Integrated Assessment Modeling on Air pollution and Climate Change

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Contents

- Introduction of the Air pollution modeling with the Integrated Assessment Model used for the Climate Change Study (AIM: Asia Pacific Integrated Assessment Model)
- Some examples of Air Pollution modeling studies along the Integrated Assessment Model framework.
  1. Quantification of Co-benefit of Regional Low Carbon Society Policies on Air Pollution
- Idea on a possible collaborative program

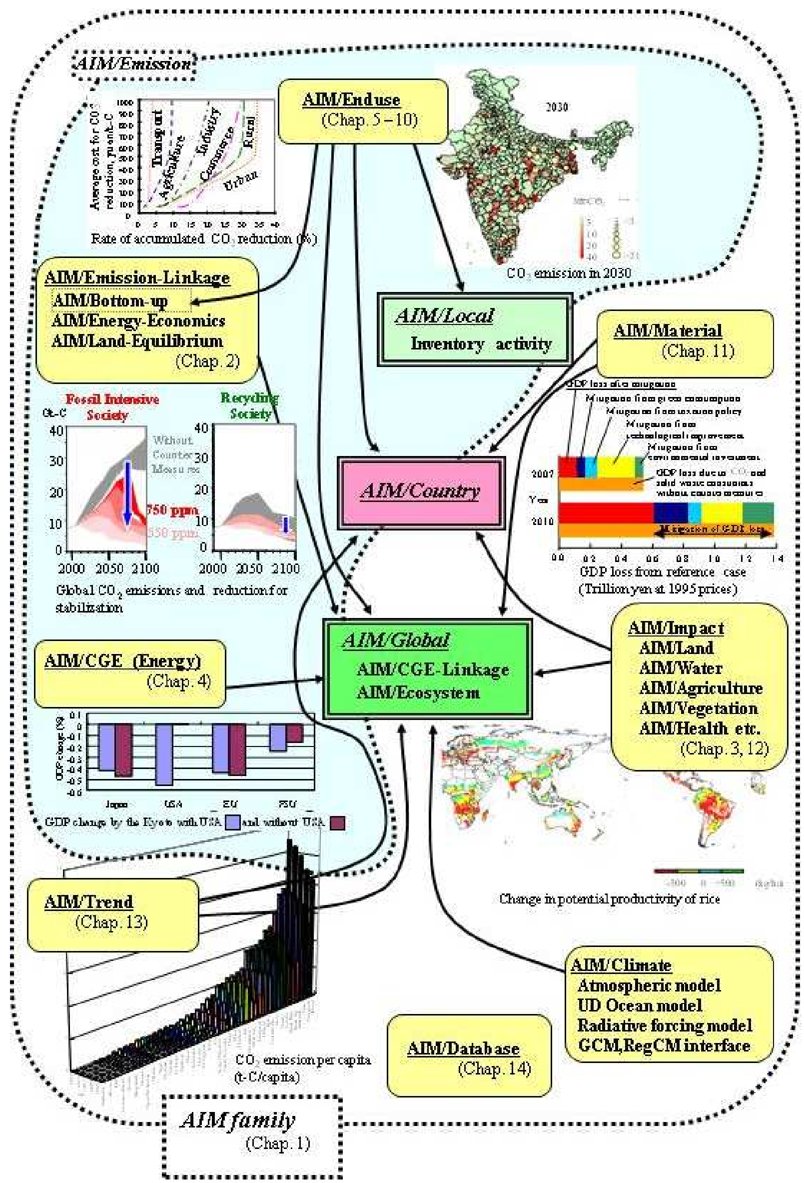
Overview of AIM (1)

AIM (Asia-Pacific Integrated Model) is an integrated assessment model to assess mitigation options to reduce GHG emissions and impact/adaptation to avoid severe climate change damages.
The model is extended to assess sustainable development policies together with Asian researchers.

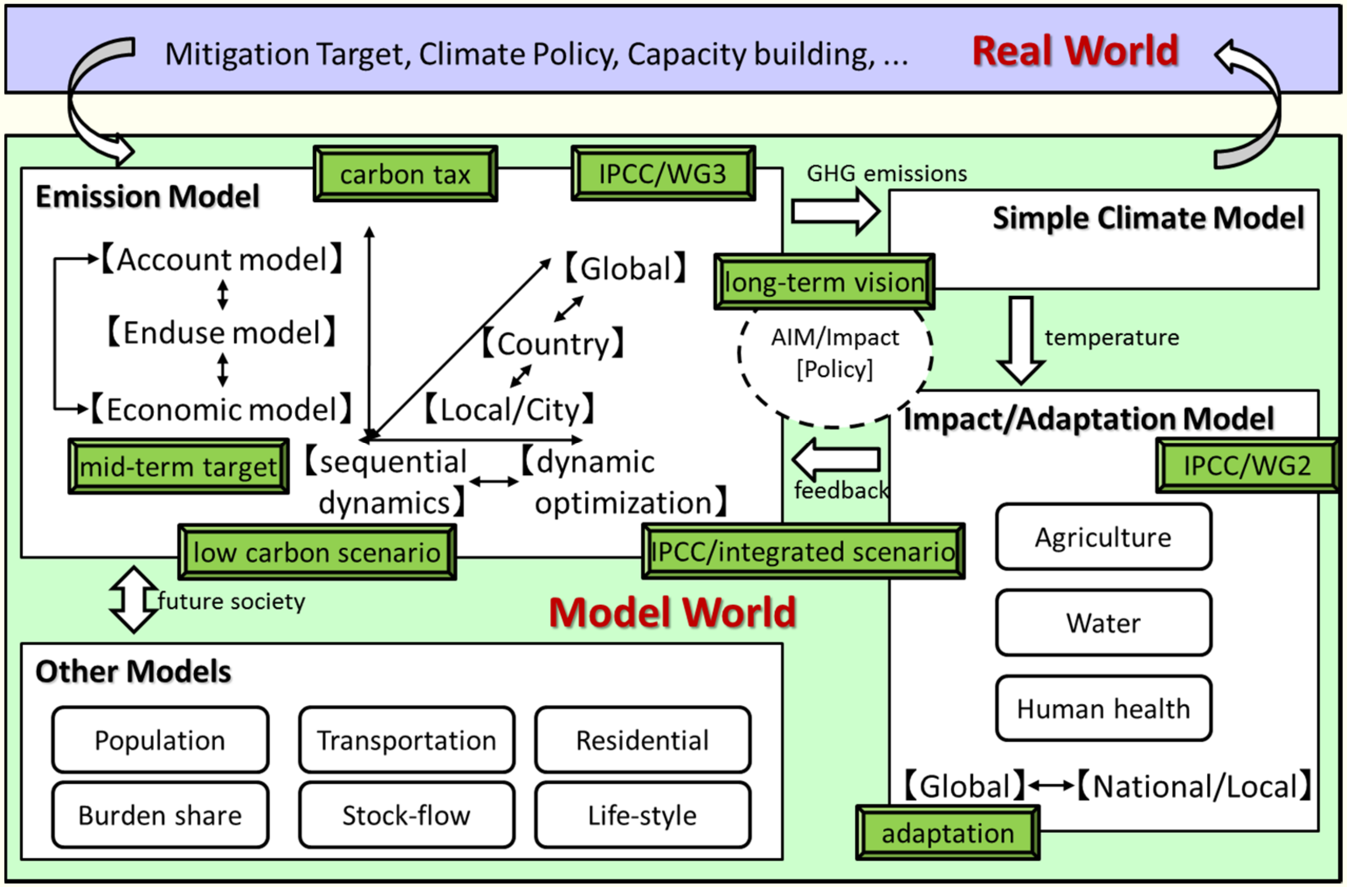
(1) Emission modules ....
- World Economic Model
- Energy Technology Selection Model
- Material Recycle Model ・Industry Model
- Landuse / Landuse Change Model
- Scenario development Model ・Simplified Model

(2) Climate Modules...
- Carbon cycle Model ・Chemical Transport Model
- Global Average Climate Model
- Regional Climate Model

(3) Impact Modules ...
- Water Resource Impact Model
- Agriculture Impact Model
- Potential Vegetation Impact Model
- Health Impact Model ・Economic Impact Model

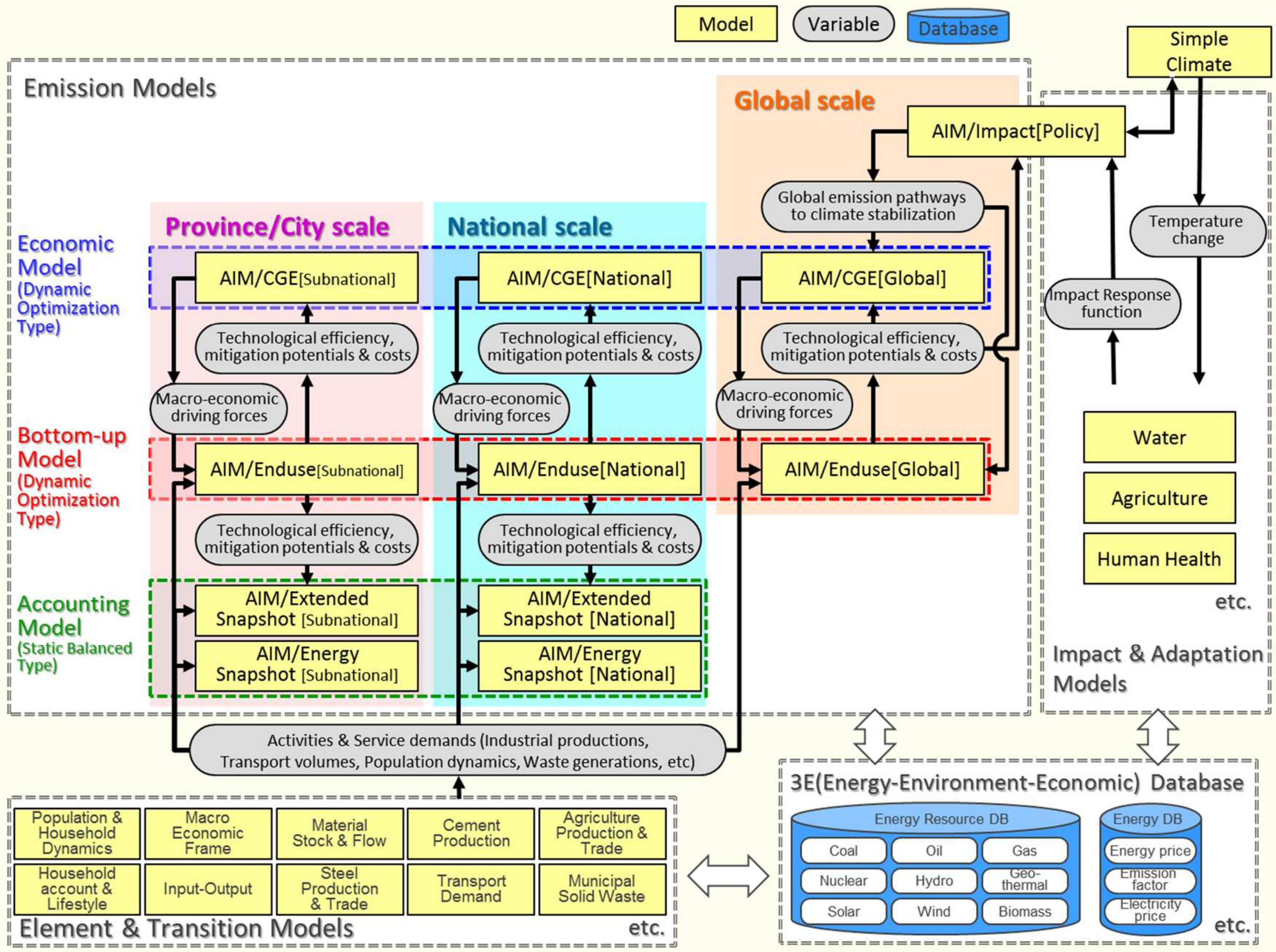


Overview of AIM (2)



http://www-iam.nies.go.jp/aim/

AIM models for GHG mitigation analyses



MOEJ-S12: Active evaluation of SLCP impacts and seeking the optimal pathway (2014-2018)

PI: Terry Nakajima

- Reduction of **SLCP** is easier than that of **LLGHG** due to their short lifetime, but the effects are very complex.
- Therefore, search for optimum mitigation paths is important for society.
- It is needed to develop an active evaluation system for **LLGHG** and **SLCP** mitigation policy, by overarching emission inventory, integrated models, and climate models.

Regional AQ change events: Regional modeling

Emission inventory

Emission scenario

Emission scenario & Optimum mitigation path: Socio-economical & technology model (AIM)

Upscaling the regional mitigation experiences to global

Impacts of mitigation/ adaptation

Global climate impacts: Climate modeling

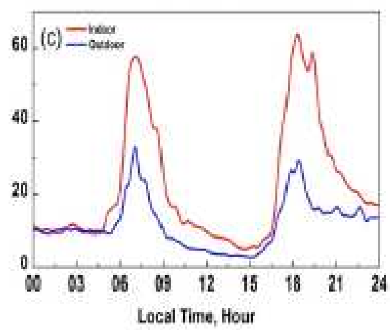
Improving emission inventories through analysis of regional air quality change events

Improvement of AIM to reflect the SLCP regional change

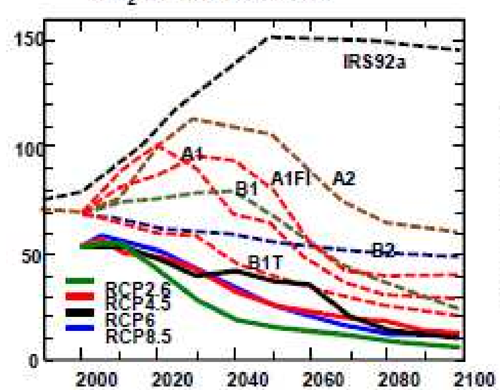
Assessment of regional and global climate/agriculture, and heath environment impacts

ex.: Project Surya (India)

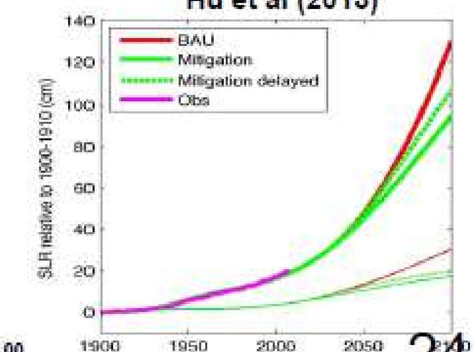
Black Carbon ($\mu g\ m^{-3}$)
Praveen et al (2011)



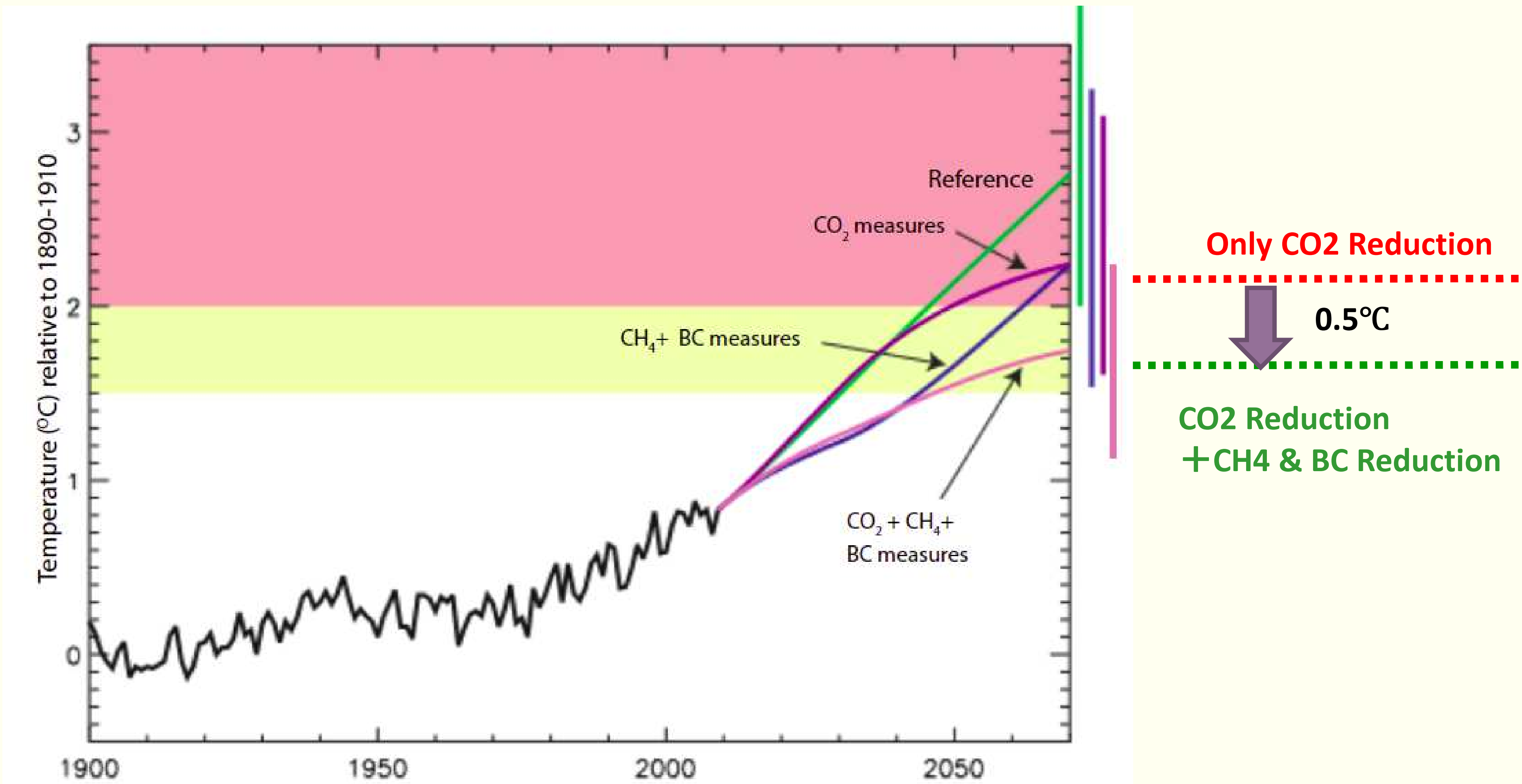
SO_2 future scenarios



Sea level rise
Hu et al (2013)



