The 22nd AIM International Workshop
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Cobenefits and Tradeoffs of Reducing GHGs, SLCPs, Air Pollutants Emissions When Exploring the 2 ℃ Target Scenarios

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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

Improved emission inventory

Regional Emission Inventories and Chemical Transfer Model

REAS Inventory

Integrated Assessment Model (AIM

SLCP emissions scenario

SLCP, AP, GHG emissions Based on SSP scenario

imate and ironment 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

Theme 4: Integrated operation system (Toolkits, data archive)

Science

Model improvement

Experiment setup
Database development
Metric definitions

Stakeholders
Policy makers

System utilization

CCAC, UNFCC, IPCC, EANET
Proposal and assessment of climate and air pollution policies

Society

Information transmission

MDG・SDG・Future Earth

Regional strategy

⇅

Global strategy

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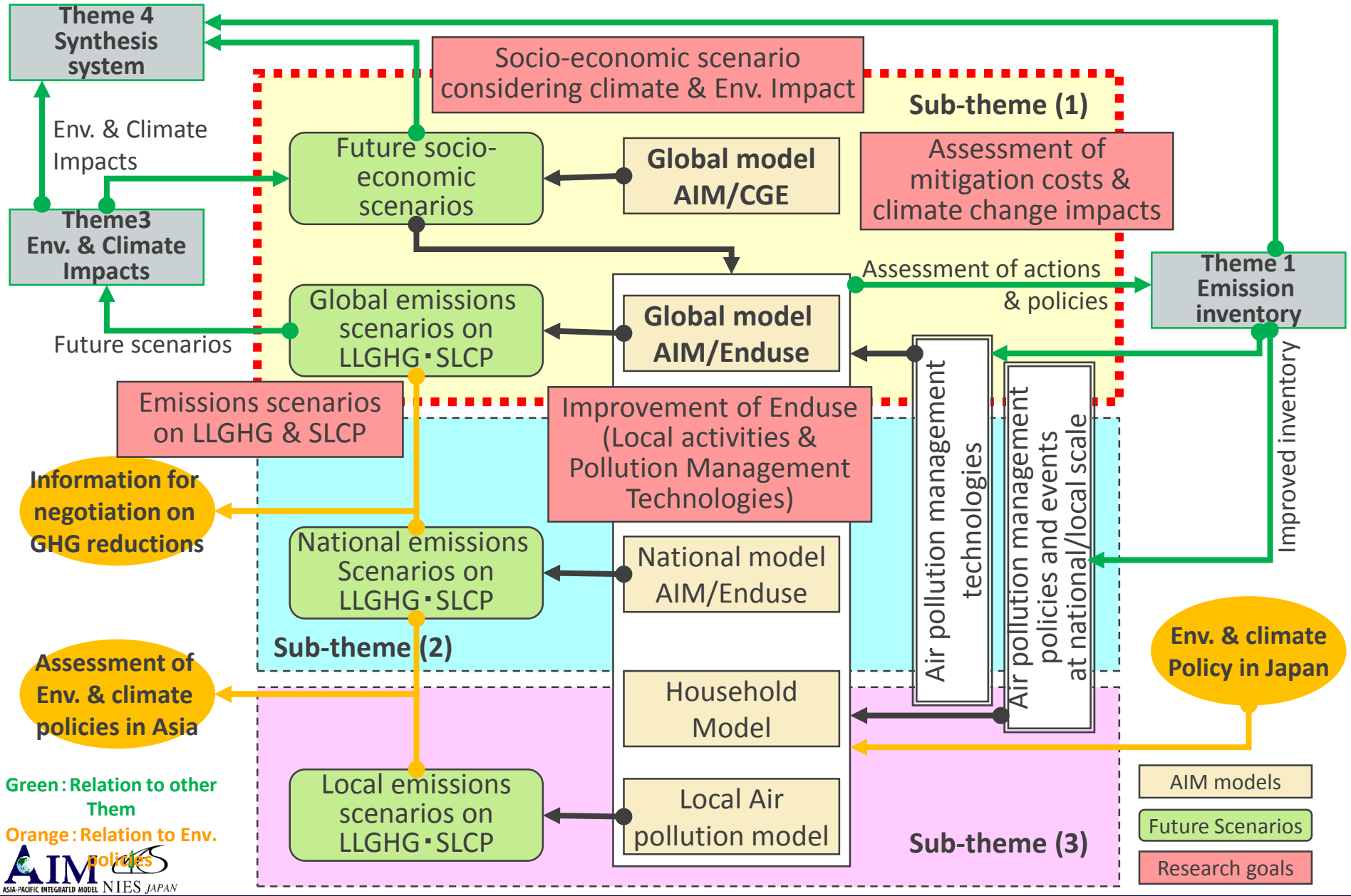
MOEJ-S12: Promotion of climate policies by assessing environmental impacts of SLCP and seeking LLGHG emissions pathways (FY2014-FY2018)



Challenges of S-12 Theme 2

1. Estimating **future (energy & non-energy) service demands based on new socio-economic scenarios** (i.e. SSPs: Shared-Socioecnomic Pathways) considering climate change and environmental impacts
2. indicating **emissions scenarios of Long-lived GHGs(LLGHG) and Short lived Climate Pollutants (SLCP) and air pollutants,** based on new service demands estimations
3. Evaluating **co-benefits of LLGHG mitigation measures and SLCP reduction measures**, and analyzing regional characteristics in detail, **in a manner consistent with long-term global scenarios such as 2℃ target**.
4. Exploring the **appropriate (optimal?) balance among LLGHGs measures, SLCPs measures and air pollutants measures from the viewpoint of health benefits and climate benefits.**

Today's topics

Characteristics of AIM/Enduse[Global] model

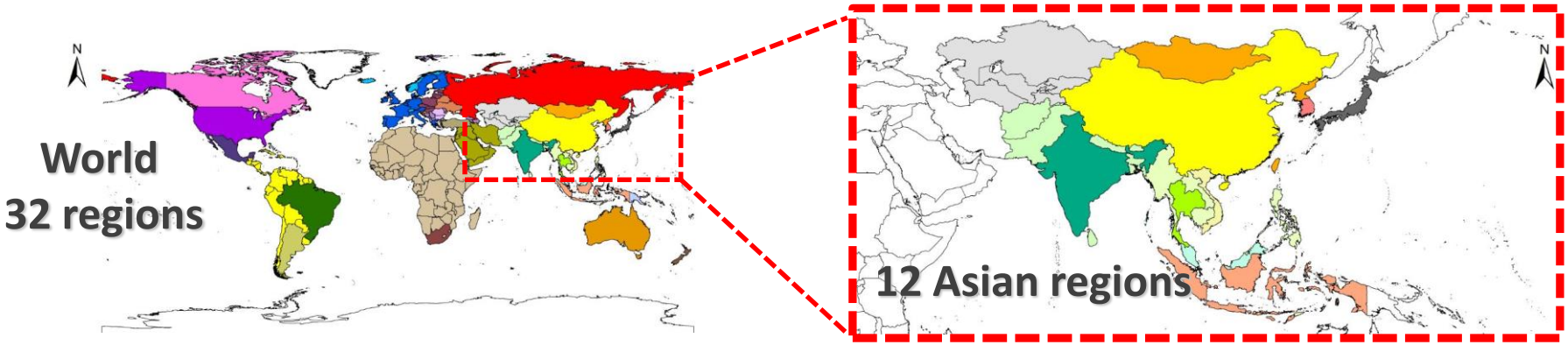
- Bottom-up type model with detailed technology selection framework with optimizing the total system cost
- Recursive dynamic model (=Calculating year by year)
- Assessing technological transition over time
- Analyzing effect of policies such as carbon/energy tax, subsidy, regulation and so on.
- Target Gas: both Long-Lived GHGs and Short-Lived Climate Pollutants
  CO_2, CH_4, N_2O, HFCs, PFCs, SF_6, CFCs, HCFCs, SO_2, NOx, BC, 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 sector

  (each of these can be further disaggregated into sub-sectors)

AIM/Enduse[Global] - Regional Classification, Target Gases and Sectors -

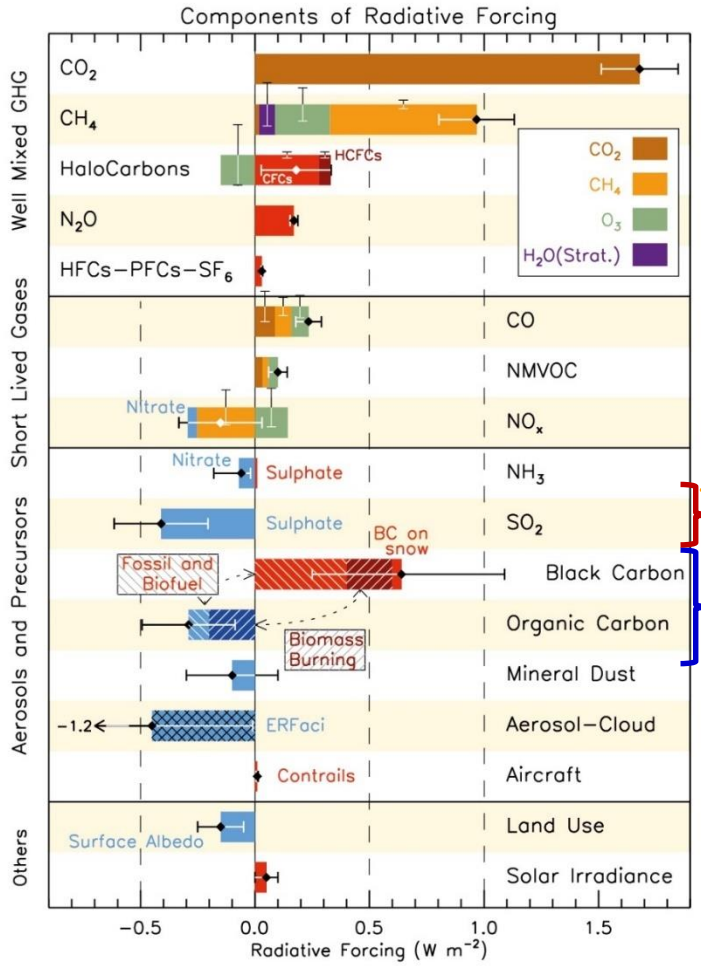
Sector	Sub sectors whose mitigation actions are considered in Enduse model (other subsectors are treated as scenario)
Power generation	Coal power plant, Oil power plant, Gas power plant, Renewable (Wind, Biomass, PV), Nuclear, Hydro, Geothermal, Heat
Industry	Iron and steel, Cement , Other industries（Boiler, motor etc）
Transportation	Passenger vehicle, Truck, Bus, Ship, Aircraft, Passenger train, Freight train (except for pipeline transport and international transport)
Residential & Commercial	Cooling, Heating, Hot-water, Cooking, Lighting, Refrigerator, TV, Other equipments
Agriculture	Livestock rumination, Manure management, Paddy field, Cropland
MSW	Municipal solid waste, Waste water management
Fugitive	Fugitive emission from fuel production
Fgas emissions	By-product of HCFC-22, Refrigerant, Aerosol, Foams, Solvent, Etching, Aluminum production, Insulation gas, others.



	CO2	CH4	N2O	HFCs	PFCs	SF6	CFCs	HCFCs	SO2	NOx	PM10	PM2.5	BC	OC	CO	NH3	NMVOC	Hg
Fuel combustion	✔	✔	✔						✔	✔	✔	✔	✔	✔	✔	✔	✔	
Industrial process	✔	✔	✔	✔	✔	✔	✔	✔	✔		✔	✔	✔	✔	✔	✔	✔	
Agriculture		✔	✔													✔		
Waste		✔																
Fuel mining		✔																
Others	✔	✔	✔													✔	✔	

Emission factors can be set by energy, by sector and by region over time.
Settings on technology options are the same, too

Seeking for Emissions Pathways of GHGs, SLCPs and Aps - climate impacts of reducing SO2 and BC -



- **From the viewpoint of health impacts**, SO_2 should be reduced largely.
- **From the viewpoint of climate impacts**, due to local cooling effects, SO_2 should not be reduced drastically.

If low-carbon actions toward 2 ℃ target are taken,

- SO_2 will be reduced largely, by necessity
- Not only BC but also OC will be reduced simultaneously.

- **From the viewpoint of health impacts**, BC should be reduced largely.
- **From the viewpoint of climate impacts**, BC should be reduced largely.
- **From the viewpoint of climate impacts**, due to local cooling effects, OC should not be reduced drastically.

