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Global modelling for simultaneous achievement of "Deep Decarbonization", "Air Quality Improvement", and "Nitrogen Waste Reduction"

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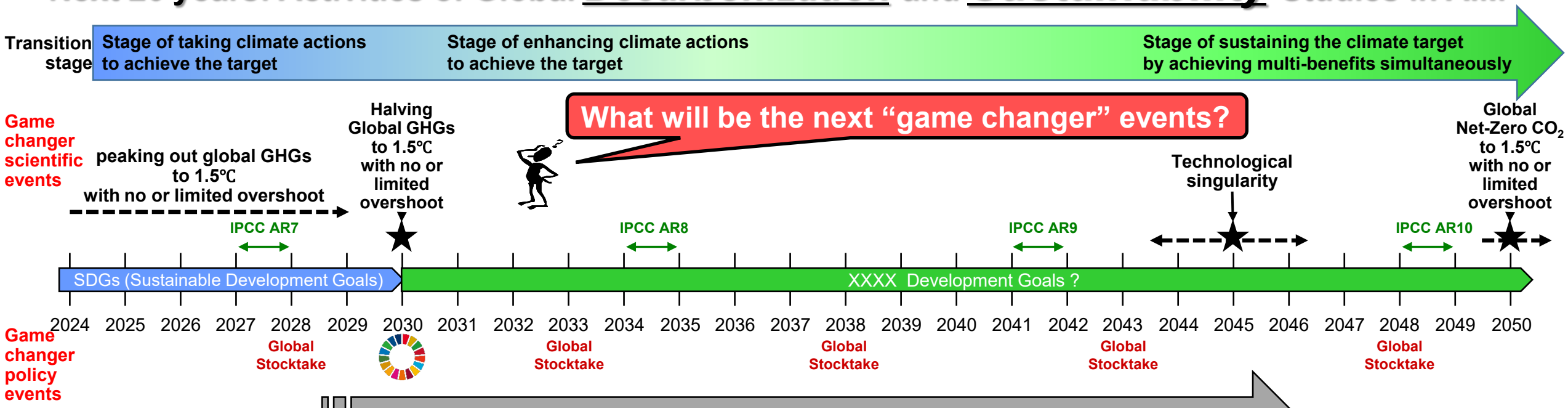
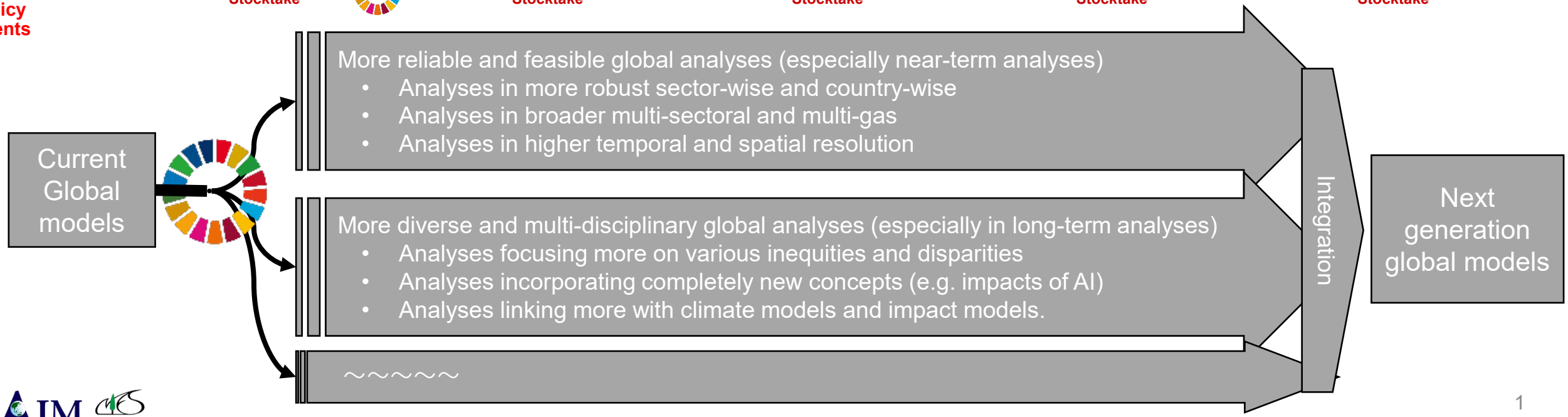
AIM ASIA-PACIFIC INTEGRATED MODEL

NIES JAPAN

Next 20 years: Activities of Global *Decarbonization* and *Sustainability* Studies in AIM





