MIT Global Change Outlook

https://globalchange.mit.edu/

Lead Authors: Sergey Paltsev and Adam Schlosser

Co-Authors: Henry Chen, Sebastian Eastham, Xiang Gao, Angelo Gurgel, Henry Jacoby, Jennifer Morris, Ronald Prinn, John Reilly, Popat Salunke, and Andrei Sokolov

Contributors: Claire Walsh and Anne White

Design and Editing: Jamie Bartholomay, Mark Dwortzan, and Anne Slinn

THE OUTLOOK

The **MIT Joint Program**'s latest projections for:

- ★ the **future of the Earth**'s energy, managed resources (including water, agriculture and land), and climate;
- ★ as well as prospects that result from "current trends" and short-term targets;
- ★ and benefits and avoided impacts from accelerated actions to meet aggressive targets

What's new in the 2023 Outlook?

Two scenarios: **Current Trends** and **Accelerated Actions**

Separate the **India&China** regional group (results for all 18 regions in Excel files)

Changes in GDP due to **climate impacts** on **labor**

Downscaling Climate Response

Climate, Air Quality, and **Health**

Confirmed that **without aggressive actions** the world will **surpass critical** GHG concentration **thresholds** and climate targets in the coming decades

Good news: Costs of action are more manageable

Further reduction in costs of wind and solar => further reduction in natural gas use

However, finding good solutions for liquids (heavy-duty, air, shipping, chemicals feedstock) is still a challenge

Scenarios

We focus on the following scenarios:

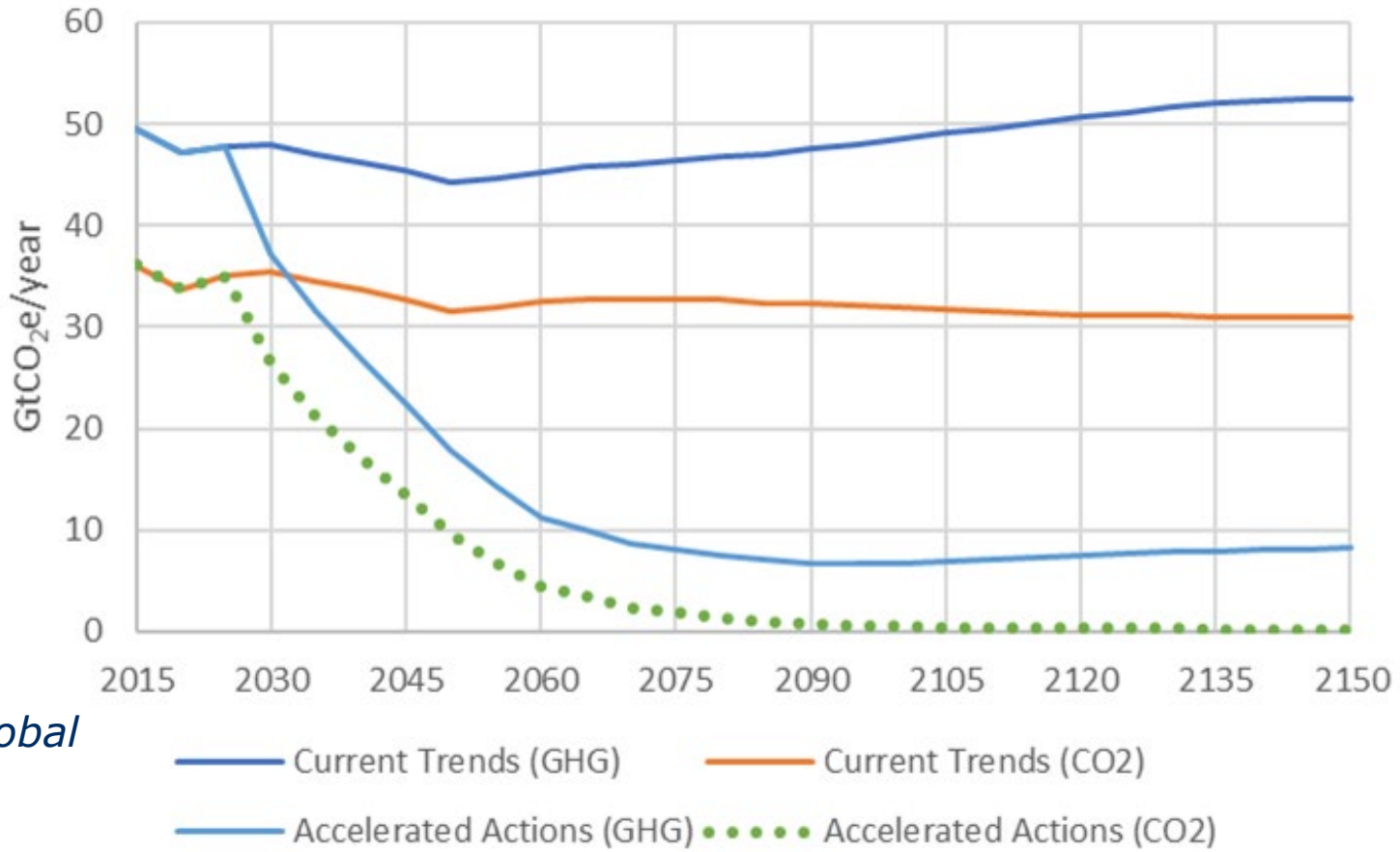
- **Current Trends**, which assumes implementation of the current policy settings;

