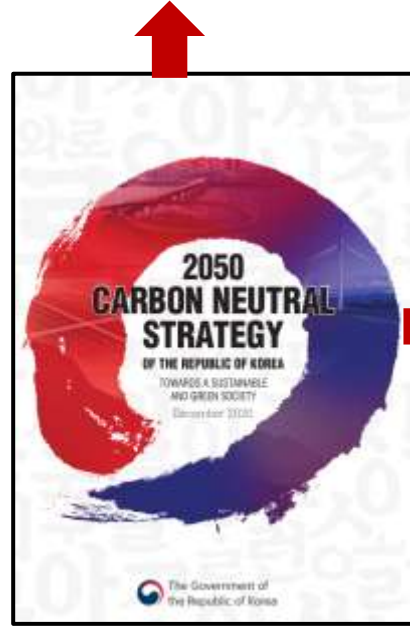


AQNEA : Collaborative IAM framework and Future Scenarios in NE Asia

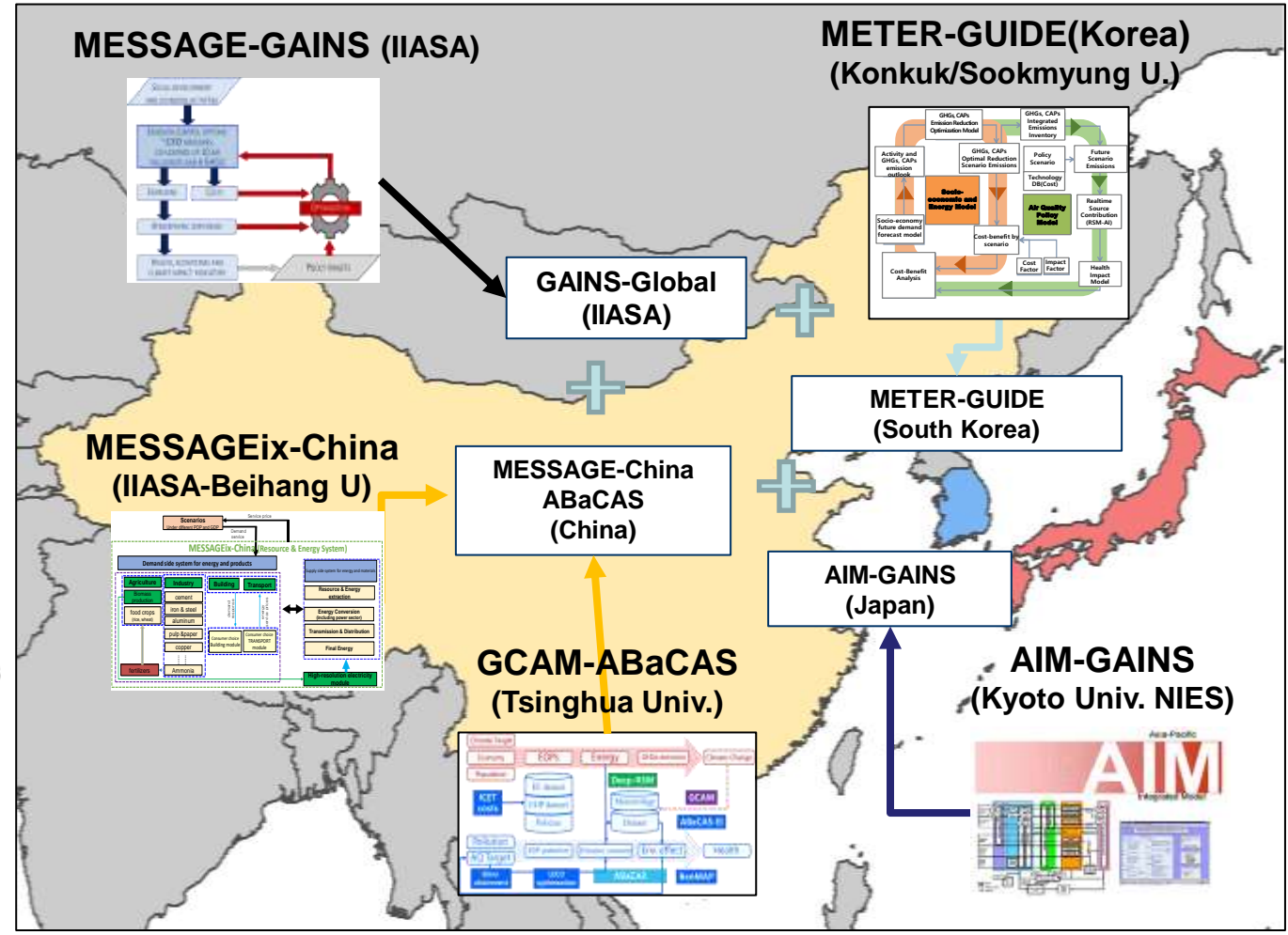
Carbon Neutrality in Korea

Key elements of the 2050 Vision

- ❶ Expanding the use of **clean power and hydrogen** across all sectors
- ❷ Improving **energy efficiency** to a significant level
- ❸ Commercial deployment of **carbon removal** and other future technologies
- ❹ Scaling up the **circular economy** to improve industrial sustainability
- ❺ Enhancing **carbon sinks**

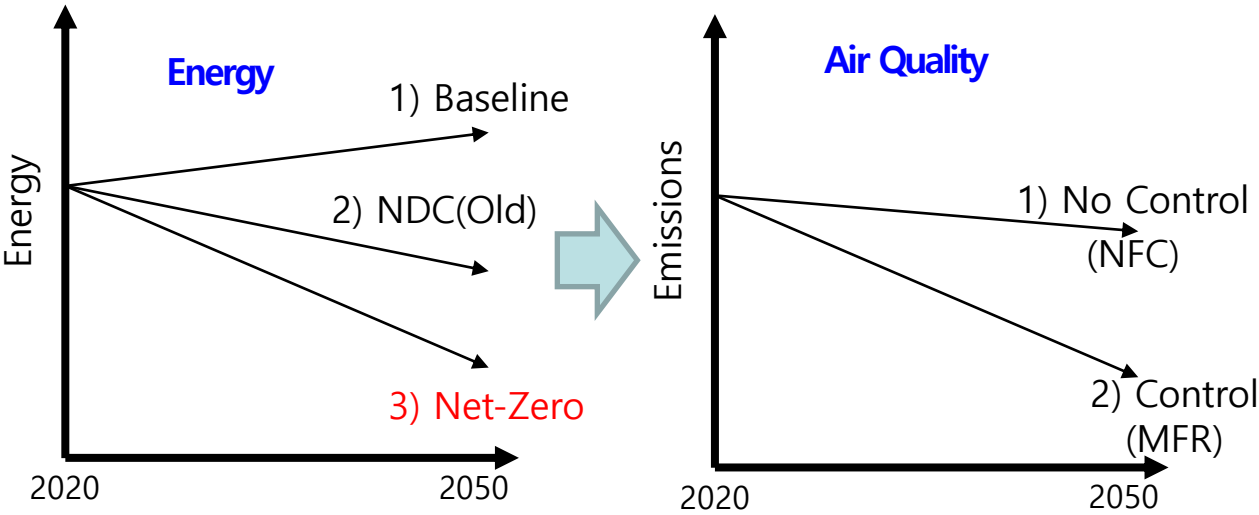


AQNEA Integrated Assessment Modeling (IAM) Framework



AQNEA : Future Energy and Air Quality Scenario Pathways in NE Asia

Energy and AQ scenario pathways setup (NDC and Net-Zero scenario)