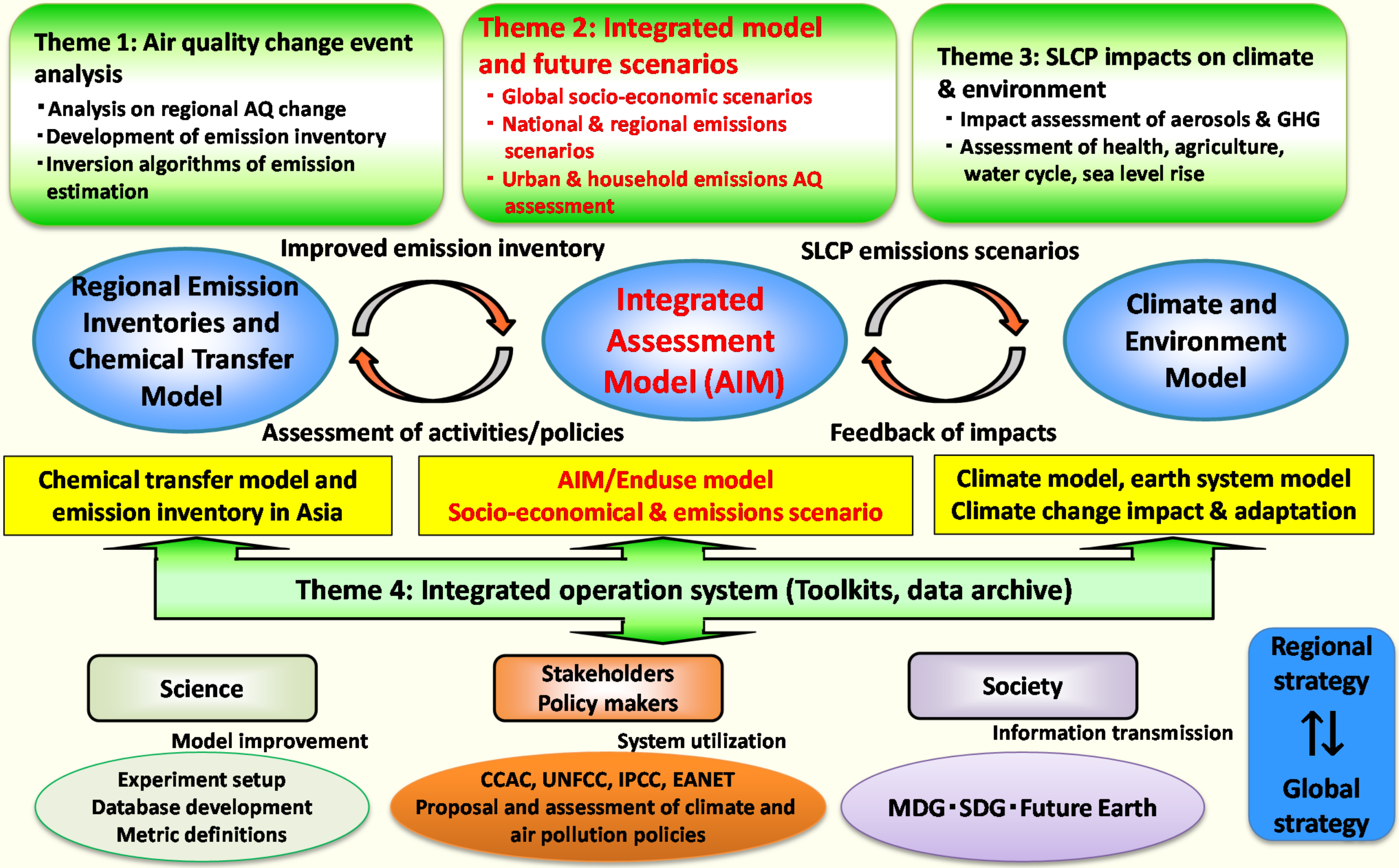
Reduction of Short lived Climate Pollutants and Global average temperature



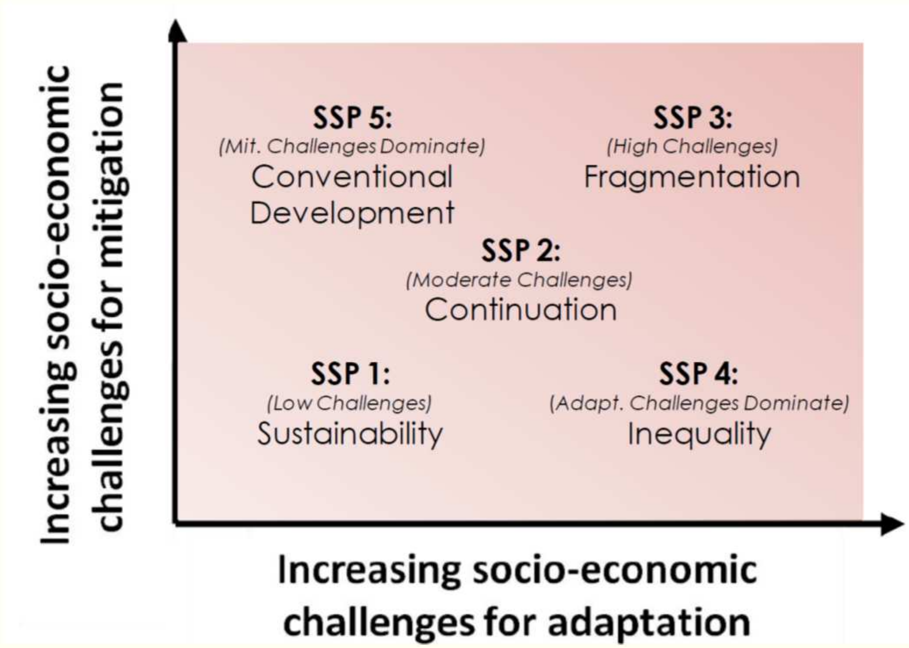
Source）Figure6.1, UNEP/WMO (2011) Integrated Assessment of BC and tropospheric O3

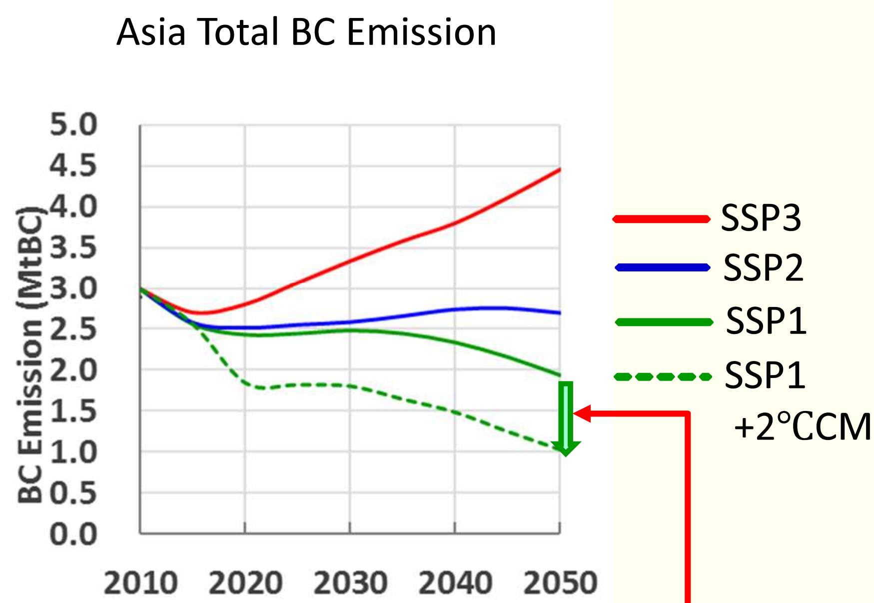
SLCP emission in AIM model

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



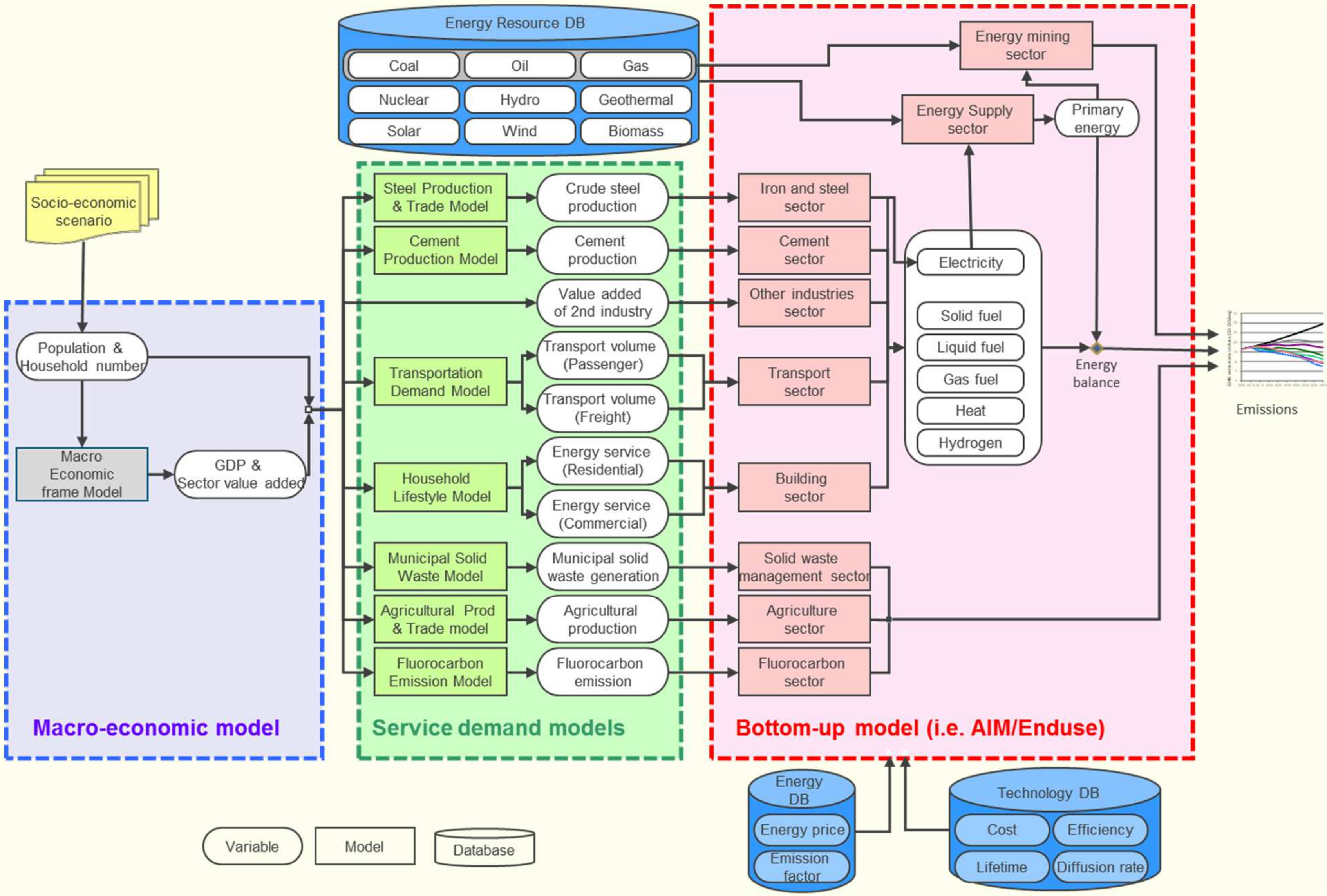
SSPs(Shared Socioeconomic Pathways) and effect of additional Climate & Air Pollution policy



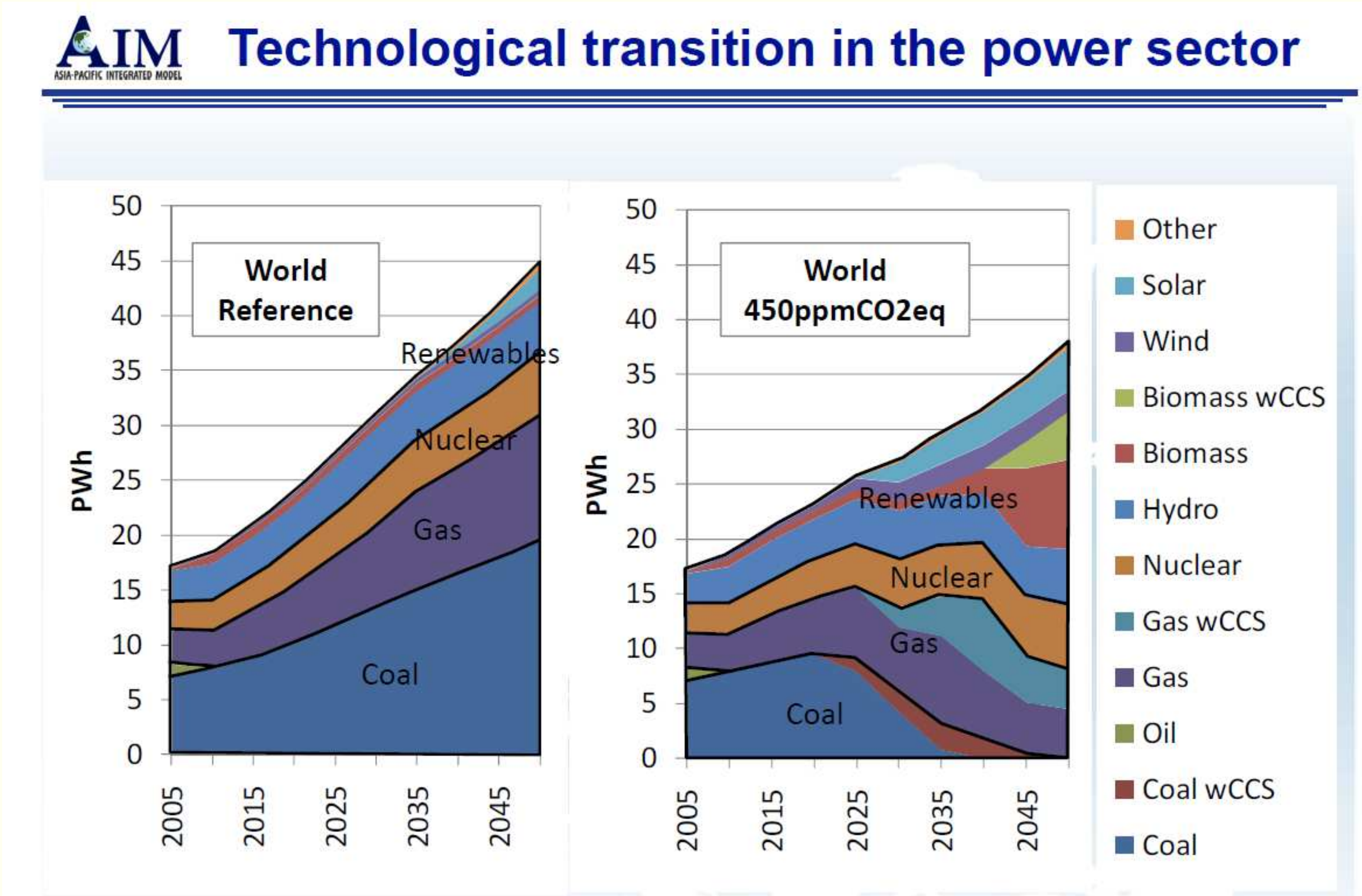


① SCLP emission abatement technology: FDG, CM on Agriculture, etc.,
② improvement of Fuel Quality
③ Energy saving, Improvement of Energy Efficienc
④ Fuel shift