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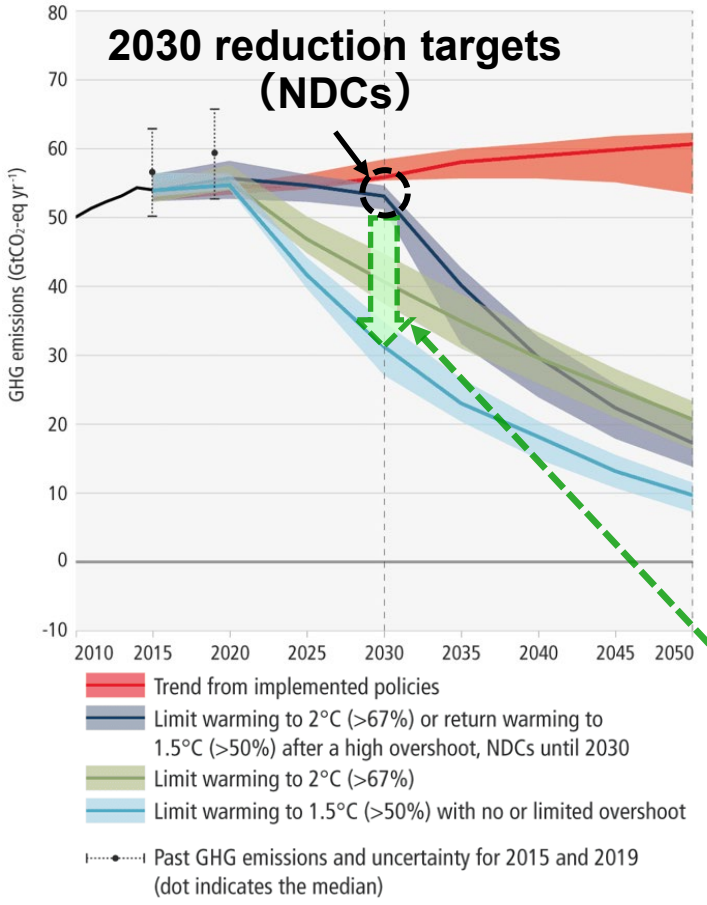
Messages from IPCC AR6 WG3

Mitigation pathways and timing to achieve net zero emissions

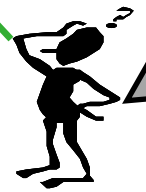
- We are not on track to limit warming to 1.5 ℃.
- Unless there are **immediate & deep GHG emissions reductions across all sectors**, 1.5℃ is beyond reach.



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 we simultaneously achieve “***Deep Decarbonization***” and “***Air Quality Improvement***” ?
- How can **SLCFs** reduction measures contribute & accelerate to the realization of the 1.5℃ target ?

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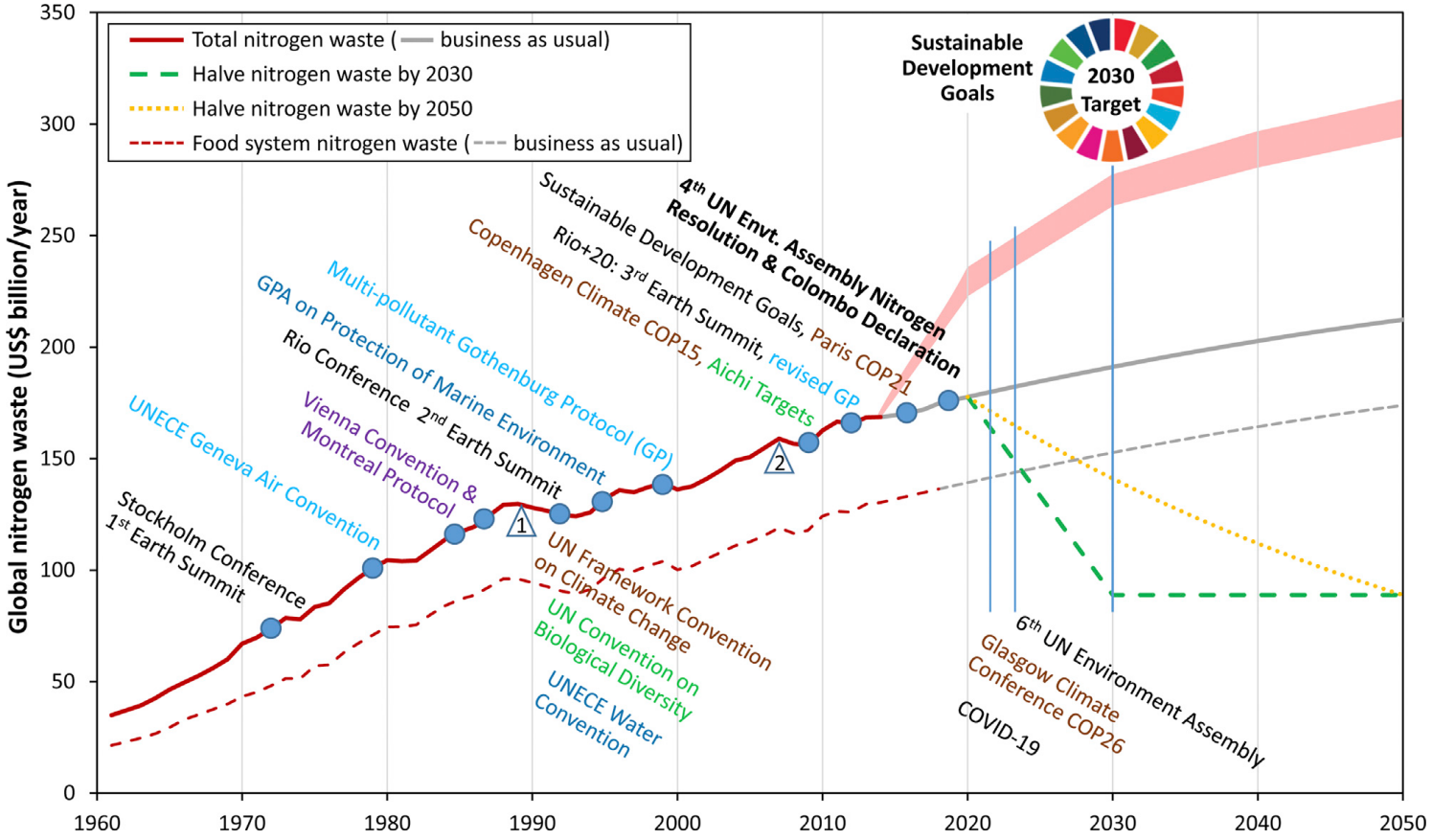
Halving Global Nitrogen Waste at UNEA 4 (2019)