Seeking for Emissions Pathways of GHGs, SLCPs and Aps - climate impacts of reducing NOx -

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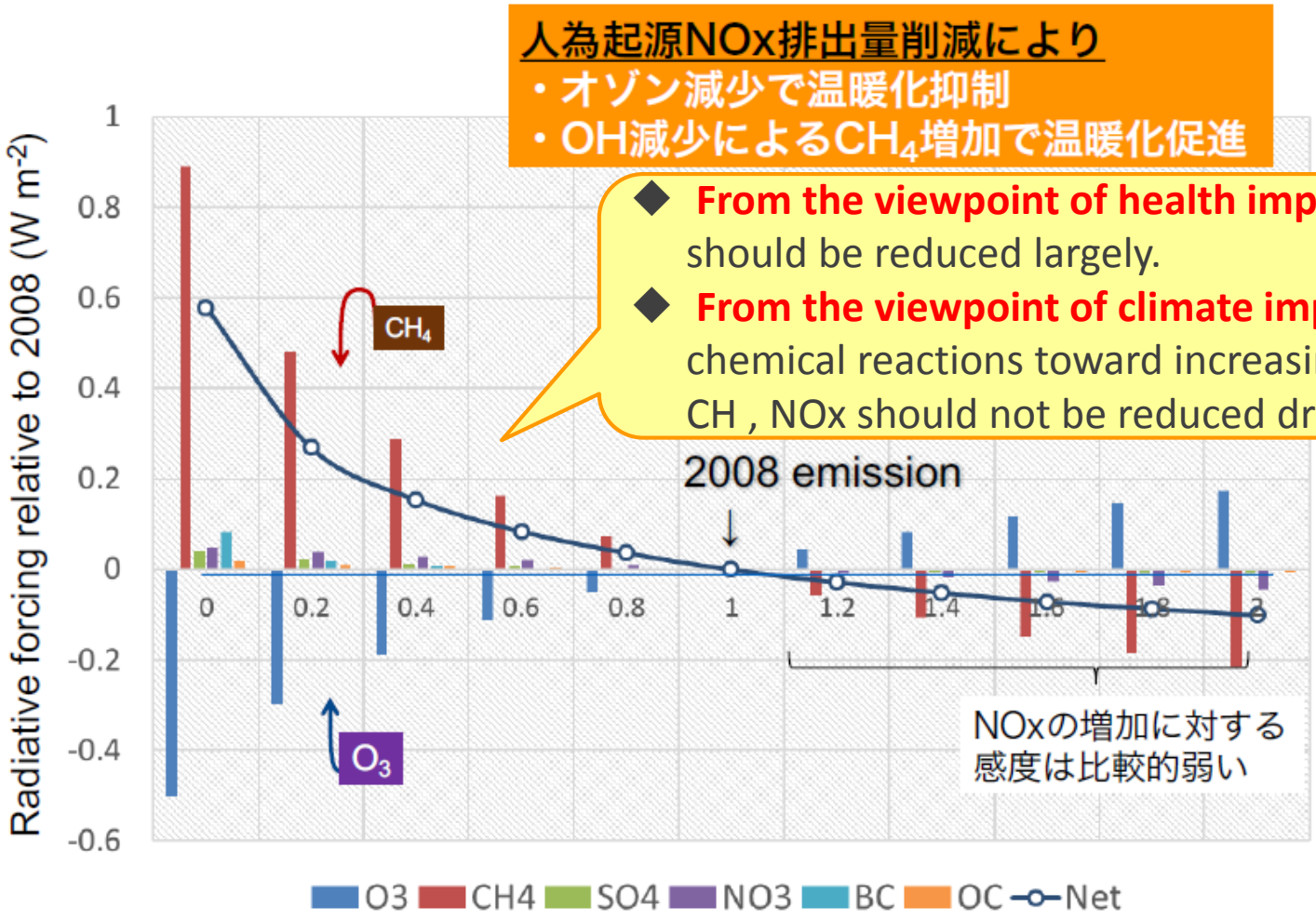


各種微量気体排出量増減に伴う気温・降水量変化などの気候応答を解析するための実験を実施中

環境省環境研究総合推進費S-12中間評価ヒアリング（2016年7月27日, 東京）　竹村 俊彦

Concepts of future scenarios under S12 project
- Seeking for Balance of LLGHGs, SLCPs, air pollutants emissions -

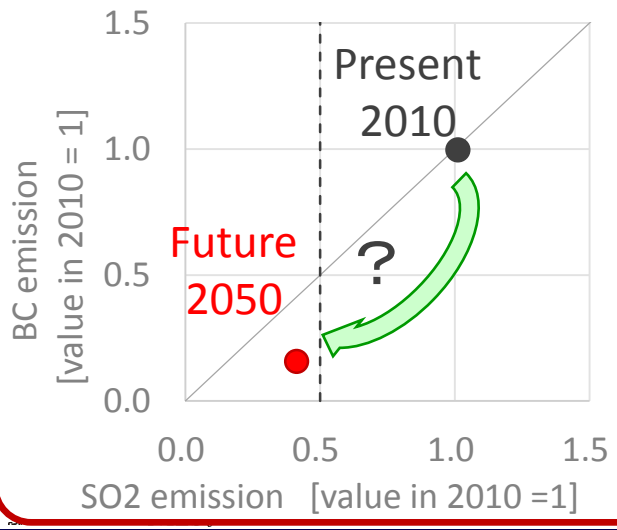
① Targeting at achieving the 2 degree target, as the COP21 decided

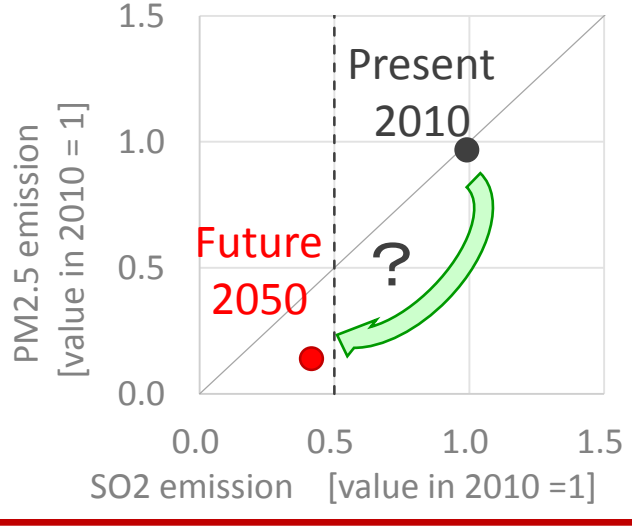
② From the viewpoint of climate impacts of positive radiative forcing, LLGHGs (CO_2, N_2O, HFCs, PFCs, SF_6) and SLCPs (CH_4, BC) should be reduced largely.

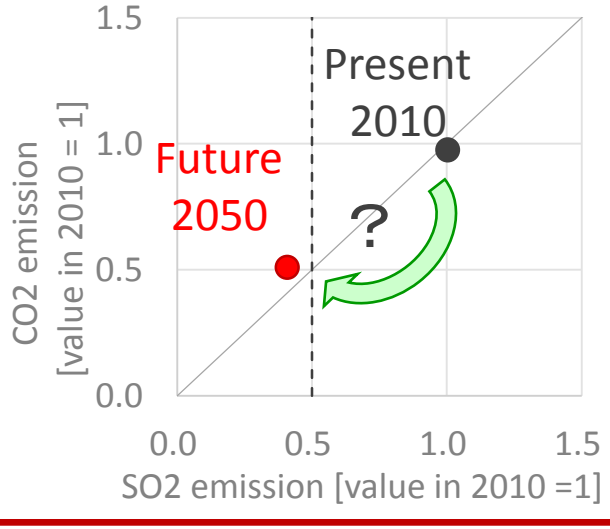
③ From the viewpoint of health impacts, air pollutants ($PM_{2.5}$, SO_2, BC, etc) should be reduced to a high enough level .

④ From the viewpoint of climate impacts of negative radiative forcing, some air pollutants (SO_2, OC) are preferable to be reduced only to some extent.

Example of diagnosis figures





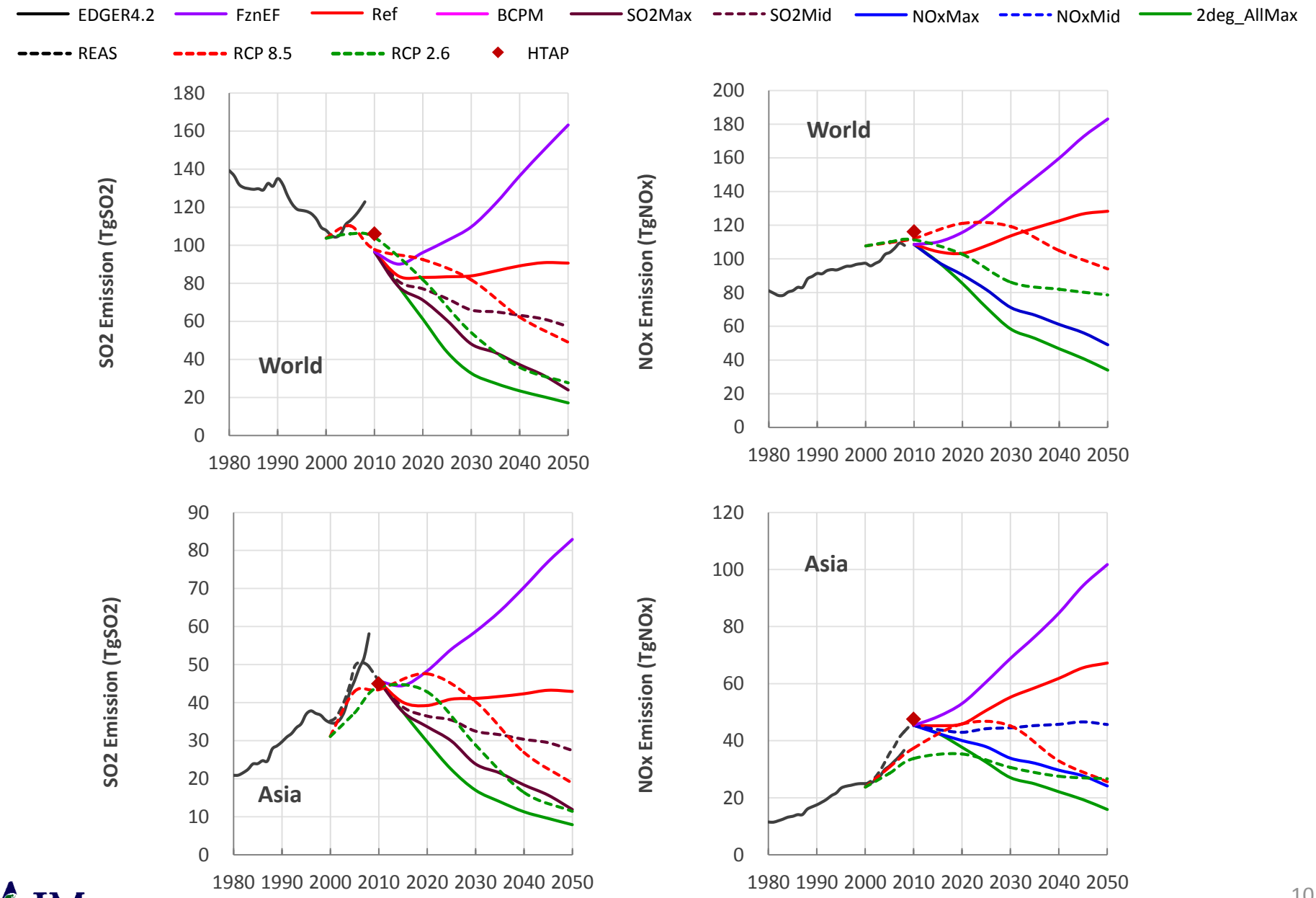


S12 original scenarios for collaborative research under the S12 project

To evaluate reductions of health impacts due to air pollutant measures and reductions of climate impacts due to GHG & SLCP measures, S-12 project sets the following scenarios