- **Accelerated Actions**, a 1.5°C stabilization pathway, in which countries impose more aggressive emissions targets that represent an illustrative pathway of increased mitigation

2030 emission reductions from Global Methane Pledge (10-20%), Global Deforestation Pledge (50%).

*We also explore global economic cost of a **Net-Zero by 2050** scenario*

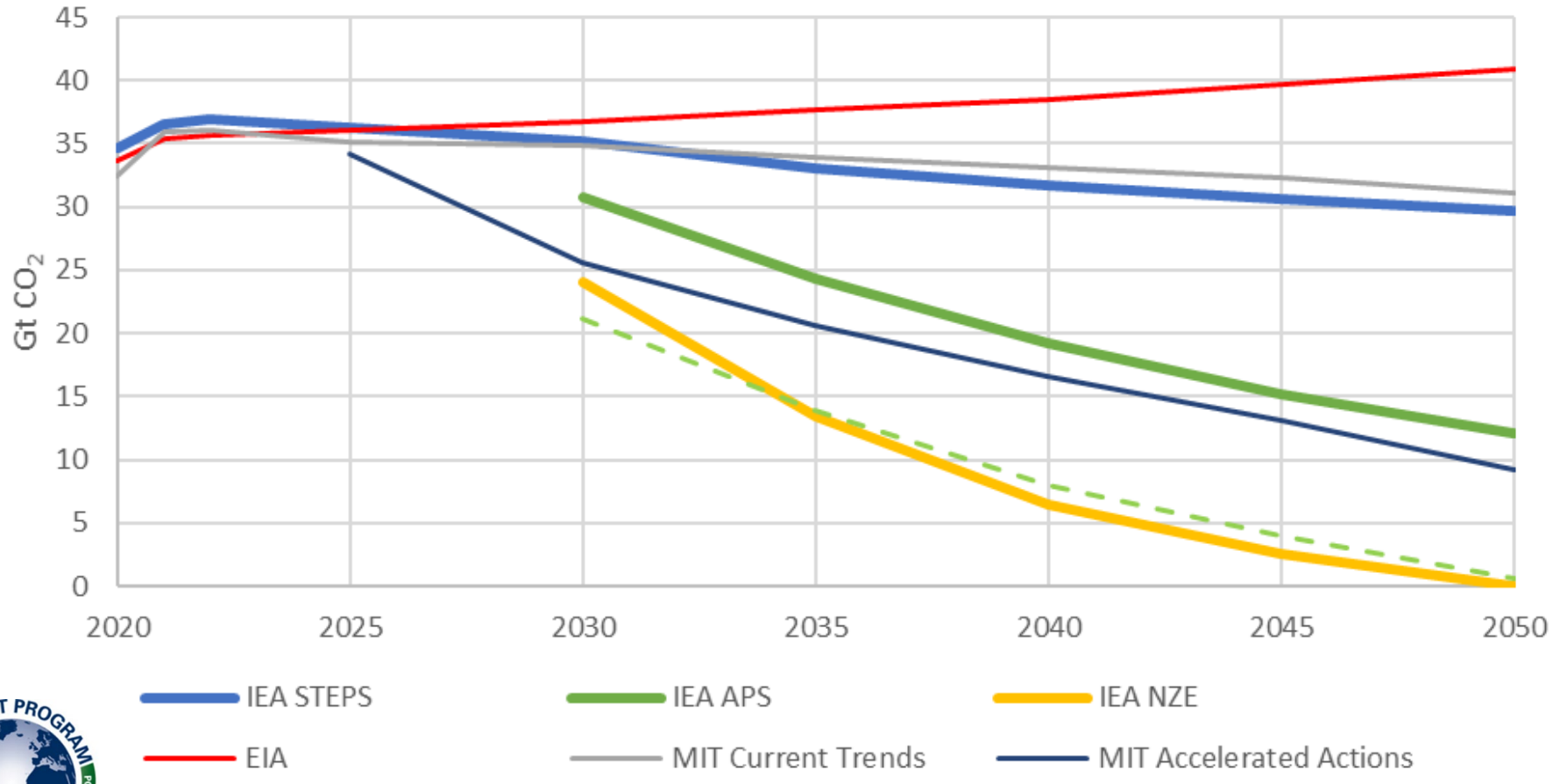
Global emission profiles 2015-2150