Overview of AIM/Enduse[Global] and element models

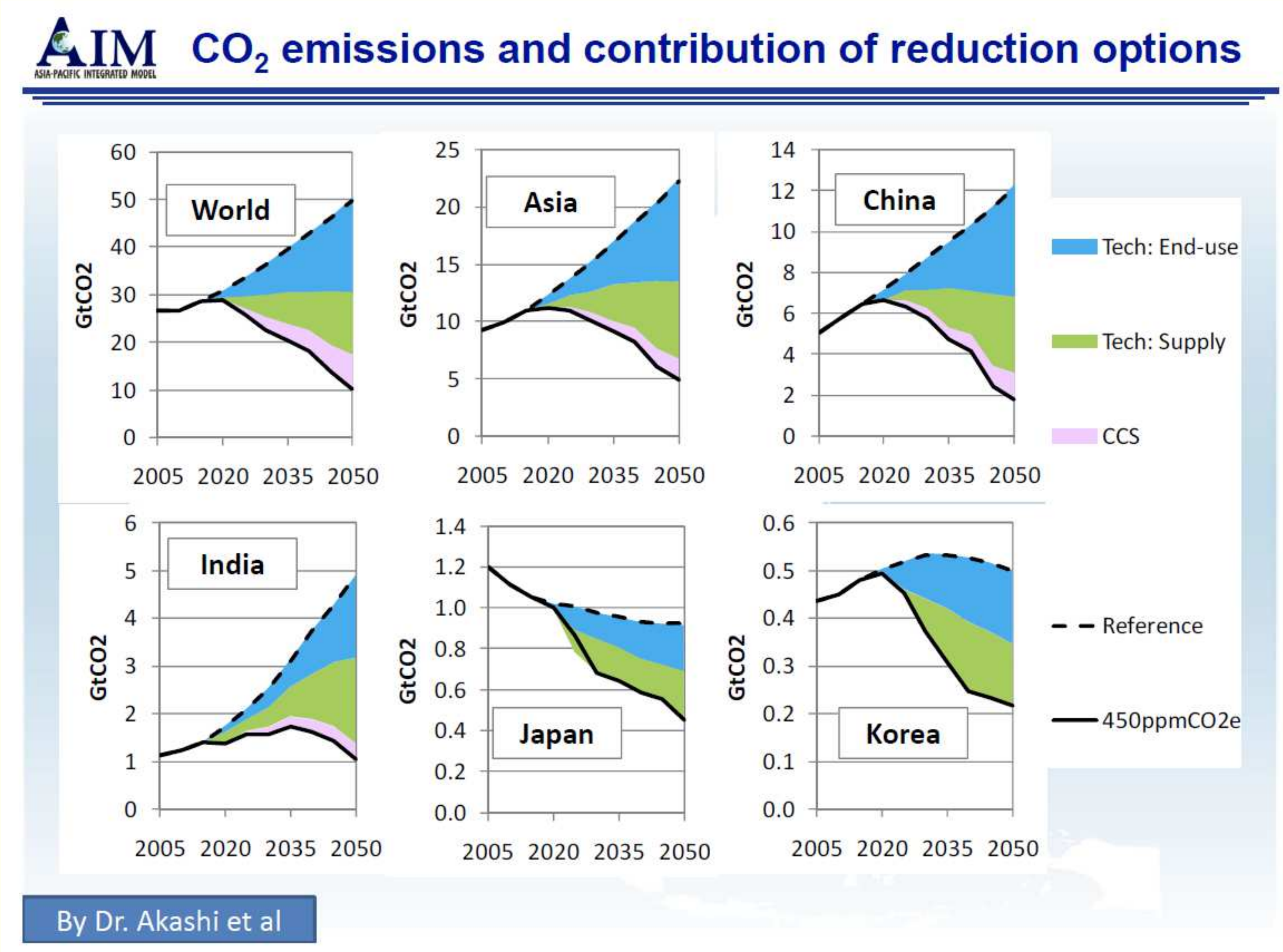


Sample Output from AIM/Enduse[Global] Model

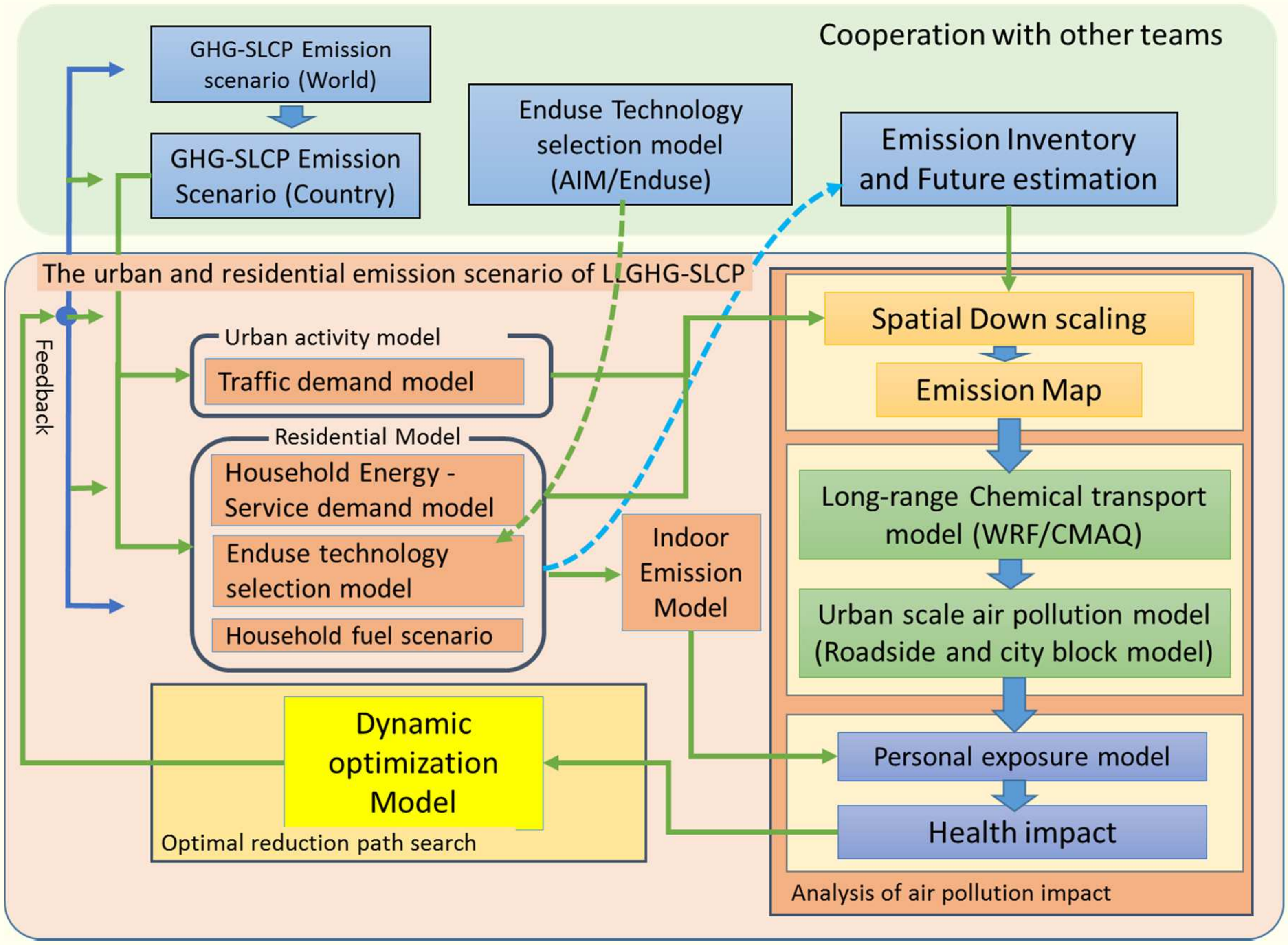


By Dr. Akashi et al

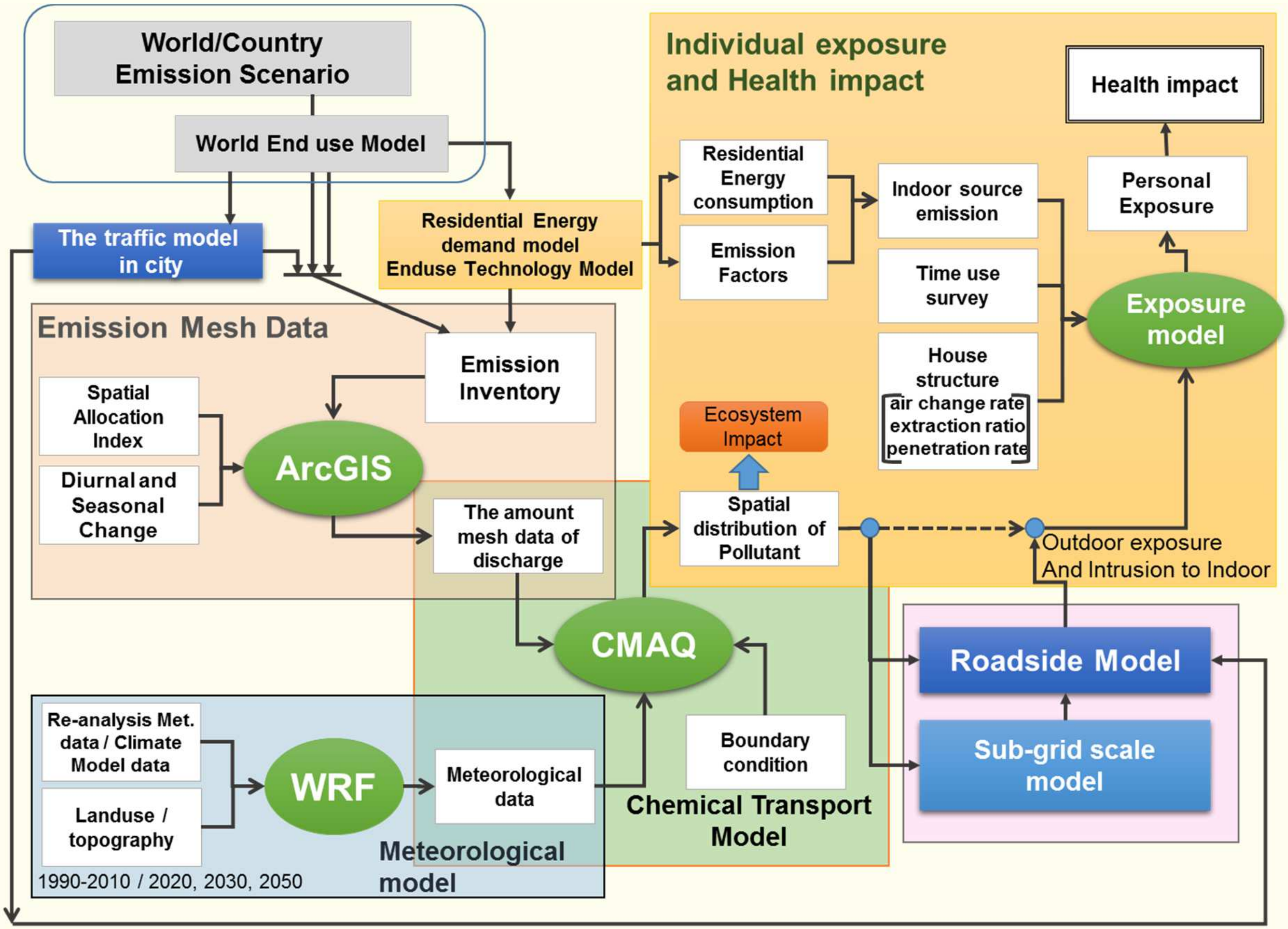
Sample Output from AIM/Enduse [Global] Model



Socio-Economic, Emission, Concentration, Impact



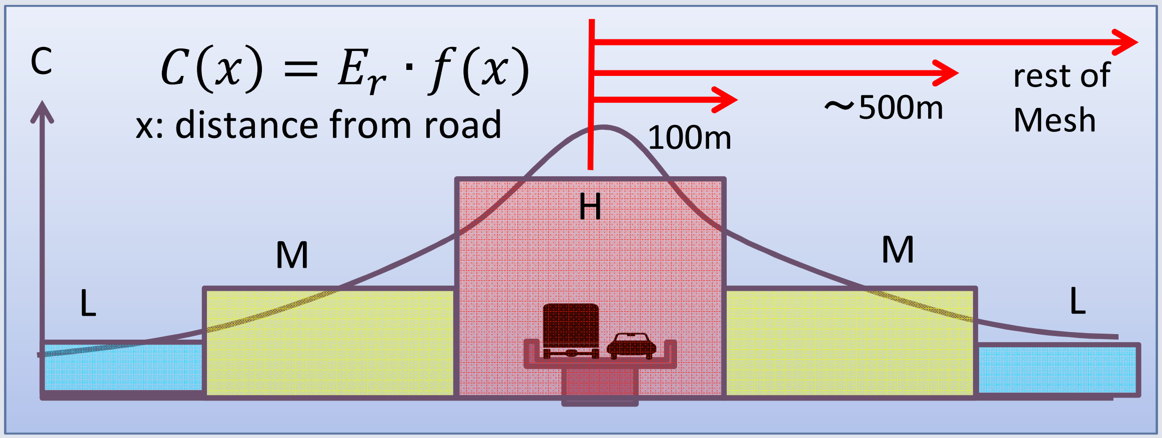
Detail component of the Air Quality, Impact Model

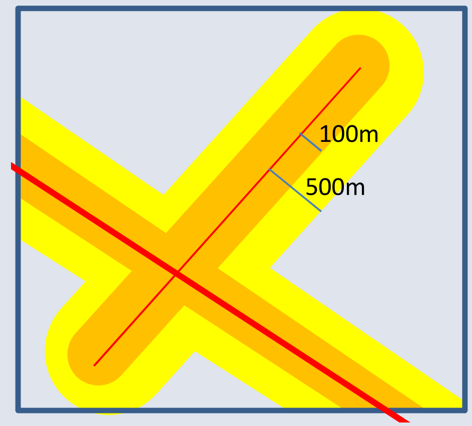


Roadside Model

Road Network Data: OpenStreetMap

- Calculation case and mesh size :
  Fine Case :   1km
- Divided a mesh to 3 classes by the distance from road.