Scenario	Overview
① **Frozen Technology**	Technologies and emissions factors are frozen in the base year. Thus, as the service demand increase, all emissions will also increase.
② **Reference (=SSP2)**	Reference scenario that future mitigation polices & technologies are in line with the current trends
③ **BC&PM Max**	Strengthening end of pipe measures for **drastically reducing BC(&OC)&PM only**
④ **SO2 Max**	Strengthening end of pipe measures for **drastically reducing SO2 only**
⑤ **SO2 Mid**	Taking end of pipe measures for reducing **a certain amount of SO2** （健康影響の軽減と地域的な冷却効果について、シナリオ④との比較が目的）
⑥ **NOx Max**	Strengthening end of pipe measures for **drastically reducing NOx only**
⑦ **NOx Mid**	Taking end of pipe measures for reducing **a certain amount of NOx** （健康影響の軽減と大気中CH_4増による気候影響について、シナリオ⑥との比較が目的）
⑧ **2 degree ALLMax (cobenefit 1)**	Mixing scenario③、④、⑥ and **Low carbon measures toward 2℃ target**, by taking into account cobenefits of reducing SLCPs and air pollutants
⑨ **2 degree ALLMid (cobenefit 2)**	Mixing scenario ③、⑤、⑦ and **Low carbon measures toward 2℃ target**, by taking into account cobenefits of reducing SLCPs and air pollutants （健康影響の軽減、地域的な冷却効果、大気中CH_4増による気候影響について、end of pipe 対策や低炭素対策による共便益効果のシナリオ⑧との比較が目的）

Results of S12 scenarios – example of global and Asia-



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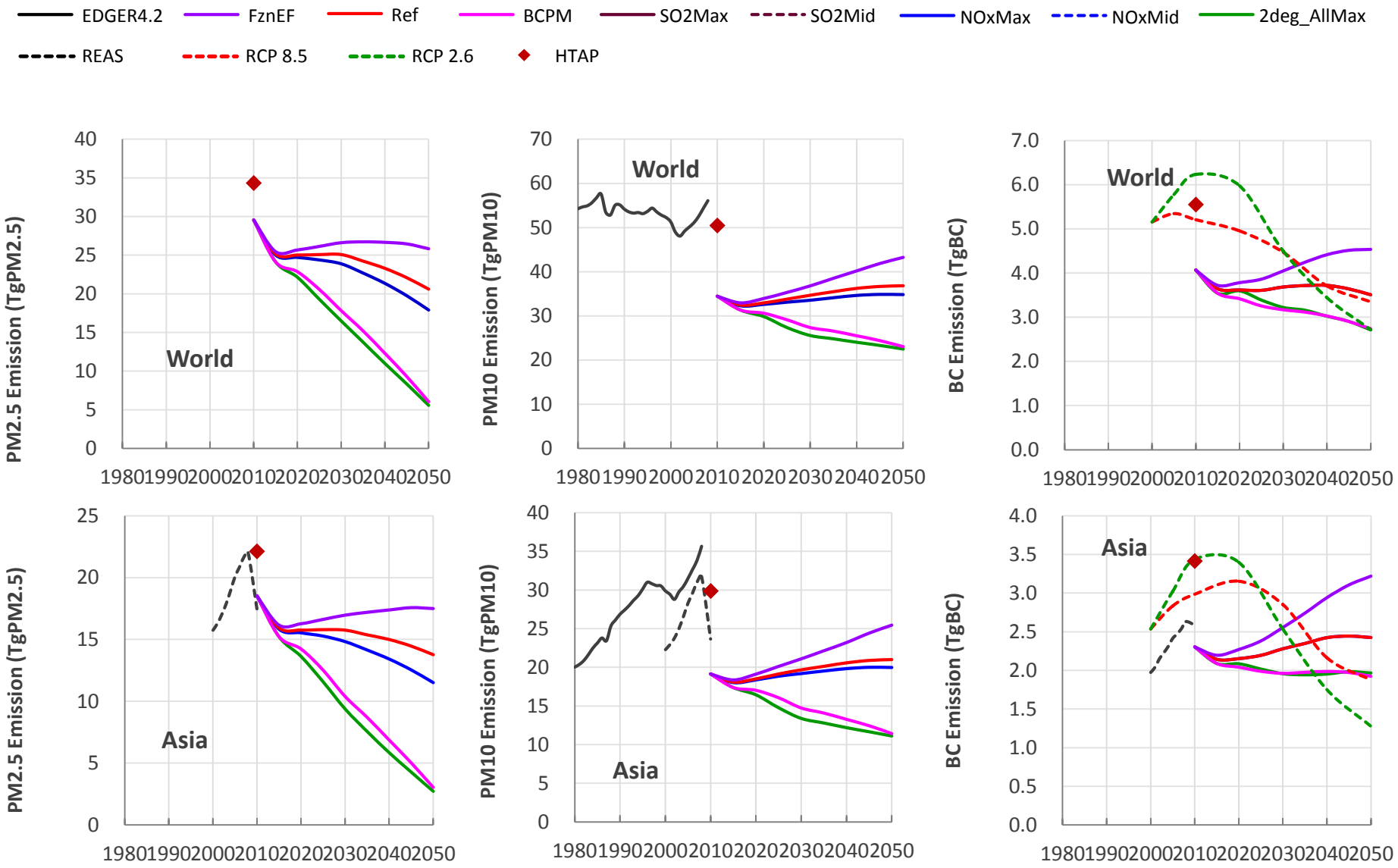
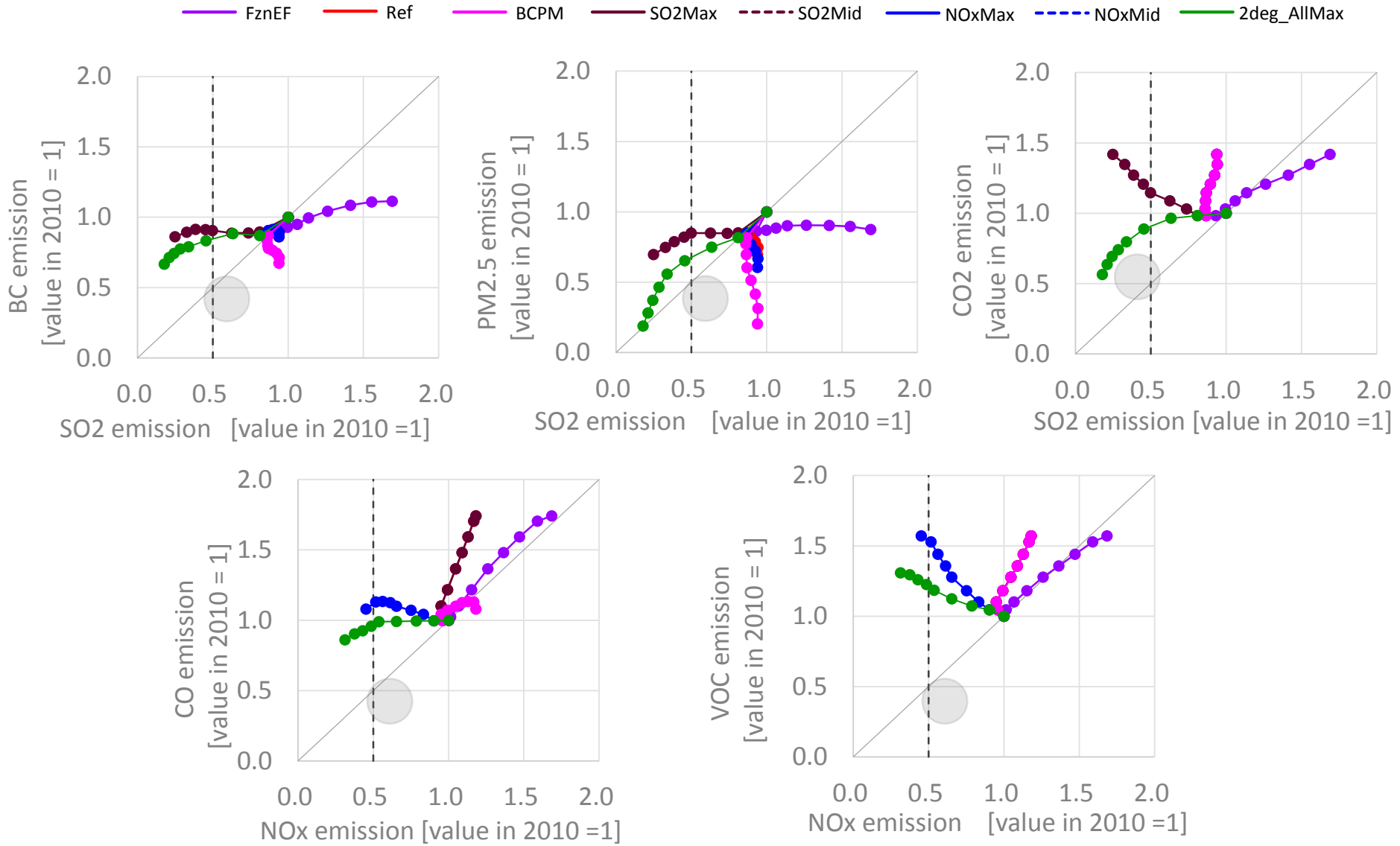


Results of S12 scenarios – example of global and Asia-



To reach "Hatching Area" in 2050, it is necessary to further consider of combinations of end-of-pipe measures and their intensity as well as combinations of energy mix constraints and low-carbon measures

Overview of additional Scenario Settings
- Seeking for balance of LLGHGs, SLCPs, air pollutants emissions -

- Changing the settings of carbon taxes in order to discuss low-carbon society
- Changing the levels of air-pollutant control measures in order to discuss local air quality
- Changing energy policy choices: one of examples of discussing cobenefits & tradeoffs.
  - ① Promoting drastic energy shift (from high-carbon fossil fuel to less-carbon intensive fuels or renewable energies) rather than coal & biomass power plant with CCS
  - ② Allowing coal & biomass power plant with CCS rather than drastic energy shift.

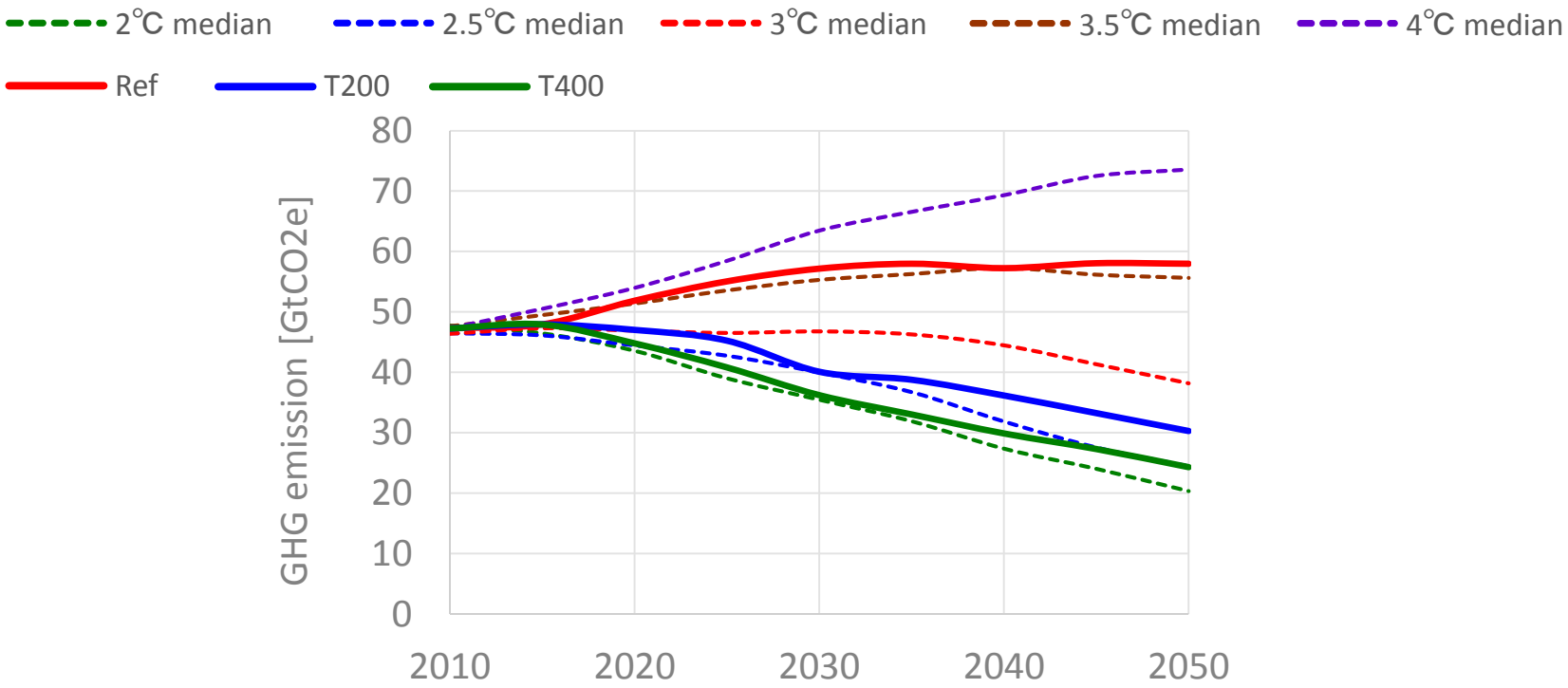
Scenario name	2010	2015	2020	2030	2040	2050	Air pollution measures	Energy policy
Reference: SSP2	0	0	0	0	0	0	SSP2 level (i.e. BaU)	SSP2 level (i.e. BaU)
T200	0	0	50	100	150	200	SSP2 level	Promoting energy shift rather than coal & biomass power with CCS
T400	**0**	**0**	**100**	**200**	**300**	**400**	SSP2 level	Promoting energy shift rather than coal & biomass power with CCS
T400ccs	**0**	**0**	**100**	**200**	**300**	**400**	SSP2 level	Allowing coal & biomass power with CCS rather than drastic energy shift
T400ccs_BCPM	**0**	**0**	**100**	**200**	**300**	**400**	SSP2 level +BCPM measure high	Allowing coal & biomass power with CCS rather than drastic energy shift
T400ccs_ALL	**0**	**0**	**100**	**200**	**300**	**400**	SSP2 level + all air pollutant measure high	Allowing coal & biomass power with CCS rather than drastic energy shift