Socioeconomy – Energy – Air pollution Scenarios

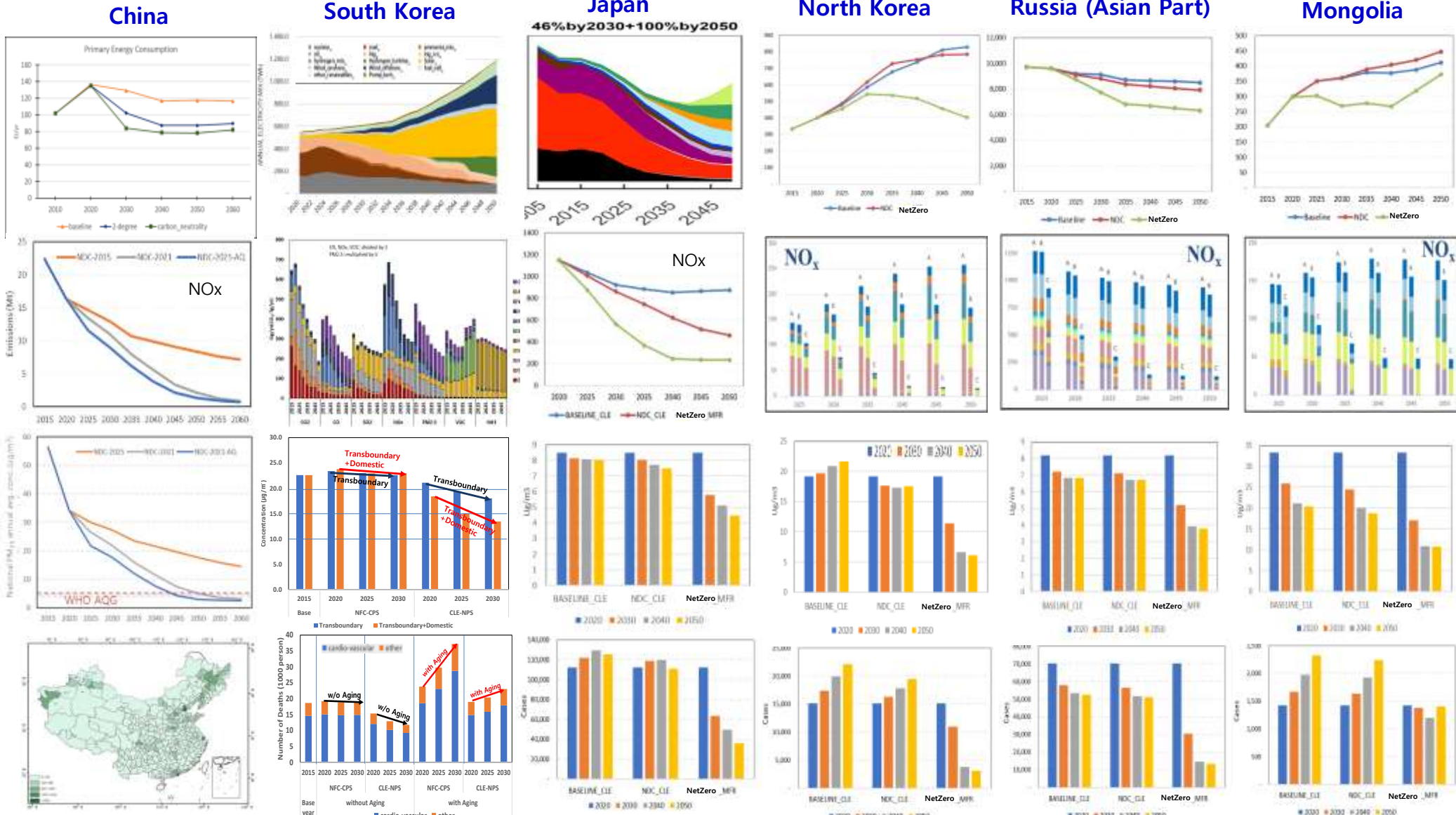
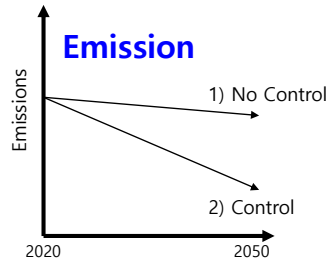
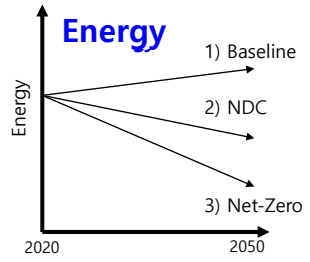
| Socio-economy | Energy Scenario pathway | | Air Pollution Control | |
|---------------|-------------------------|----------------------------|-----------------------|---|
| SSP2-4.5 | Baseline | No policy scenario | No Control | No Further Control (NFC) scenario |
| | NDC (Old) | Middle range scenario | | |
| | Net-Zero | Carbon-Neutrality scenario | Control | Maximum Feasible Reduction (MFR) scenario |

| Country | IAM; Integrated Assessment Model Framework | Scenario group | Scenario in IAM | Description |
|-----------------|--|-----------------|-------------------|---|
| Korea | GUIDE-METER | Baseline | BAU | BAU |
| | | Middle scenario | Stated Policies | Stated Policies Scenario (Previous NDC) |
| | | Net-Zero | NetZero | Carbon neutrality plan for Korea |
| Japan | AIM/Hub-Japan 2.4 | Baseline | Baseline | BAU |
| | | Middle scenario | 26by30 + 80by50 | Outdated NDC + outdated **LTS goal for 2050 |
| | | Net-Zero | 46by30 + 100by50 | Updated NDC + zero emissions in 2050 |
| China | MESSAGEix-GLOBIOM 1.1-M-R12 | Baseline | Baseline | BAU |
| | | Middle scenario | 2-degree | Global carbon budget: 1,000 Gt CO ₂ ; China carbon budget: 165 Gt CO ₂ |
| | | Net-Zero | Carbon neutrality | Global carbon budget: 600 Gt CO ₂ ; China carbon budget: 60 Gt CO ₂ |
| Rest of NE Asia | IIASA GAINS (WEO) | Baseline | STEPS | Current policy settings |
| | | Middle scenario | APS | Including NDCs and longer-term net zero targets |
| | | Net-Zero | NetZero | Sets out a pathway for the global energy sector to achieve net zero CO ₂ emissions by 2050 |

Source : Woo et al., AQNEA project(2022) *NDC : Nationally Determined Contribution

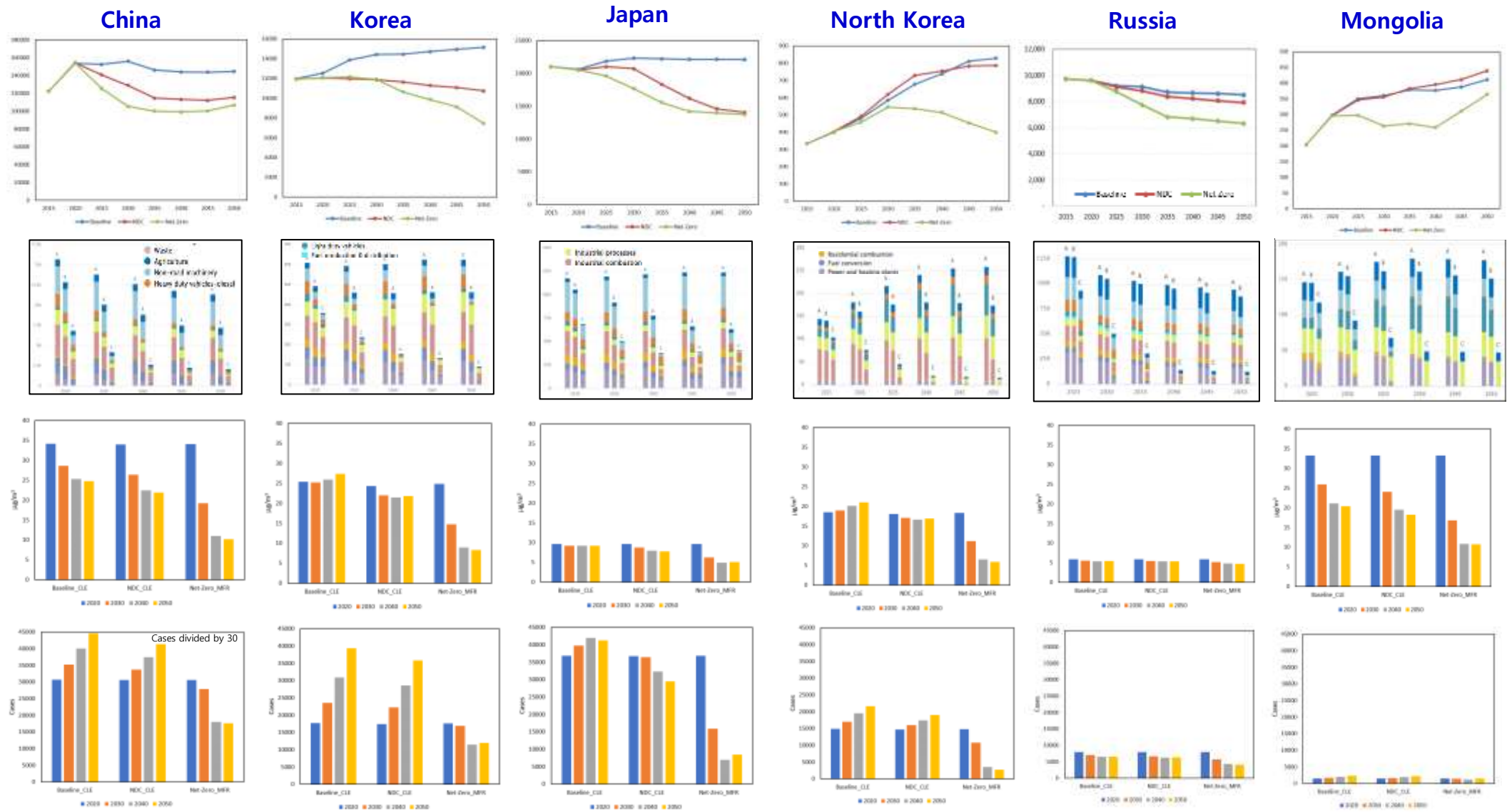
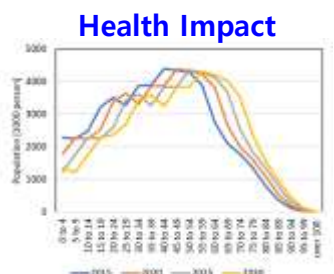
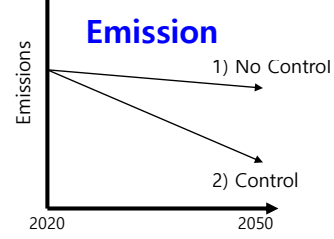
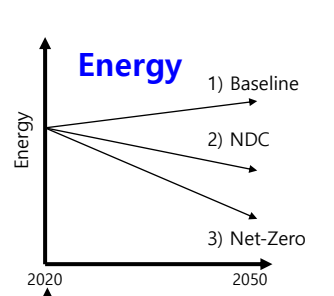
02. AQNEA : IAM