For current trends, typically, scenarios assess NDCs and other pledges

Since the contributions are determined nationally, countries decide what is "fair" (conditional vs unconditional)

COP-28: "transitioning away from fossil fuels in energy systems, in a just, orderly and equitable manner ... so as to achieve net zero by 2050 in keeping with the science."



Current Trends: current policies

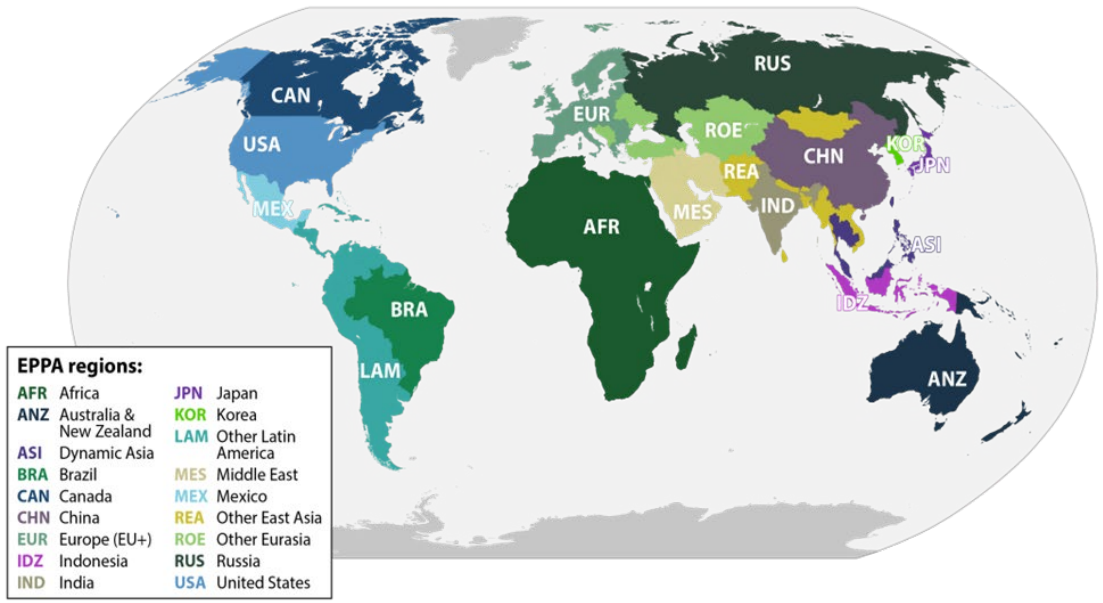
Ultimately, all countries have to be at "net-zero"