[Unit: US$/tCO$_2$ eq]

Global Emissions pathways in this study

- comparing with a set of well-known GHG emissions pathways by the UNEP Gap Report -

- The reference scenario corresponds to the level of 3.5℃ increase pathway.
- To achieve the 2℃ target, future carbon price will be much higher than the current levels, around 400 US$/tCO$_2$eq in 2050



Note 1) Dashed lines show median values in the range of well-known GHG emissions pathways with a "likely" (greater than 66%) chance of staying below 2℃, 2.5℃, 3℃, 3.5℃, 4℃, compared to pre-industrial levels reported by UNEP Gap Report

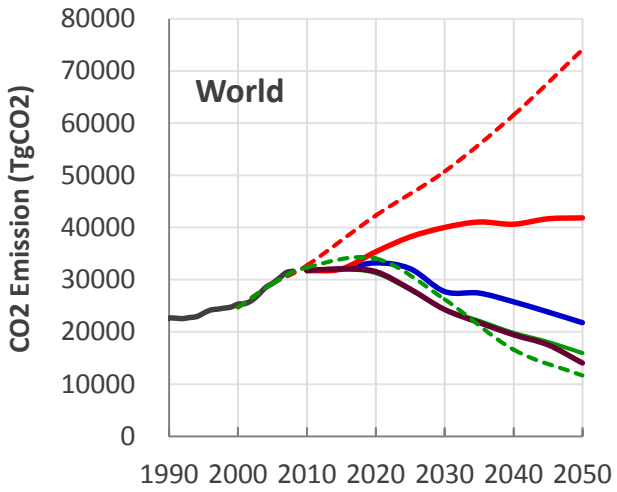
Emissions pathways of CO2, SLCPs, Air pollutants

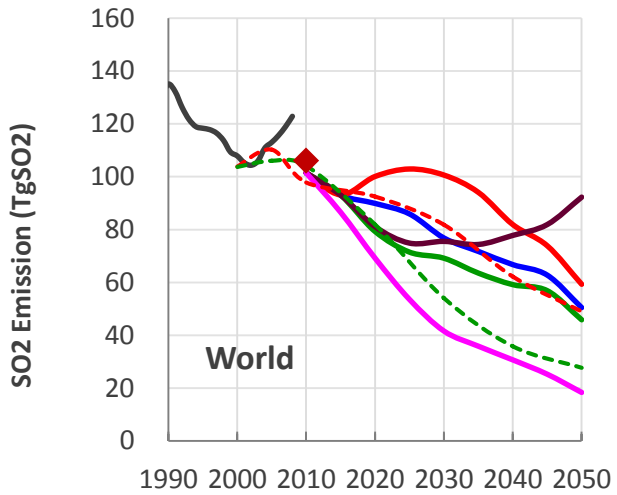
- compared to emission inventory (EDGER, REAS, HTAP) & emissions pathways of RCP8.5, RCP2.6 -

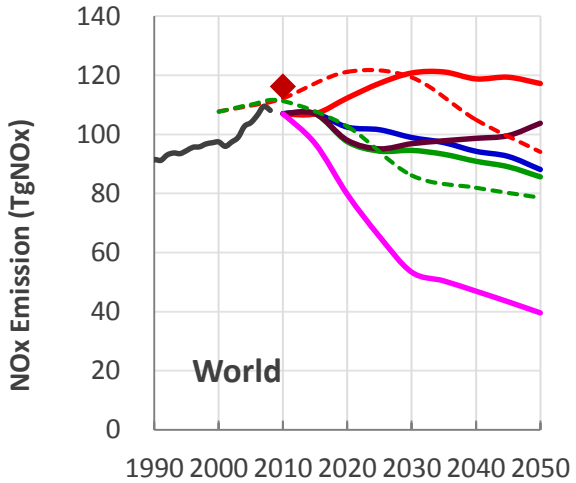
EDGER4.2 | REAS | HTAP | RCP 8.5 | RCP 2.6

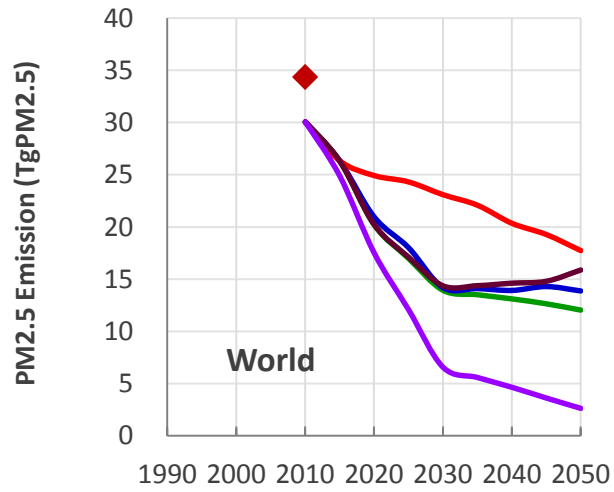
Ref | T200 | T400 | T400ccs | T400ccs_BCPM | T400ccs_All

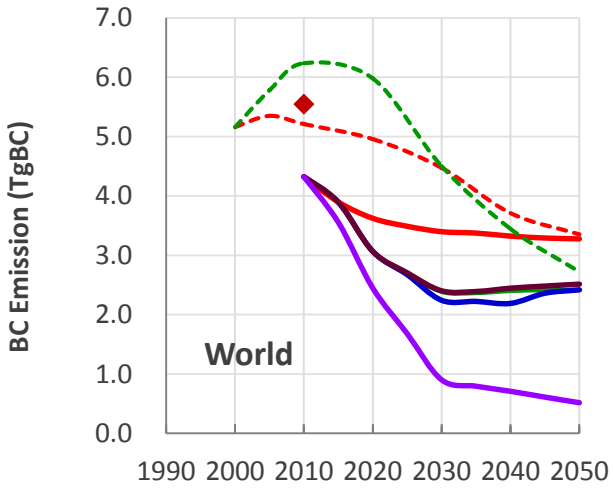
Equivalent to 2℃ target

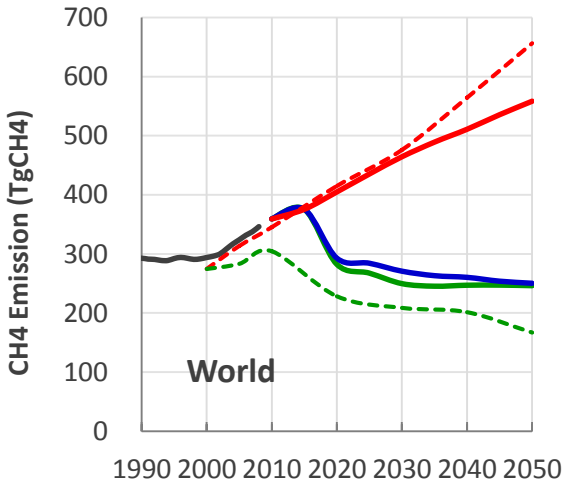












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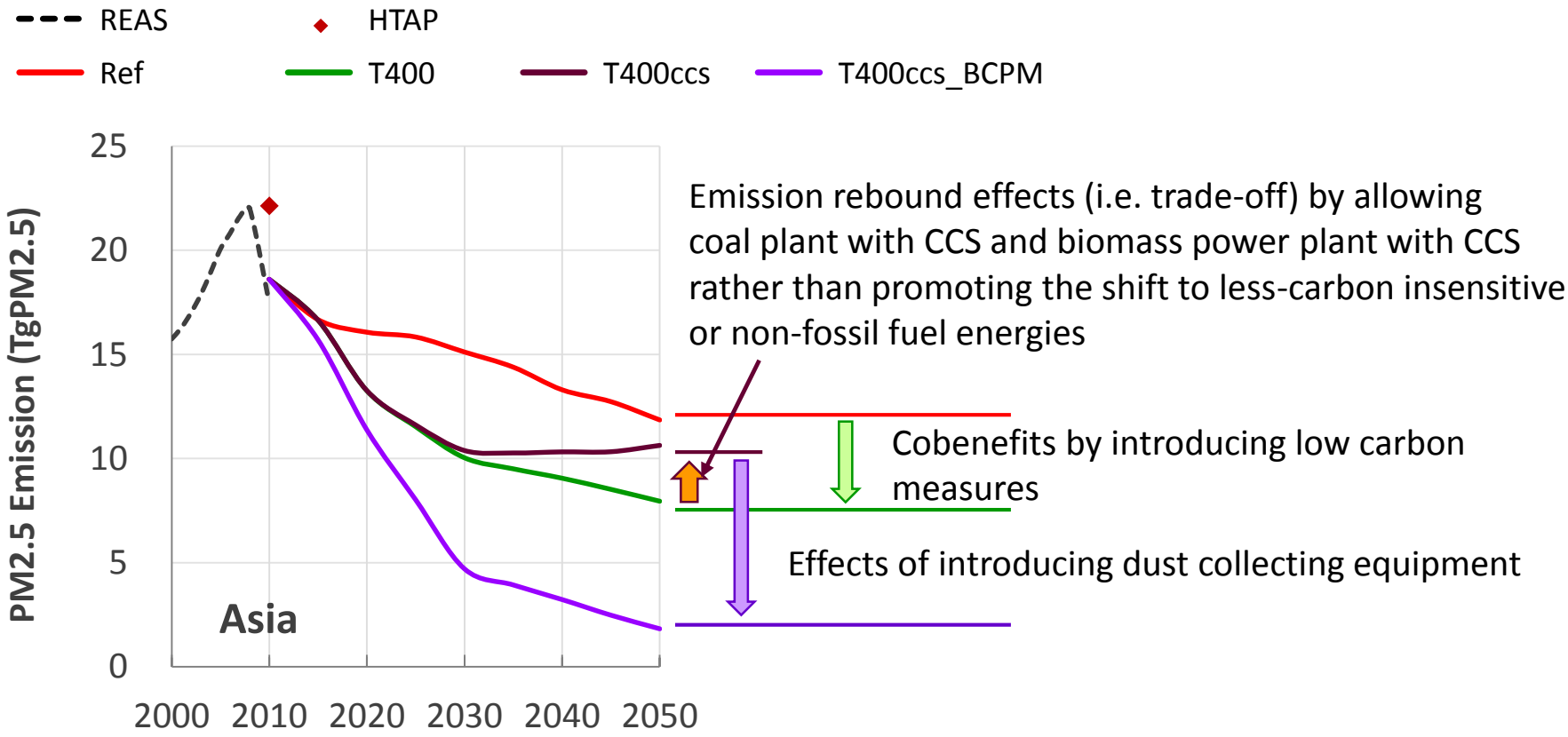
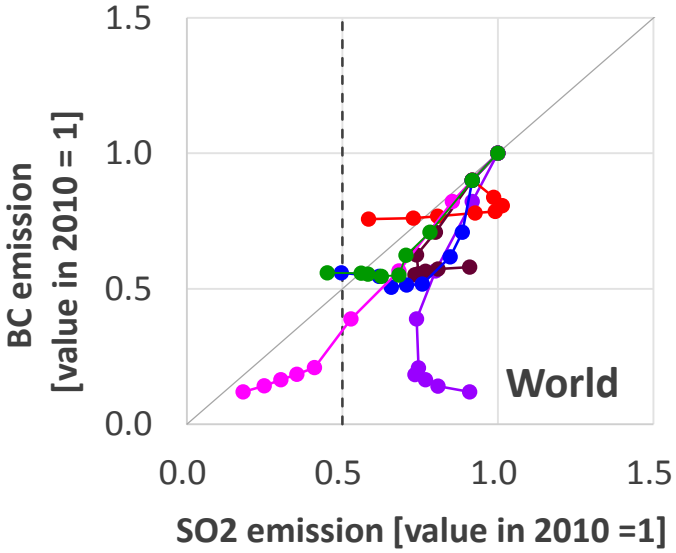
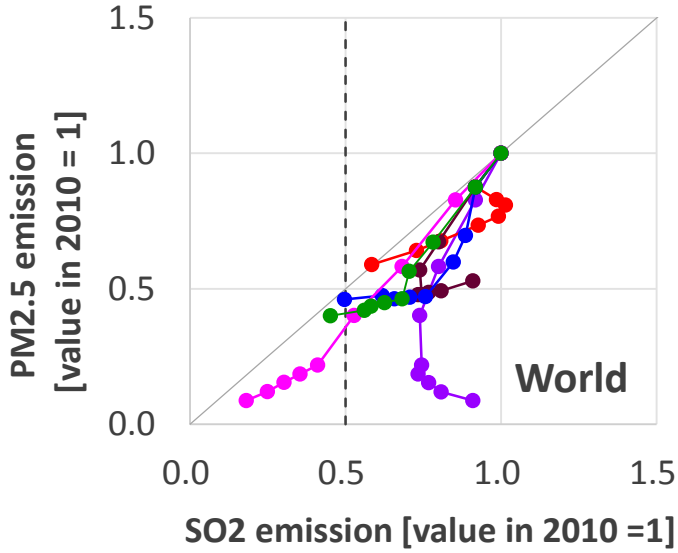
How to interpret 2℃ emissions scenarios in this study - example of $PM_{2.5}$ in Asia

