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Environment Research and Technology Development Fund S-20-3
[FY2021 ～ FY2025]

# Introduction of S-20-3 Project: Evaluation of emission scenarios for mitigating environmental impacts caused by Short-Lived Climate Forcers

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Environment Research and Technology Development Fund S-20 [FY2021 – FY2025]

# Title: Research on Mitigation to Climate Change and Environmental Impacts caused by Short-Lived Climate Forcers

**Generating scientific knowledge for policies on climate change and environmental impact mitigation cased by *region-specific* Short-Lived Climate Forcers**

## Theme 1 [i.e. S-20-1]

**Assessment of regional-scale climate change caused by Short-Lived Climate Forcers**

Atmosphere-ocean coupled model
High-resolution climate model

- Temperature
- Precipitation
- Extreme event

**Kyusyu Univ.**, Nagoya Univ., NIES, Tokyo Univ., JAMSTEC, Okayama, Univ.

## Theme 2 [i.e. S-20-2]

**Regional-scale and multi-sectoral assessments of the impacts of Short-Lived Climate Forcer**

Impact Assessment Model

- Health
- Agriculture
- Flood Drought

**Tokyo Univ.**, Hokkaido Univ., NIES

**SLCFs**

- Aerosol #1
- Gas #2

## Theme 3 [i.e. S-20-3]

**Evaluation of emission scenarios for mitigating environmental impacts caused by Short-Lived Climate Forcers**

Integrated Assessment model

- GHGs & SLCFs air pollutants scenarios
- Inventory In ASIA

Today's topic

**NIES**, Tokyo Univ. MHRT, MURC, ACAP, IGES

#1) Sulfate, BC, OC, itrate, those precursors
#2) $CH_4$, tropospheric $O_3$, HFCs, those precursors

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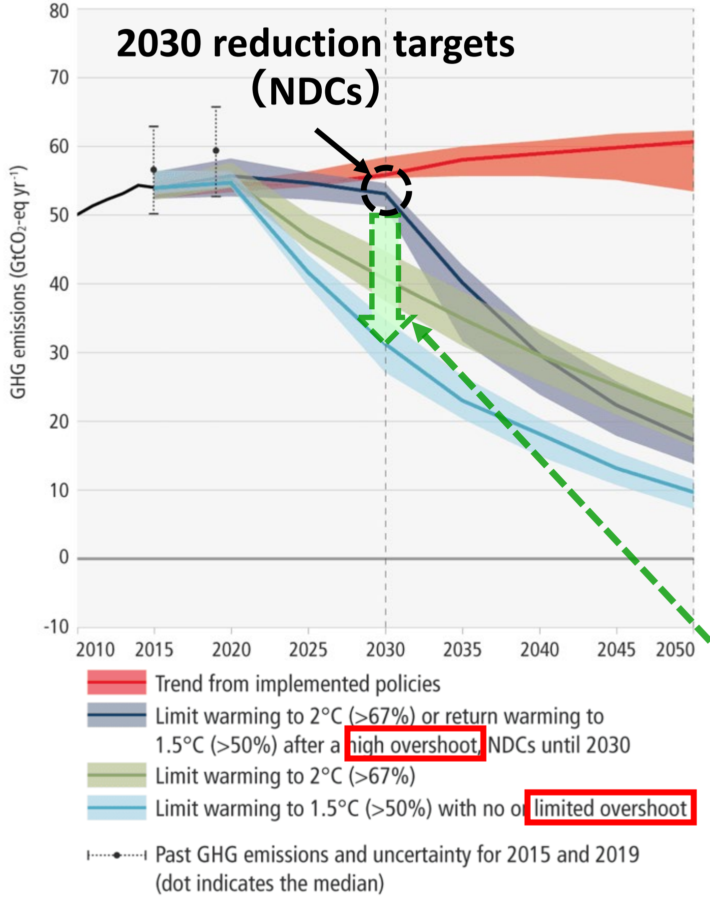
## Background on Mitigation Scenarios

# Messages from IPCC AR6 WG3, SPM 2 & SPM4

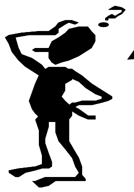
- ☐ We are not on track to limit warming to 1.5 ℃.
- ☐ Unless there are **immediate & deep GHG emissions reductions across all sectors**, 1.5℃ is beyond reach.




Source) IPCC AR6 WG3 SPM Figure SPM.4

| Category | | | GHG emissions reductions (compared to 2019) | | Emissions milestones | |
|---|---|---|---|---|---|---|
| | | | 2030 | 2050 | Net zero $CO_2$ | Net zero GHGs |
| C1 | Limiting warming to 1.5℃ with no or limited overshoot | >50% | **43%** (34~60%) | **84%** (73~98%) | **2050-2055** (100%) | **2095-2100** (52%) |
| C2 | Return warming to 1.5℃ after a high overshoot | >50% | 23% (0~44%) | 75% (62~91%) | 2055-2060 (100%) | 2070-2075 (87%) |
| C3 | Limiting warming to 2℃ | >67% | 21% (1~42%) | 64% (53~77%) | **2070-2075** (91%) | … - … (30%) |

Source) IPCC AR6 WG3 Table SPM.2



- ☐ How can SLCFs reductions contribute & accelerate to the realization of the 1.5℃ target ?
- ☐ How can SLCPFs measures help avoiding “overshoot” ?

# Project Goals and Objectives of S-20-3

Considering 2℃/1.5℃ targets and reduction of environmental impacts,

- ☐ Exploring **optimal mitigation scenarios** for reducing **short-lived climate forcing factors (SLCFs)** as well as **long-lived greenhouse gases (GHGs)**
- ☐ Assessing **technological mitigation potentials** by region, by sector and by gas type and **economic impacts** of mitigation measures
- ☐ Identifying **technological, economic, and institutional barriers and challenges**, to discuss the feasibility of drastic and early mitigation actions