Accelerated Actions by 2050

Advanced economies: 70-80% reduction

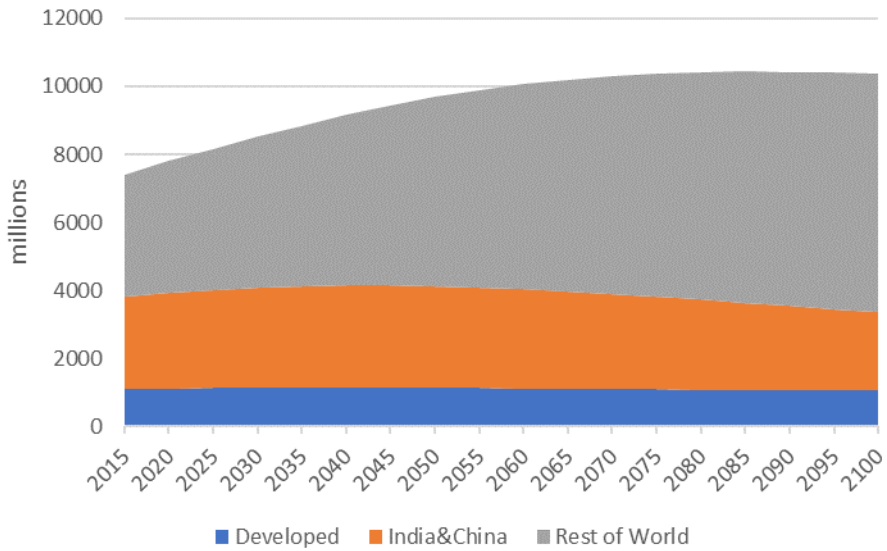
Emerging economies: 50-75% reduction

Regional Groups



Regional Group	Region	Abbreviation
Developed	United States	USA
	Canada	CAN
	Europe	EUR
	Japan	JPN
	Korea	KOR
	Australia, New Zealand and Oceania	ANZ
India&China	China	CHN
	India	IND
Rest of the World	Africa	AFR
	East Asia	ASI
	Indonesia	IDZ
	Other East Asia	REA
	Brazil	BRA
	Mexico	MEX
	Other Latin America	LAM
	Middle East	MES
	Russia	RUS
	Other Europe and Central Asia	ROE

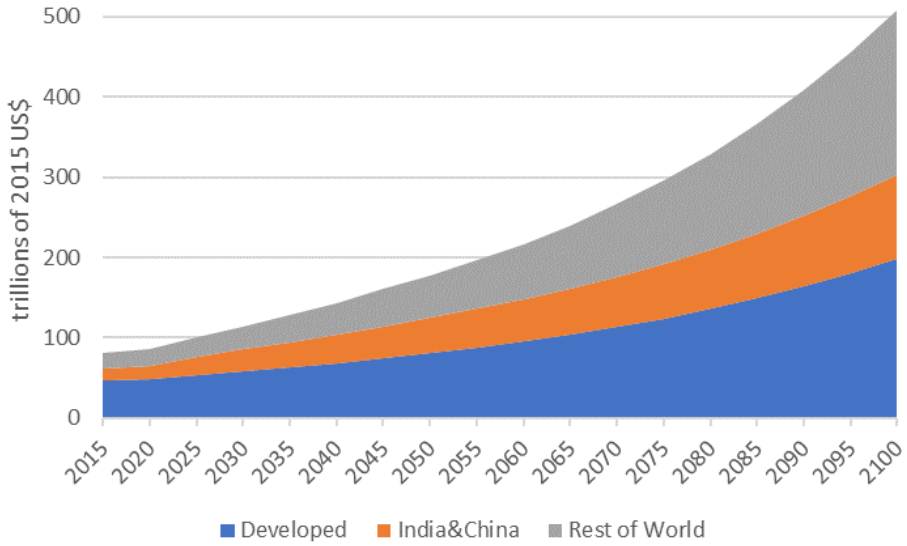
Global Drivers



Global population grows from 7.8 billion people in 2020 to 9.7 billion in 2050, and to 10.4 billion in 2100