JEA: Gaussian Plume model

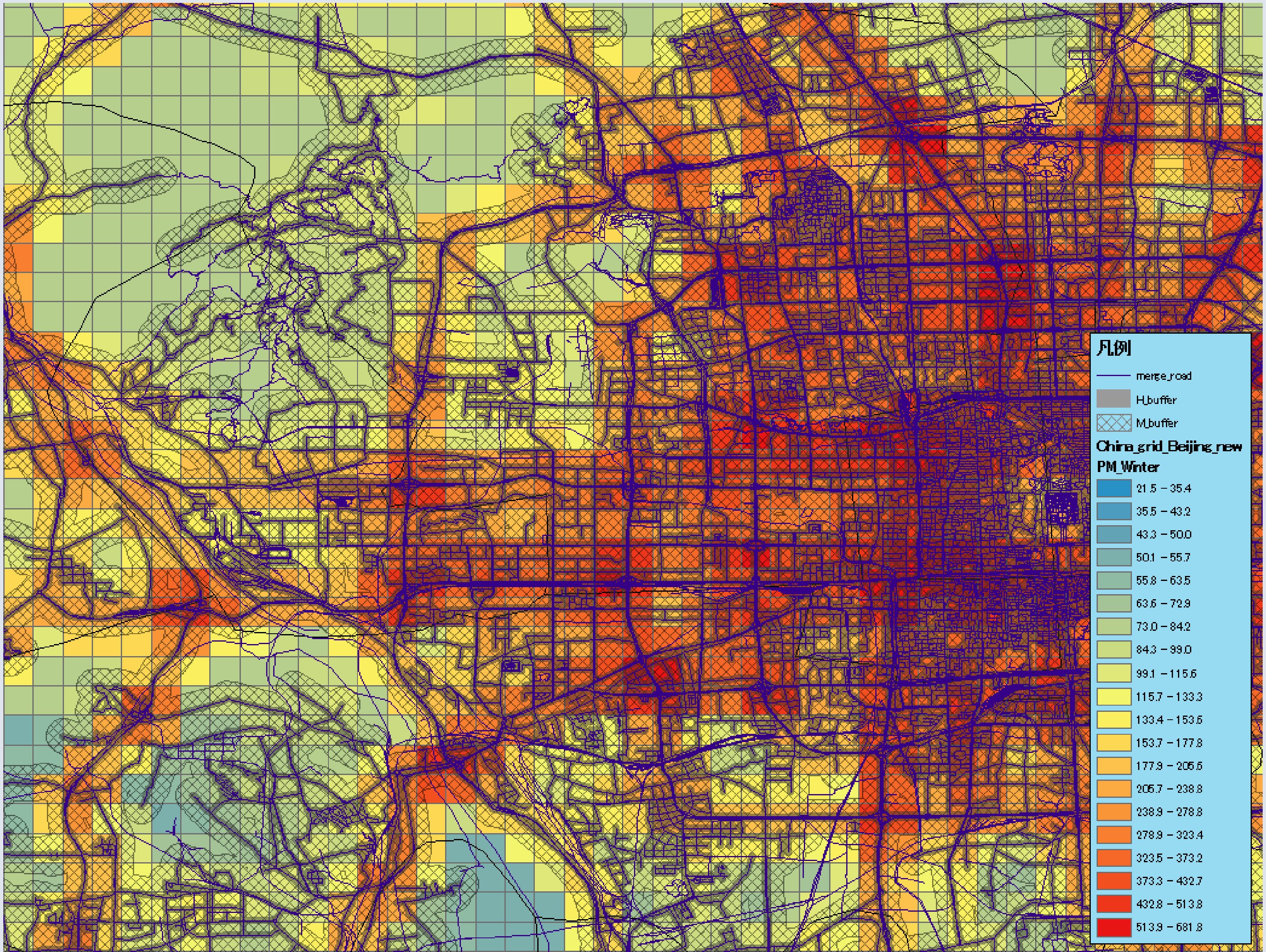
$$C(x, z) = \frac{Q_L}{(u \sin\theta)^{0.5}} \cdot \frac{A}{x^s} \cdot \exp\left(-B\frac{z^p}{x}\right) \times W(x : y_1, y_2)$$

Cx,y): Concentration, x: distance from road, z: height, QL: emission intensity, u: wind velocity
θ : angle between Road and Wind,

Road : OpenStreetMap

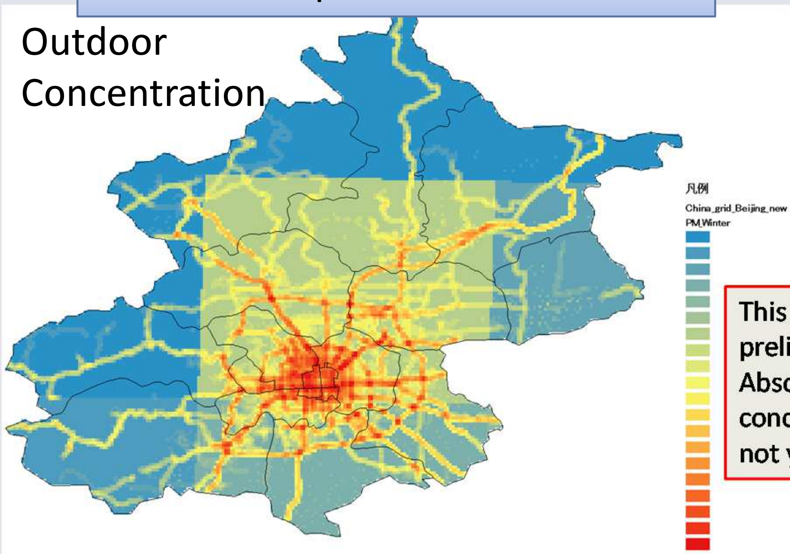
Definition of the buffer area of Roadside Model

In the case of Beijing 1 km mesh case.



Individual Exposure Concentration

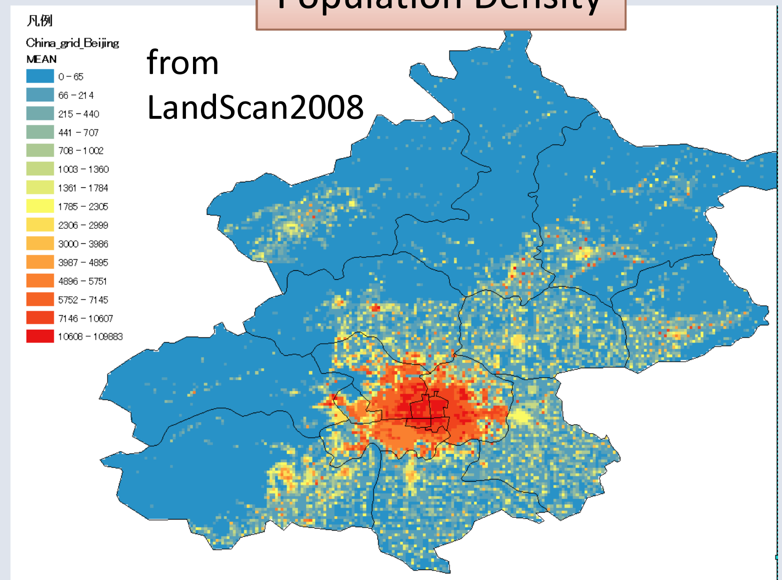
Outdoor Concentration



This result is still preliminary. Absolute value of concentration is not yet validated.

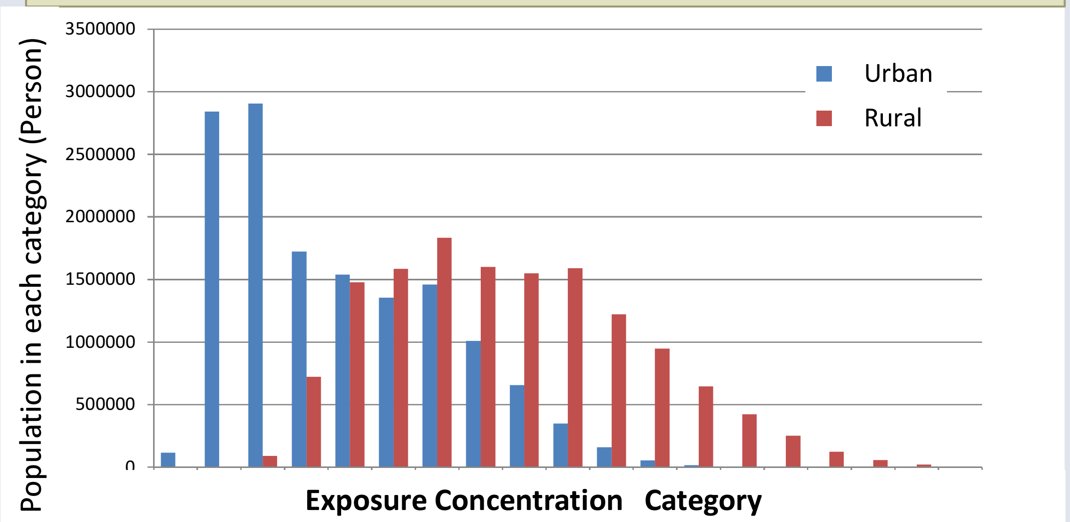
Population Density

from LandScan2008



+ Contribution from Indoor emission

Population Histogram in Exposure concentration.



- **In the Urban area, Major contributor is “indoor w/o emission”, this mean source of pollutants is outdoor, and stay duration to indoor is much longer than duration at outdoor.**
- **Still exposure in rural area is higher than urban area due to the high usage of biomass fuel in Kitchen and Heating.**

Feedback of Health impact to Socio-Economic Model (1)

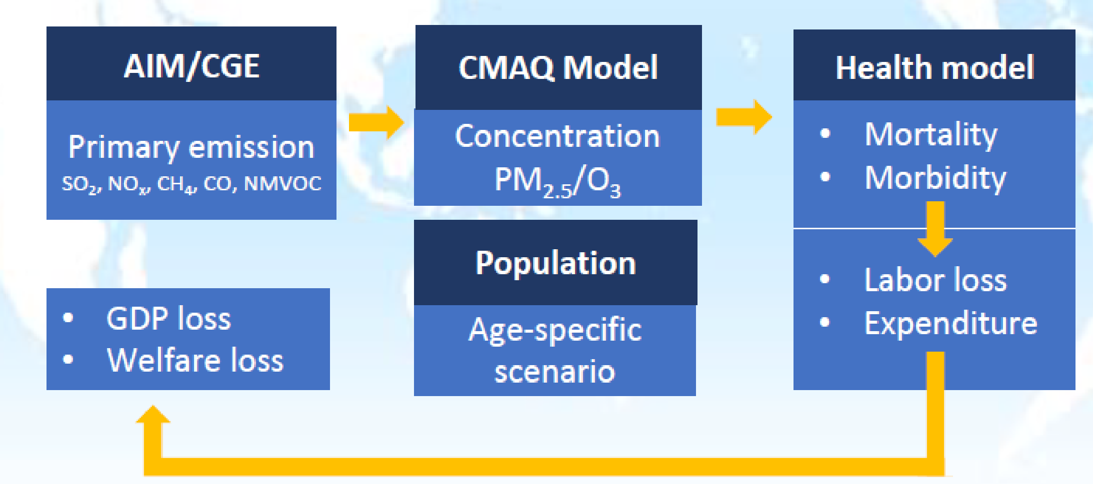
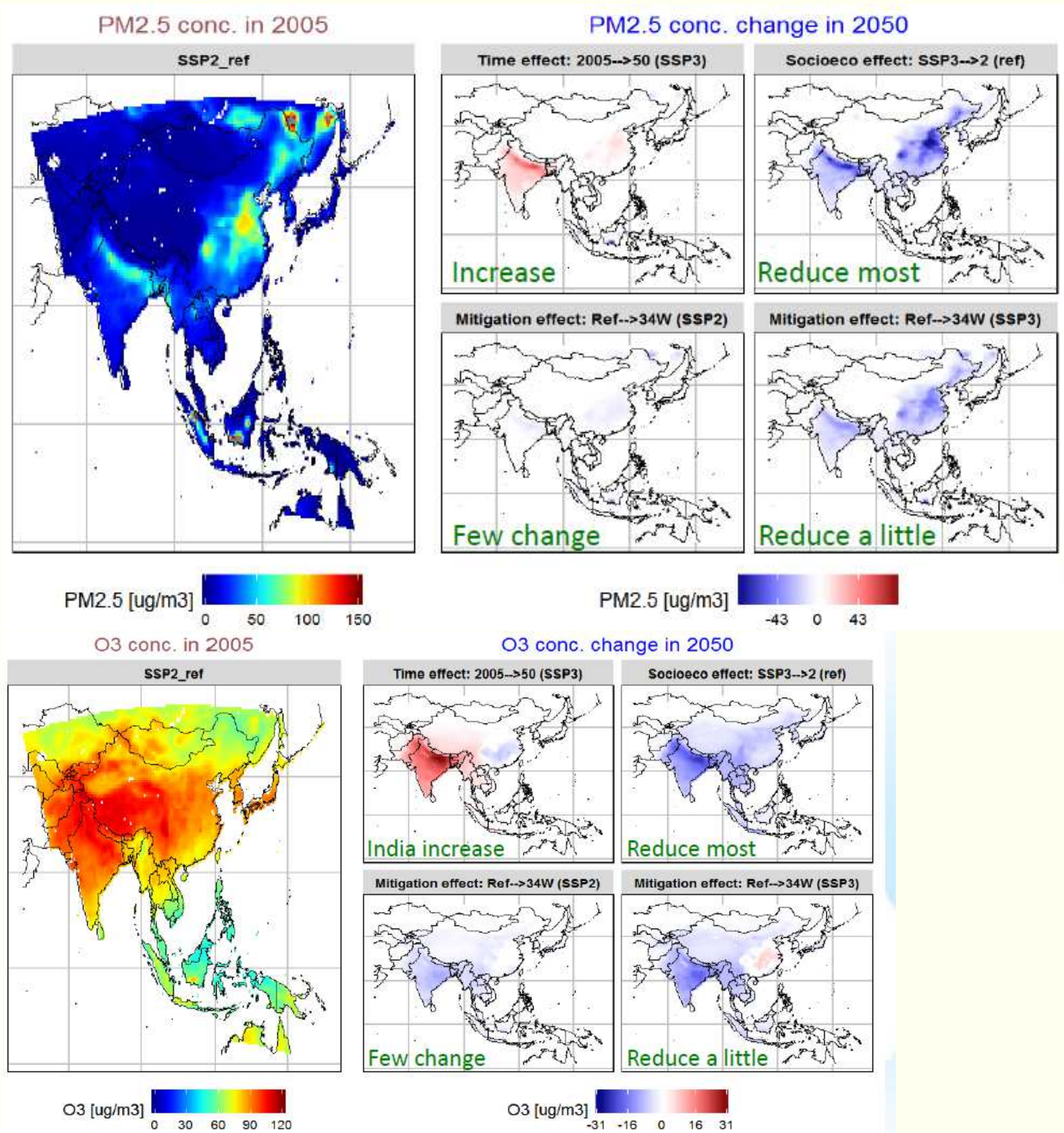


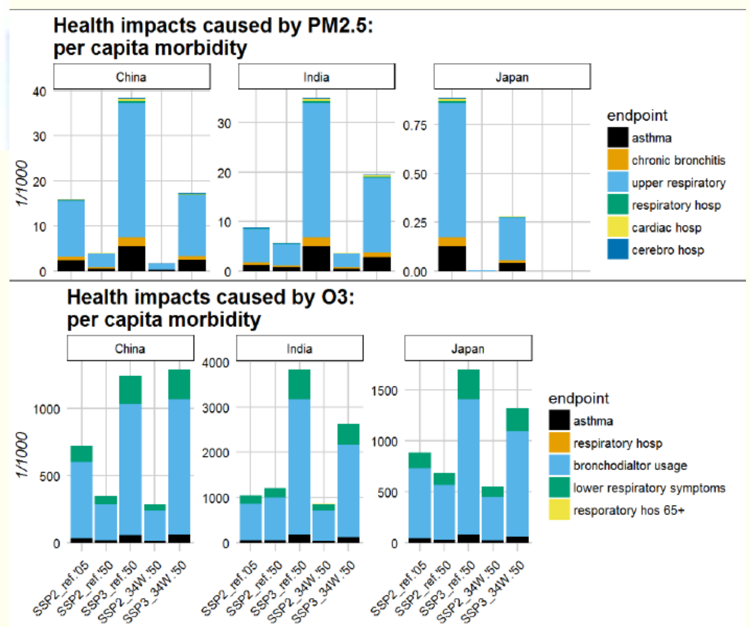
Fig.1 Research Framework.