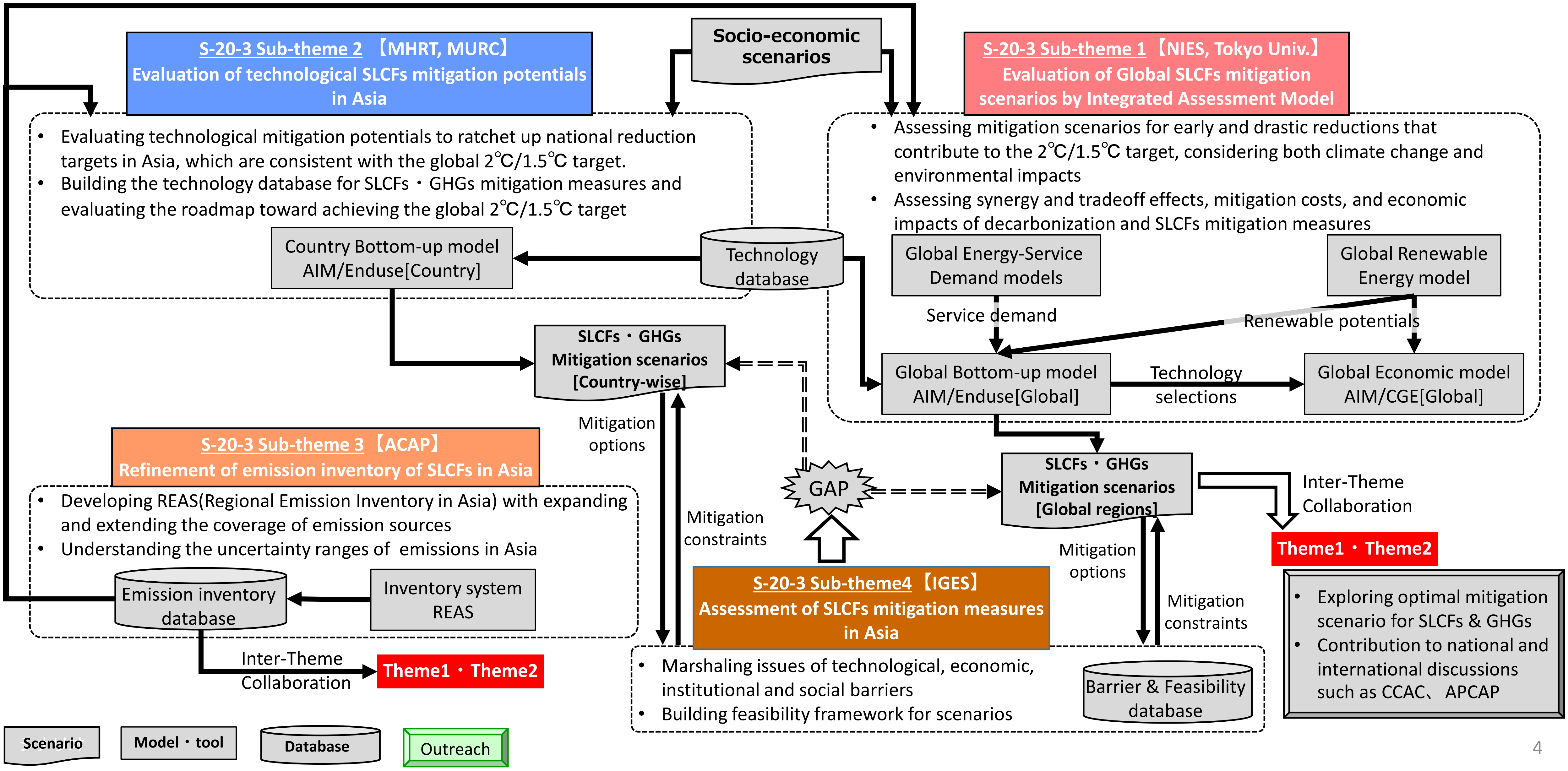
① Explore **sustainable GHGs and SLCFs optimal mitigation scenarios** in Asia and global regions to achieve a decarbonized society and reduce environmental impacts simultaneously, and **quantitatively evaluate the costs and economic impacts of measures under GHGs and SLCFs emission mitigation pathways**

② Explore **scenarios for drastic and early mitigations** in GHGs and SLCFs that contribute to the 1.5°C target, and quantify the **synergy and tradeoff effects of combining decarbonization measures and SLCFs mitigation measures**

③ Evaluate a roadmap of mitigation measures to achieve the 2°C / 1.5°C target, by considering strengthening of mitigation measures to **significantly rachet up emission reduction targets** in Asian countries under the Paris Agreement, technological mitigation potentials through countermeasures and those feasibility under technological, economic and institutional barriers and challenges, and **regional disparity and diversity of major emission sources that are biased toward certain sectors or countries**.

④ Develop S20's original GHGs and SLCFs optimal mitigation scenarios, based on the climate impact assessment under S-20-1, the environmental impact assessment under S-20-2, together with the socio-economic assessment of mitigation measures under S-20-3.

# Research Project Structure and Content of S-20-3



Collaboration between S-20-3(1) and S-20-3(2)

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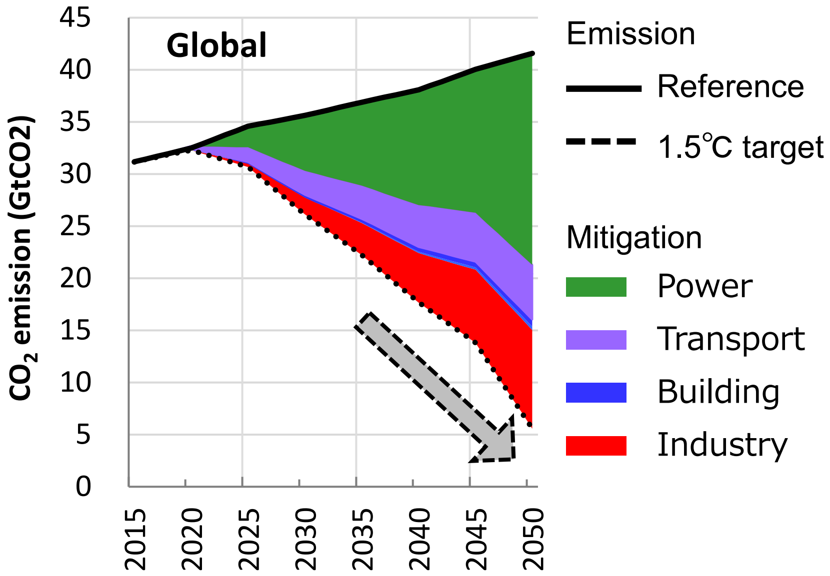
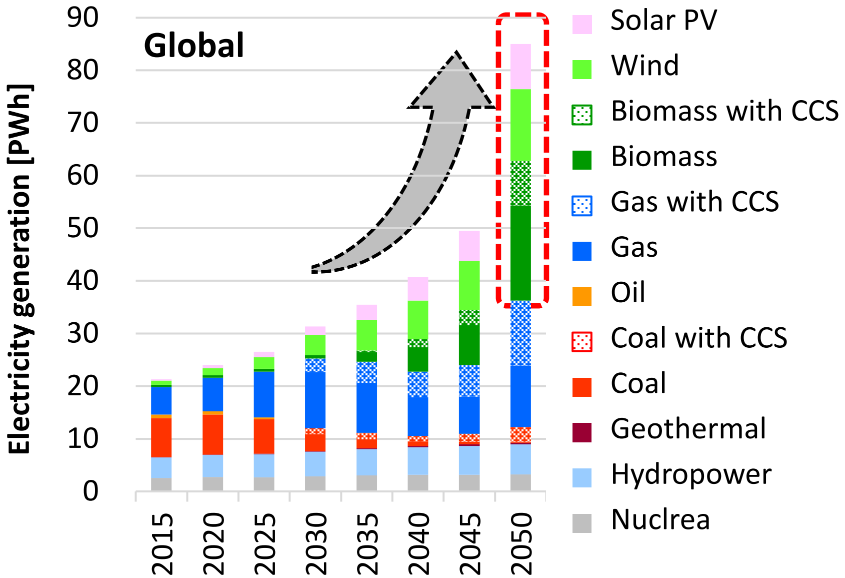
**Outcome 1**