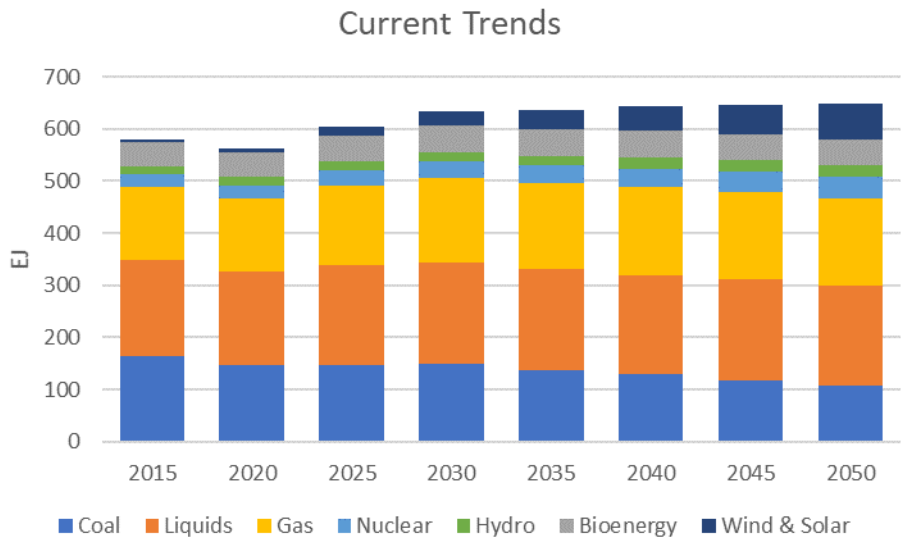
Developed – stable at 1.1 billion
India&China – growth and decline
Rest of the world – from 4 to 7 billion (Africa)

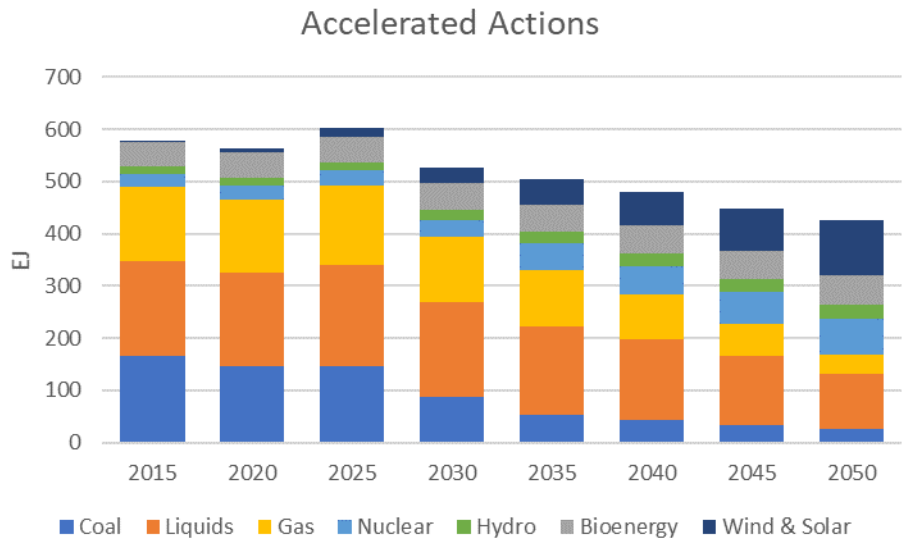
In contrast to population, most of the current global economic value is in the Developed region (56% of global GDP MER)



Despite the higher economic growth in the Rest of the World, its share of global GDP catch up with the Developed region only by the end of the century.