Socioeconomic /Climate policy	Ref	34W
SSP2	SSP2_ref	SSP2_34W
SSP3	SSP3_ref	SSP3_34W

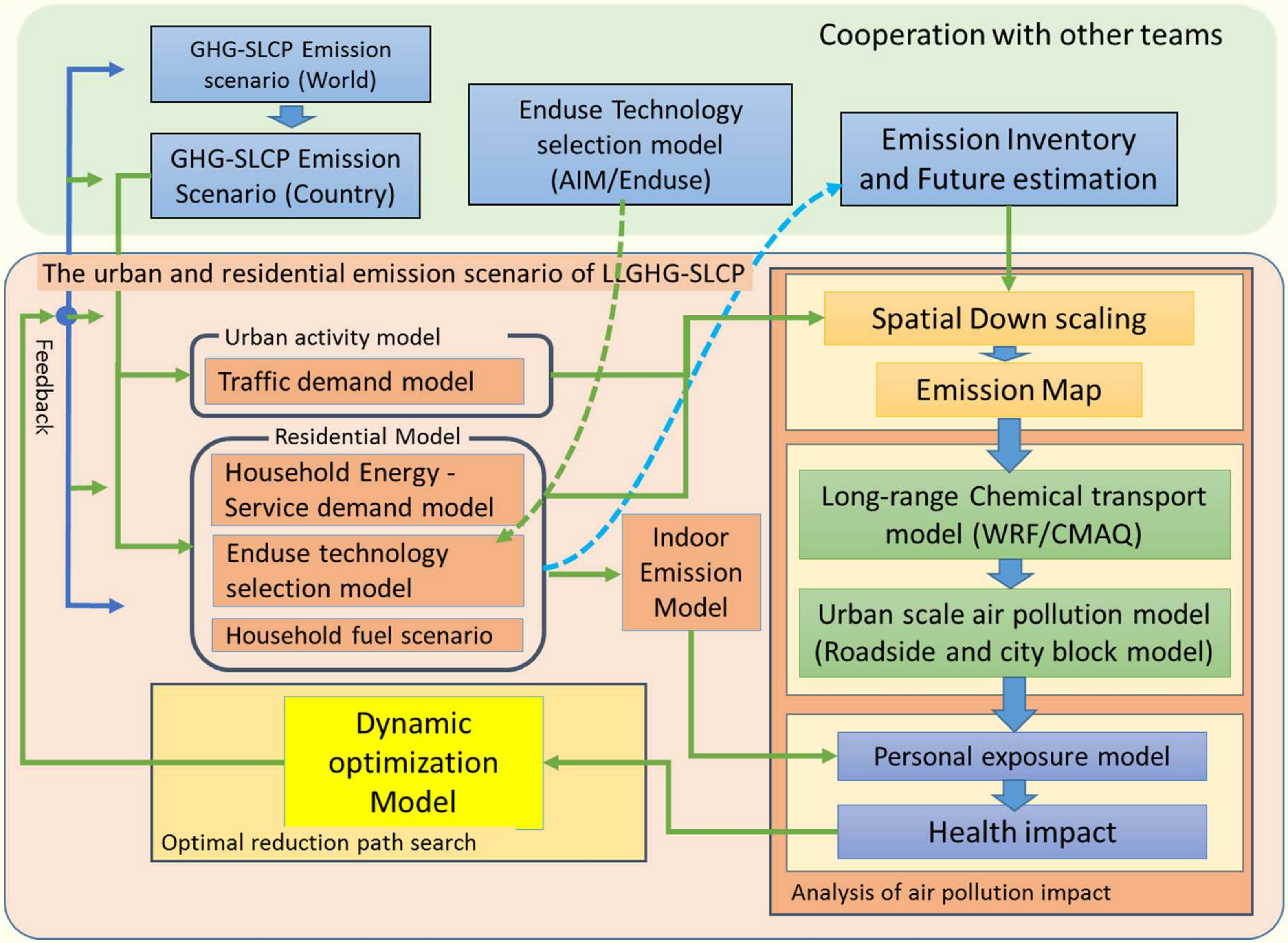
Category	Endpoint PM2.5	Endpoint ozone
Work loss	Work loss day from morbidity	
	Work loss day from cumulative mortality	
Morbidity	Respiratory hospital admissions	Respiratory hospital admissions
	Cerebrovascular hospital admission	Lower respiratory symptoms
	Cardiovascular hospital admissions	Bronchodialtor usage
	Chronic bronchitis	
	Asthma attacks	
	Respiratory symptoms days	
Mortality	All cause	All cause

Feedback of Health impact to Socio-Economic Model (2)

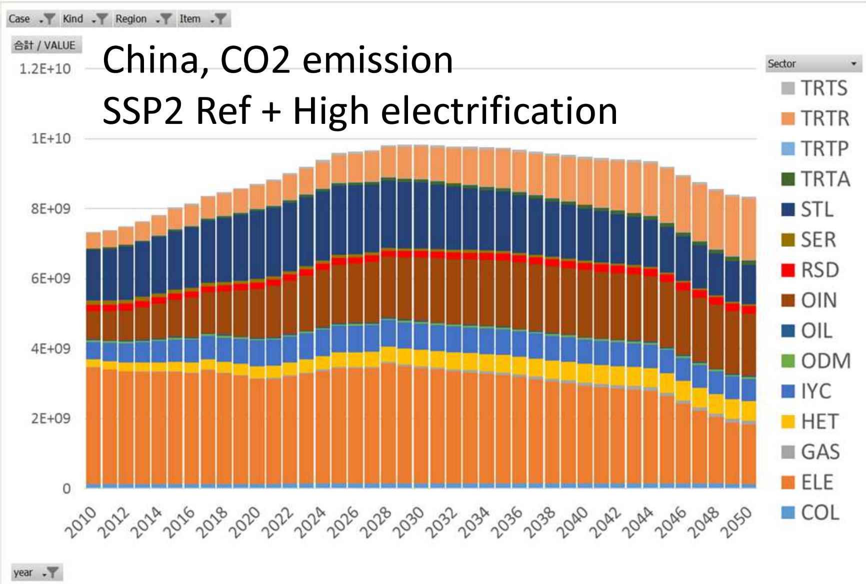


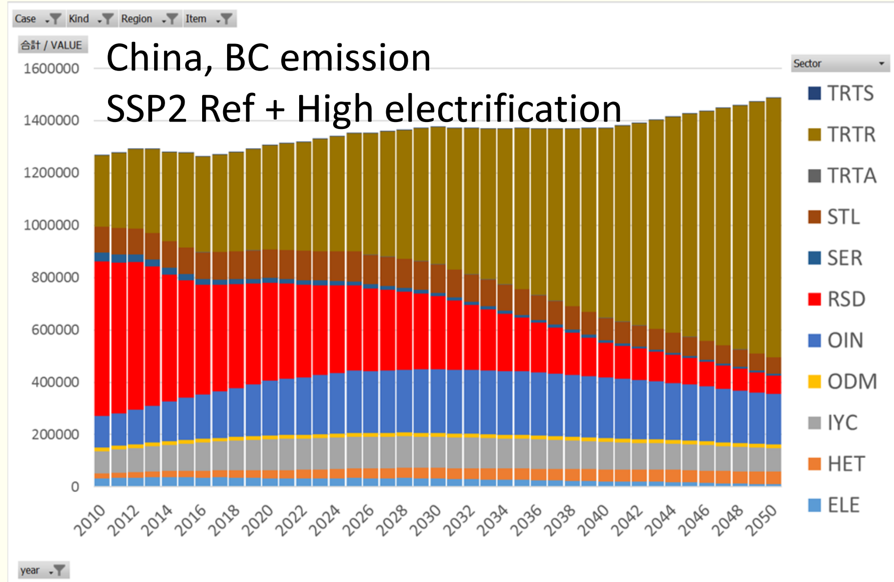


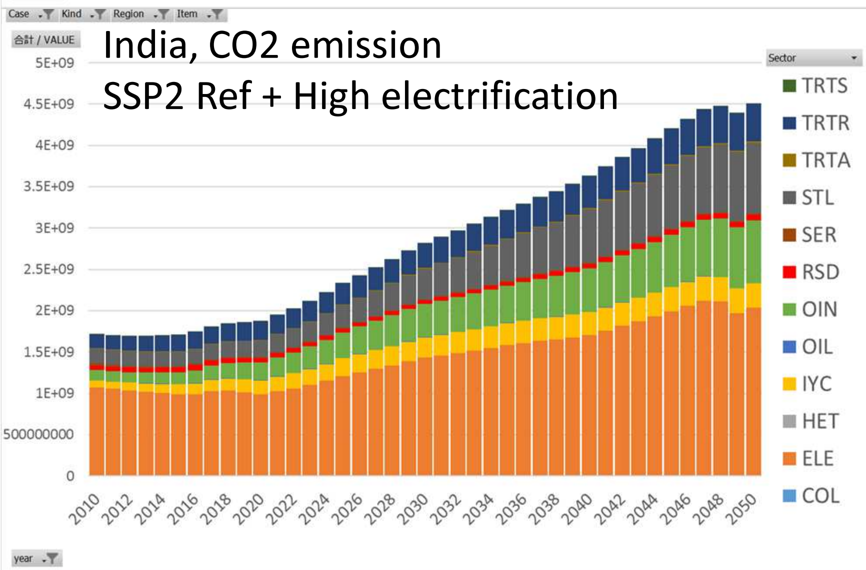
Socio-Economic, Emission, Concentration, Impact

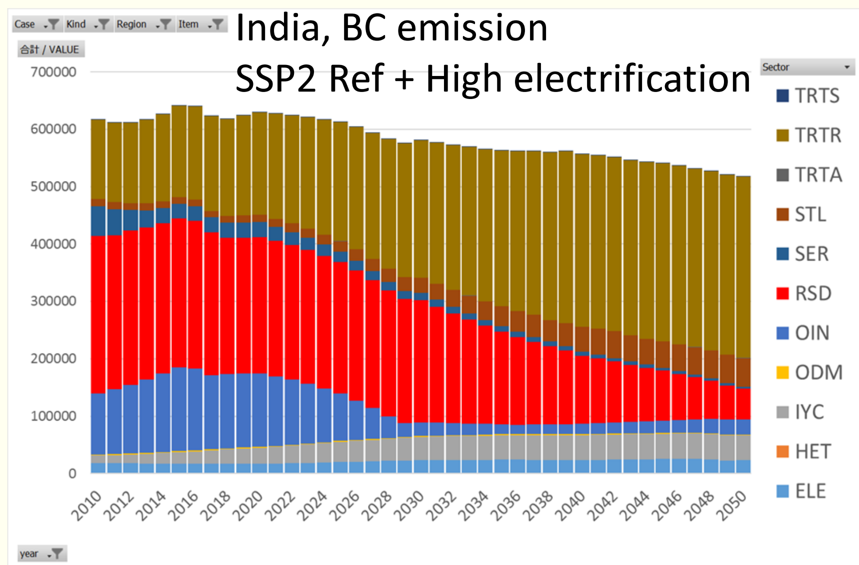


Importance of Residential Sector

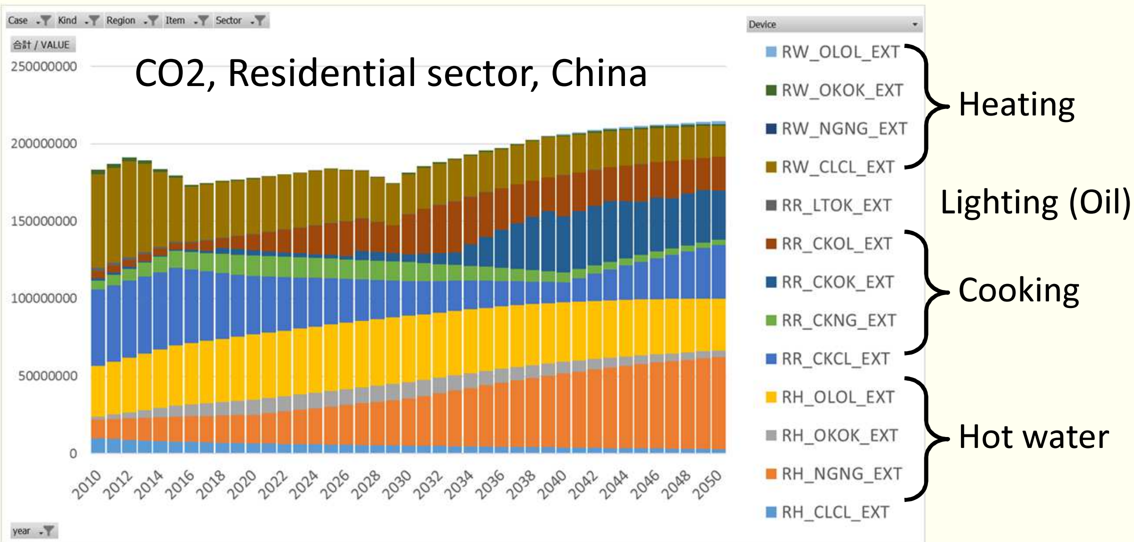


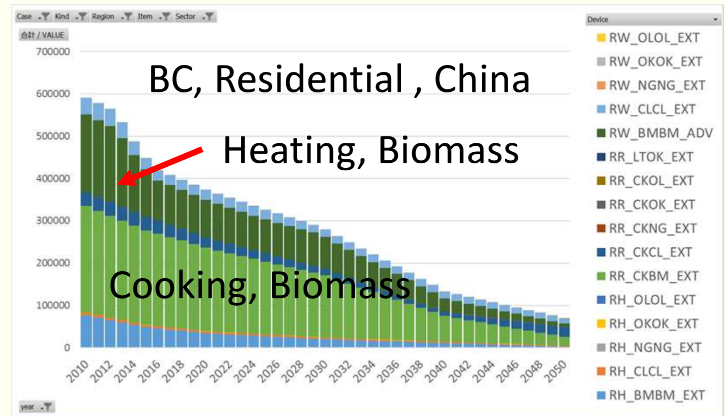




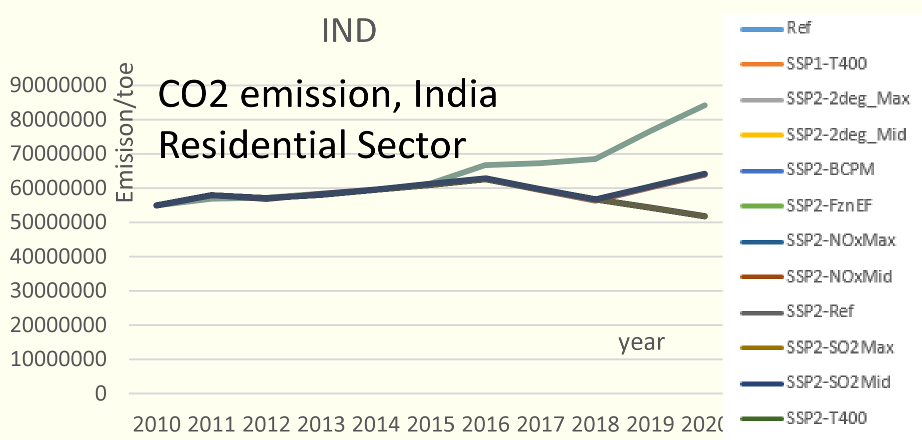


Lack of attention to Residential Sector





SSP2 Reference CO2 emission by Technology
for Residential sector 2010-2050 China



There are no difference between Countermeasure cases for Climate Change

Because, the Climate Policy mainly focus on the Power generation, industrial sector and Transportation sector.

Improvement of Residential sector model

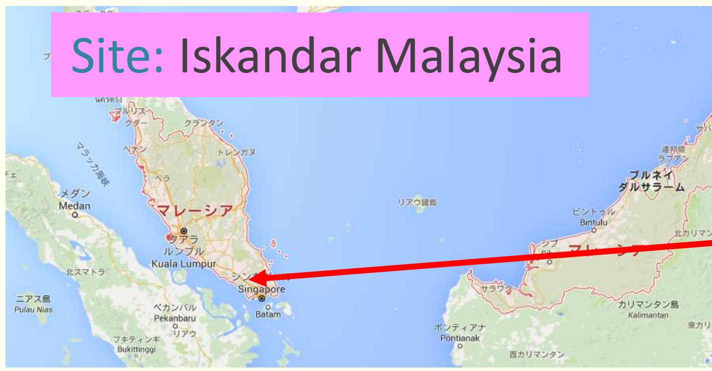
- Lack of Future Service demand estimation
  - Because there are large differences in lifestyle between regions, it is difficult to estimate the service demand in the future residential sector.
- Lack of Technology Information
  - Bottom-up model carries out technology selection according to economic rationality. However, in addition to the lack of information on the initial cost and running cost of the household equipment, it differs greatly from country by country.
- Lack of Emission Factor for air pollutants.
  - The emission factors of air pollutants from household equipment are extremely limited.

Example 1

Quantification of Co-benefit of Regional Low Carbon Society Policies on Air Pollution

- We focus on the city level co-benefits under the detail Low Carbon Society Scenario and quantified the reduction of air pollutants by each LCS policies on Iskandar Malaysia’s LCS scenarios.

Target Area



- Population: 2005 1.8million ⇨ 2025 3.0million
- GDP: ×4.0 GHG emission (BaU): × 2.75
- Low Carbon Society Scenario for 2025 have been developed
- Co-benefit of LCS policies on air pollution was considered.