AQNEA : Future Scenario Pathways on Emissions, Air Quality and Health Impacts by NE Asian Countries



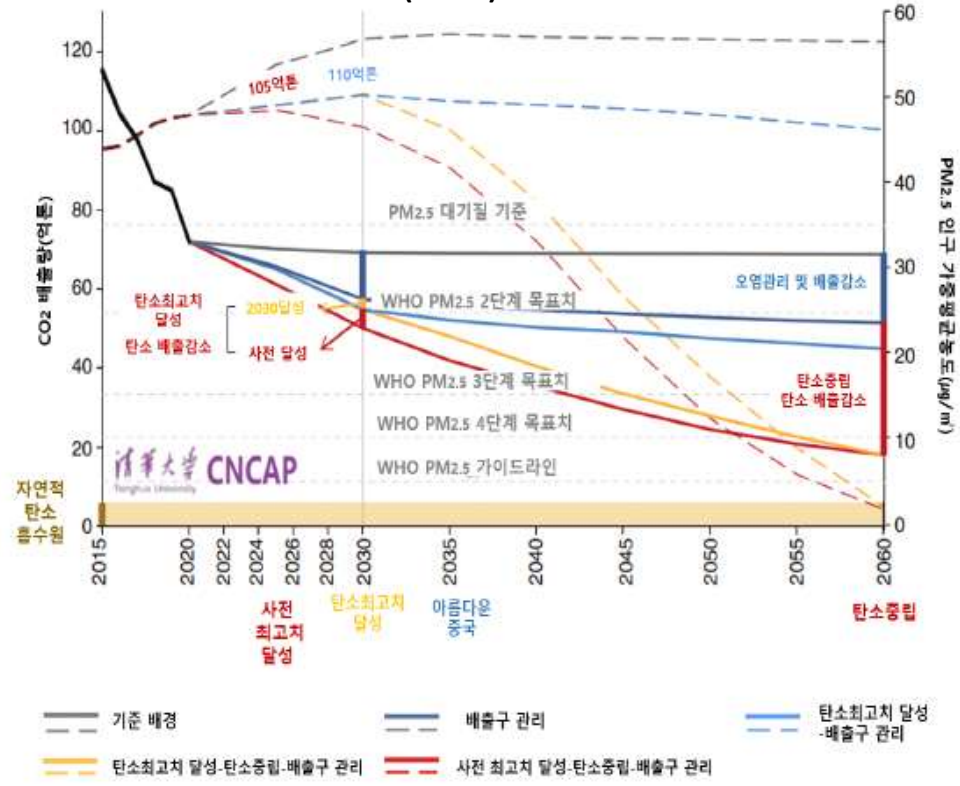
AQNEA : Future Scenario Pathways on Emissions, Air Quality and Health Impacts by NE Asian Countries

Energy: Primary energy consumption (PJ/yr) (Baseline, NDC, Net-Zero)
Emission: NO_x emissions (Gg/yr) (Baseline_CLE, NDC_CLE, Net-Zero_MFR)
Air Quality: PM_{2.5} concentration (µg/m³) (Baseline_CLE, NDC_CLE, Net-Zero_MFR)
Health Impact: Premature Death (Cases) (Baseline_CLE, NDC_CLE, Net-Zero_MFR)



AQNEA : Effect of Energy and Air Pollution Control in China and South Korea

Integrated Strategy for Carbon Neutrality and Clean Air (China)



Carbon Neutrality Policy in Korea

탄소중립 녹색성장 국가전략 및 제1차 국가 기본계획 (중장기 온실가스 감축목표 포함)

2023. 4.