# Exploring scenarios for early & drastic global mitigations in GHGs/SLCFs toward the 1.5℃ target

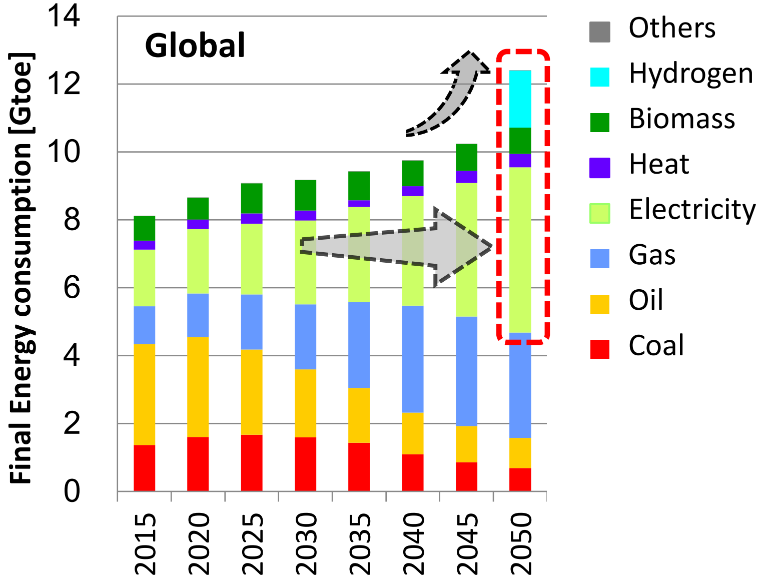
- Analyze scenarios that contribute to the 1.5°C target of achieving net-zero $CO_2$ emissions around 2050 for developed countries and around 2060 for developing countries, based on AIM/Enduse[Global]
- In order to achieve net-zero $CO_2$ emissions toward the 1.5℃ target, large-scale decarbonization measures are required as follows.
  1) **Accelerate the coal phase-out** under the Glasgow Climate Pact and **all remaining coal-fired power generation shall be with CCS**.
  2) **Penetrate biomass electricity generation with CCS (BECCS) significantly** in order to offset emissions from hard-to-abate sectors.
  3) Promote not only **electrification** but also the use of **hydrogen and synthetic fuels** after 2040, in the demand sectors.
  4) Substantial diffusion of renewable energy and hydrogen production using green electricity (green hydrogen)




**Global $CO_2$ pathway and mitigation potentials**




**Global electricity generation and power supply structure**




**Global final energy consumption and energy mix**

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Source) Hanaoka, et al (2023) 10th International Conference on Acid Deposition,
Hanaoka, et al (2023) 9th International Symposium on Non-CO2 Greenhouse Gases

Collaboration between S-20-3(1) and S-20-3(2)

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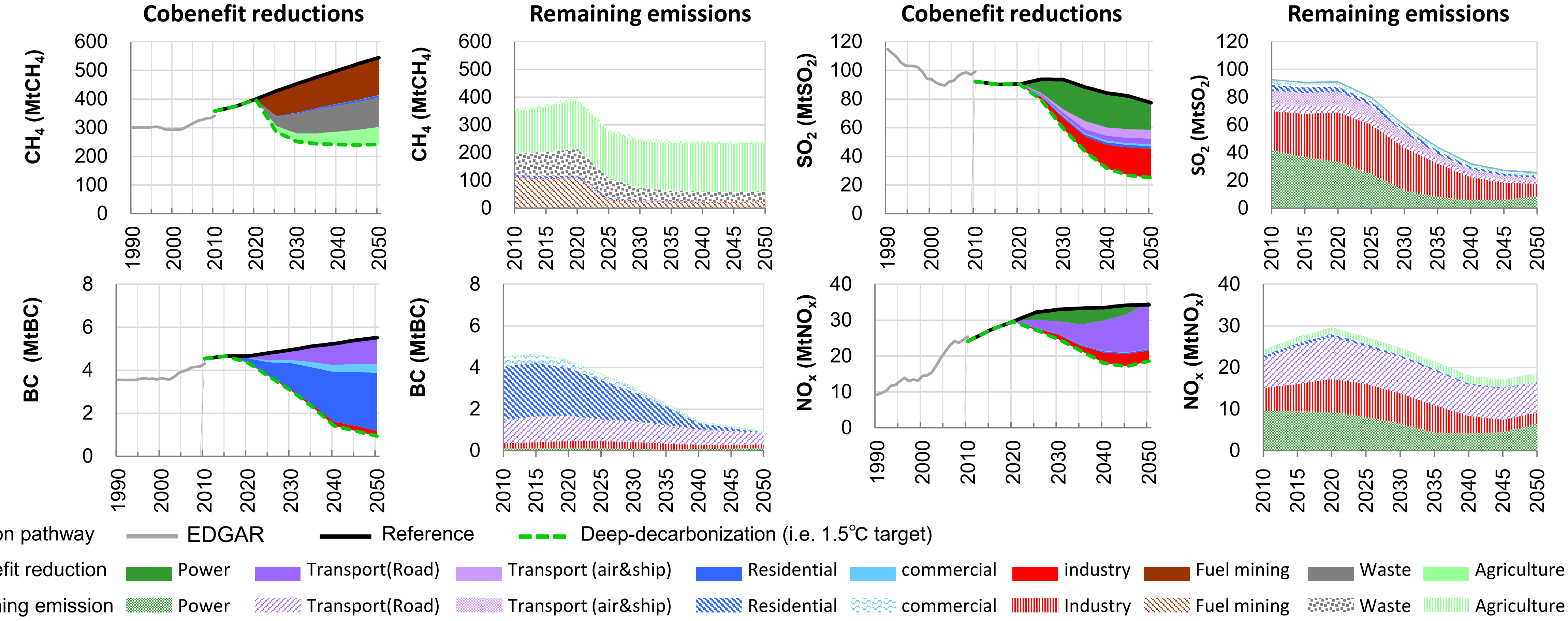
## Outcome 2

# Exploring scenarios for early & drastic global mitigations in GHGs/SLCFs toward the 1.5℃ target

- **Co-benefit reduction of SLCFs & air pollutants due to fuel reductions** can be expected by decarbonization toward the 1.5°C target.
- **GHGs, SLCFs, air pollutants from non-energy sectors and hard-to-abate sectors will remain** at a certain amount, but those trends will differ depending on gas type, sector, and country. It is necessary to evaluate those trends to identify sectors and countries that should make significant emission reductions. (e.g. $CH_4$ remains in agriculture largely, NOx will increase after 2040 in the power sector, etc.)