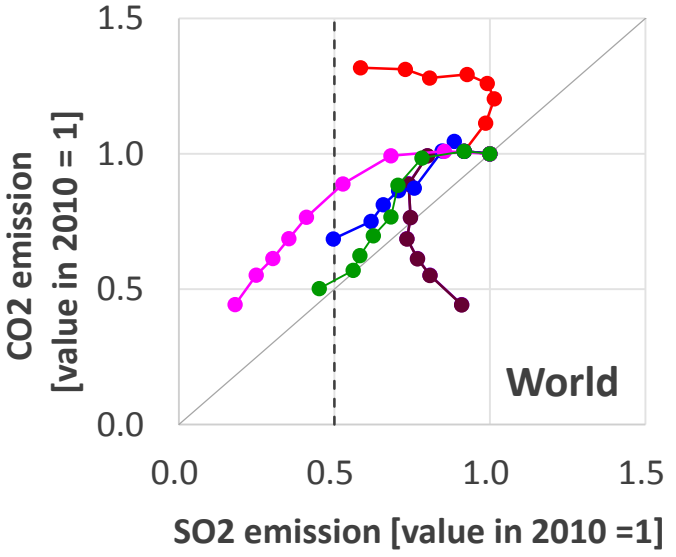
- Due to low carbon measures, there are large cobenefits of reducing air pollutants.
- However, if only considering low carbon measures, there are tradeoffs (i.e. emission rebound effects) from the viewpoint of nonCO2 emissions
- Combinations of low carbon measures and nonCO2 measures are important

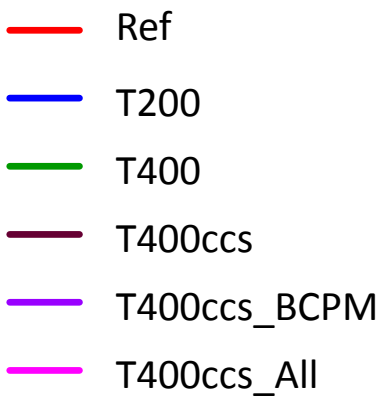


Seeking for balanced emissions pathways
- reduction ratio among GHGs, SLCPs and Air pollutions -

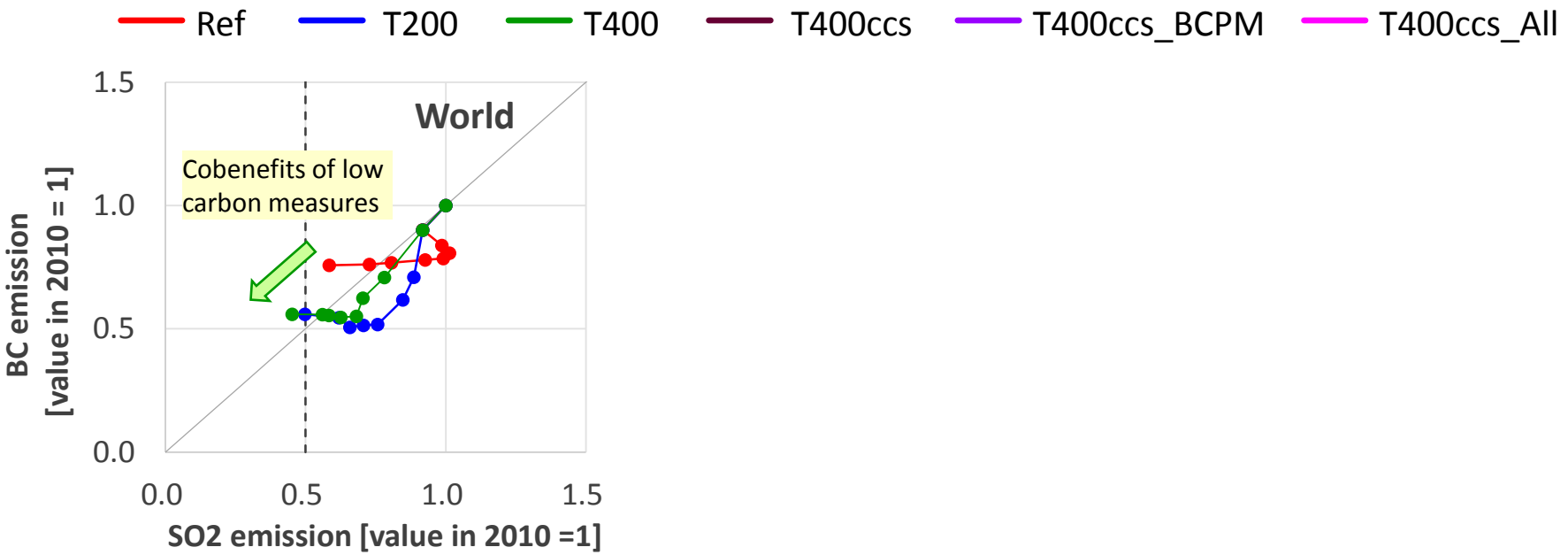








How to interpret the relations of relations of reducing SO2 and BC due to low carbon measures and air pollution controls



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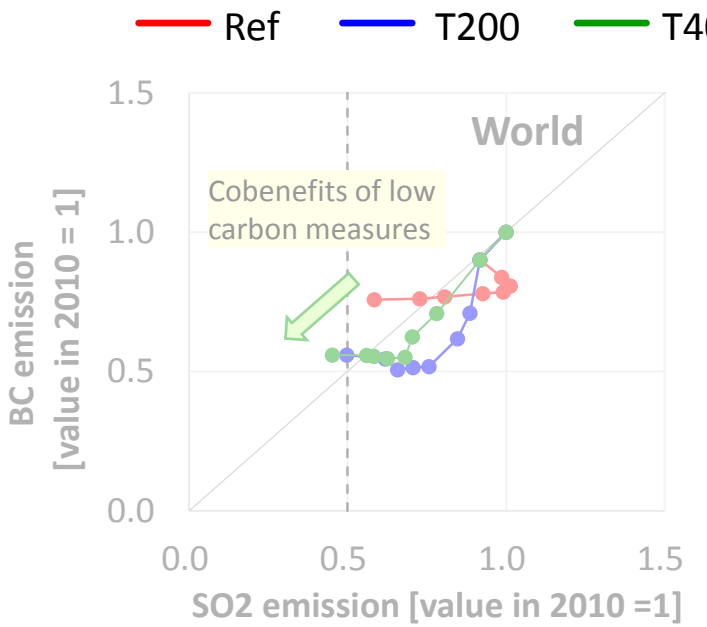

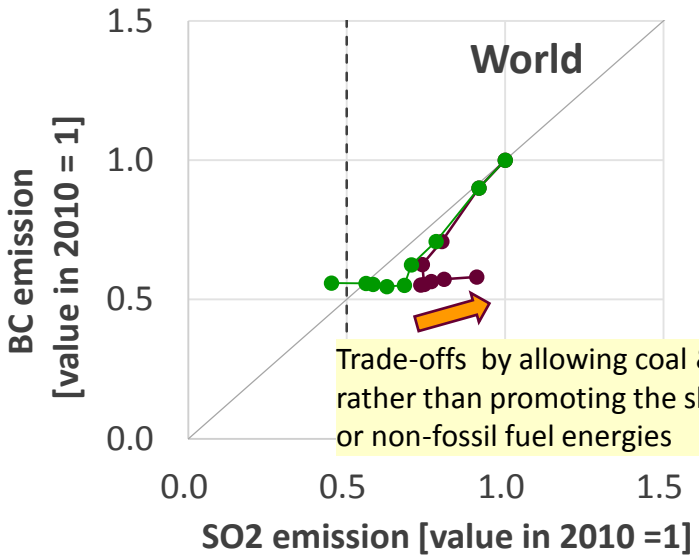

Trade-offs by allowing coal & biomass power plant with CCS rather than promoting the shift to less-carbon insensitive or non-fossil fuel energies

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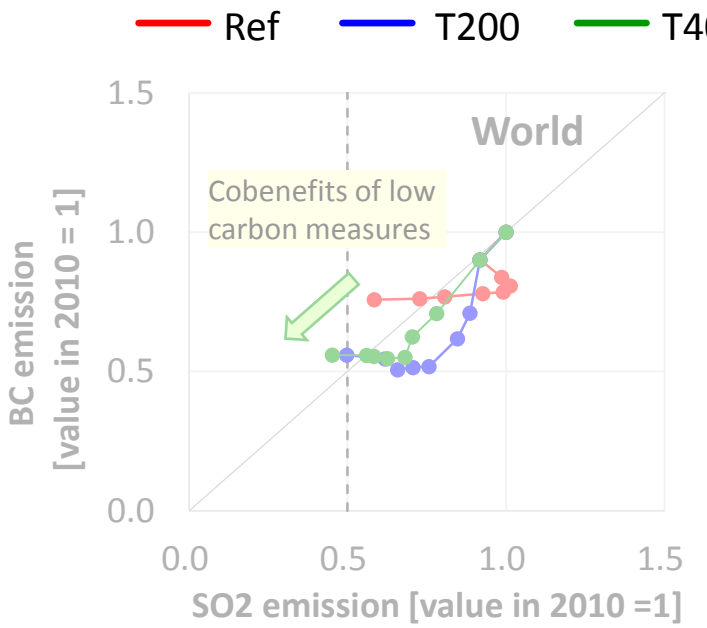