관계부처 합동

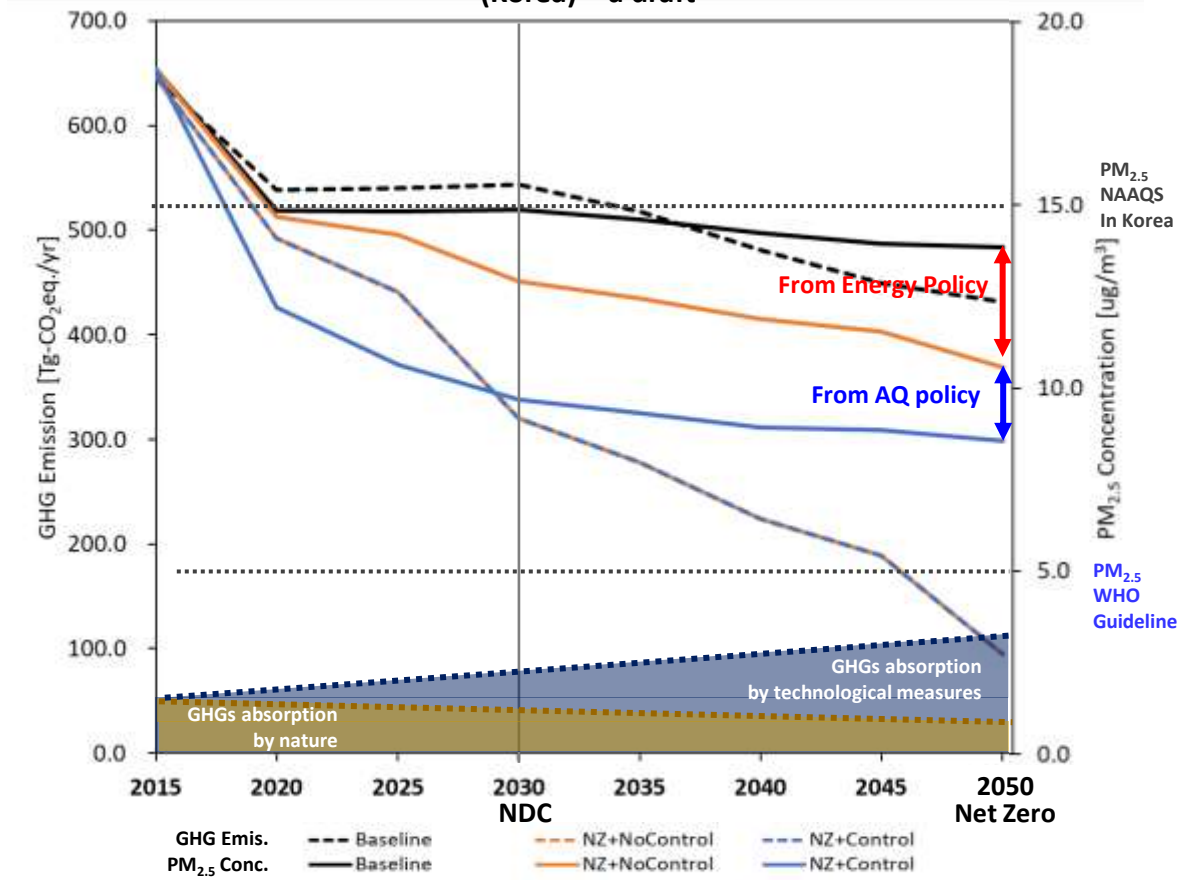
Air Quality Policy in Korea

제1차 2020-2030년 대기환경개선 종합계획

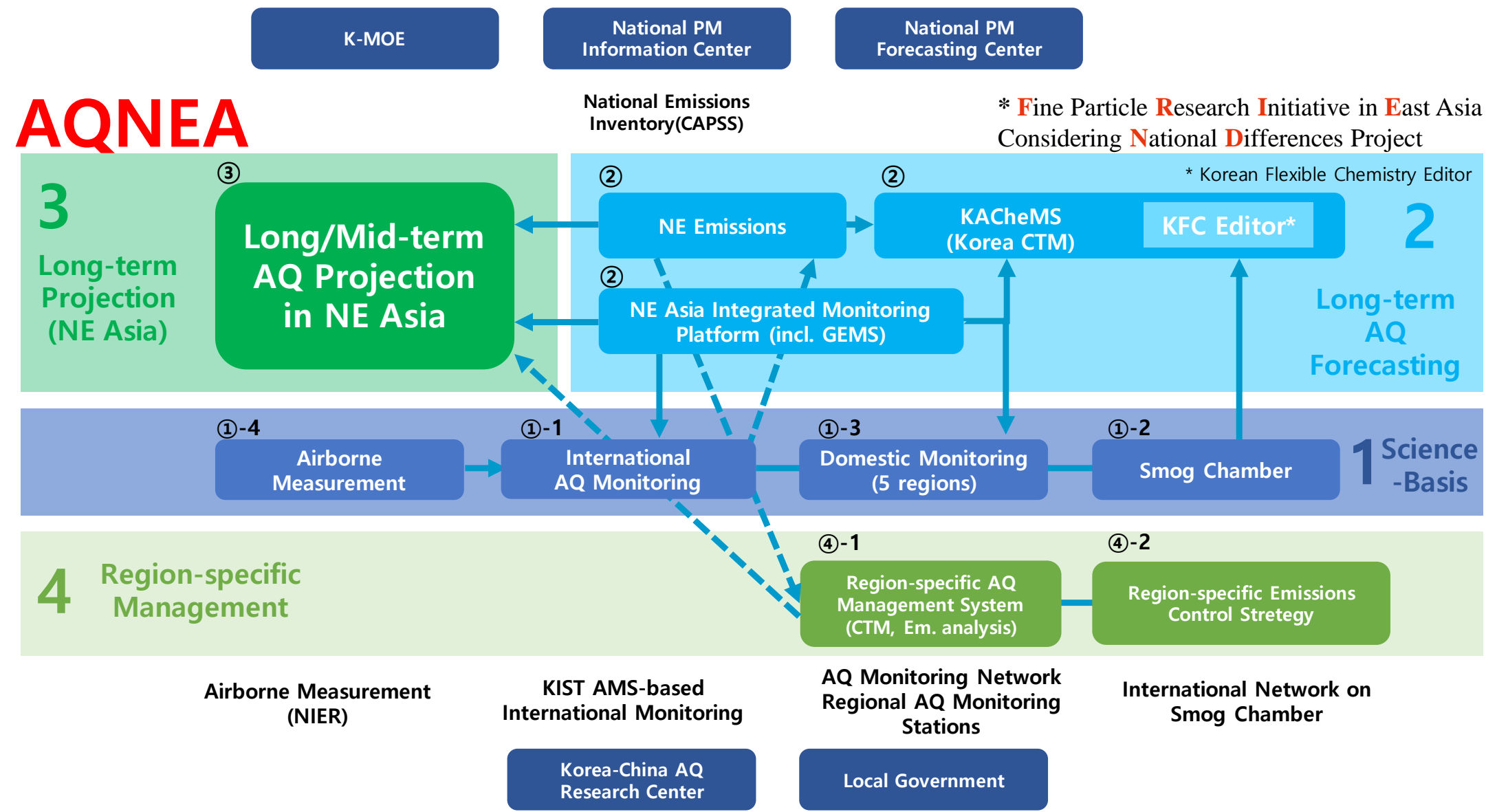
2022. 12. 27.

환경부

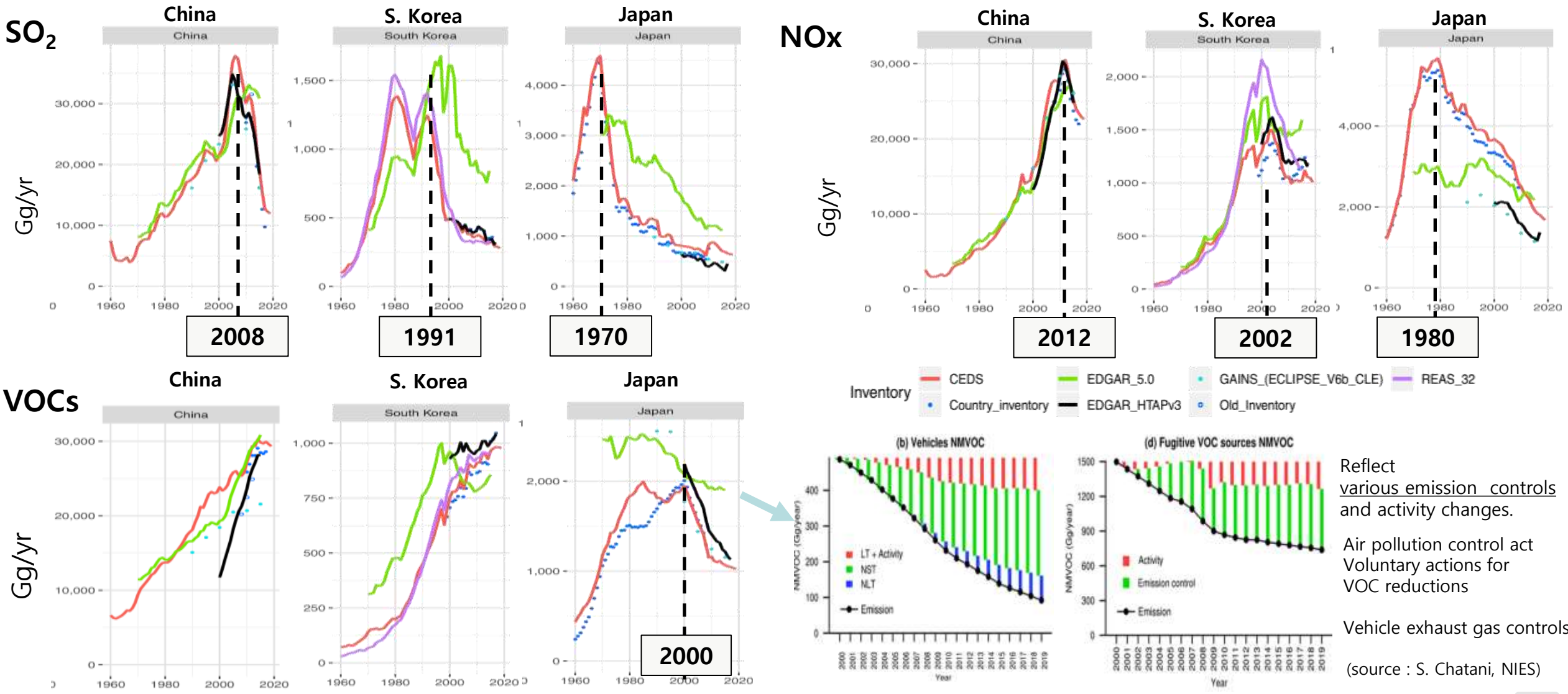
Integrated Strategy for Carbon Neutrality and Clean Air (Korea) – a draft



Linkage among the Components of the FRIEND Project



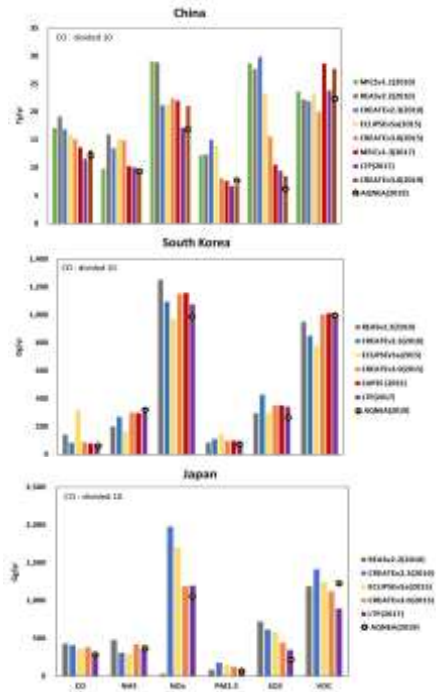
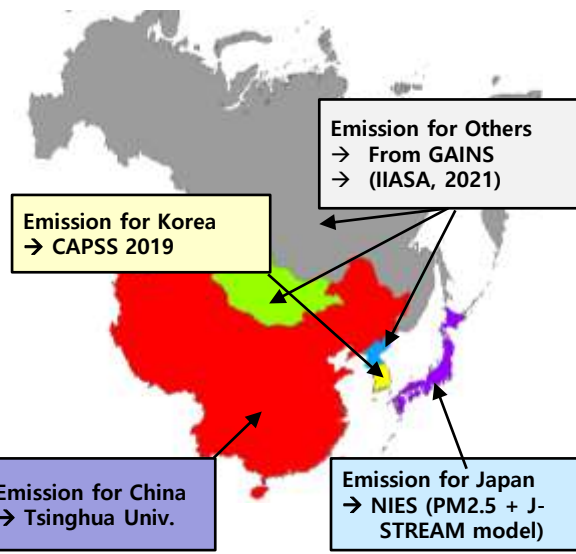
TF HTAP : Historical Emissions Trends in Three NE Asia Countries



(Source: S. Chatani and J. Woo , 2022)