Source) Hanaoka, et al (2023) 10th International Conference on Acid Deposition,
Hanaoka, et al (2023) 9th International Symposium on Non-CO2 Greenhouse Gases

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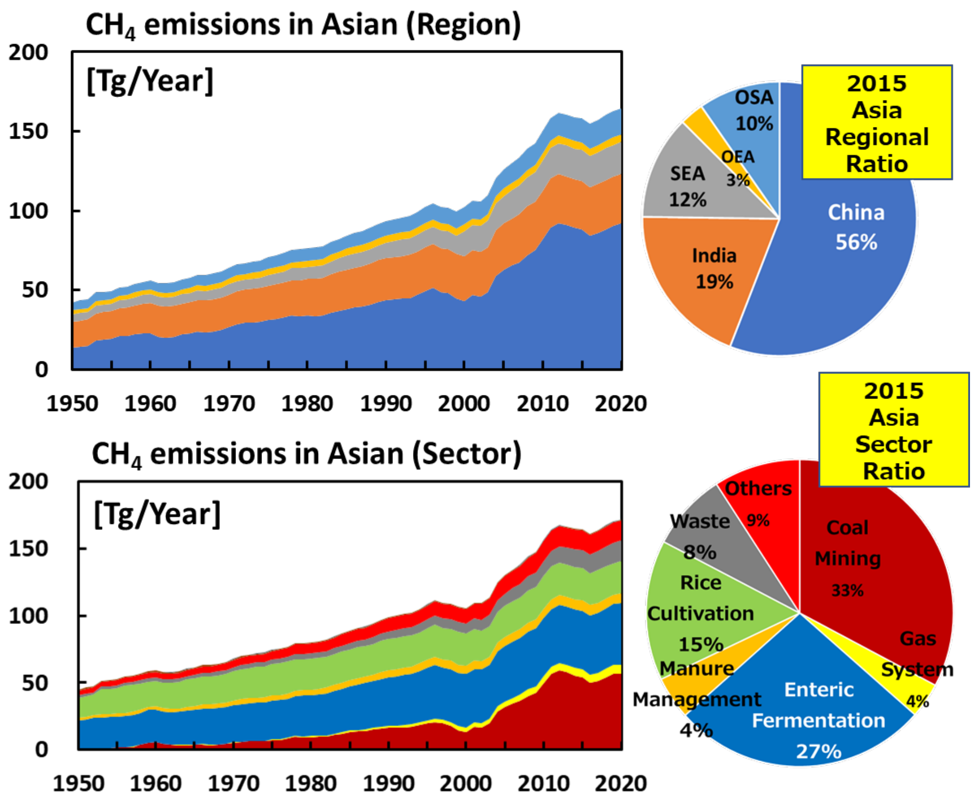
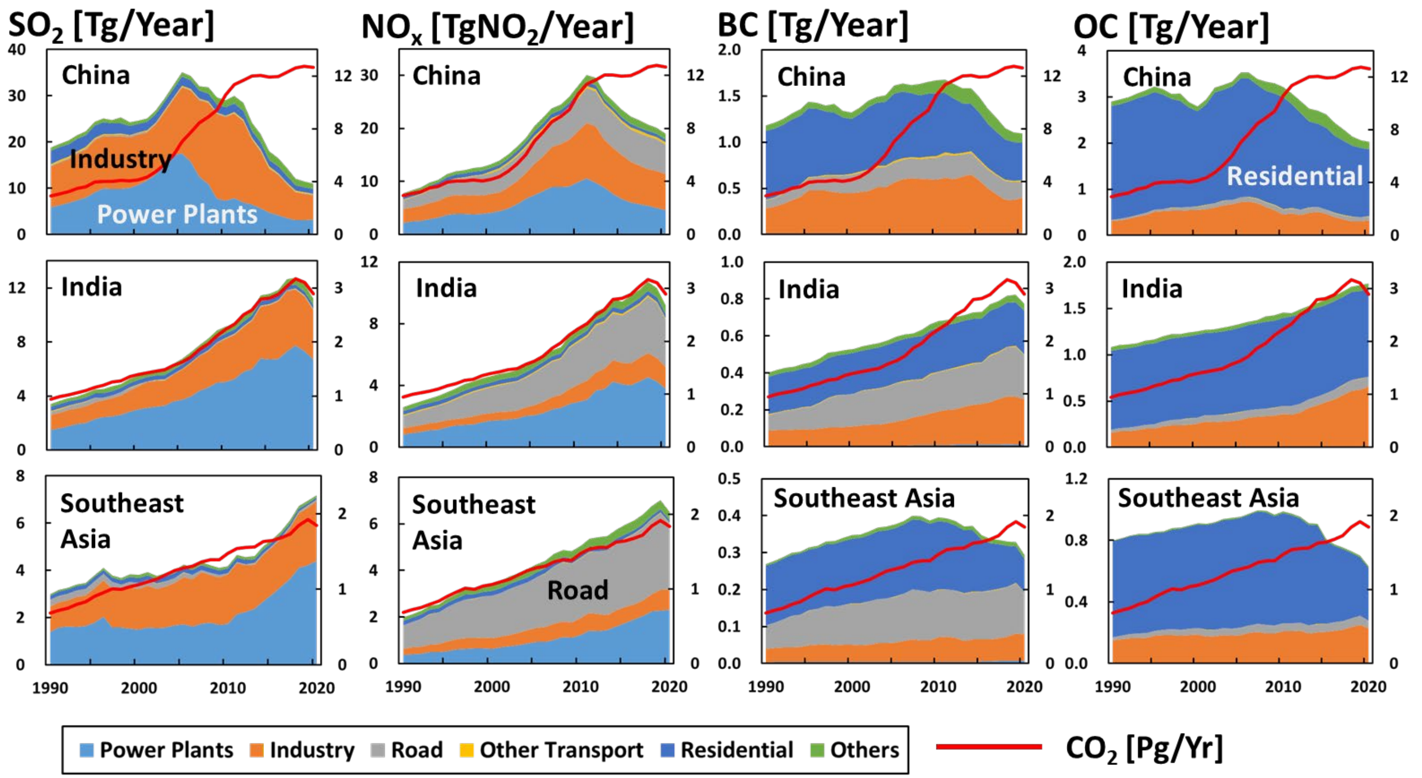
## Outcome 3

# Expanding the Regional Emission inventory in Asia (REAS) system and recent SLCF emissions in Asia

- **$CH_4$ emissions have increased about 3.5 times in the last 70 years.** China is the largest, followed by India (two countries accounted for about 75% recently). $CH_4$ increase has been about 2 times for agriculture, 7.5 times for waste, but 50% for fugitive (esp. coal mining).
- The largest source of $CH_4$ recently is coal mining in China, followed by livestock enteric fermentation in India, rice cultivation in ASEAN.
- Recently, $SO_2$ emissions in China and India have reversed, and BC & OC are nearly equal, but NOx emissions remain about twice as high in China as in India.