Global Primary Energy

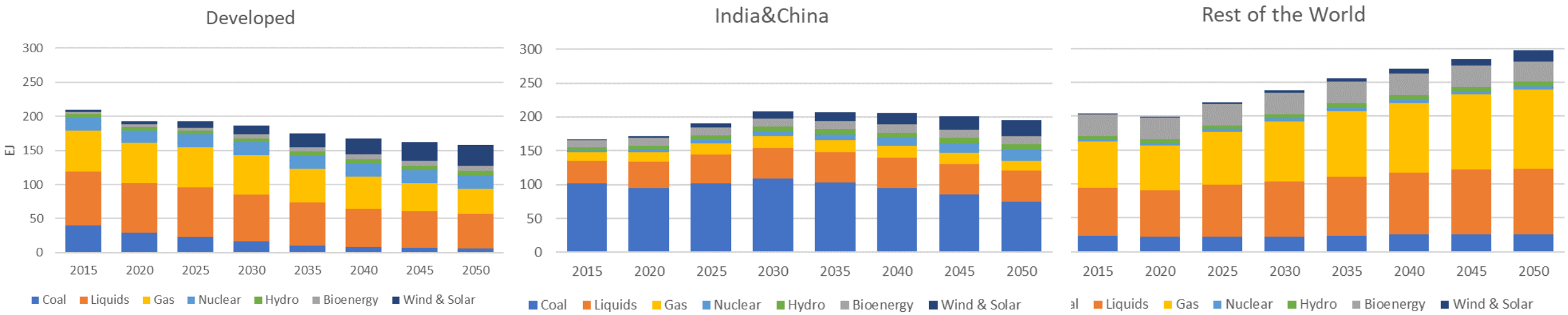




Global primary energy use in the *Current Trends* scenario grows to about 650 exajoules (EJ) by 2050, up by 15% from about 560 EJ in 2020. The share of fossil fuels drops from the current 80% to **70%** in 2050. Wind and solar - **8.6**-fold increase in EJ (from <2% to **11%** share).

In the *Accelerated Actions* scenario, global energy use is reduced due to efficiency and demand response. The fossil fuel share drops to **39%**. Wind and solar energy grow more than **13** times from 2020 to 2050 (to **25%** share).

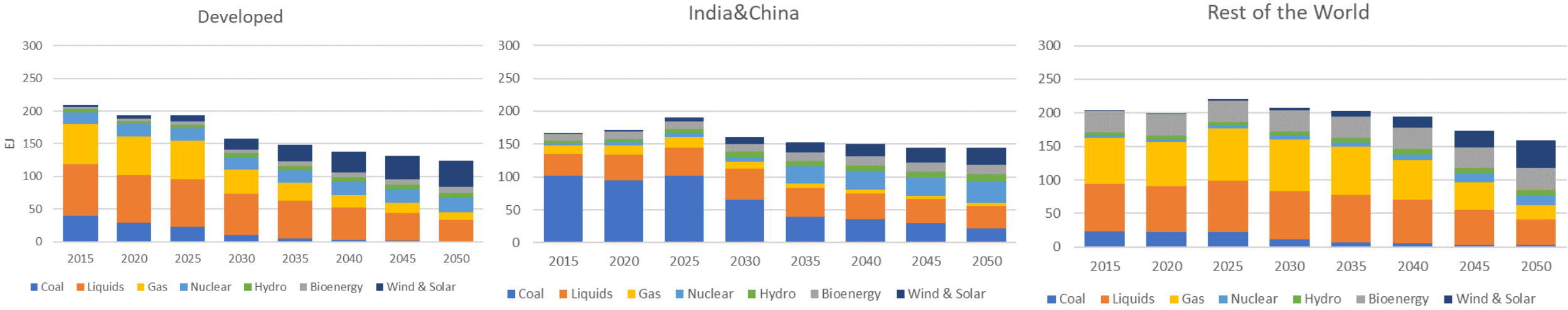
Current Trends: Global Primary Energy by Regional Group



Energy consumption declines by 20% in the Developed region (driven by more aggressive emissions mitigation policies), while growth in energy use is 10% in the India&China region and 50% in the Rest of the World region.

Developed: oil and gas still provide a large share of energy, coal declines, the share of low-carbon sources grows from about 17% in 2020 to about 40% in 2050.
India&China: continue to rely heavily on coal.
Rest of the World: coal does not play a large role, but this region continues to consume large quantities of oil and gas.