Source) Sutton et al. 2021, One Earth

- Can we technically reduce global nitrogen waste by half?
- How can we simultaneously achieve
  "***Deep Decarbonization***" and "***halving Nitrogen Waste***" ?

Today's topics

- We have been developing a global AIM/Enduse model to simultaneously analyze triple issues of "**Global Deep Decarbonization**", "**Global Air Quality**", and "**Global Nitrogen Waste Reduction**".

Today's talks are the following sectors among multiple-sectors.

1) Global renewable energy sector
2) Global non-energy & non-CO_2 sectors

The purposes are:

① It is necessary to promote the spread of renewable energy (solar & wind) to a large extent, which can contribute not only to the realization of "**Deep Decarbonization**" but also to the simultaneous solution of "**Air Quality Improvement**".

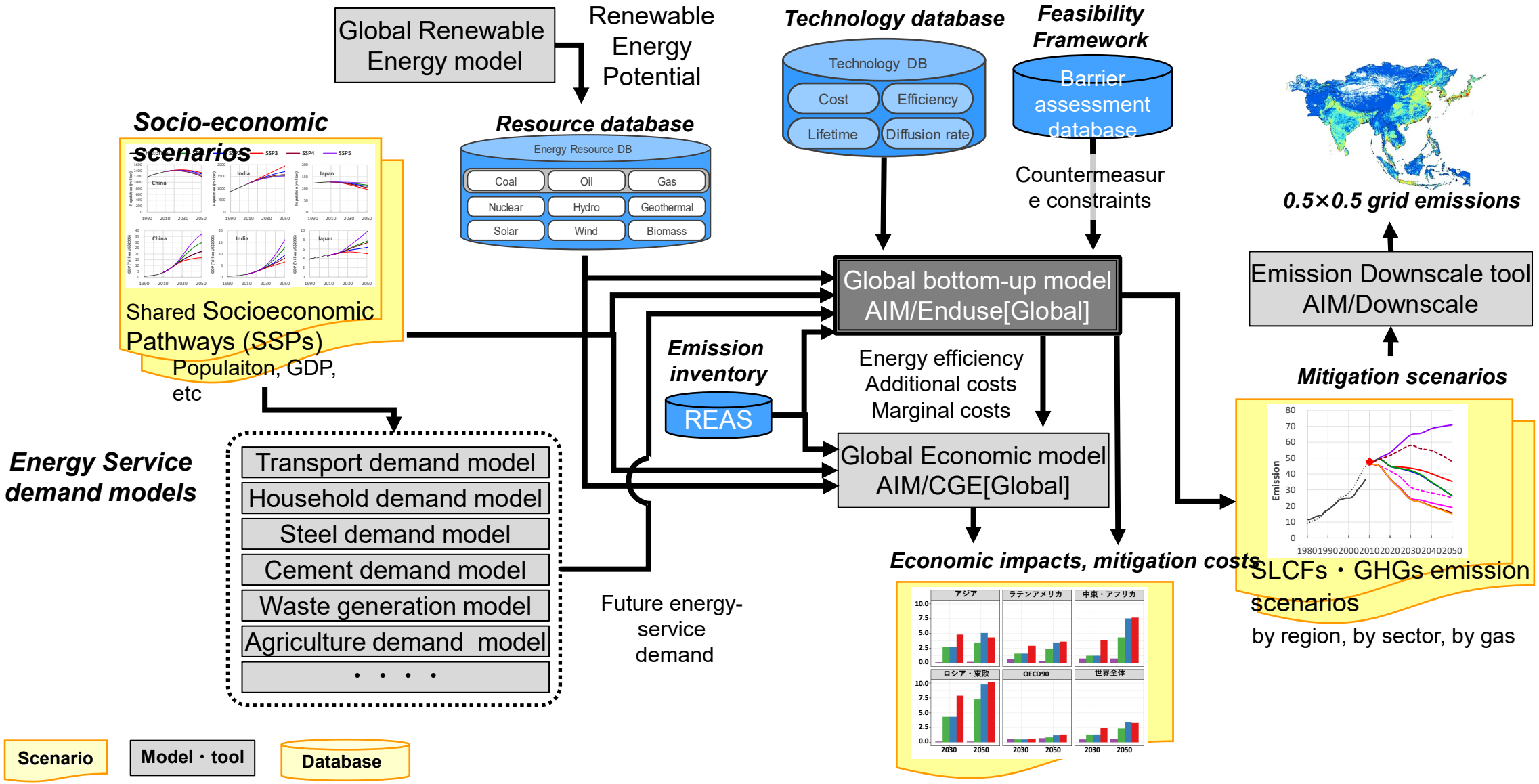
② Renewable energy is also needed to promote **green hydrogen** and **green ammonia fuel**.