Source) Detailed REAS data cited by CRIPPA, ~~, KUROKAWA, ~~ et al (2023) Earth System Science Data (IF: 11.4)
KUROKAWA, KIRIYAMA, and HANAOKA (2023) 20th GEIA Conference (GEIA: Global Emission InitiAtive)

Collaboration between S-20-3(2) and S-20-3(1) and S-20-3(3)

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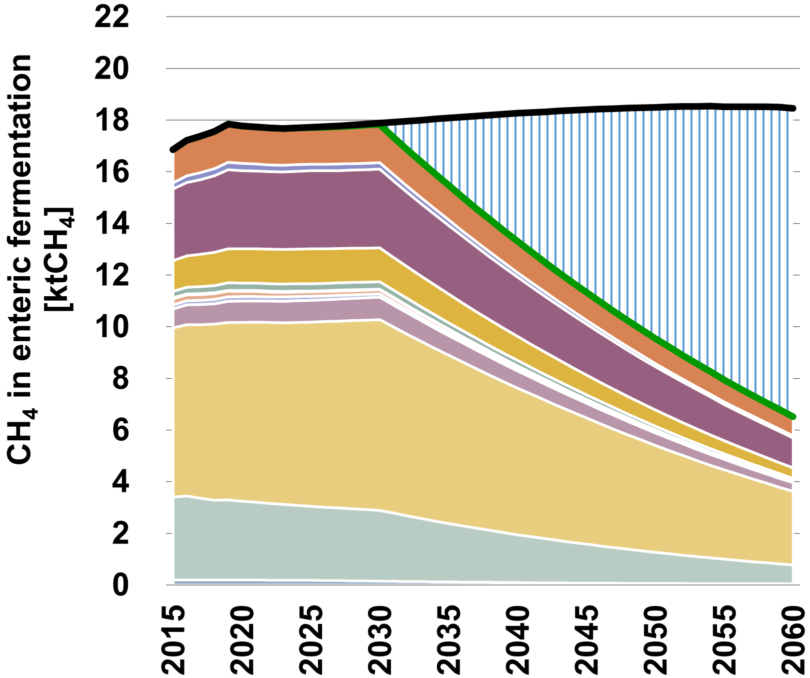
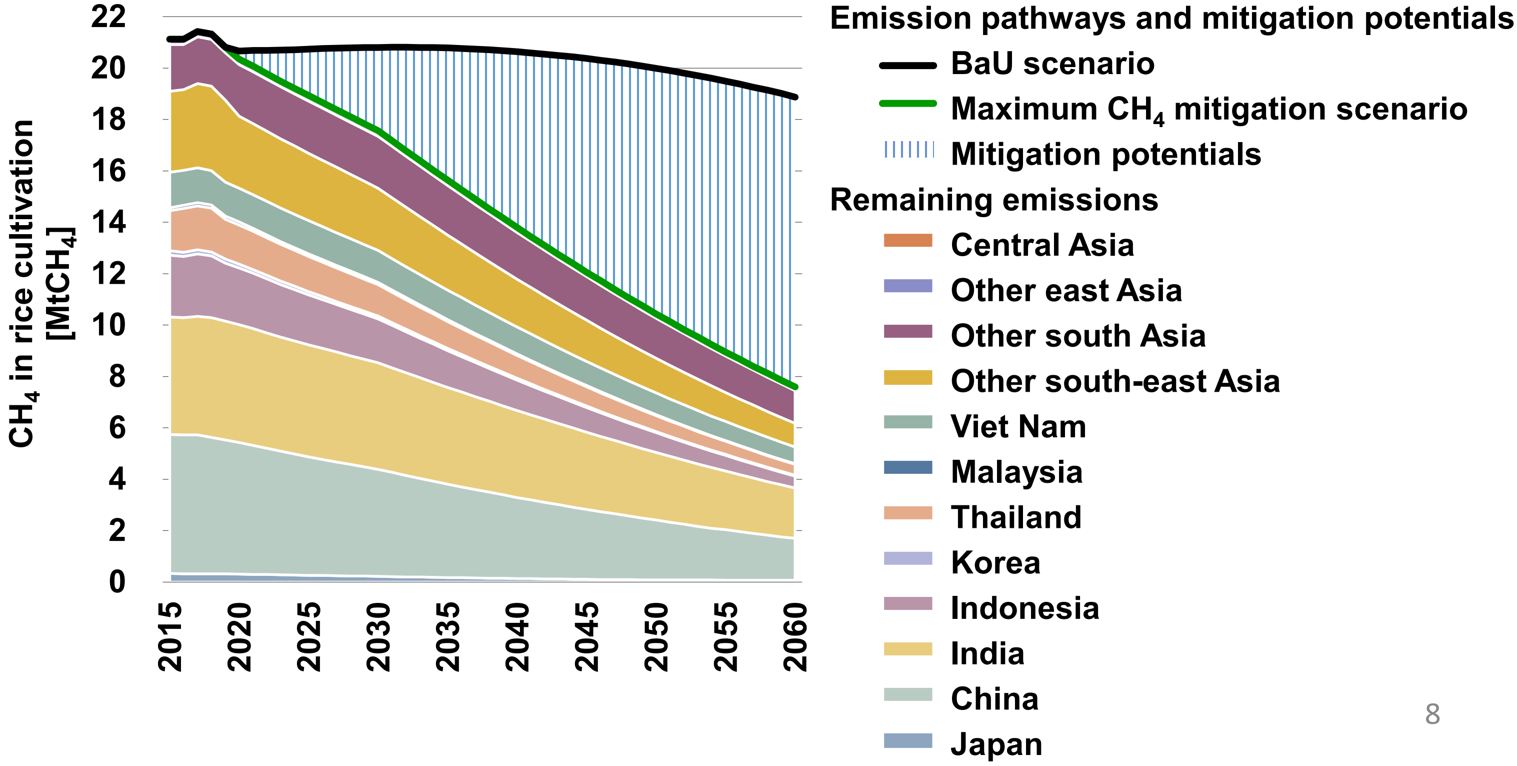
## Outcome 4

# Exploring scenarios for drastic SLCFs mitigations in the non-energy sector toward the 1.5℃ target

- Examining **the BaU scenario** for agriculture which is the largest $CH_4$ emitter in Asia, and analyzing the **"maximum $CH_4$ reduction" scenario** in which available $CH_4$ mitigation measures are deployed to the maximum extent possible by 2060. (see the figure below).
  - such as "addition of $CH_4$ generation inhibitors to feed", "feeding management improvement", "cattle breeding improvement" in livestock enteric fermentation, and "water management improvement", "change in organic matter" in rice cultivation
  - Up to the **maximum reduction by 61% in enteric fermentation and 64% in rice cultivation by 2060** (compared to 2015), but **$CH_4$ emissions will remain at around 40% in 2060.**
- Developing the waste models covering solid waste and wastewater for the calculation of GHGs and SLCFs emissions.
- Developing the HFCs emissions model, by focusing on refrigerant applications and evaluating emissions the latest inventory.