AQNEA Collaborative Air Quality Modeling(AQM) Framework

AQNEA V1.0 Emissions



National Emissions (AQNEA v1.0, Yr. 2019; Unit: Gg/yr; CO₂ Tg/yr)

| Country | CO | CO ₂ | NH ₃ | NO _x | PM ₁₀ | PM _{2.5} | SO ₂ | VOC |
|----------|---------|-----------------|-----------------|-----------------|------------------|-------------------|-----------------|--------|
| S. Korea | 711 | 604 | 316 | 997 | 204 | 84 | 262 | 1,005 |
| China | 120,180 | 12,429 | 9,341 | 17,004 | 10,341 | 7,617 | 5,983 | 22,260 |
| Japan | 2,567 | - | 360 | 1,062 | 105 | 50 | 244 | 1,215 |
| N. Korea | 244 | 35 | 106 | 118 | 118 | 68 | 88 | 106 |
| Mongolia | 547 | 34 | 100 | 98 | 88 | 57 | 176 | 55 |
| Russia | 2,530 | 734 | 416 | 1,237 | 803 | 482 | 1,481 | 1,517 |

AQNEAv1.0 AQM Framework

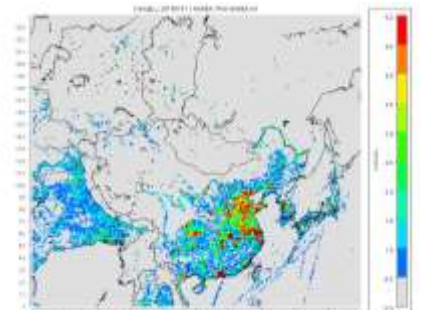
| | |
|-----------------------------------|---|
| Chemical Transport Model | CMAQ v5.3.2 |
| Chemical Mechanism | VOC : SAPRC07 PM _{2.5} : AERO5 |
| Anthropogenic emission processor | SMOKE v4.5 |
| Emissions inventory | AQNEA 2019 emission inventory |
| Biogenic emission processor | MEGAN v2.1 |
| Meteorological Model | WRF v3.7 |
| Projection type: | Lambert Conformal Conic |
| Grid Resolution (Number of Grid): | 27 km × 27 km (270 × 240) |
| Domain information (Below-Left) : | (-5,513,000, -2,324,500) Reference Lon., Lat. : 126.0, 38.0 Standard Parallel : 30, 60 N. |
| Modeling Period | Base Year : 2019 Spin up : 2018.12.30~ |

(Source: S. Chatani and J. Woo , 2022)

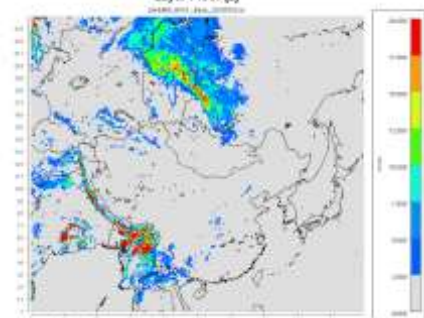
For more information

14:15 Integrated framework to evaluate impact of future climate and environmental scenarios on air quality in northeast Asia
Satoru Chatani (National Institute for Environmental Studies (NIES))

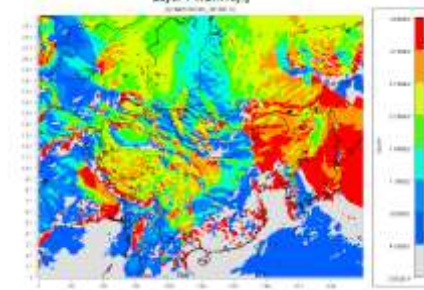
Anthropogenic NO_x Emission



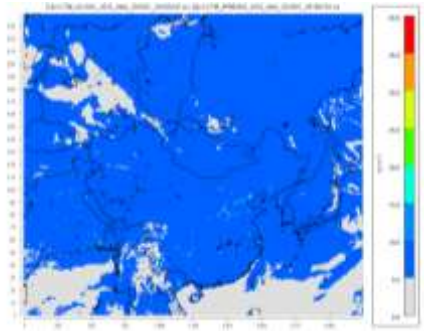
Biogenic Isoprene Emission



Meteorological data (Wind Dir.)



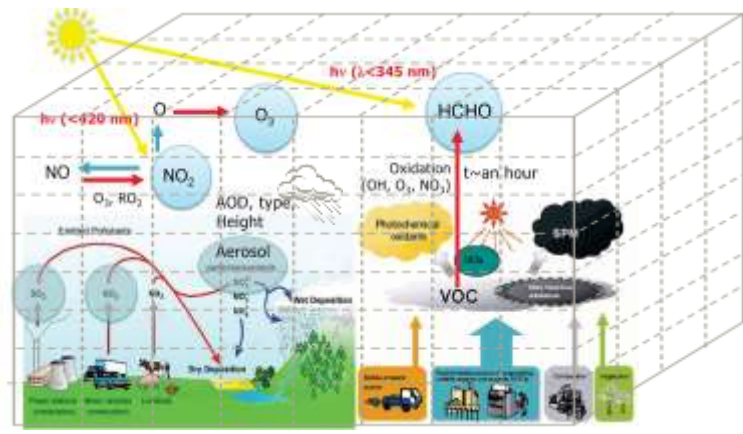
PM_{2.5} Concentration



AQNEA : Atmospheric Concentration Field in the GUIDE IAM

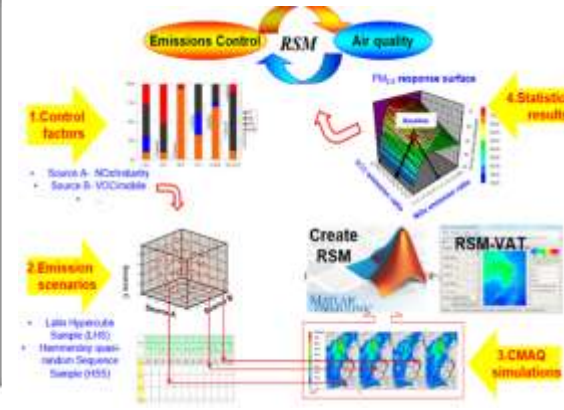
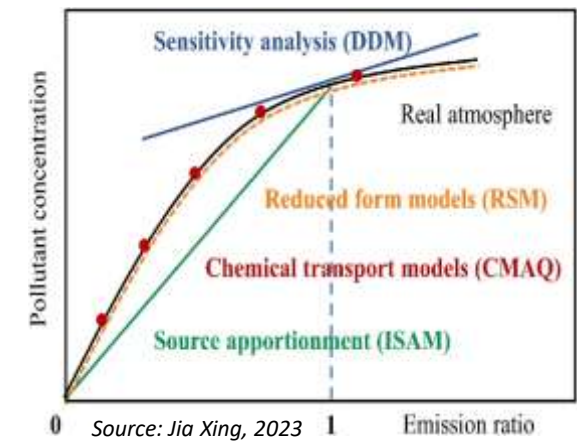
Chemical Transport Modeling for Science Support

Meteorology (WRF), Emissions (SMOKE), and Chemical Transport Model (CMAQ)

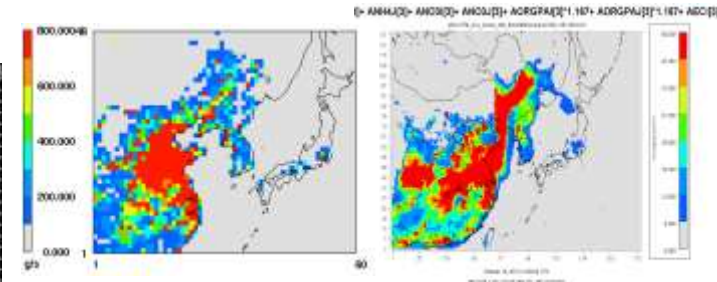
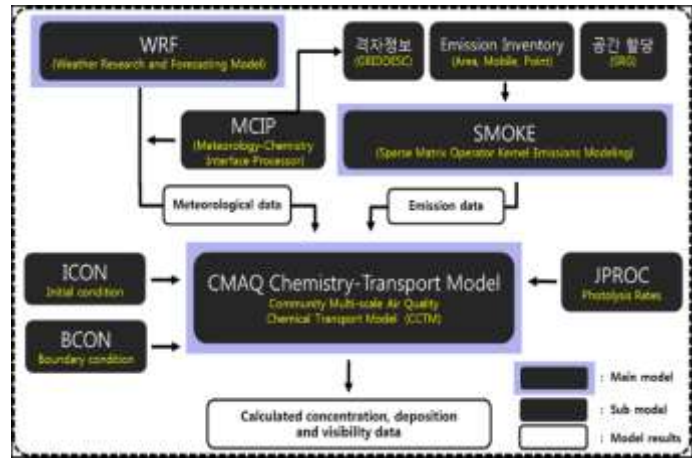


| | |
|------------------------------|--|
| Chemical Transport Model | CCTM in CMAQ v4.7 (U.S. CMAS) |
| chemical mechanism | SAPRC-99 aero3 |
| Emissions | |
| anthropogenic emission model | SMOKE-Asia (Woo et al., 2009) |
| emissions inventory | CREATE v. 2.3 (Woo et al., 2016) |
| Meteorological Model | WRF (U.S. NCAR) |
| Period | January, April, July, October, 2013 |
| Domain | <ul style="list-style-type: none"> Extent: Domain 1 (East Asia), Domain 2 (South Korea) Grid resolution (domain): 27 × 27km²(174 × 128), 9 × 9km²(67 × 82) N. of vertical layer: 30 |