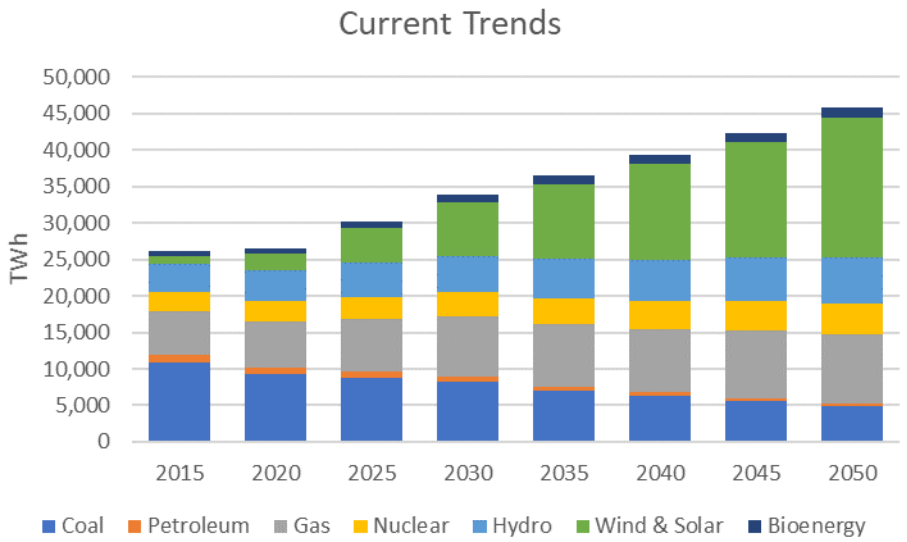
Accelerated Actions: Global Primary Energy by Regional Group

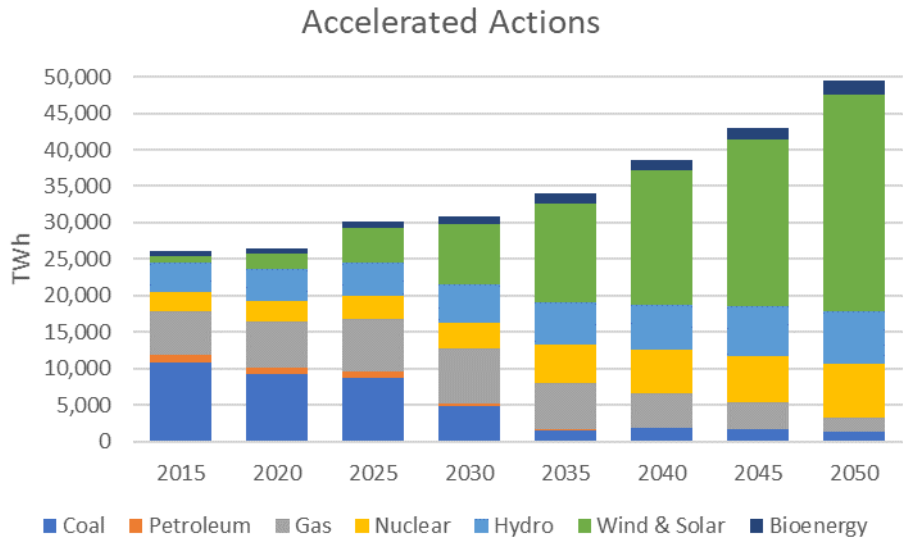


Energy consumption declines in all regions by mid-century

Developed: liquid and gaseous fuels are reduced (but not eliminated), coal eliminated, renewables grow 10-fold.
India&China: coal is substantially reduced, renewables grow 10-fold.
Rest of the World: very different (reduced) role for natural gas, renewables grow 45-fold, much bigger role for energy efficiency.