Source) Kawashima and Hanaoka (in preparation)

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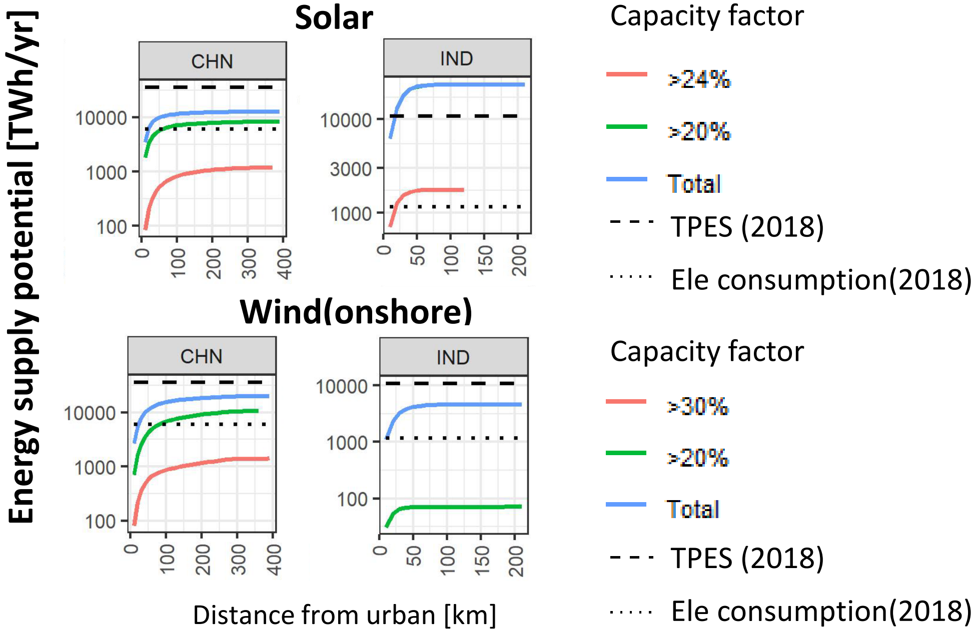
S-20-3(1)

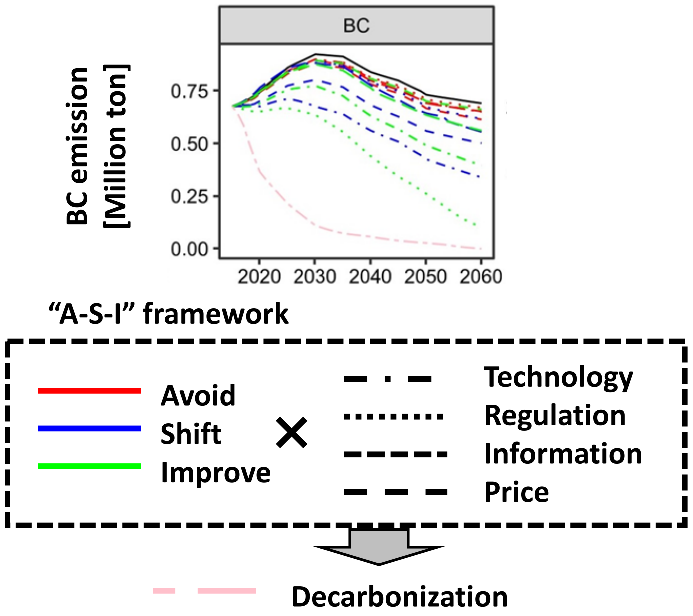
# Outcome 5

## Sector-wise assessment toward the 1.5℃ target (renewable potentials, multi-gas reduction potentials, etc.)

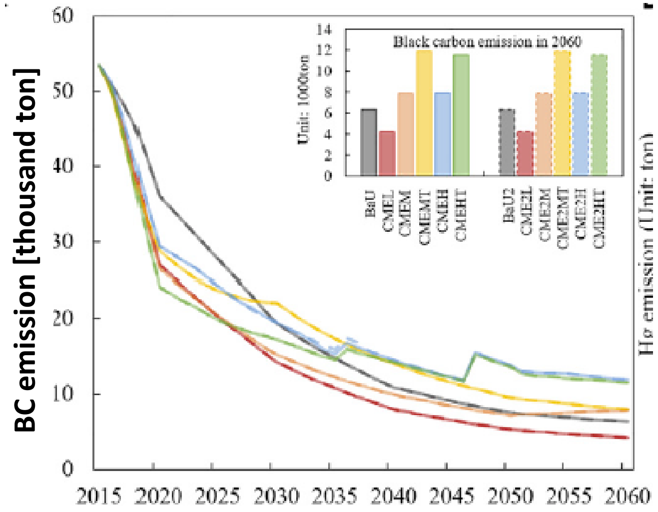
- Estimating renewable energy supply potentials by considering areas with wind and solar supply potentials and distances from urban. **Characteristics of wind and solar supply potential differ by country/region**. (See left figure by Global Renewable Energy Model)
- Developing a new method to integrate the transportation demand model with the AIM/Enduse model to apply "Avoid-Shift-Improve" framework to decarbonization analysis toward net-zero $CO_2$ emissions in China (paper published) and in global (on-going). **Decarbonization also has a large cobenefit in reducing BC and air pollutants**. (see mid figure by the transport-AIM/Enduse model)
- Analyzing decarbonization in the iron & steel sector in China, which accounts for half of global steel production and is considered as a hard-to-abate sector. **Decarbonization also has a large cobenefit in reducing BC and air pollutants**. (see right figure by AIM/Enduse)




Source) SILVA HERRAN and ASHINA (2023)
Environmental Research Communications
https://doi.org/10.1088/2515-7620/ace2b6




Source) ZHANG and HANAOKA (2022)
Nature Communications
https://doi.org/10.1038/s41467-022-31354-9
ZHANG and HANAOKA (under review)
Renewable and Sustainable Energy Reviews




Source) LI and HANAOKA (2022)
One Earth
https://doi.org/10.1016/j.oneear.2022.07.006

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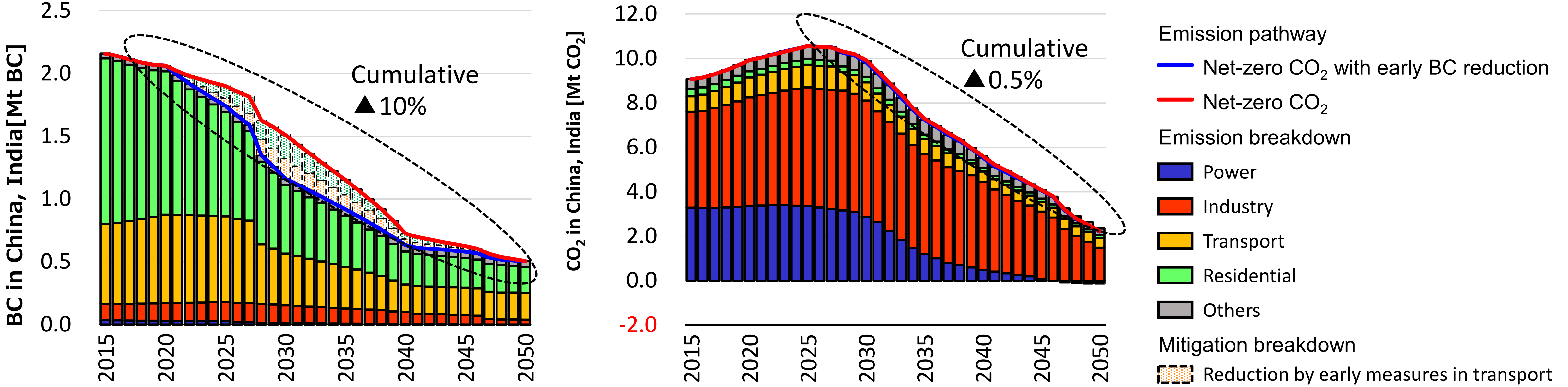
Collaboration between S-20-3(2) and S-20-3(1)

## Outcome 6

# Exploring scenarios for early & drastic mitigations in GHGs/SLCFs toward the 1.5℃ target in Asia

- In China and India, we compared two scenarios; **the scenario of 2060 net-zero $CO_2$ emission** and **the scenario of 2060 net-zero $CO_2$ emission with early BC reduction** which we accelerate decarbonization measures by five years earlier that are also effective in reducing BC in the residential and transport sectors simultaneously. (See the figure below)
  - **Cumulative BC emissions would be reduced by around 10%** by pushing forward BC reduction measures, but **cumulative additional mitigation costs would only increase by 3.2%**. Thus, enhanced measures for major BC emission sources can significantly reduce cumulative BC emissions without increasing large additional investment costs.
  - The impact on cumulative $CO_2$ reduction by accelerating measures for major BC emissions is small, with a reduction of only 0.5%.
- To understand the characteristics in ASEAN, we also conducted similar analyses in Thailand, Indonesia and Viet Nam; comparing "mid- to long-term low-GHG emission development strategy" and "net-zero $CO_2$ emission".