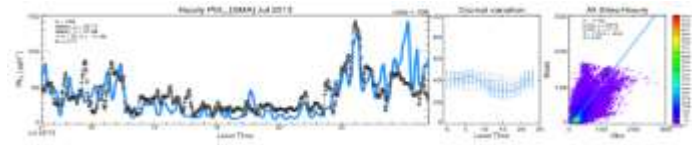
Response Surface Modeling for Policy Support



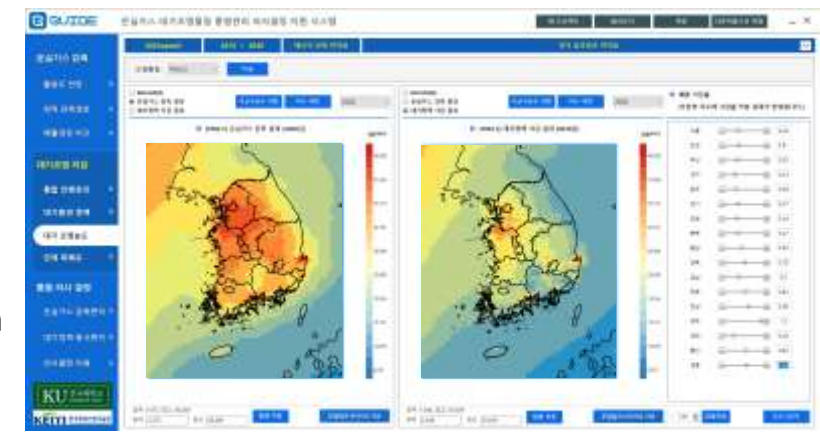
WRF-SMOKE-CMAQ



PM_{2.5} (Seoul Metro)



RSM in GUIDE IAM : PM_{2.5} concentration



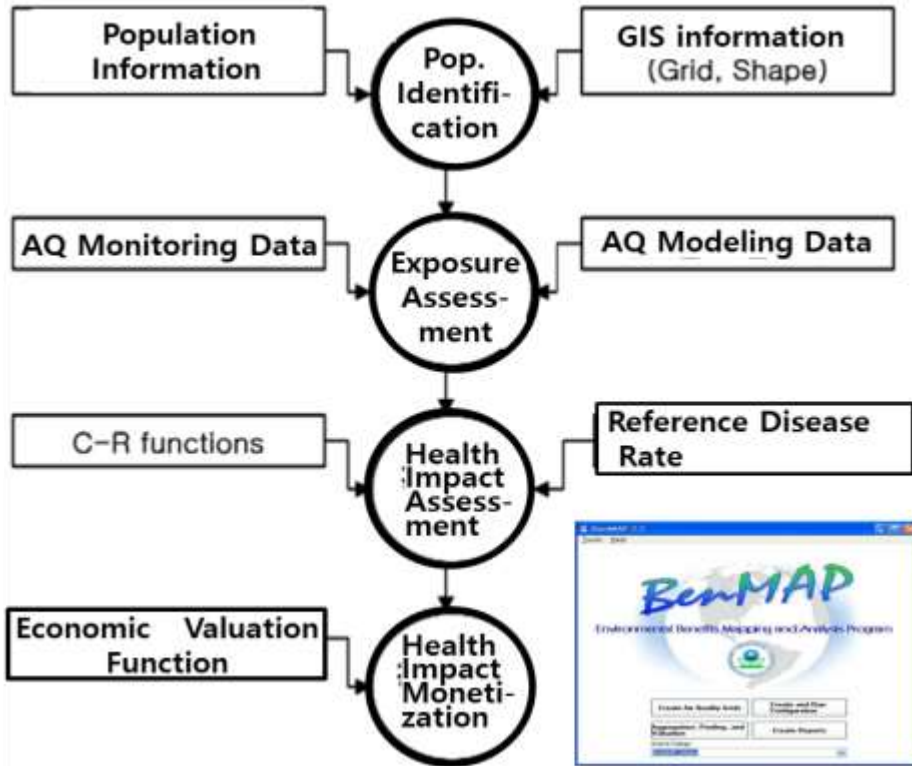
For more information



15:15 AI-based fast air quality modeling in support of integrated policy assessment
Jung Hun Woo (Konkuk University)

AQNEA : Health Impact Analysis Model in the GUIDE IAM

Health Impact Analysis using BenMAP Model



BenMAP: Environmental Benefits Mapping and Analysis Program

Source : BENMAP, US EPA

Source: KMOE, 2007

PM_{2.5}

Assessment of diseases with data about Mortality, Morbidity, population, life expectancy in Korea

$$\Delta Y = Y_0 \left(1 - \frac{1}{e^{(\beta \times \Delta X)}} \right)$$

$$= \left(1 - \frac{1}{e^{(\beta \times \Delta X)}} \right) \times \text{Incidence} \times \text{Population}$$

where,

ΔY : Variation of Health Impact

Y_0 : Current Health Impact (e.g. Current # of death)

β : Concentration Reaction (CR) Value

ΔX : Variation of air pollution concentration

Incidence: Incidence rate

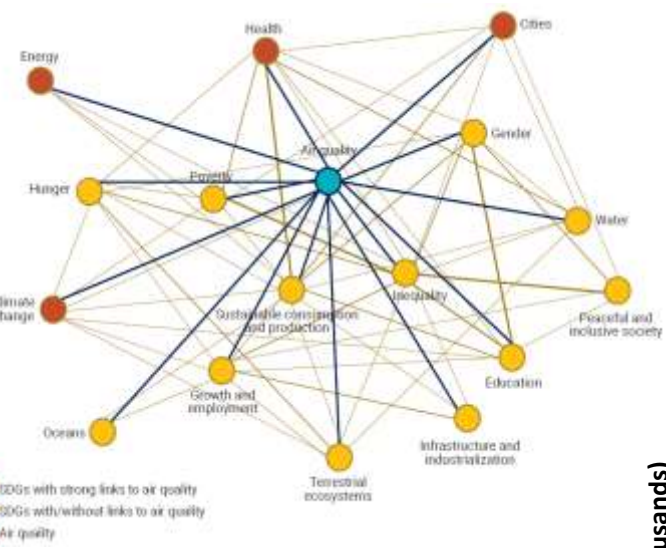
(e.g. Current Mortality rate)

Population: Exposed Population

Parameters used for the health impact analysis in the GUIDE IAM

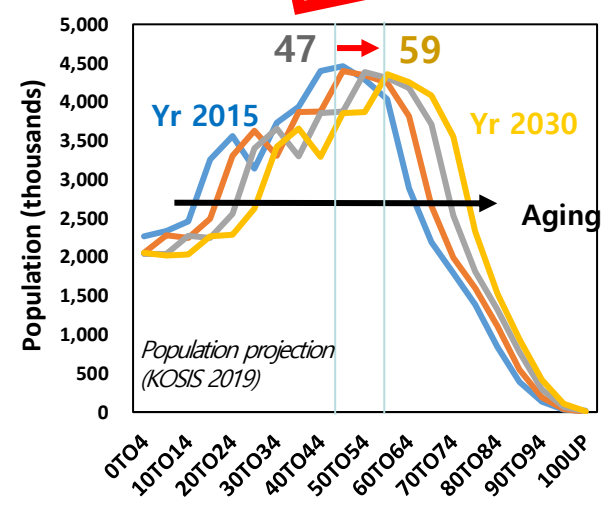
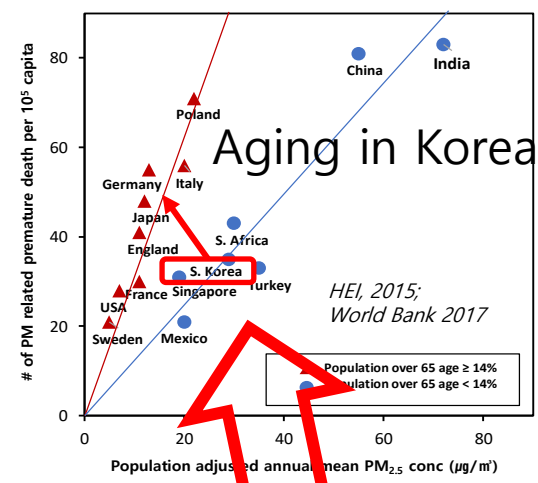
| Item | Parameter | Data source |
|------------------------|---------------------------------------|--|
| Concentration | PM _{2.5} , Ozone | WRF-SMOKE-CMAQ Chemical Transport Modeling System |
| Population | Regional population by age | National Statistical Office > Census Population (2016) Age and Gender Population by Si, Gun, Gu |
| Health impact function | Domestic CRFs standard | J.-S. Ha et al. (2016), 「A Study on Health Risk Assessment for Environmental Policies in the Areas of Climate and Atmosphere: Focused on Concentration Response Functions」, Korea Environment Institute. |
| Disease incidence | Prevalence Number of hospitalizations | Health Insurance Review and Assessment Service : Statistics of hospitalization for health insurance recipients 2010-2016 |
| | Death rate | National Statistical Office: Number of deaths by gender/age (5 years interval), mortality rate_2016 |