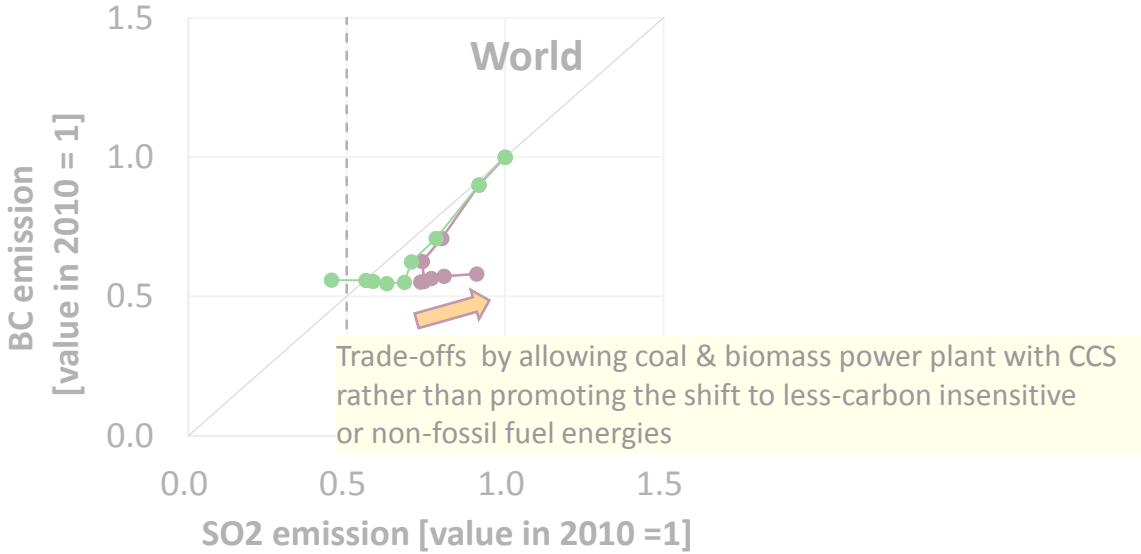

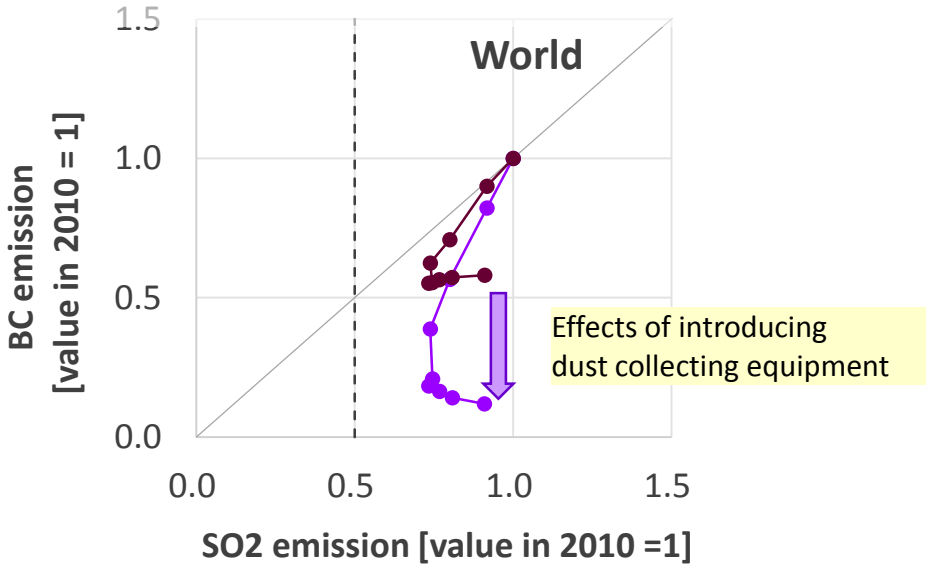

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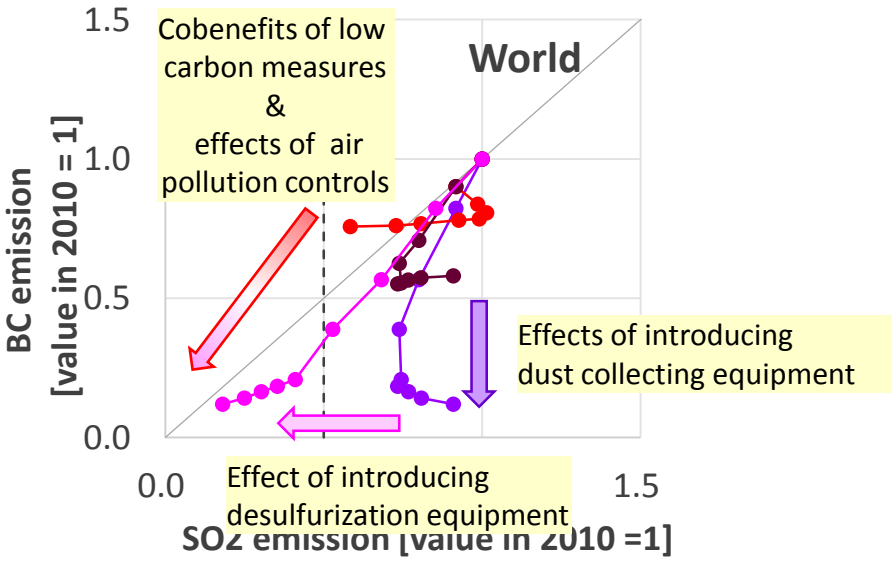

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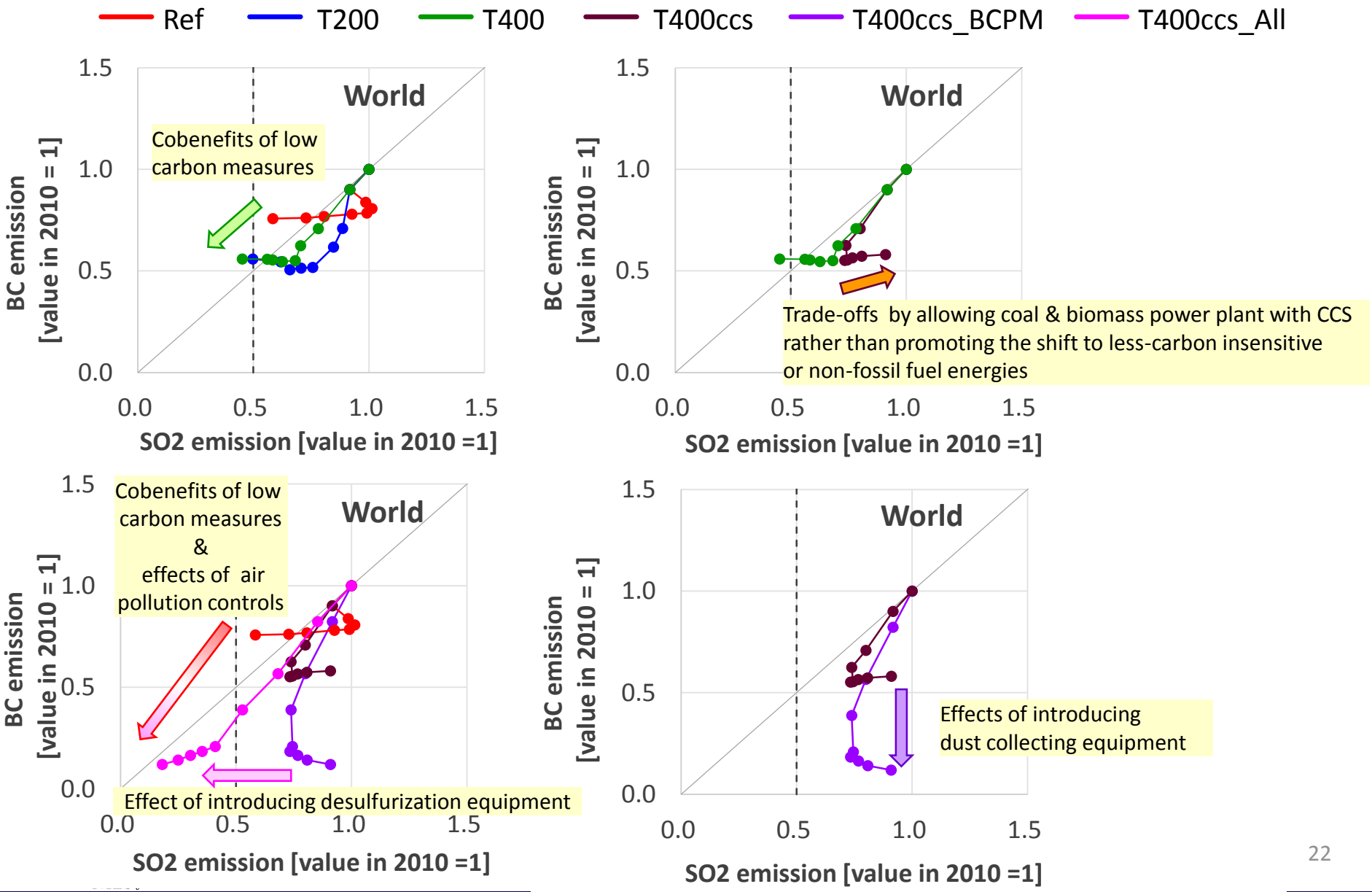
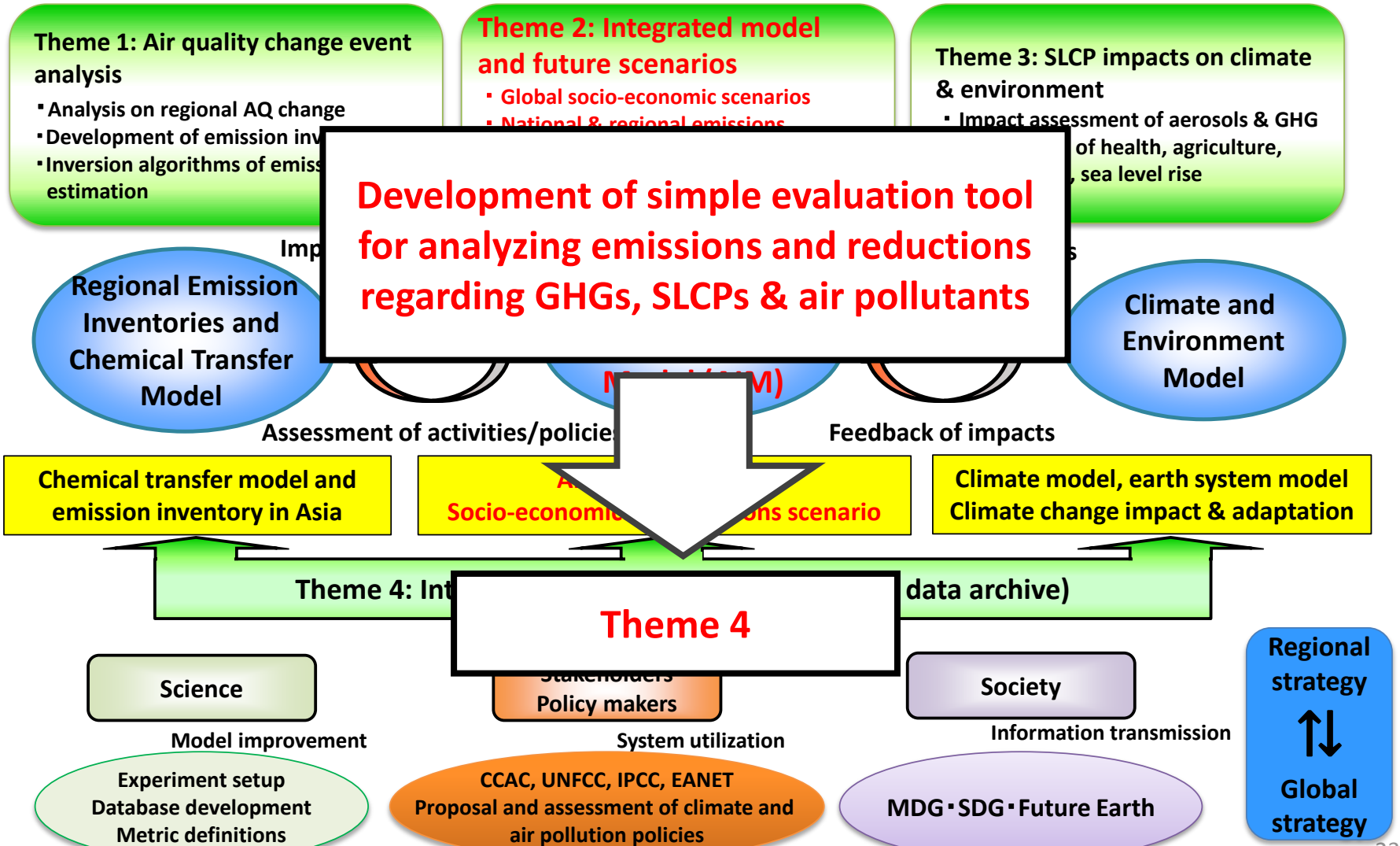
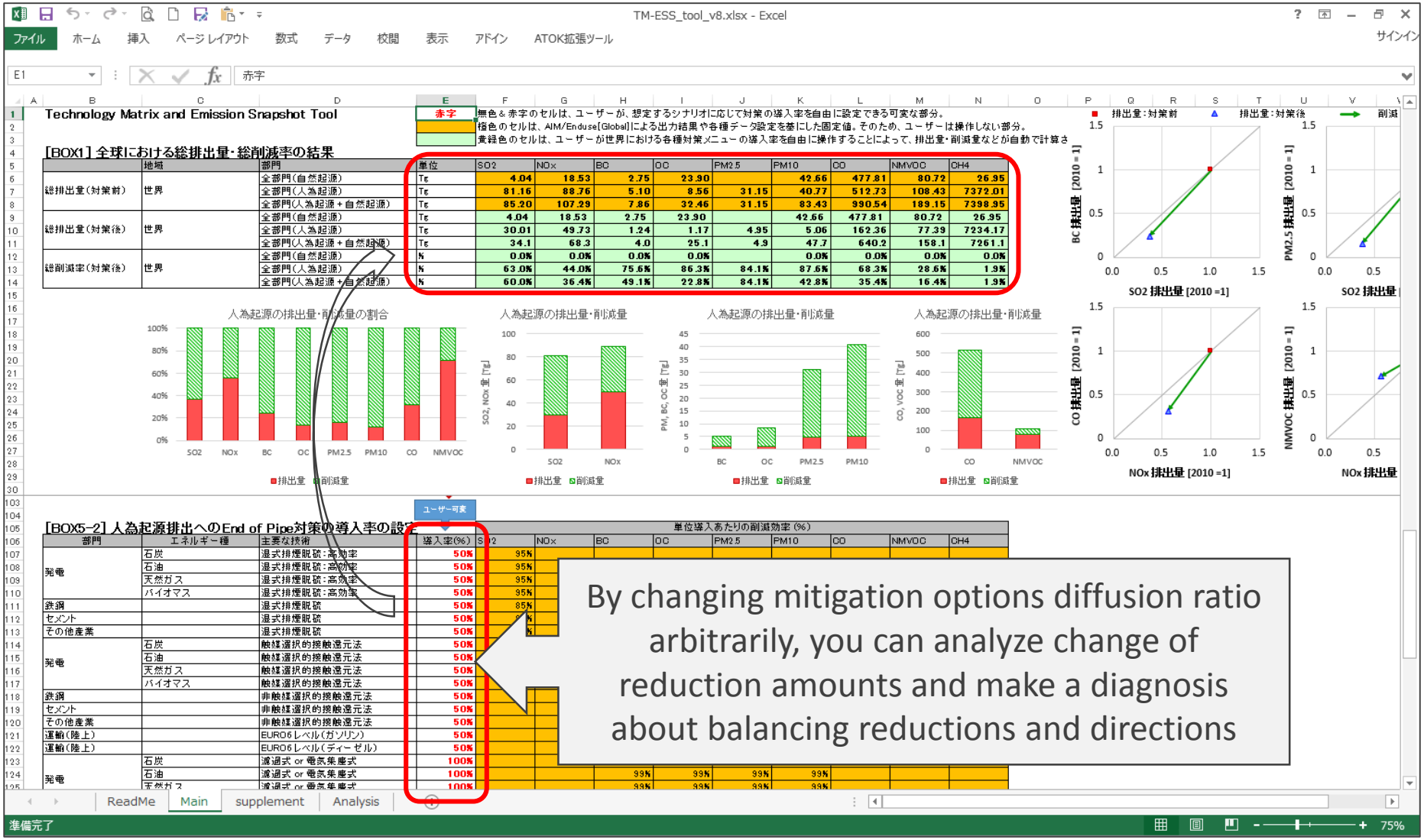