③ In order to solve "**Deep Decarbonization**," "**Air Quality Improvement**," and "**Nitrogen Waste Reduction**" simultaneously, it is essential to take **measures in the non-energy sector**, which is called **the hard-to-reduce sector**.

Environment Research and Technology Development Fund S-20 Theme3 Sub-theme 1[FY2021 – FY22025]

Title: Evaluation of Global SLCFs mitigation scenarios by Integrated Assessment Model

- Overview of Global Research Framework on Emissions Projections in S-20-3(1) -

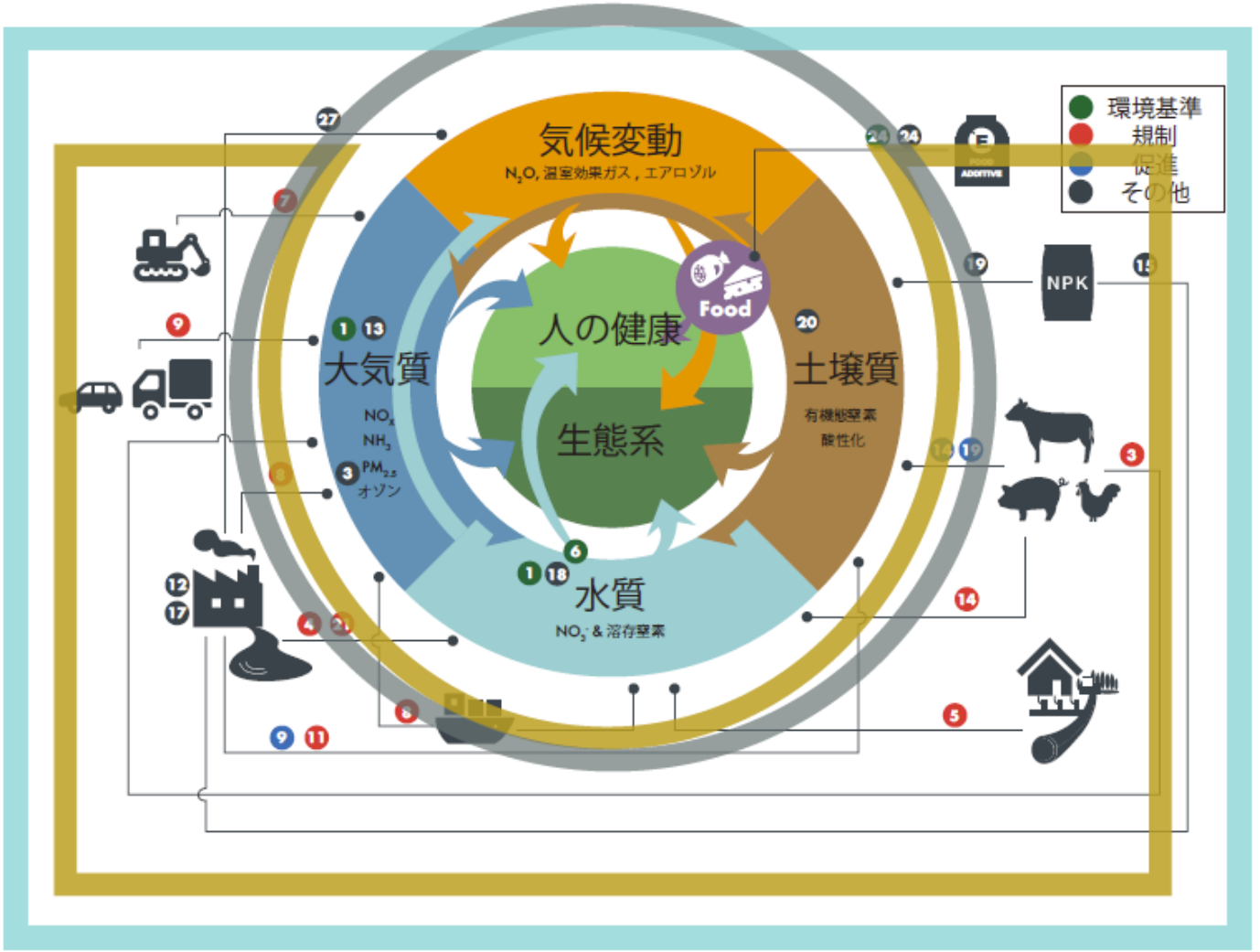


Environment Research and Technology Development Fund 5-2301 [FY2023 – FY22025]

Title: Comprehensive Japanese Nitrogen management for reducing nitrogen waste

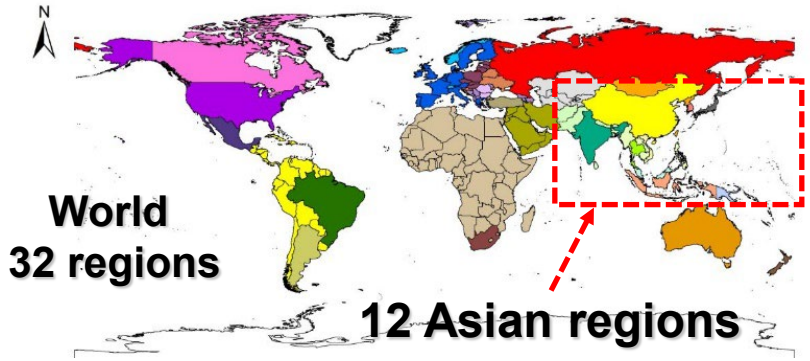
JpNwst

Comprehensive Japanese Nitrogen management
for reducing nitrogen waste



AIM/Enduse v3.0: Overview of the 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)
- Analyzing effects of technological transitions and policies such as carbon/energy tax, subsidy, regulation and so on.
- Global 32 regionals, especially focusing on Asia, such as Japan, China, India, Korea, Indonesia, Thailand, Vietnam, Malaysia, etc.