New Challenge: Transition with Justice

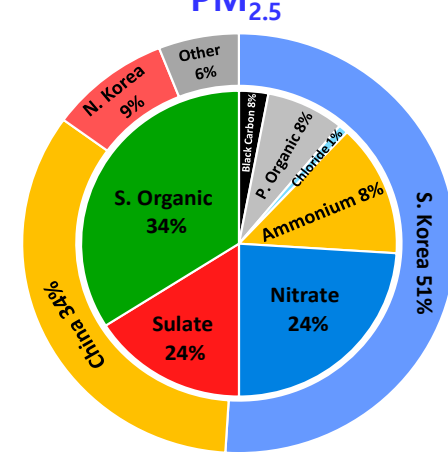


Air Quality and SDGs (UNEP, 2018)

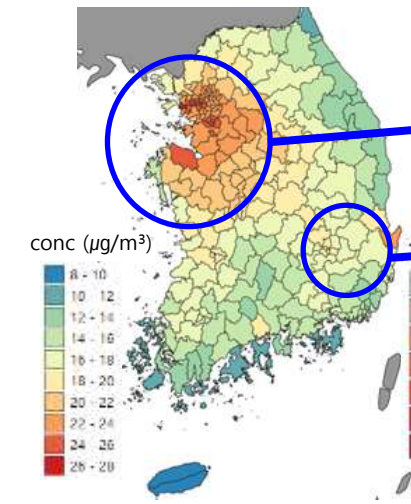
Health Impact Sensitivity



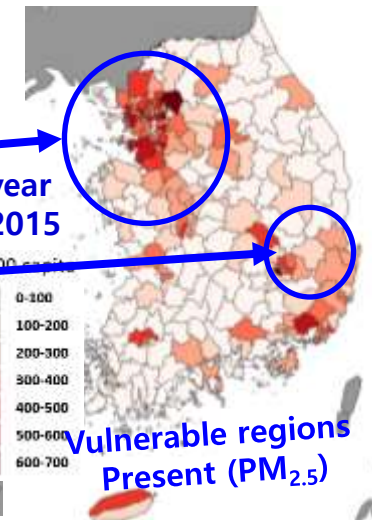
Secondary Formation PM_{2.5}



PM_{2.5} Concentration

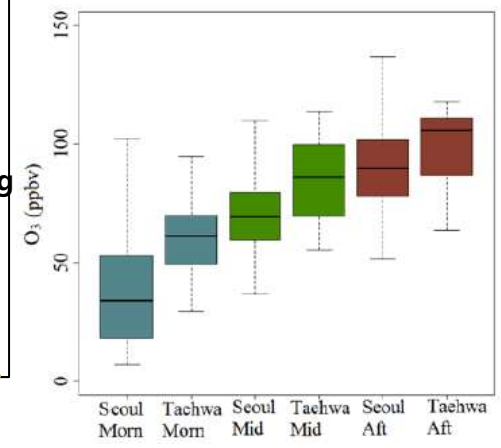


Population



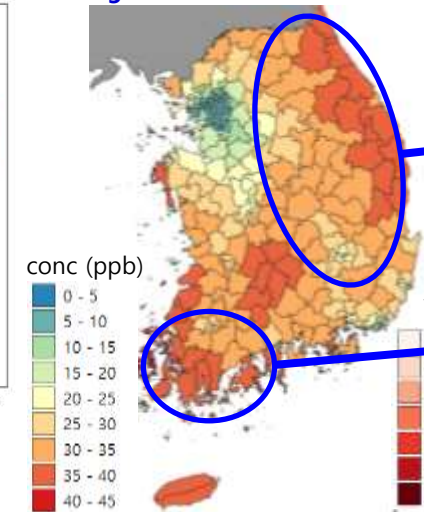
Vulnerable regions Present (PM_{2.5})

O₃ production from source

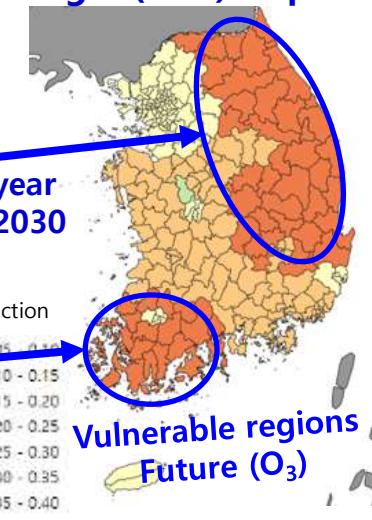


KORUS-AQ RSSR (NASA 2017)

O₃ Concentration



Aged (>60) Pop.



Vulnerable regions Future (O₃)

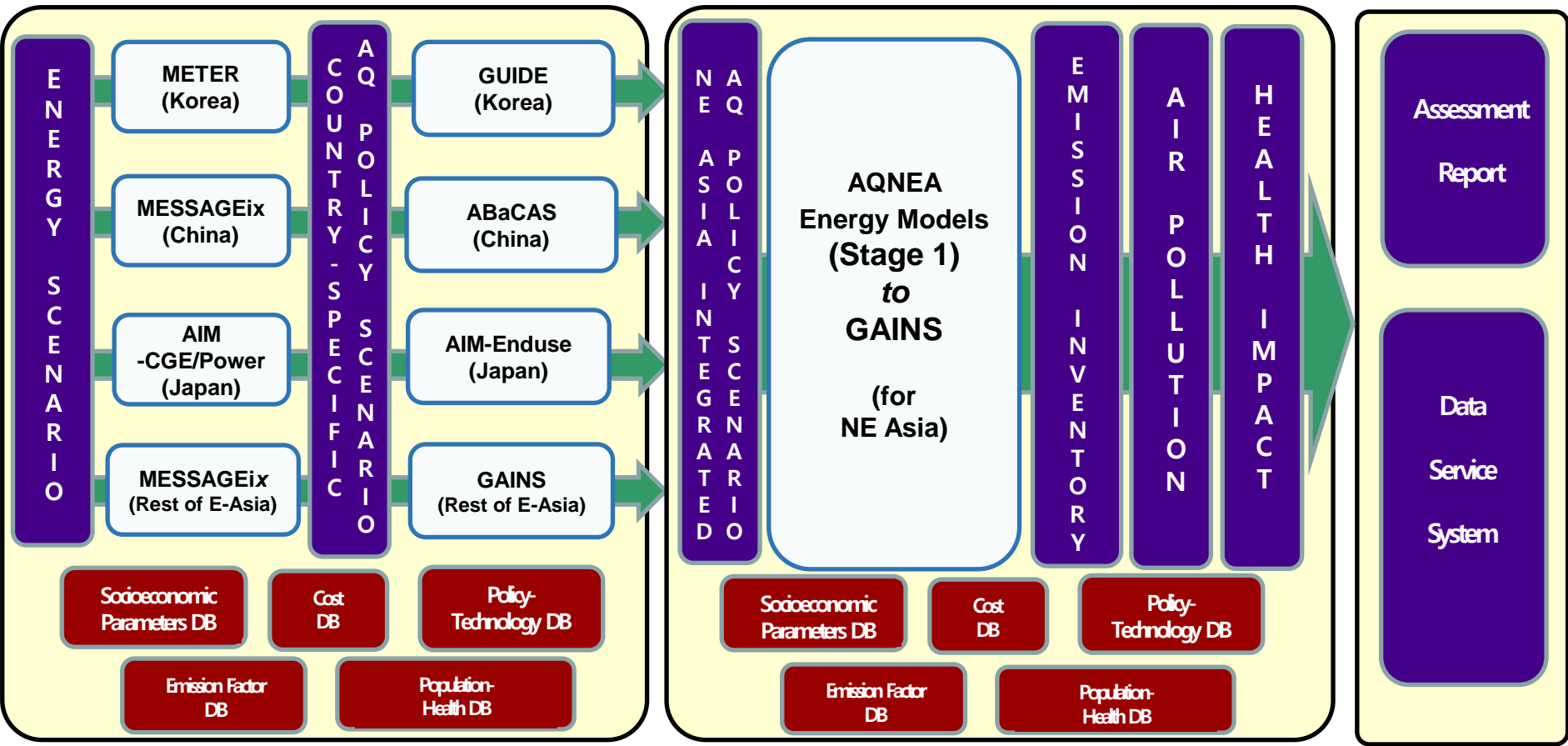
04. AQNEA : On-Going Work

Energy-AQ IAM Linkage for AQNEA Stage 1 and Stage 2

Stage 1 : Energy-AQ IAM Linkage by Country/Region

Stage 2 : Energy-AQ IAM Linkage for NE Asia

Outcome



Conference Day 1 (July 19 (Wed.))