Example 1

Methodology (1)

1. Development of Low Carbon Society Scenario for 2025 for Iskandar Malaysia

2. Downscaling the emission source to Map (NOx, SO_2, CO, $PM_{2.5}$)

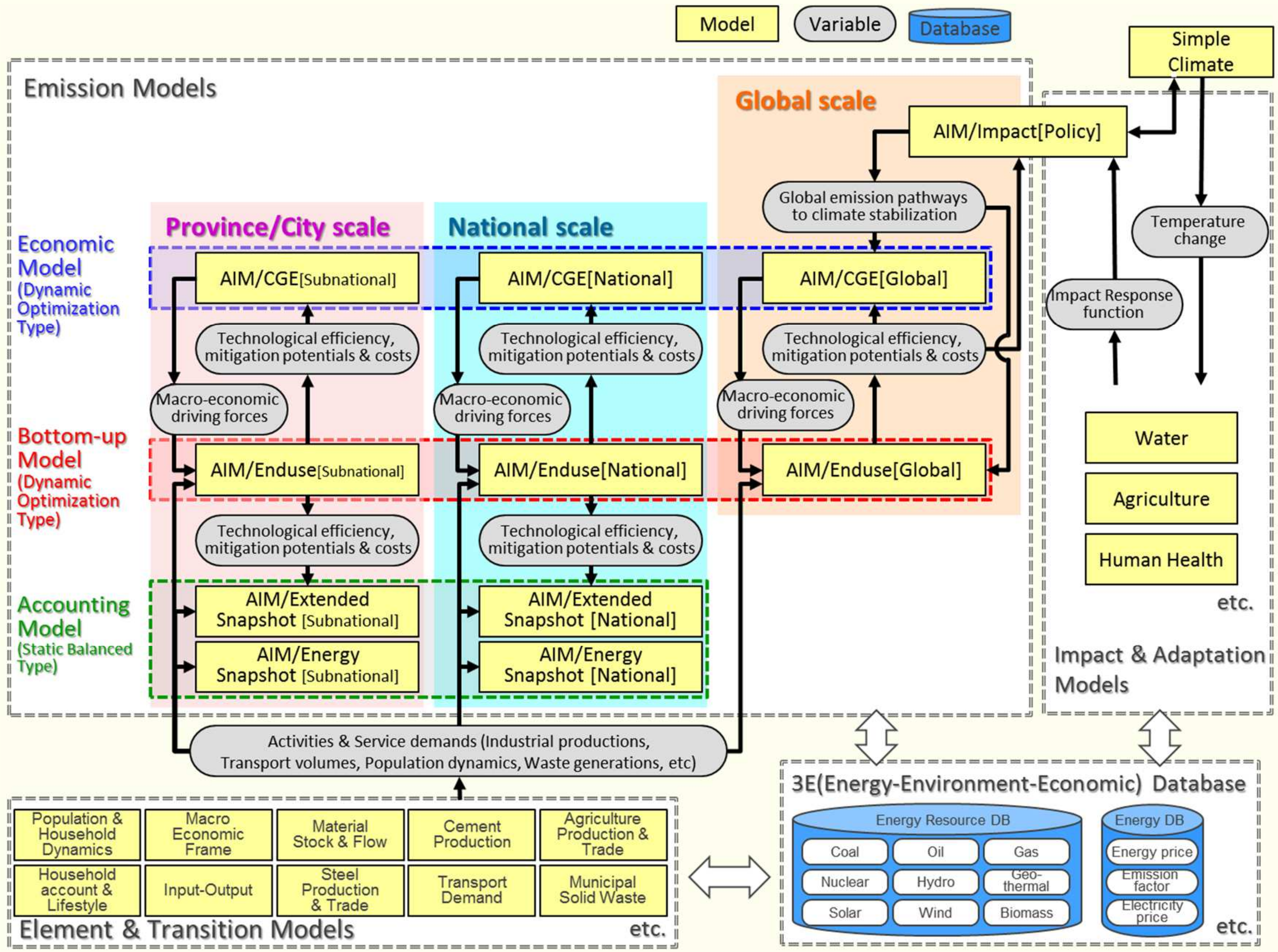
   Transportation Sector
   - Traffic Demand Analysis Model
   - Downscaling by road network

   Other Sector
   - Downscaling by population, Landuse and LPS

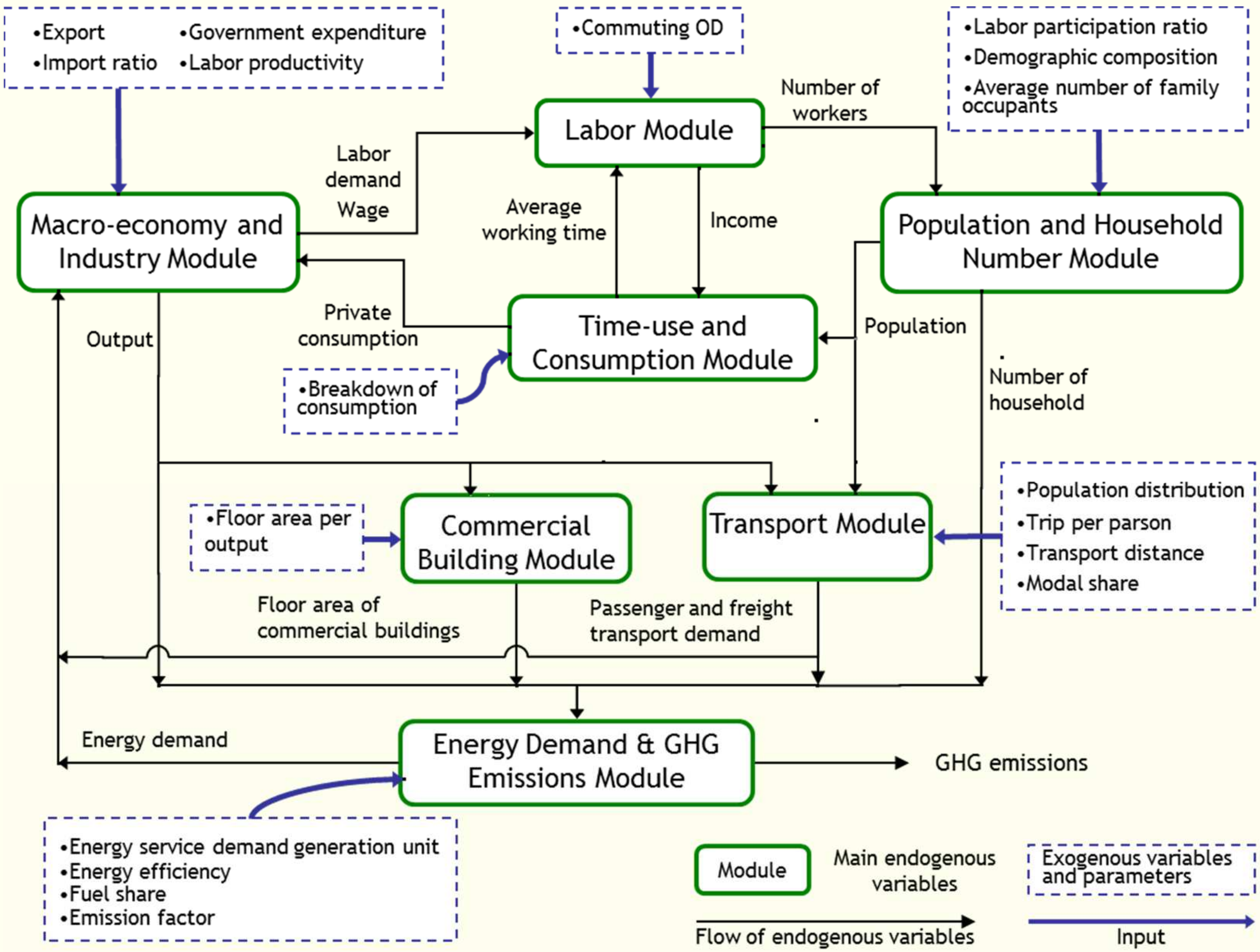
3. Calculate the yearly average concentration in the region by using WRF/CMAQ.

4. Estimate the premature death by the long-term exposure to $PM_{2.5}$

AIM models for GHG mitigation analyses



Model Framework of ExSS



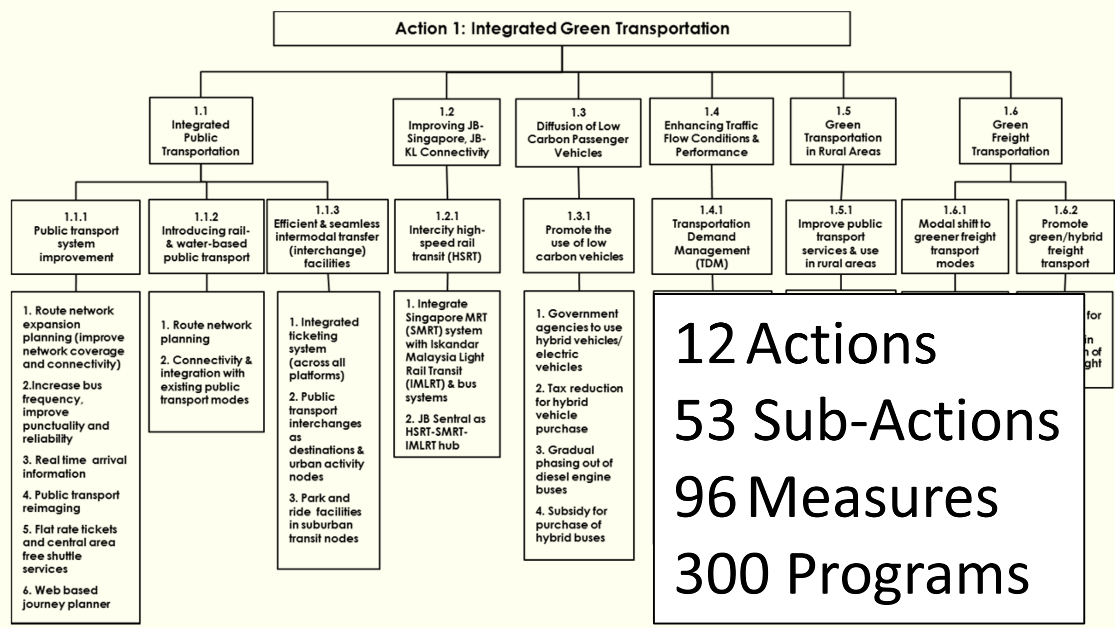
Example 1

Methodology (2)

Mitigation Options
Green Economy
Action 1 Integrated Green Transportation
Action 2 Green Industry
Action 3 Low Carbon Urban Governance**
Action 4 Green Building and Construction
Action 5 Green Energy System and Renewable Energy
Green Community
Action 6 Low Carbon Lifestyle
Action 7 Community Engagement and Consensus Building**
Green Environment
Action 8 Walkable, Safe and Livable City Design
Action 9 Smart Urban Growth
Action 10 Green and Blue Infrastructure and Rural Resources
Action 11 Sustainable Waste Management
Action 12 Clean Air Environment**
Total

Quantify and Parameterize each Program to Socio-Economic parameters

Sub-action	Measures
Integrated Public Transportation	Public transport system improvement
	Introduce rail based and water based public transport
	Efficient/ seamless inter-modal transfer (interchange) facilities
Improve JB – Singapore, JB-KL Connectivity	Intercity High Speed Rail Transit (HSRT)
Diffusion of Low Carbon Passenger Vehicles	Promote use of low carbon vehicles
Enhancing Traffic Flow Conditions and Performance	Transportation Demand Management (TDM)
Green Transportation in Rural Areas	Improve public transport services & use in rural areas
Green Freight Transportation	Modal shift to greener freight transport modes
	Promote green / hybrid freight transport



12 Actions
53 Sub-Actions
96 Measures
300 Programs

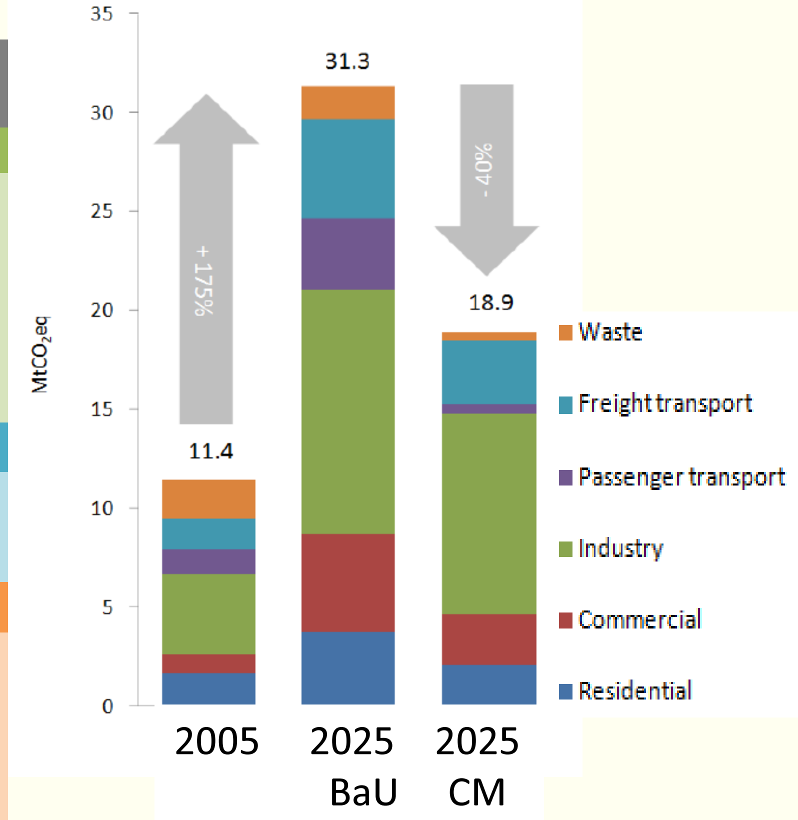
Example 1

LCS scenarios for policy development in IM

GHG reductions by Actions

Mitigation Options	$ktCO_2$ Reduction	%
Green Economy	6,937	54%
Action 1 Integrated Green Transportation	1,916	15%
Action 2 Green Industry	1,094	9%
Action 3 Low Carbon Urban Governance**	-	-
Action 4 Green Building and Construction	1,203	9%
Action 5 Green Energy System and Renewable Energy	2,725	21%
Green Community	2,727	21%
Action 6 Low Carbon Lifestyle	2,727	21%
Action 7 Community Engagement and Consensus Building**	-	-
Green Environment	3,094	25%
Action 8 Walkable, Safe and Livable City Design	263	2%
Action 9 Smart Urban Growth	1,214	10%
Action 10 Green and Blue Infrastructure and Rural Resources	392	3%
Action 11 Sustainable Waste Management	1,224	10%
Action 12 Clean Air Environment**	-	-
Total	12,467**	100%

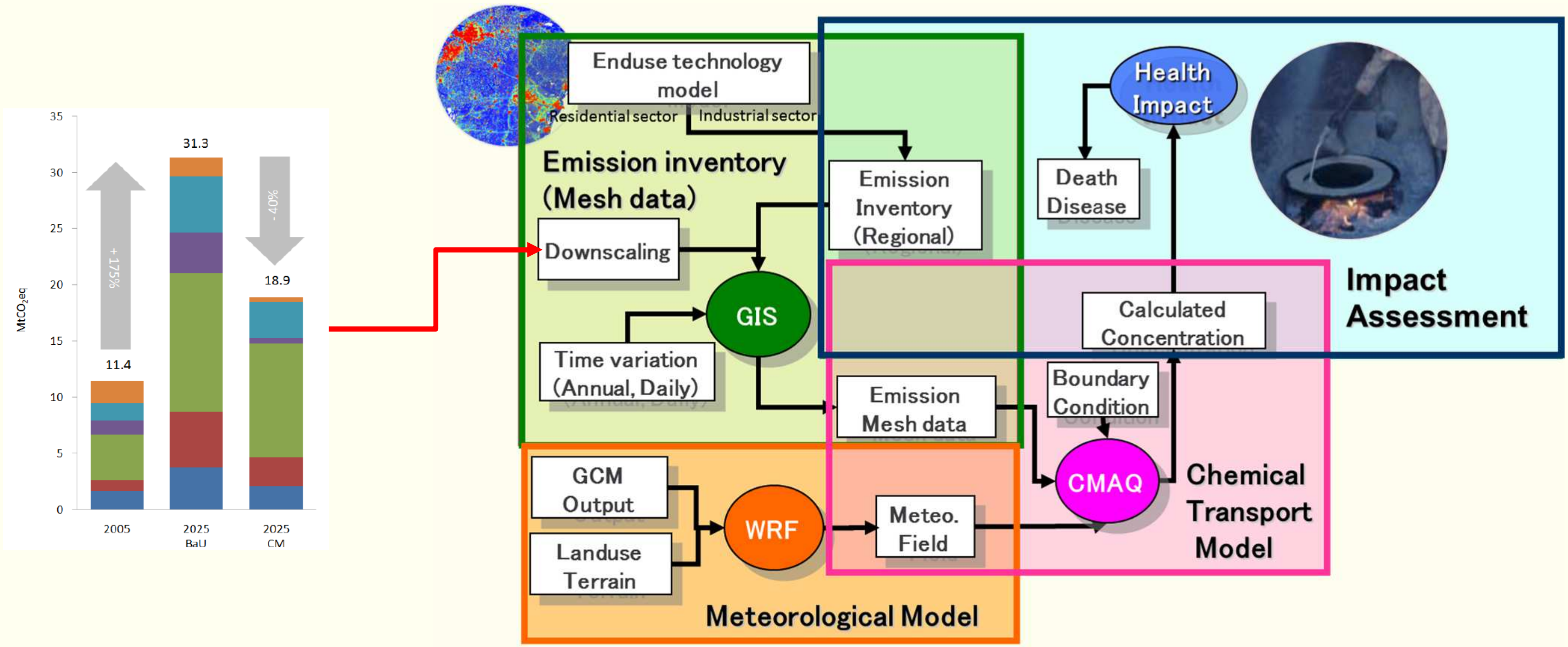
Estimated from ExSS Model



Estimated GHG reduction by each LCS actions

Example 1

Model description (Quantification of Co-benefits)