The model was updated to better accommodate the non-energy and non-CO_2 sectors

Sector	CO_2	CH_4	N_2O	SO_2	NOx	BC	OC	PM_{10}	$PM_{2.5}$	CO	NMVOC	NH_3	HFCs	PFCs	SF6	CFCs	HCFCs	Hg
Power	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔						✔
New energy	✔	✔	✔	✔	✔	✔	✔	✔	✔									
Fuel mining		✔									✔							
Industry	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔						
Transport	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔						✔
Building	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔						✔
Waste		✔	✔								✔							
Agriculture		✔	✔									✔						
Fgas													✔	✔	✔	✔	✔	✔
Others	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔						

Note1) ✔ shows the coverage of target gases in the model
Note2) Within the same gas-type,

- ✔ most major emitting sector
- ✔ 2nd major emitting sectors
- ✔ relatively emitting sectors
- ✔ minor sectors

S20 scenario design by linking AIM/Enduse v3.0 & Global demand models

Today's

Today's

Scenario	Overview	Code	Combinations of mitigation measures and mitigation intensities (★)											
			Air pollution End-of-pipe enhance	Energy related GHG measures						Energy related SLCF measures	Non-energy related SLCFs measures			SLCF Barriers
				PWR REN enhance	PWR CCS enhance	All sectors Coal phasedown	All sectors Efficiency enhance	Demand sectors Electrification	PWR / IND / TRT Hydrogen	PWR / IND / TRT NH3 fuel	BLD・TRT BMS phasedown	AGR enhance	Waste enhance	F-gas enhance	
Worst case	Technology fixed	Fixed													
Reference	BaU (SSP2)	BaU	★	★			★	★				★	★	★	
EoP	BaU+EoP	BaU-EP	★★	★			★	★				★	★	★	
Low Carbon	2050 global GHG halving	LC	★★	★★	★★	★★	★★	★★				★★	★★	★★	
Deep Decarbonization	Adv2050CN / Dev2060CN	DD-REN	★★	★★★	★★	★★★	★★★	★★★	★★			★★	★★	★★	
	Adv2050CN / Dev2060CN	DD-CCS	★★	★★	★★★	★★	★★★	★★★	★★			★★	★★	★★	
	Adv2050CN / Dev2060CN	DD-INV	★★	★★★	★★	★★	★★★	★★	★★★	★		★★	★★	★★	
DD +SLCF enhance	Adv2050CN / Dev2060CN + SLCF enhance	DD-REN-S	★★	★★★	★★	★★★	★★★	★★★	★★		★★★	★★★	★★★	★★★	
	Adv2050CN / Dev2060CN + SLCF enhance	DD-CCS-S	★★	★★	★★★	★★	★★★	★★★	★★		★★★	★★★	★★★	★★★	
	Adv2050CN / Dev2060CN + SLCF enhance	DD-INV-S	★★	★★	★★	★★	★★★	★★	★★★	★	★★★	★★★	★★★	★★★	
DD +SLCF enhance +EoP enhance	Adv2050CN / Dev2060CN + SLCF enhance + EoP enhance	DD-REN-S-EP	★★★	★★★	★★	★★★	★★★	★★★	★★		★★★	★★★	★★★	★★★	

Note1) "Low-Carbon" and "Deep-Decarbonization" are equivalent to 2 degree and 1.5 degree target
Note2) ★ represent mitigation intensities
★ (if cost effective) measures will be introduced spontaneously based on the inertia from the past to the present trends.
★★ (Toward policy targets, mitigation goals etc) measures will be introduced in phases, step by step
★★★ maximum reduction measures will be introduced in both developed and developing countries by 2060, regardless of sectors
Note3) Socio-economic assumptions such as POP, GDP are based on SSP2

AIM ASIA-PACIFIC INTEGRATED MODEL

Objectives: the Agriculture Sector

- The agriculture sector is **a major source of N_2O, NH_3 and CH_4 emissions**, especially in Asia.
  - **N_2O** need to be reduced as one of **long-lived GHGs & Ozone Depleting substance (ODS)**
  - **CH_4** need to be reduced as one of **short-lived climate forcers (SLCFs)**
  - **NH_3** need to be reduced as one of the sources of **$PM_{2.5}$**
  - **N_2O** and **NH_3** emissions need to be reduced as one of the sources of **reactive nitrogen**

- However, the agricultural sector is considered as one of the **"hard-to-abate" sectors**.
  But how hard?