Source) Hirayama, et al (2023) 10th International Conference on Acid Deposition (China, India scenarios)
Goto et al (2023) 10th International Conference on Acid Deposition (Thailand, Indonesia scenarios)
Ota et al (2023) 10th International Conference on Acid Deposition (Viet Nam scenarios)

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Collaboration between S-20-3(4) and S-20-3(1) and S-20-3(2)

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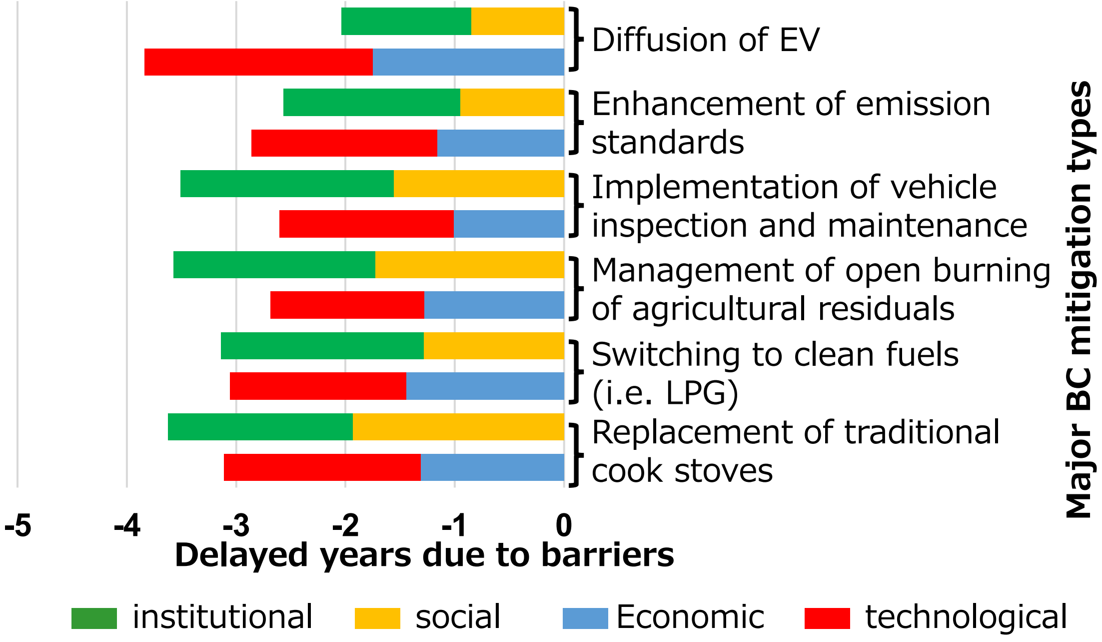
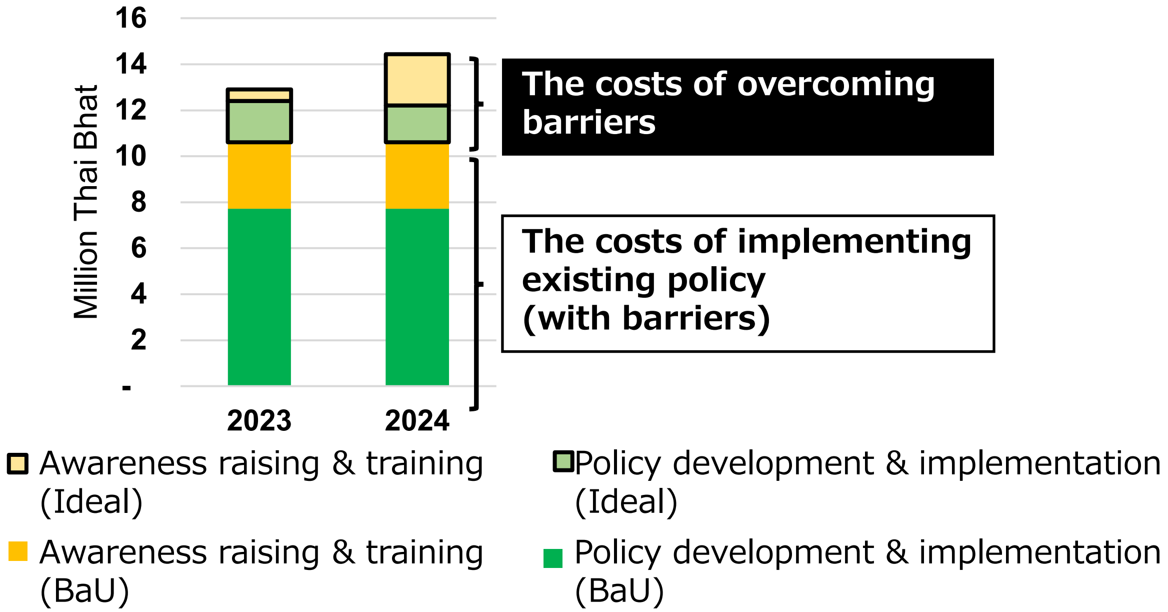
## Outcome 7

# Developing feasibility framework and barrier assessment methodology

- We newly developed **a feasibility framework** by quantifying **the impacts of barriers on SLCFs mitigation in four levels (i.e., no, small, moderate and significant impacts)** for **four barrier categories (i.e., economic, technological, social, and institutional barriers)**.
- We conducted literature reviews and expert interviews in Thailand to evaluate barriers to major BC mitigation measures, and quantified the **impacts of barriers on delaying the introduction of measures (i.e., in the unit of years of delay)**. Also we considered how to assess the **cost of overcoming barriers (i.e., transaction cost)**.
- For relatively small-scale measures such as vehicle inspection & maintenance, introduction of clean cook-stove, social and institutional barriers were found to be as large as or even larger than the technological and economic barriers.