Meteorological Model

- WRF 3.4.1

  NCEP-FNL (1 degree, 6 hours)

  Noah land-surface model

  WSM 3-class simple ice scheme

Chemical Transport Model

- CMAQ 5.0.1

  Chemistry: SAPRC-99 - AERO5

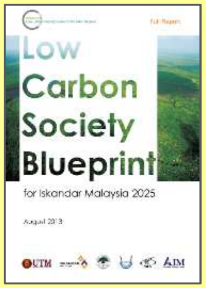
  Boundary condition : MOZART4

  Biogenic Emission: MEGAN

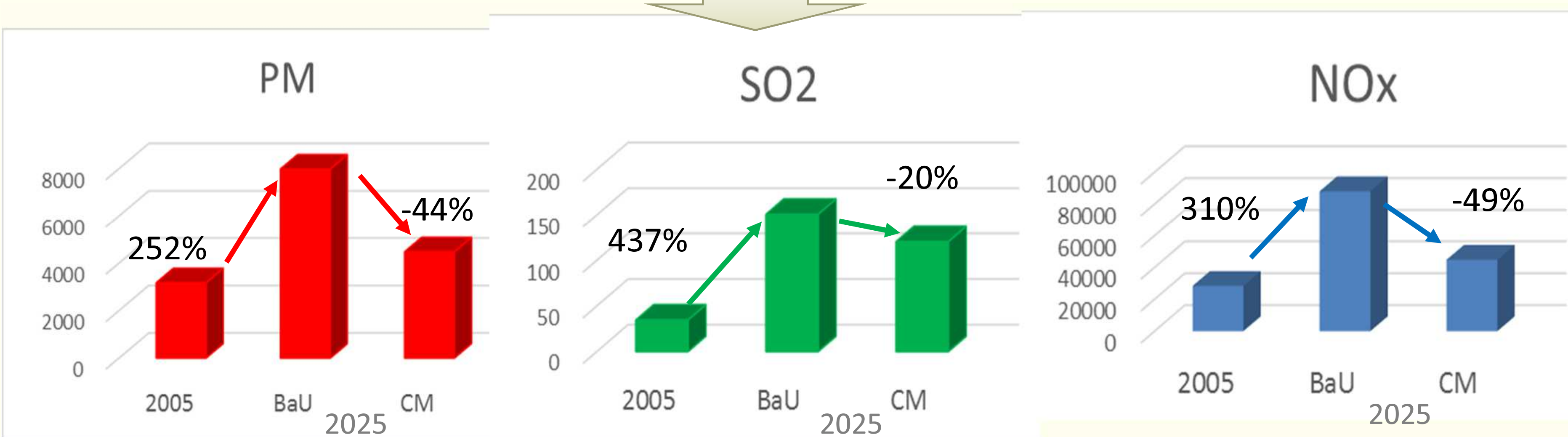
Example 1

Reduction of Regional Air Pollutants Emission

LCS Policies



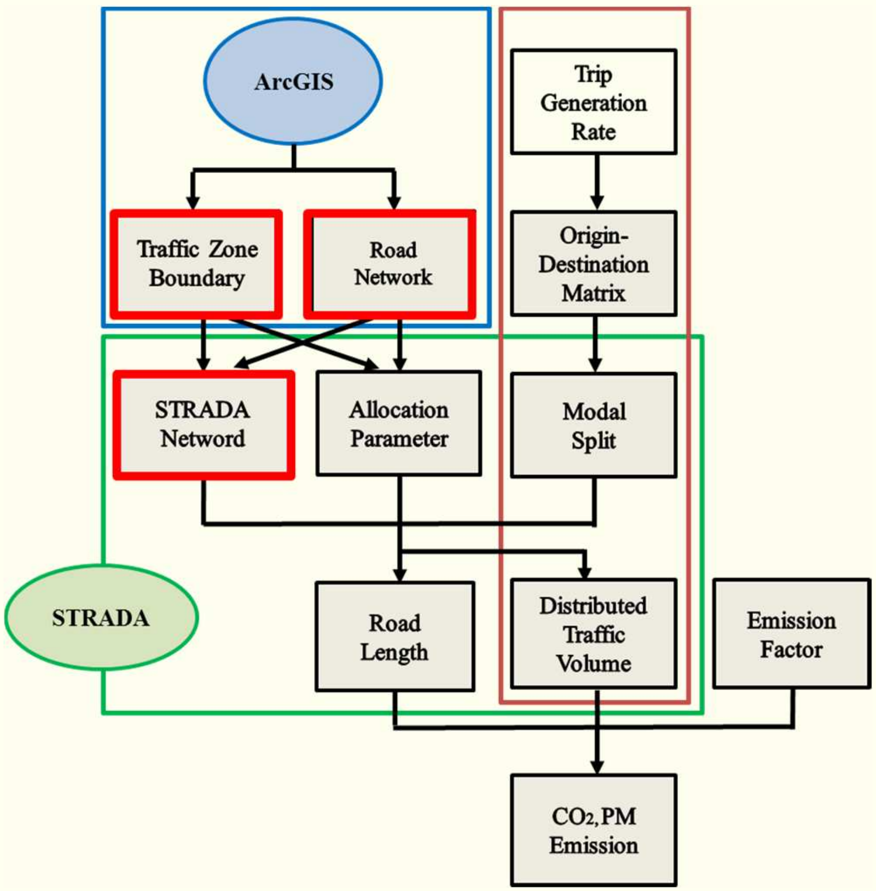
1: Green Transportation
2: Green Industry
3: Low Carbon Urban Governance
4: Green Building and Construction
5: Green Energy System
6: Low Carbon Lifestyle
7: Consensus Building
8: Walkable, Safe and Livable City Design
9: Smart Urban Growth
10: Green and Blue Infrastructure and Rural Resources
11: Sustainable Waste Management
12: Clean Air Environment



Example 1 Methodology : Emission from Road Traffic

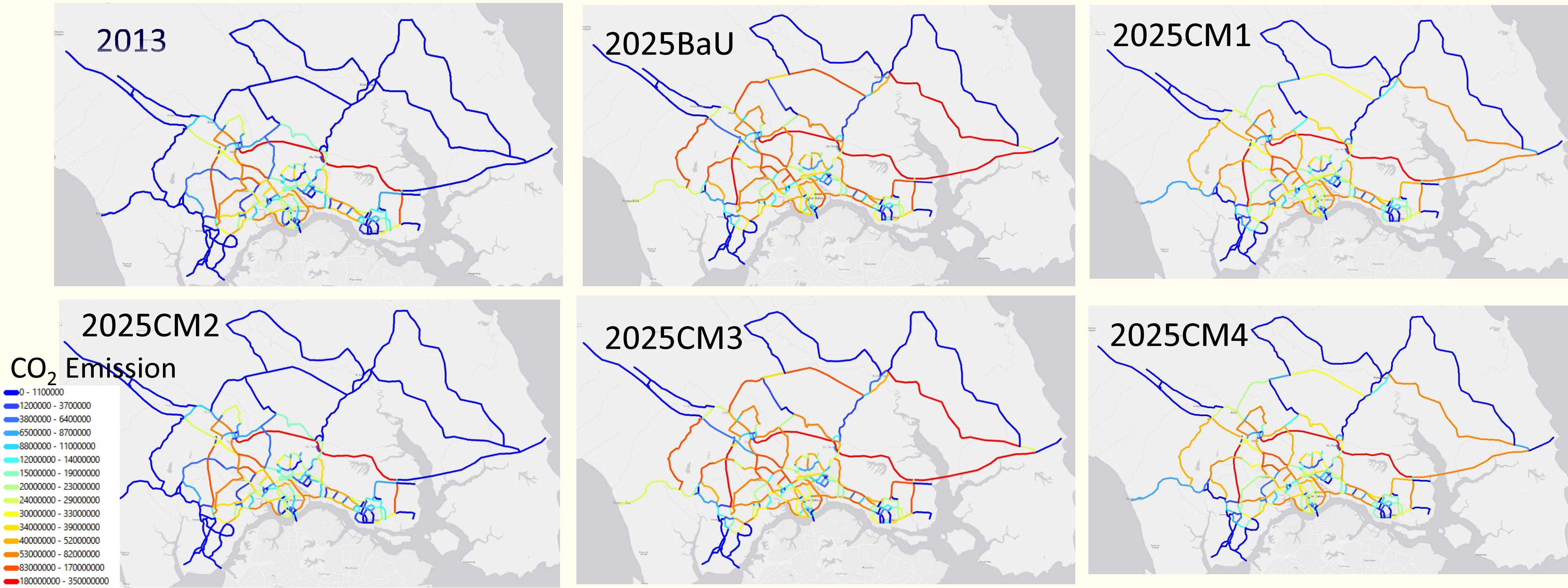
Traffic Demand Analysis Model:

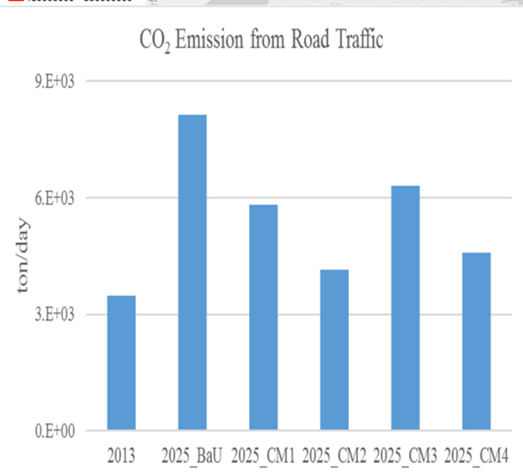
STRADA version 4.0 by JICA

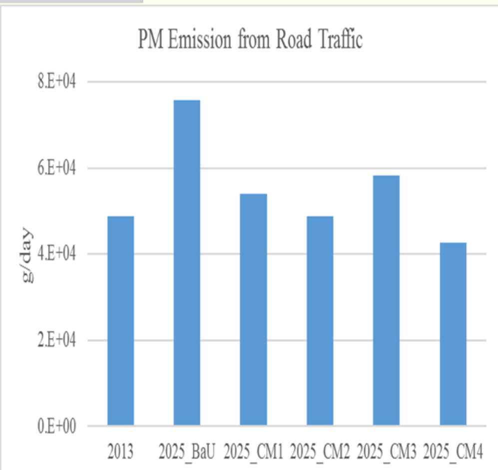


Case	Description	Change of EF
2013	Current	Current
2025 BaU	Proportional to Population growth	
2025 CM1	Bus Rapid Transit	
2025 CM2	Further Public transportation Shift	
2025 CM3	Same as 2025 BaU	Promotion of Low Emission Car
2025 CM4	Same as 2025 CM1	

Example 1 Estimated Road Transportation

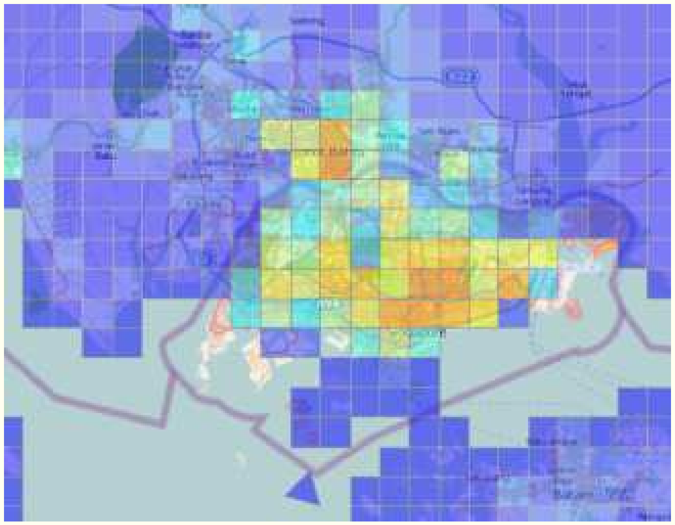




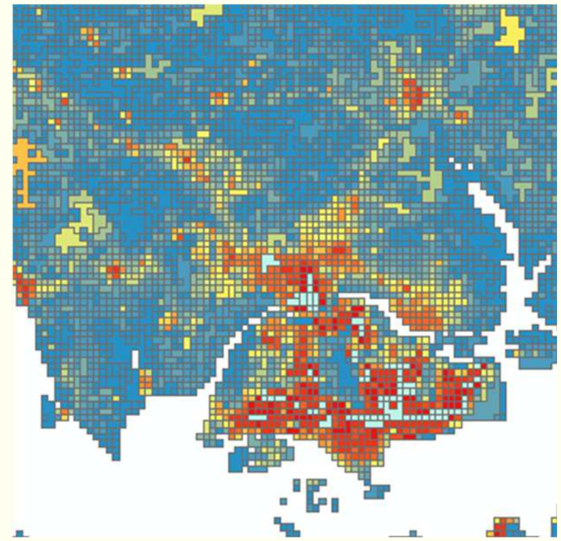


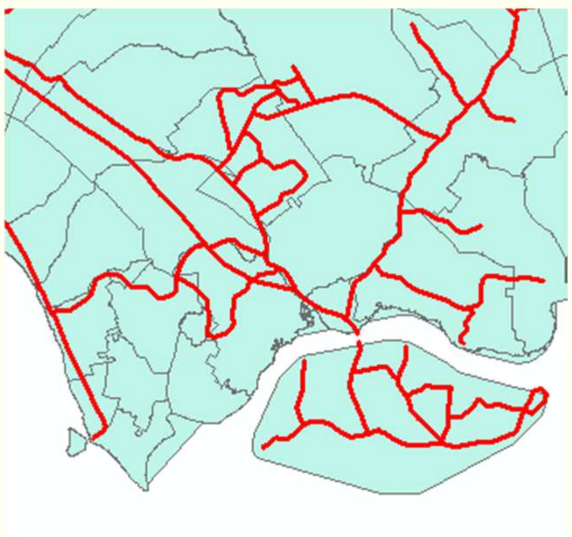
- In 2025 BaU case, Traffic volume increase with the population growth. And due to the congestion of traffic in central area, traffic volume of Suburb road is significantly increased.
- In 2025 CM2 case, Traffic volume will decrease by the shift to public transportation. Total volume is equivalent to current volume.
- Emission of PM2.5 largely depends on the emission control of public bus system.