The objectives of this study are to

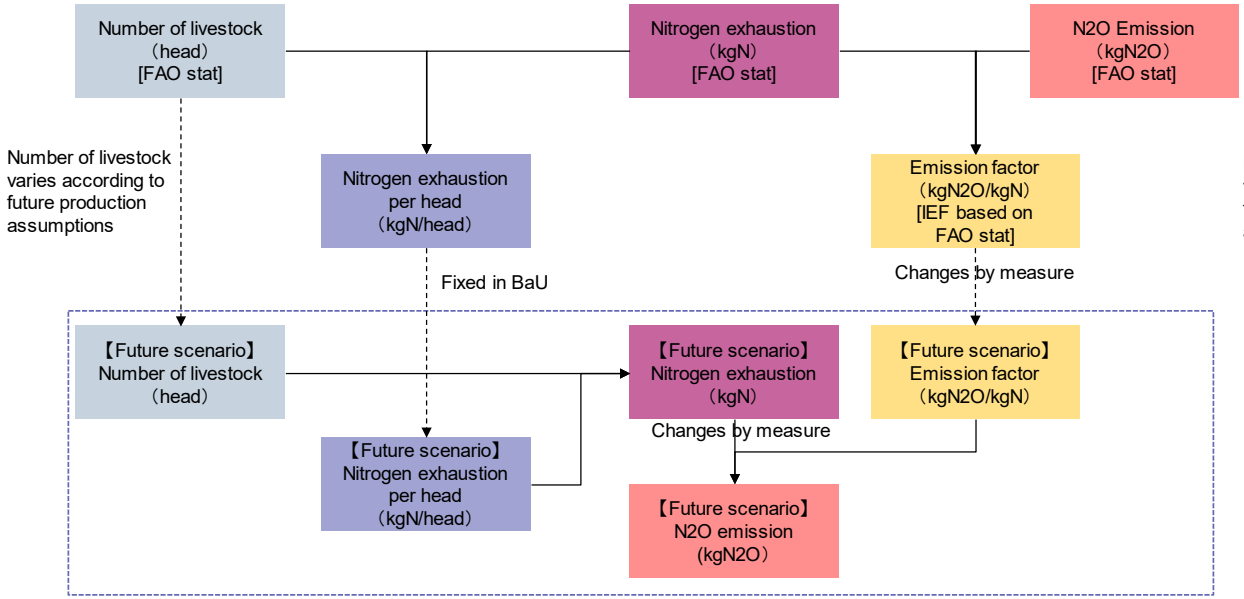
1) examine the **Business-as-Usual scenario** of CH_4, N_2O, and NH_3 emissions up to 2060 in the agricultural sector
2) examine the **technological maximum mitigation scenario** of CH_4, N_2O, and NH_3 emissions in order to contribute to discussions of both **climate mitigation targets (i.e. achieving net-zero GHGs)** and **nitrogen reduction targets (i.e. halving nitrogen waste)**.

AIM/Enduse3.0: Example of maximum mitigation of N_2O, NH_3 & CH_4 in Agriculture

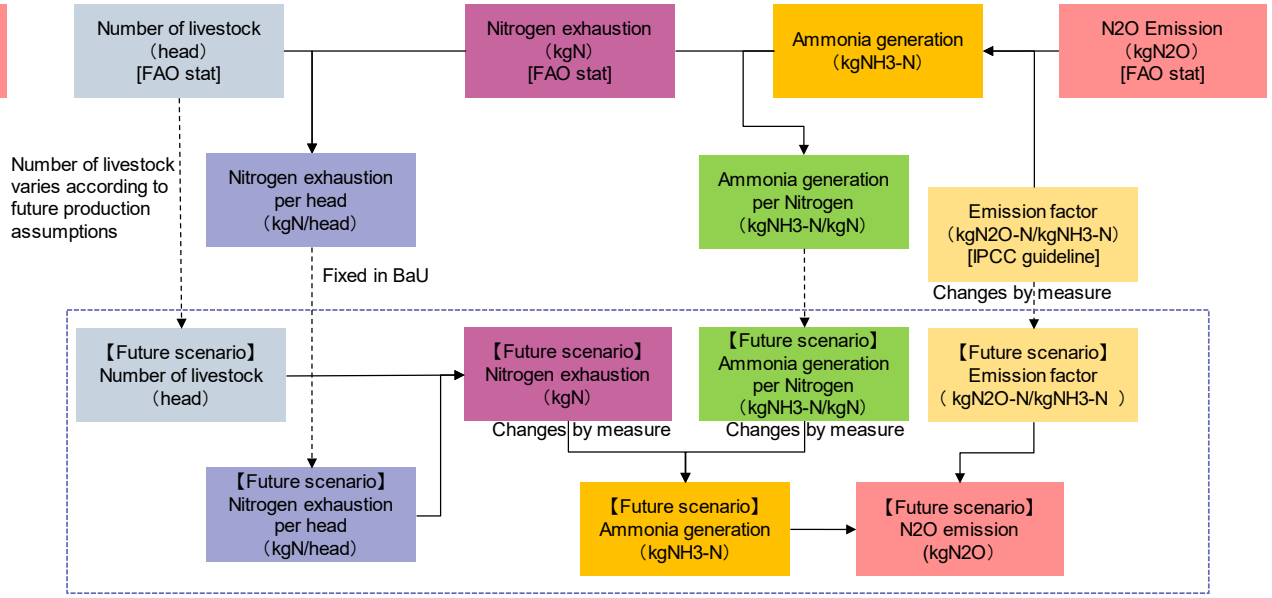
- Development of calculation sub-module of agricultural emissions -