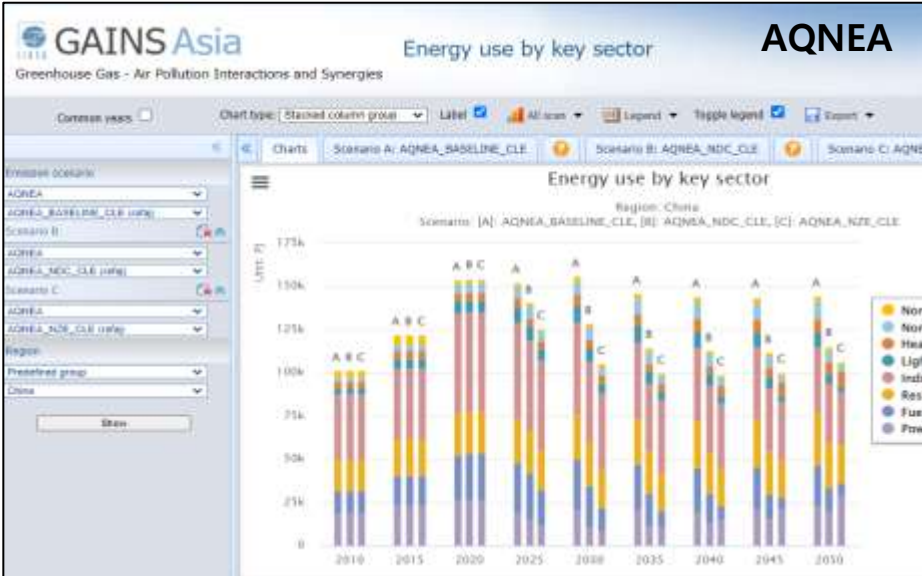
| | |
|------------|--|
| Rm 401-402 | <i>Special Session: AQNEA</i> Chaired by Satoru Chatani (National Institute for Environmental Studies) |
| 13:00 | Session keynote: A new research framework on future climate-air quality management strategy in Northeast Asia Jung Hun Woo (Konkuk University) |
| 13:30 | Air quality and health impact changes in Korea based on multiple future scenarios Jung Hun Woo (Konkuk University) |
| 13:45 | Sources of organic aerosol in China and the world: A modeling study Bin Zhao (Tsinghua University) |
| 14:00 | Scenarios of energy and air quality in North-East Asia: data linkage and harmonization Younha Kim (International Institute for Applied Systems Analysis (IIASA)) |
| 14:15 | Integrated framework to evaluate impact of future climate and environmental scenarios on air quality in northeast Asia Satoru Chatani (National Institute for Environmental Studies (NIES)) |
| 15:00 | Improving tools for assessment of air quality in North East Asia Zbigniew Klimont (International Institute for Applied Systems Analysis (IIASA)) |
| 15:15 | AI-based fast air quality modeling in support of integrated policy assessment Jung Hun Woo (Konkuk University) |
| 15:30 | Session closing discussion & summarization |

Conference Day 2 (July 20 (Thu.))

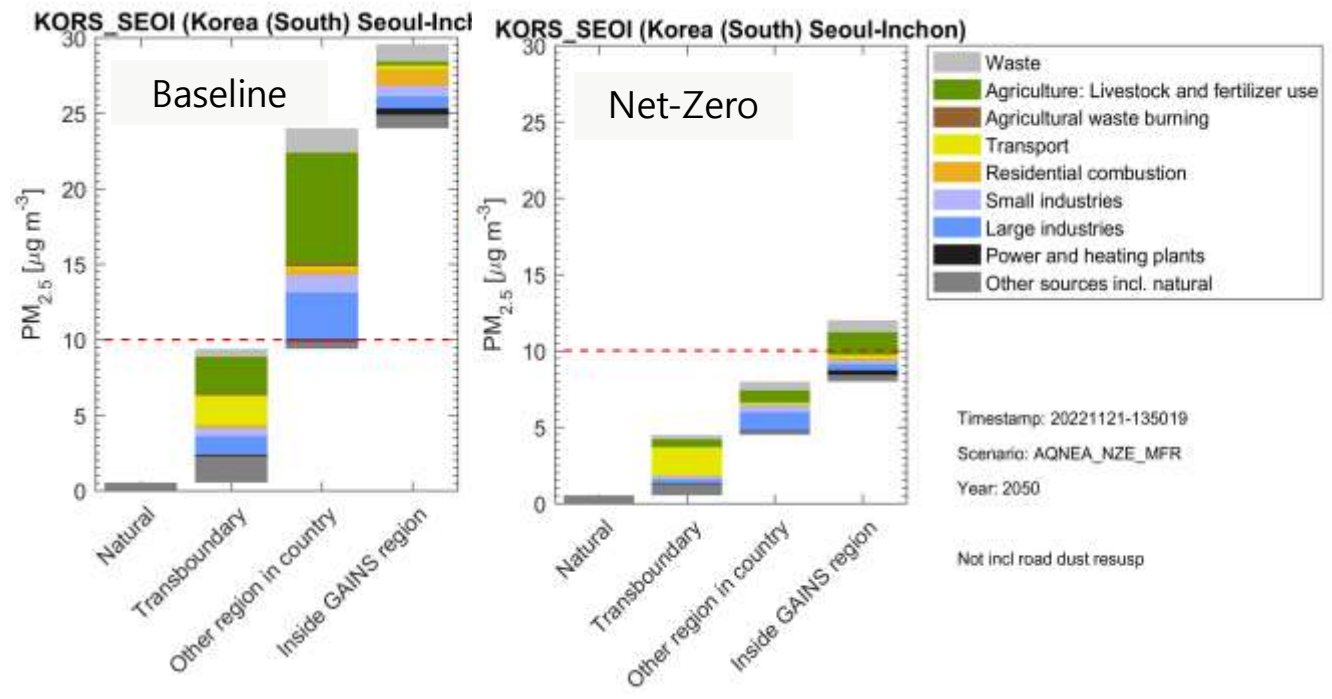
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| Rm 401-402 | <i>Ozone and PM_{2.5} pollution in Asia-Pacific region</i> Chaired by Hikari Shinadeta (Osaka University) |
| 8:30 | Session keynote: Pathways to achieve clean air and carbon neutrality in China Shuxiao Wang (Tsinghua University) |
| Rm 404 | <i>Linkage between air quality, climate, energy, and ecosystem</i> Chaired by Naga Oshima (Meteorological Research Institute) |
| 13:00 | Session keynote: Climate mitigation research: current status and challenges Shinichiro Fujimori (Kyoto University) |

04. AQNEA : On-Going Work

Energy and GAINS AQ IAM Linkage for AQNEA Stage 2 : from National to Regional (NE Asia)



PM_{2.5} Source contribution (Seoul-Incheon Draft)



For more information, Please listen following presentations



14:00 Scenarios of energy and air quality in North-East Asia: data linkage and harmonization
Younha Kim (International Institute for Applied Systems Analysis (IIASA))

15:00 Improving tools for assessment of air quality in North East Asia
Zbigniew Klimont (International Institute for Applied Systems Analysis (IIASA))

Outcome : AQNEA for Northeast Asia Air Quality Improvement Support

✓ AQNEA Data in IAMC (The Integrated Assessment Modeling Consortium) format

✓ Community Support through Web-based Data Service (Scenario Explorer)

FRIEND Project

Air Quality Forecasting

Domestic AQ Policy Support

Web-based Data Service (Scenario Explorer for AQNEA)

data.ece.iiasa.ac.at/aqnea

IPCC's Special Report on 1.5°C

ERA4CS SENSES project

AQNEA Internal Scenario Explorer

Documentation

- 4 models
- 4 scenarios
- 2507 variables
- 228 regions

AIM/Hub-Japan 2.4
MESSAGE-GLOBIOM 1.1.1M-R12
METER 1.0

AQNEA Internal Scenario Explorer

Documentation

- 4 models
- 4 scenarios
- 2507 variables
- 228 regions

AQNEA Internal Scenario Explorer

Scenario Mapping

International Cooperation

UN-ESCAP (NECAP)

UN-ESCAP (RAPAP)

Bilateral Env. Cooperation

China-Korea-Japan Research Collaboration (CRP/BAQONE)

UN-ECE (HTAP)

- *Assessment Report on NE Asia Air Quality Management Strategy*
- *Future Energy Activity-Emissions-Air Quality-Impact Data Service*



A role of science is to provide valuable, careful information to policymakers to help them make well-informed decisions.

- Detlev Helmig

ขอบคุณ!

감사합니다!

Thank you!