MOEJ-S12: Promotion of climate policies by assessing environmental impacts of SLCP and seeking LLGHG emissions pathways (FY2014-FY2018)

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



TM-ESS tool
- Technology Matrix and Emission SnapShot Tool -

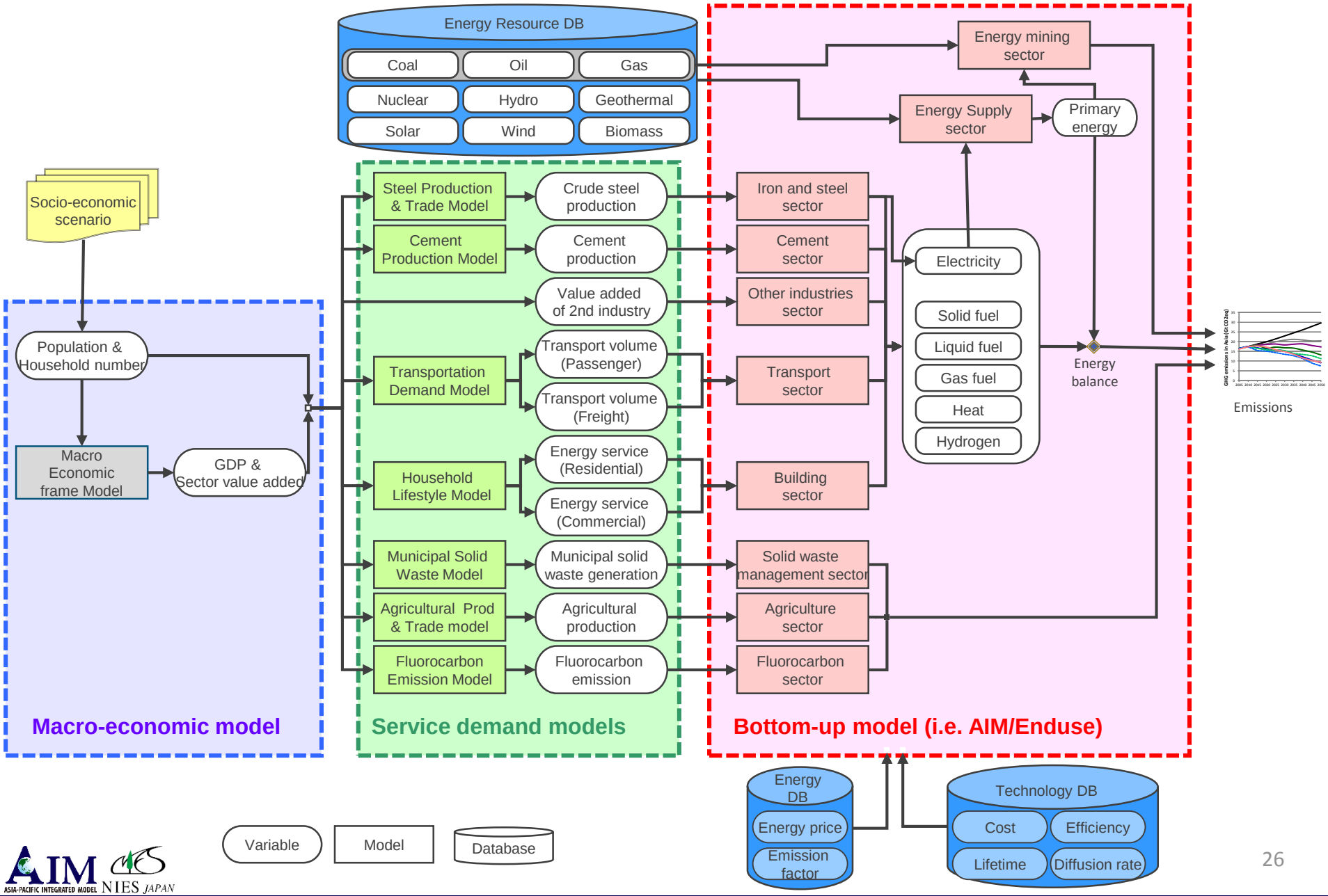


By changing mitigation options diffusion ratio arbitrarily, you can analyze change of reduction amounts and make a diagnosis about balancing reductions and directions

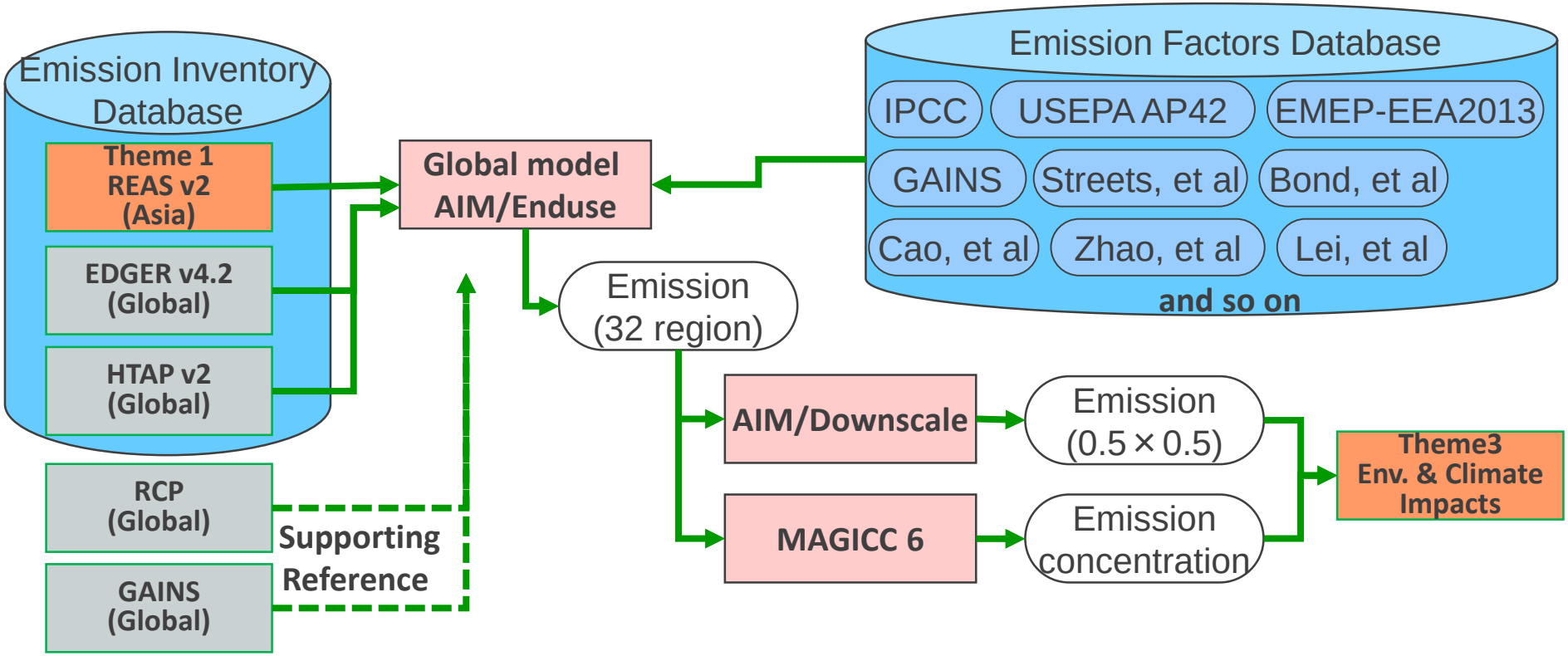
ご清聴ありがとうございました

Thank you for your attention

AIM/Enduse[Global] and element models



Roles of S12 Theme2 and collaboration with Theme 1 & 3



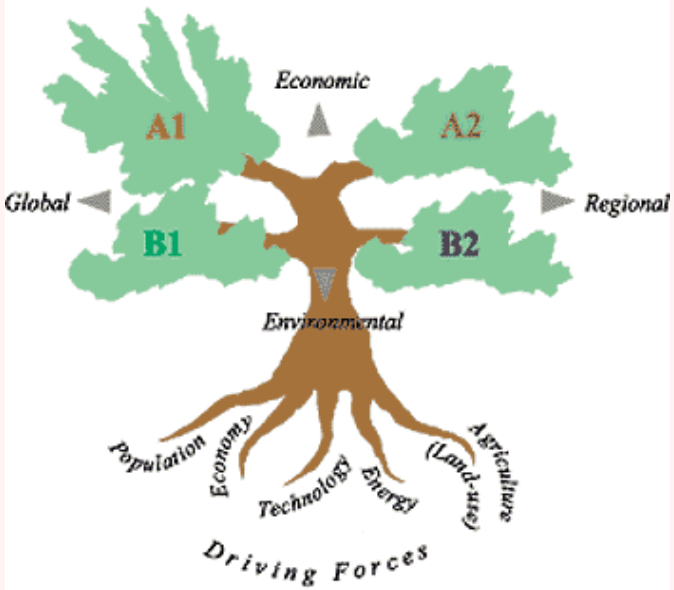
			CO2	CH4	N2O	HFC	PFC	SF6	CFC	HCFC	SO2	NOx	PM10	PM2.5	BC	OC	CO	NH3	NM VOC
Enduse	Global 32 regions	2010 −2050	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔
REAS v2.2	Asia 29 regions	2000 −2010	✔	✔	✔						✔	✔	✔	✔	✔	✔	✔	✔	✔
EDGER v4.2	Global 234 regions	1970 −2008	✔	✔	✔						✔	✔	✔				✔	✔	✔
HTAP v2	Global 17 regions	2010									✔	✔	✔	✔	✔	✔	✔	✔	✔
RCP	Global 6 regions	2000 −2100	✔	✔	✔						✔	✔			✔	✔	✔	✔	✔