- We fully followed **the IPCC inventory guidelines** to estimate emissions projections
- We estimated **N_2O, NH_3, and CH_4 in 32 global regions to cover all emission sources in the agricultural sector.** (The figure below shows an example of the calculation flow for livestock manure management in accordance with the IPCC guidelines.)
- We estimated the **BaU scenario of activity data (heads, ha, etc.) and associated emissions**, based on historical trends and correlations between activity data and socioeconomic data.
- To explore **maximum technological mitigation potentials**, we assumed **maximum diffusions of currently available mitigation measures by 2060 worldwide (in both developed and developing countries)**

Estimation flow of manure management（direct N_2O)



Estimation flow of manure management (indirect N_2O)



Note1）We calculated by livestock: “dairy cattle”, “beef cattle”, “swine”, egg-laying hen”, “broiler”, “buffalo”, “goat”, “sheep”, “others (horses, camels, donkeys, mules, llamas)”, and “other poultry (ducks, turkeys)”.

Note2) For "others" and "other poultry“, the number of horses, camels, donkeys, mules, llamas, ducks, and turkeys are counted separately, and then aggregated as "other" and "other poultry" when calculating emissions.

Settings of reduction efficiency of currently available mitigation measures

- **Technological measures are assumed to be introduced to the maximum (100%) worldwide (i.e. not only in developed countries but also in developing countries) by 2060**.
  (Note: Only the introduction of methane recovery and decomposition masks is an exception.)
- **Activity reductions (e.g. chemical fertilizers)** due to productivity improvement are assumed to be **up to 30% reduction** worldwide by 2060.
- **Impact of behavior change** (e.g. **diet change** from vegetables to meats and vice versa) can be considered in this framework
- **Conversion to intensive grazing** is assumed to be **up to 10%** reduction worldwide by 2060

e.g.)

Enteric fermentation

1) Breeding with low methane generation cattle (around 10% CH_4 reduction)
2) Improvement of livestock feeding management (around 10% CH_4 reduction)
3) Addition of methane generation inhibitors to feed for livestock (around 20% CH_4 reduction)
4) Introduction of CH_4 recovery and decomposition masks to cattle (around 50% CH_4 reduction)

Manure management

1) Use of feed for livestock to improve amino acid balance (around 20% N_2O reduction)
2) Conversion of Livestock Waste Disposal Methods (around 50% CH_4 reduction and 20% N_2O reduction)
3) Implementation of advanced processing and other reduction measures (around 20% CH_4 reduction and 20% N_2O reduction)
4) intensive grazing cattle (around 10% CH_4 reduction and 10% N_2O reduction)

Agricultural soils

1) Reduction of fertilizer application (around 30% N_2O reduction by inorganic fertilizer and 20% N_2O reduction by organic fertilizer)
2) Microorganism utilization technology to control N_2O emissions (around 30% N_2O reduction)
3) Application of chemical fertilizers with nitrification inhibitors (around 30% N_2O reduction)

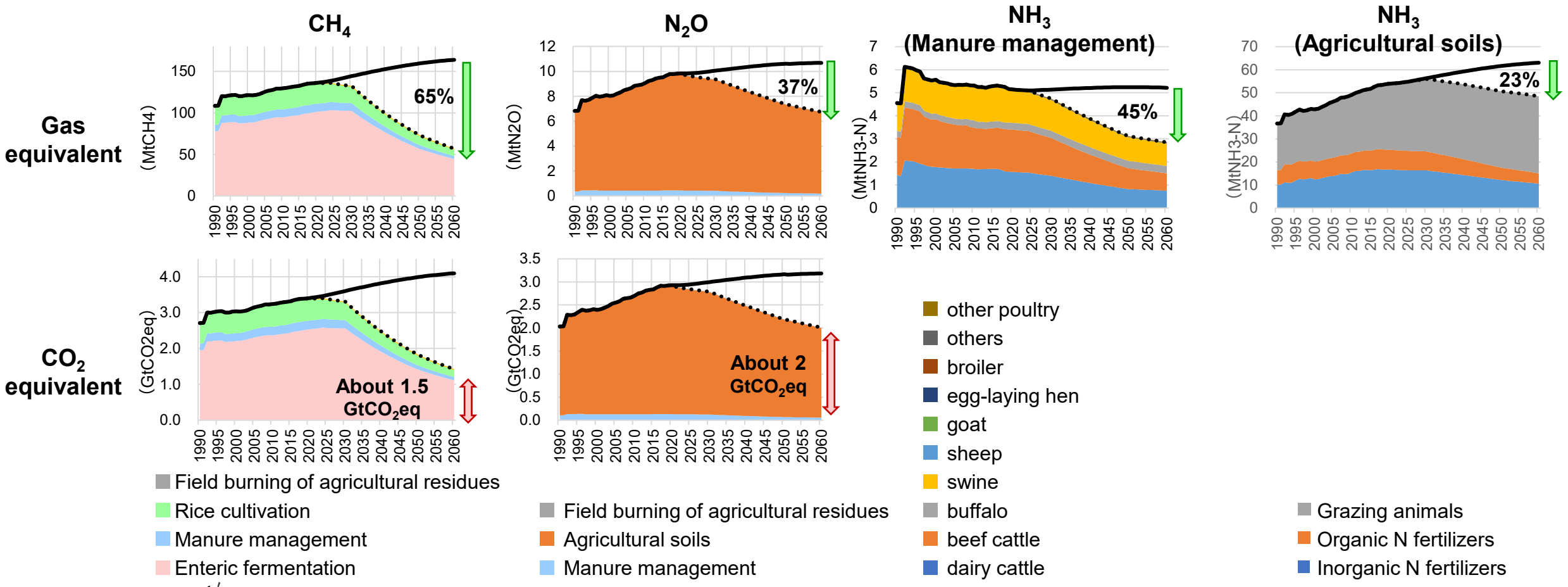
and so on

Agriculture sector: major non-combustion "Hard-to-Abate" sector

- Triple challenges to climate change, nitrogen waste & air quality: CH_4, N_2O, NH_3 -