**Major BC mitigation types and impacts of barriers in Thailand (2020-2035)**




**The costs of overcoming social & institutional barriers for introducing clean cook-stove**

Source) Zusman, Akahoshi, Hanaoka, et al (in preparation)

Source) Akahoshi, Zusman, Hanaoka, et al (in preparation)

Collaboration between S-20-3(2) and S-20-3(4) and S-20-3(1)

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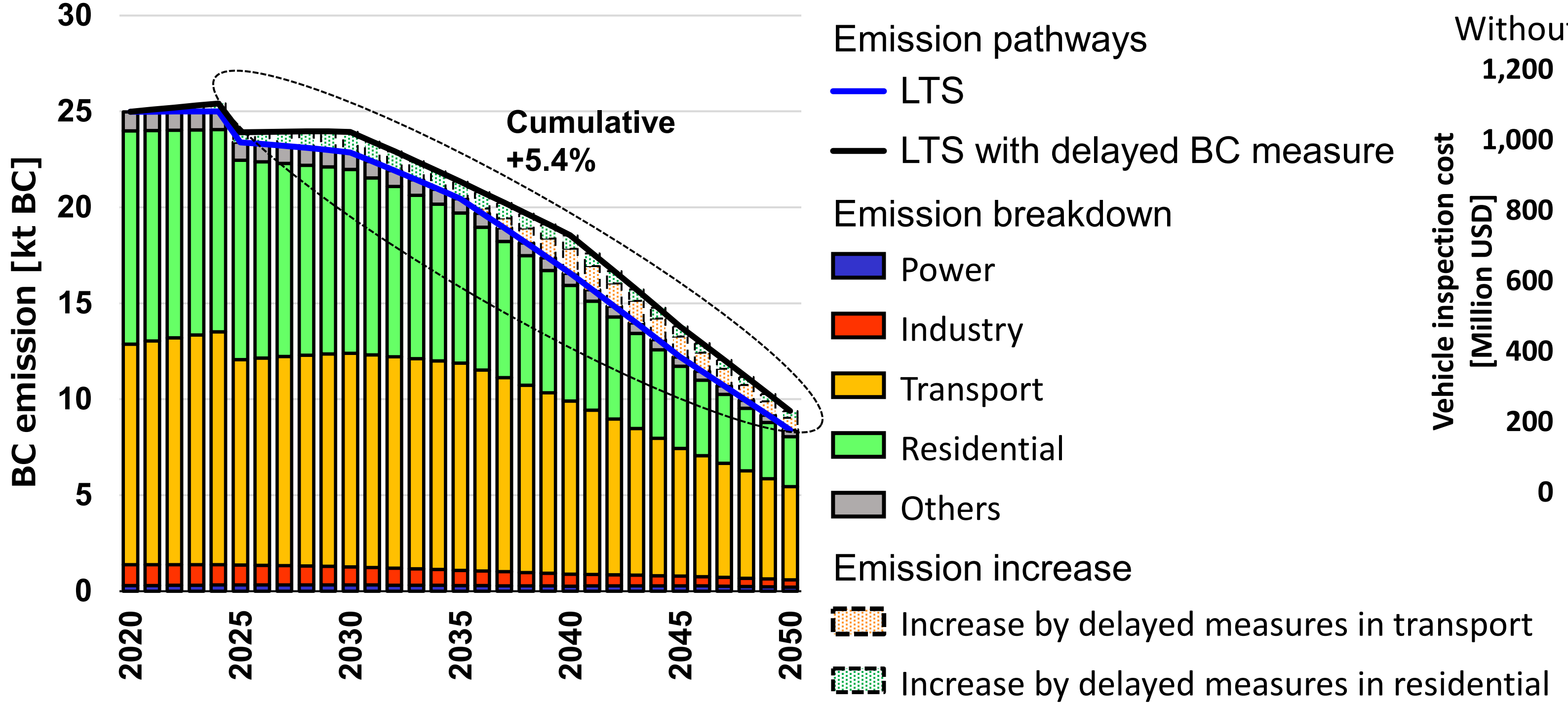
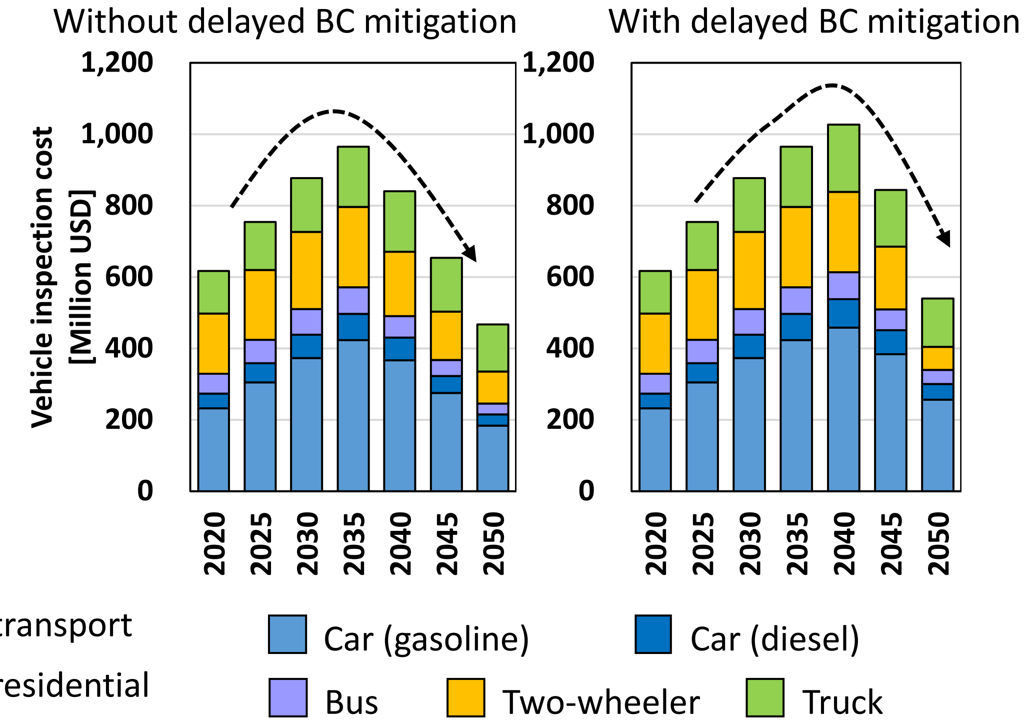
## Outcome 8

# Application of barrier assessment to the Thailand scenarios and calculation of the costs of barrier

- Using AIM/Enduse[Thailand], we compared two scenarios; **"LTS" scenario in line with Thailand's mid- to long-term low-GHG emission development strategy** and **"LTS with delayed BC measure" scenario where the impacts of barriers to BC mitigations in the residential and transport sectors delay implementation of BC measures by five years**. (See the figure below)
- Delayed implementation of BC mitigation measures because of the impacts of barriers **increases cumulative BC emissions by 5.4%**, while the impact of delayed BC mitigation measures on $CO_2$ emissions is small, **increasing cumulative $CO_2$ emissions by only 1.3%.** In addition, **the total mitigation costs would decrease by 6.6%** due to the delayed implementation of the measures.




**Assessment of the impacts of delayed BC measures on Thailand's mid- to long-term low-GHG emission development strategy**




**Example of assessment of vehicle inspection costs for internal combustion engine vehicles**

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Source) Goto, Hirayama, Hanaoka, Hibino, et al (in preparation)


## Thank you for your attention!


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## Acknowledgment

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