Scenario Dimensions – SSPs (Shared Socioeconomic Pathways) -

See details about quantitative data and qualitative stories
https://secure.iiasa.ac.at/web-apps/ene/SspDb/dsd?Action=htmlpage&page=about

Previous representative scenarios (until IPCC AR4)

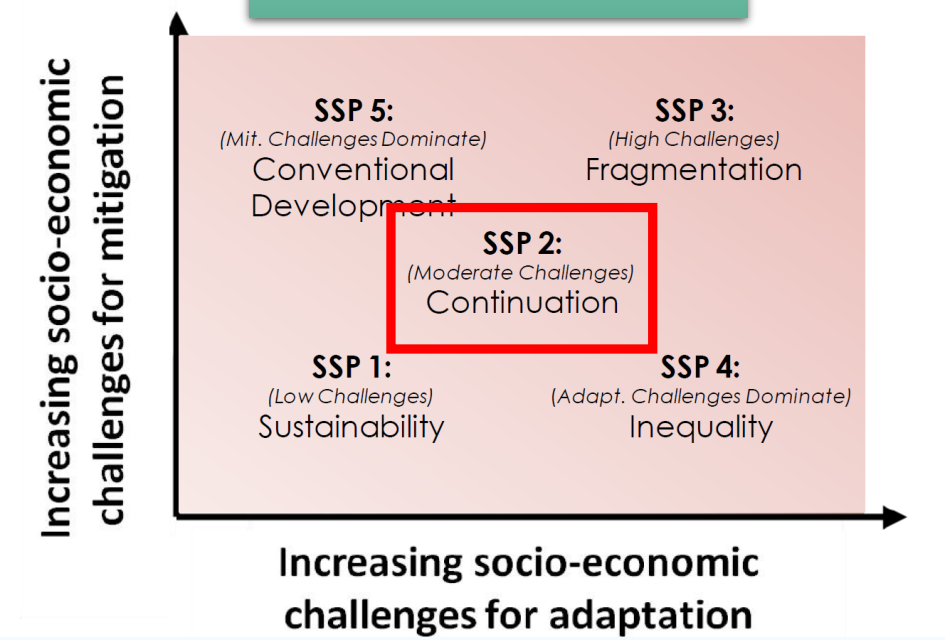
SRES



(Nakicenovic et al., 2000)

Latest representative scenarios (toward IPCC AR6)

SSPs

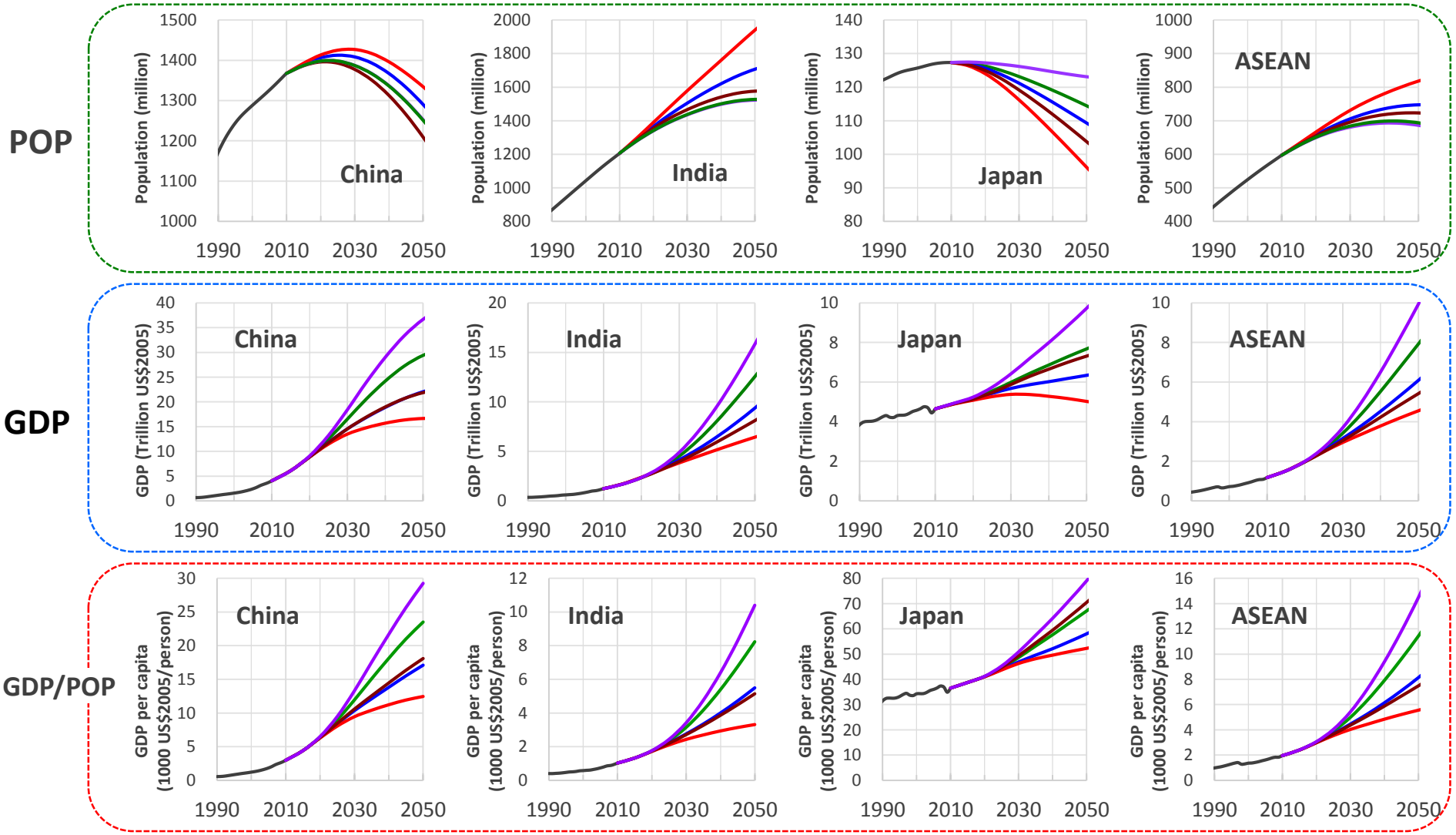


(O'Neill, 2012)

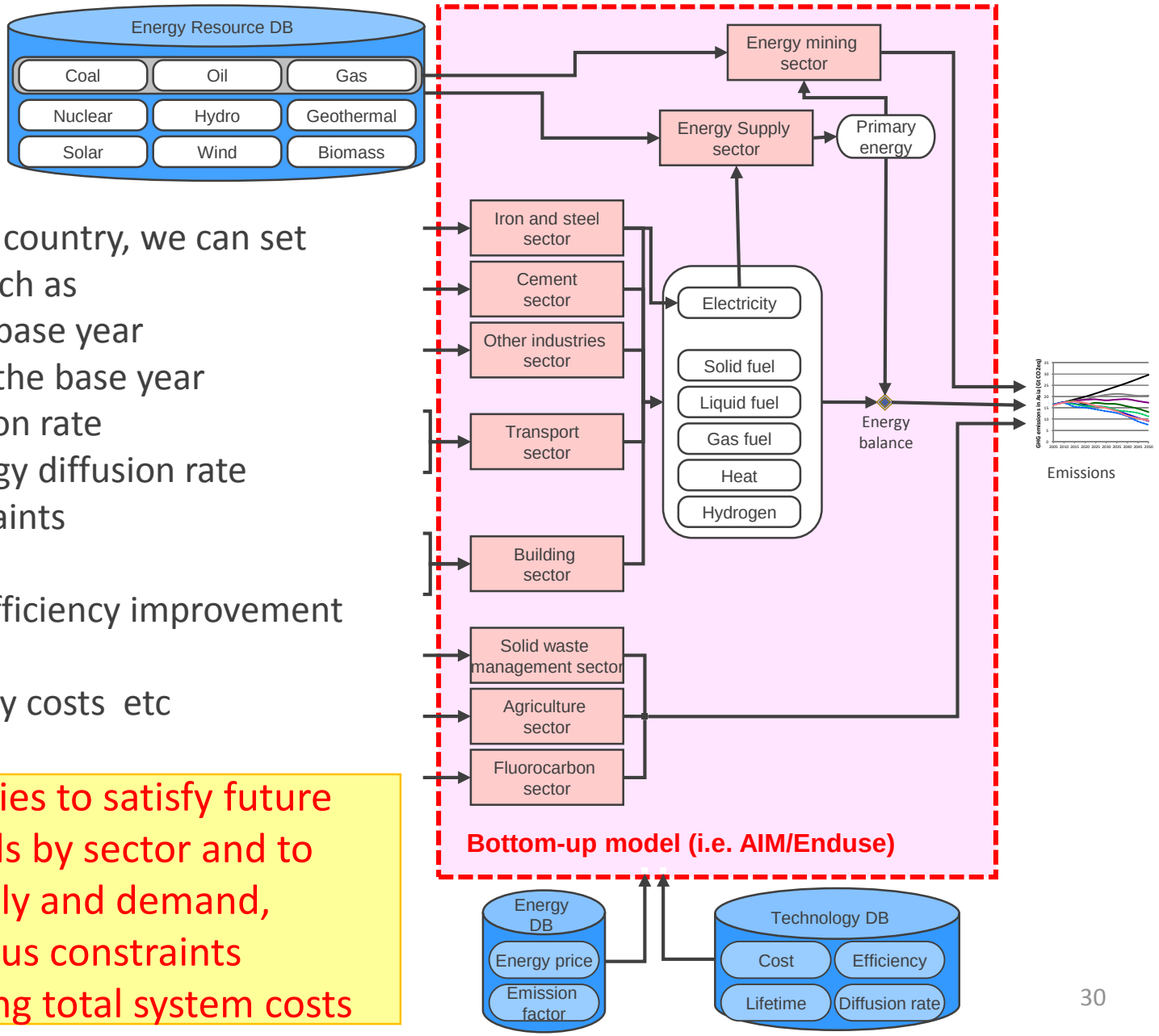
Population and GDP in Asia in SSP scenarios

Characteristics of socio-economic dynamics are different depending on countries & scenarios

⇨ They will influence on future estimations of service demands, energy consumption,etc.



AIM/Enduse[Global] model and element models



By energy, sector and country, we can set various constraints such as

- ✓ Technology 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
- ✓ Induced technology costs etc

Select technologies to satisfy future service demands by sector and to balance supply and demand, under various constraints & under minimizing total system costs

Overview of mitigation measures

various mitigation measures are available for promoting energy efficiency on both the demand and supply side, as well as reducing air pollutant by removal devices.

Four major groups of mitigation measures on GHG and air pollutants

① End-of-pipe mitigation measures ⇦ Effective for reducing (a) specific gas(es)

e.g : desulfurization equipment [=SO_2 reduction], denitrification equipment [=NOx reduciton], dust-collecting equipment [=BC, PM reduction], fertilization management in agriculture [=N_2O reduciton], manure management [=CH_4, N_2O reduction], waste management [=CH_4 reduction]

② Improvement of quality of fuels ⇦ Effective for reducing a specific gas

e.g. : shifting from high sulfur-content fuel to low-sulfur content fuel [=SO_2 reduction]

③ Improvement of energy efficiency ⇦ Effective for reducing multiple gases

e.g. : Introduction of high-energy efficient technologies and reduction of energy consumption [=CO_2・APs・ BC reduction], Low-carbon power in the supply side and electrification in the demand [=CO_2・APs・ BC reduction]

④ Drastic energy shifting ⇦ Effective for reducing multiple gases

e.g. : shifting from coal to renewables or natural gas [=CO_2・APs・ BC reduction], diffusion of hydrogen-fuel from renewables [=CO_2・APs・ BC reduction]