Do not quote

- The maximum global CH_4 mitigation is up to 65% by 2060 compared to BaU. (35% residual emissions, corresponding to about 1.5 $GtCO_2eq$)
- The maximum global N_2O mitigation is up to 37% by 2060 compared to BaU. (63% residual emissions, corresponding to about 2 $GtCO_2eq$)
- The most important point is that the main sources of CH_4, N_2O and NH_3 emissions and the characteristics of mitigation measures are different.
- NH_3 reductions from **cattle, buffalo, swine** in manure management and **chemical & organic fertilizer** in agricultural soils are important.



- Agriculture becomes **a big barrier in terms of both climate mitigation, nitrogen waste reduction & air quality**

AIM/Enduse v3.0

- Overview concepts of Domestic Wastewater sector & Domestic Solid Waste sector -

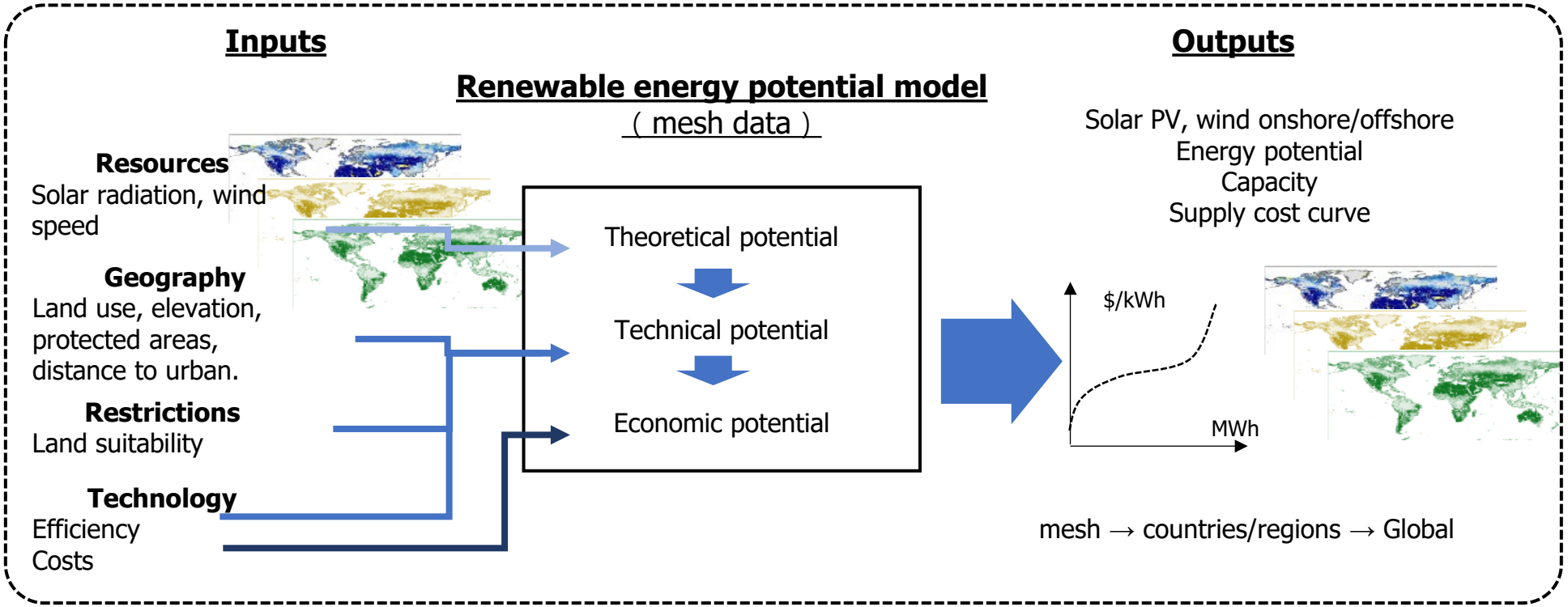
Domestic Wastewater sector

Municipal Waste sector

Renewable Energy Sector

- Model for estimating the resource availability at global scale of variable renewable energies (solar and wind).

- Resource availability estimated as the energy potential for solar photovoltaics (PV), onshore and offshore wind power.
- Based on latest geo-referenced data of climate (solar radiation, wind speed), topography (elevation, slope), land cover, among others.
- Considers restrictions on the land suitability and technology performance.
- Energy potential outputs by grid cell (~0.28km) aggregated into global regions; and by hour aggregated into annual values categorized by grade (annual average capacity factor).



Renewable Energy Sector

- Resource availability at global scale of variable renewable energies (solar and wind).

Contact

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Acknowledgment

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