Example 1 Improvement of GIS information for downscaling

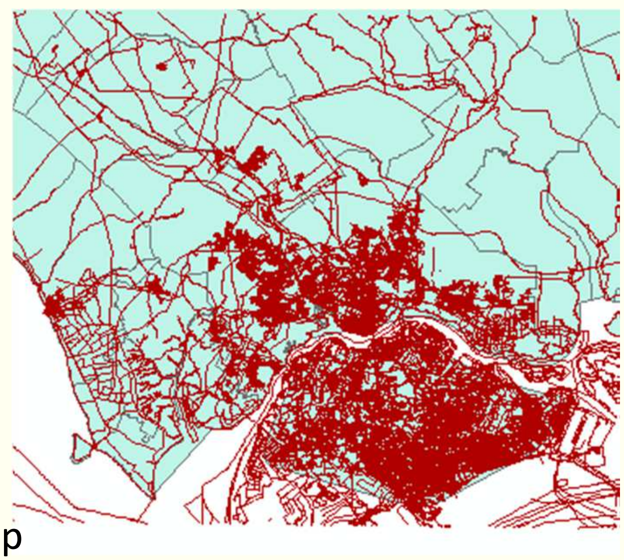


Population density
3km mesh → 0.6 km mesh





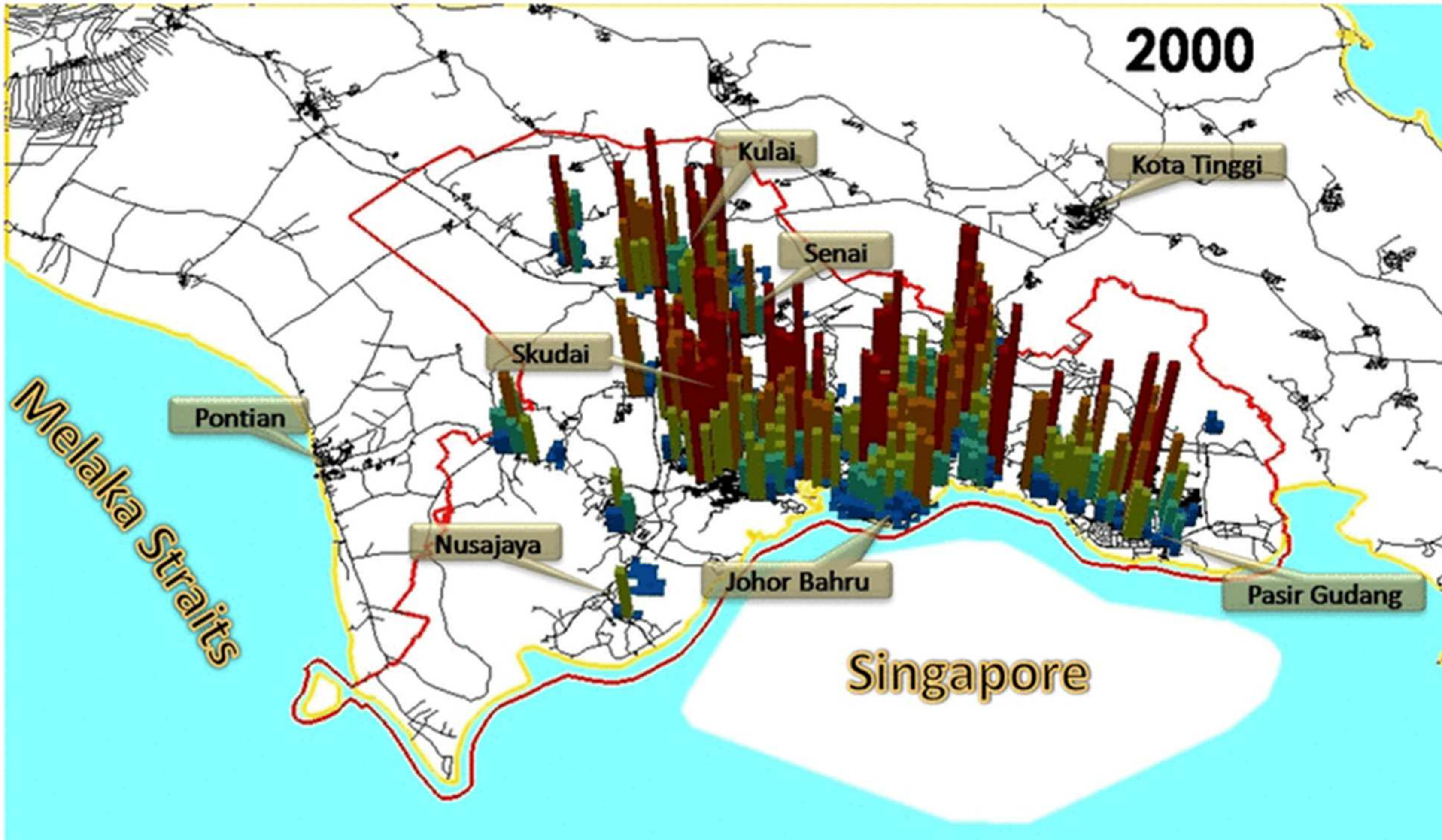
Road network



Open Street Map

Example 1

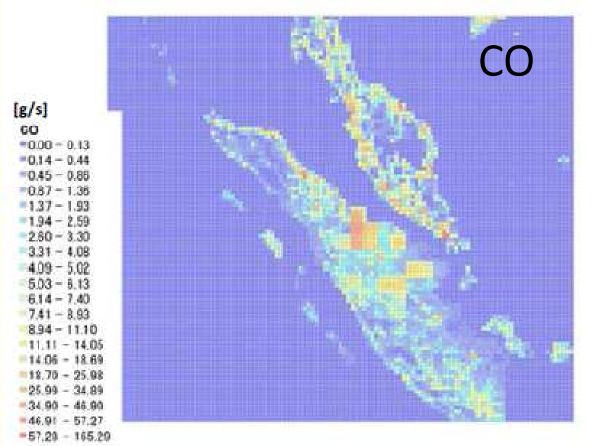
Estimation of Future Population distribution



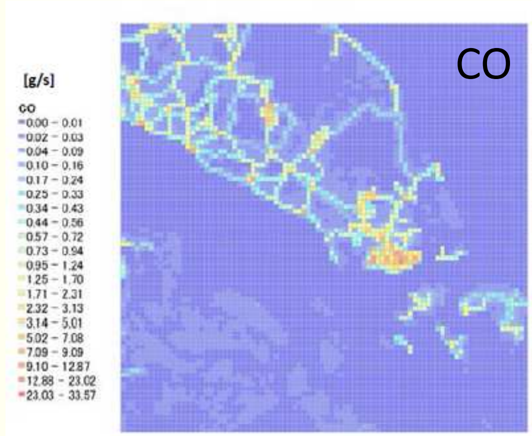
Example 1

Regional Air Quality Simulation

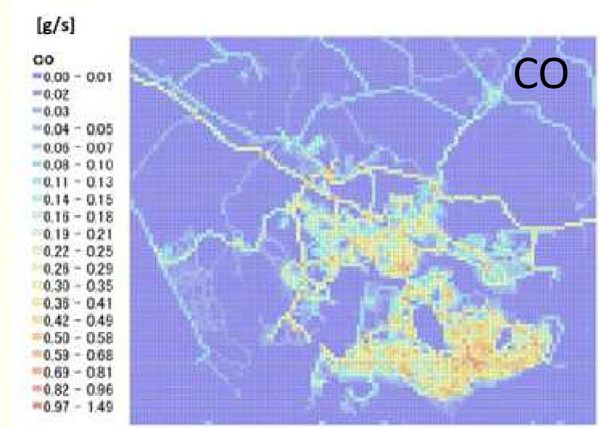
Domain 1

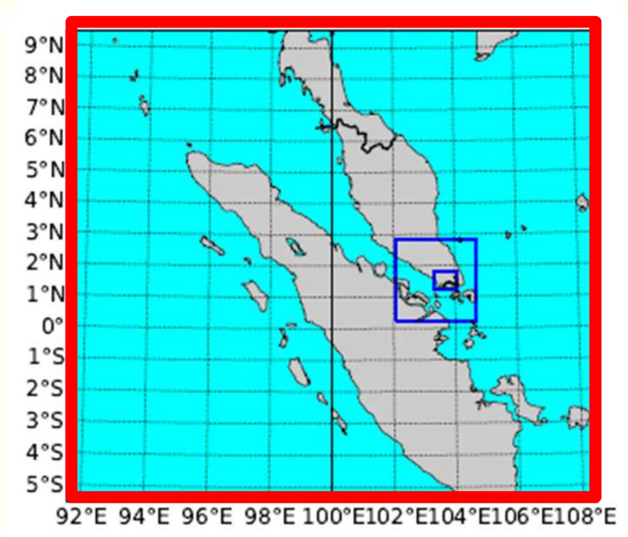


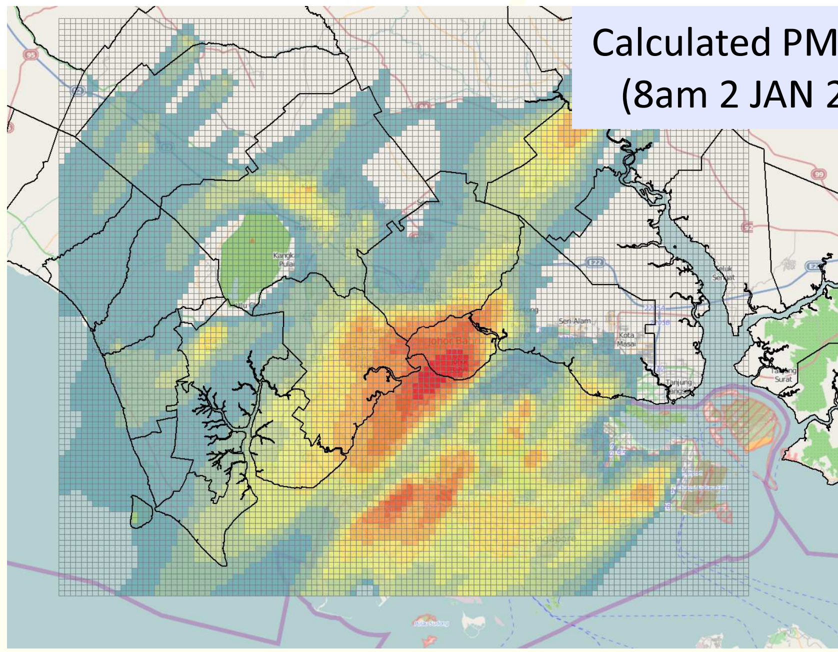
Domain 2



Domain 3



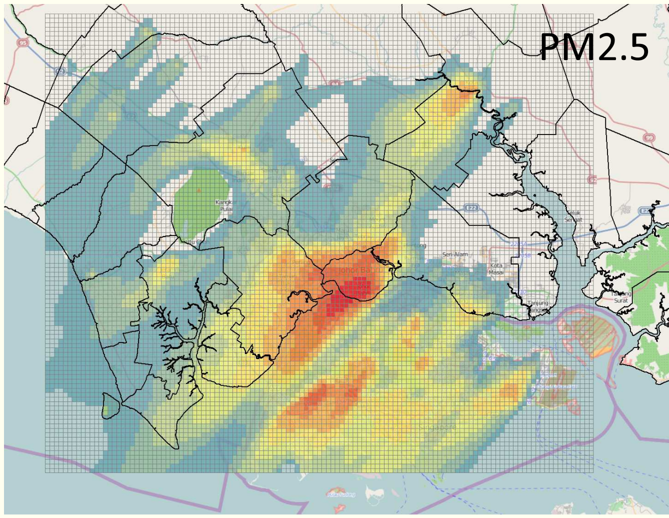




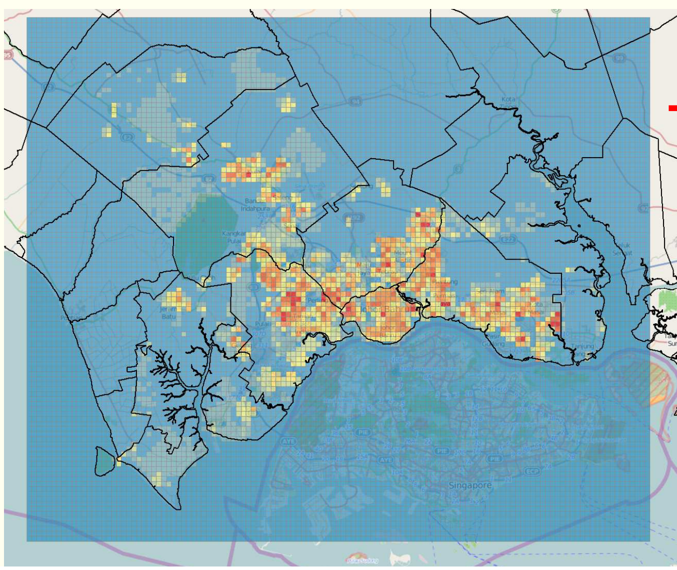
Calculated PM2.5 Concentration
(8am 2 JAN 2013)

Example 1

Health impact



Population density (2010 and 2025)



Methodology used by the Global Burden of Disease (WHO, 2004)

$$\Delta RR = \exp\left(\beta \times \Delta C\right)$$

$$\Delta AP_k = (\Delta RR - 1) \div \Delta RR$$

$$E = \Delta AP \times f \times P$$

where,

ΔRR : Change of Relative Risk

β: Relative risk coefficient

ΔC: Change of $PM_{2.5}$ concentration from base state

ΔAP: Change of attributable proportion for health endpoint

E: Number of cases of death attributed to air pollution

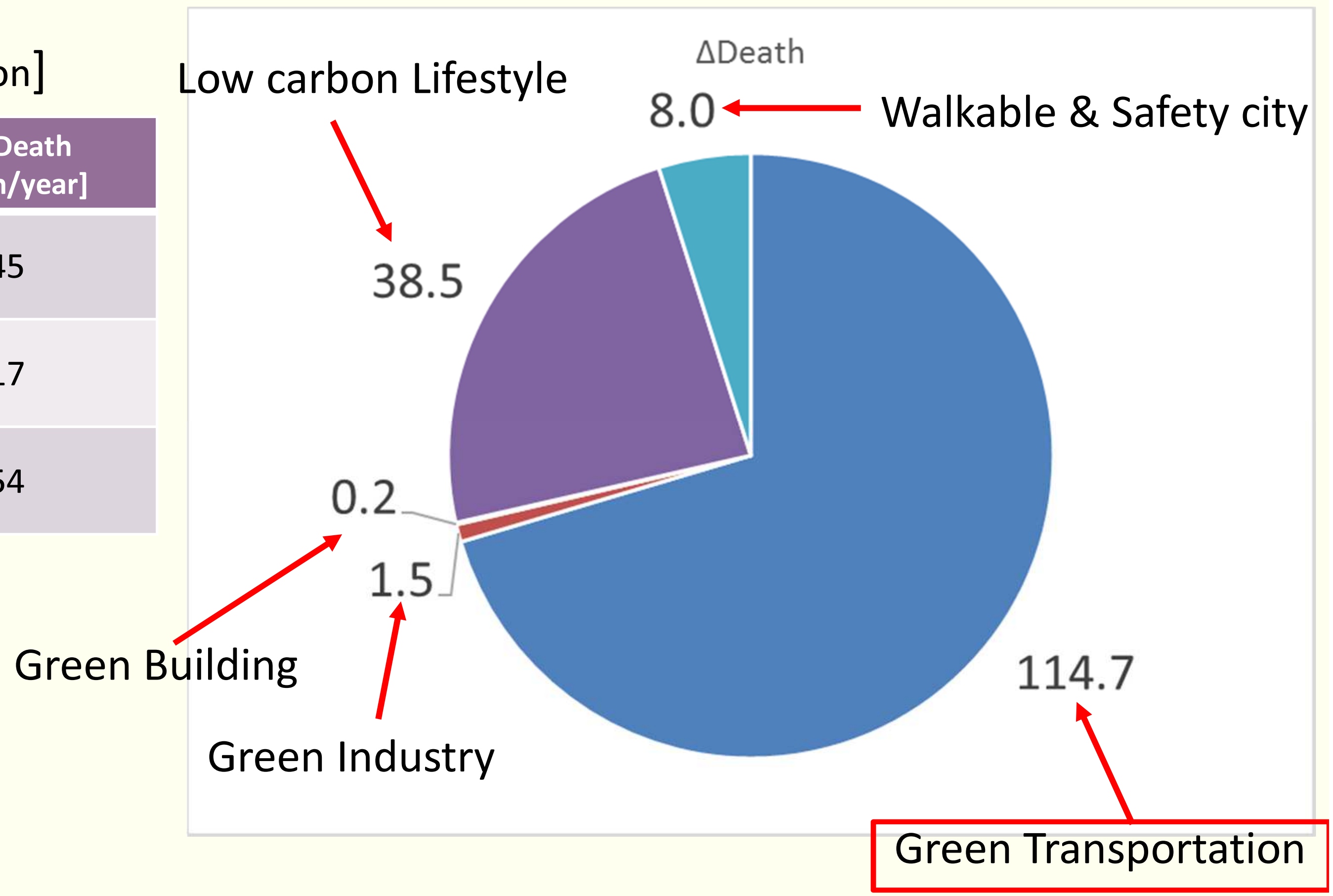
f: all cause mortality rate

Example 1 Result (Co-benefits on Health impact)

Reduced premature death (Δ=163) by each actions

Results [Whole IM region]

Case	N. of Death [person/year]
population in 2015 Base conc.	345
Population in 2025 BaU case conc.	417
Population in 2025 CM case conc.	254



Concept of IAM for Air Pollutant emission

Source-receptor matrix

Activity → Emission → Concentration → Exposure → Impact → Feedback

- Compact city
- Energy saving
- Zero energy building
- Public transportation
- .....

No policy action

- Medical system
- …

- Forecast
- Warning system
- Air cleaner

- FGD/dust collector
- High stacks

Economic Model AIM/CGE
Bottom-up Model AIM/Enduse
Accounting Model ExSS

Idea on a possible collaborative program

Issue of Integrated Assessment Modeling of Air Pollution in Northeast Asia.

- Standardization and Sharing of
  - Activity Database (Driving force of emission)
    - Past, current and Future. National level, Province level, Gridded data.
  - Technology Database (Energy Efficiency and Emission Factor)
    - Abatement Technology, Low emission Technology, etc.,
    - Especially, initial cost and running cost, lifetime, obstacle of diffusion
  - Policy Database
    - Tax and subsidy, Regulation, Urban planning, TDM, etc.,

Thank you very much for your attention