Global Electricity Production





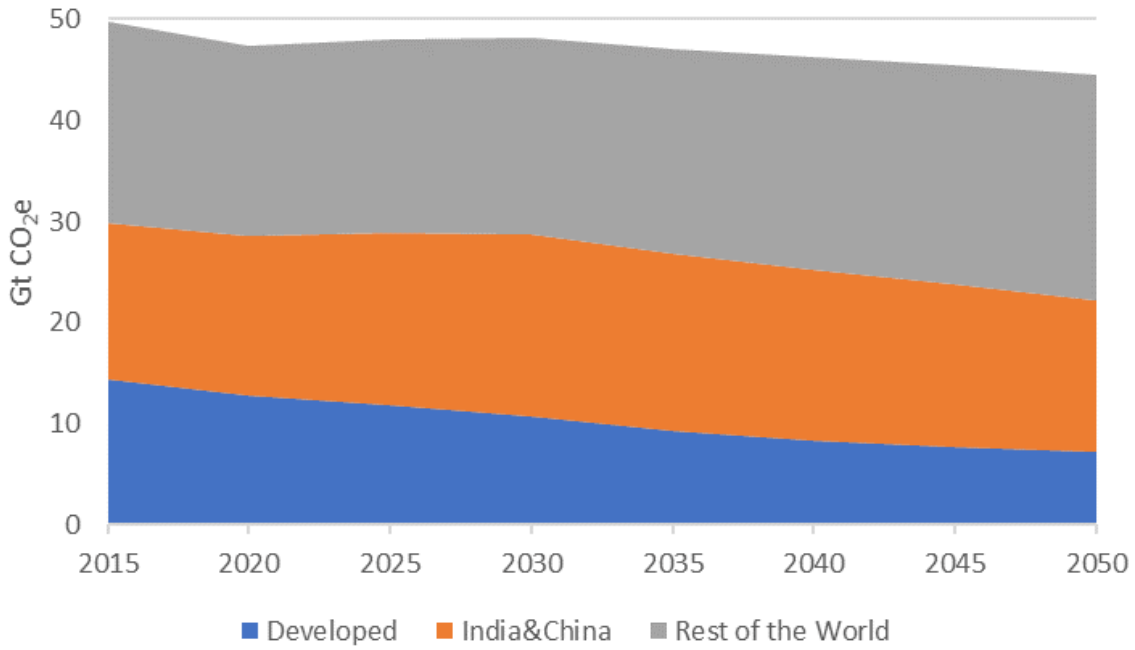
In the *Current Trends* scenario, global electricity production (and use) grows by **73%** from 2020 to 2050. In comparison to primary energy growth of 15% over the same period, electricity grows much faster, resulting in a continuing **electrification** of the global economy.

In the Accelerated Actions scenario, electricity production grows even faster (**87%** between 2020 and 2050).

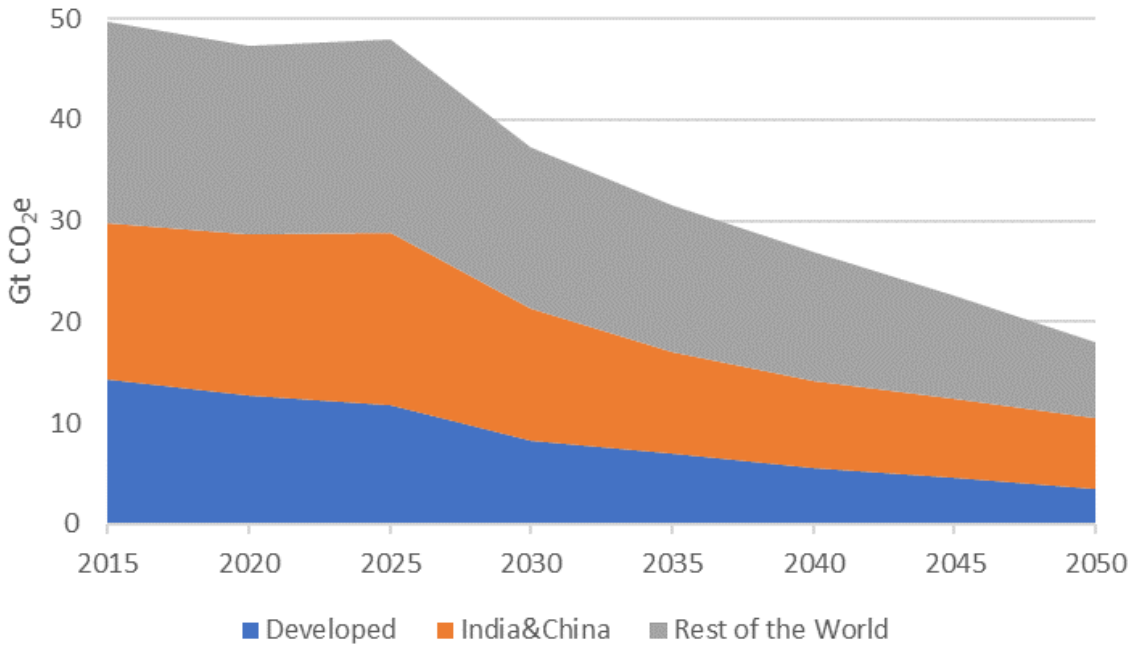
Electricity generation from **renewable (and low-carbon)** sources becomes a dominant source of power by 2050 in both scenarios, providing 60-80% (70-90%) of global power generation by midcentury.

GHG Emissions

Current Trends



Accelerated Actions

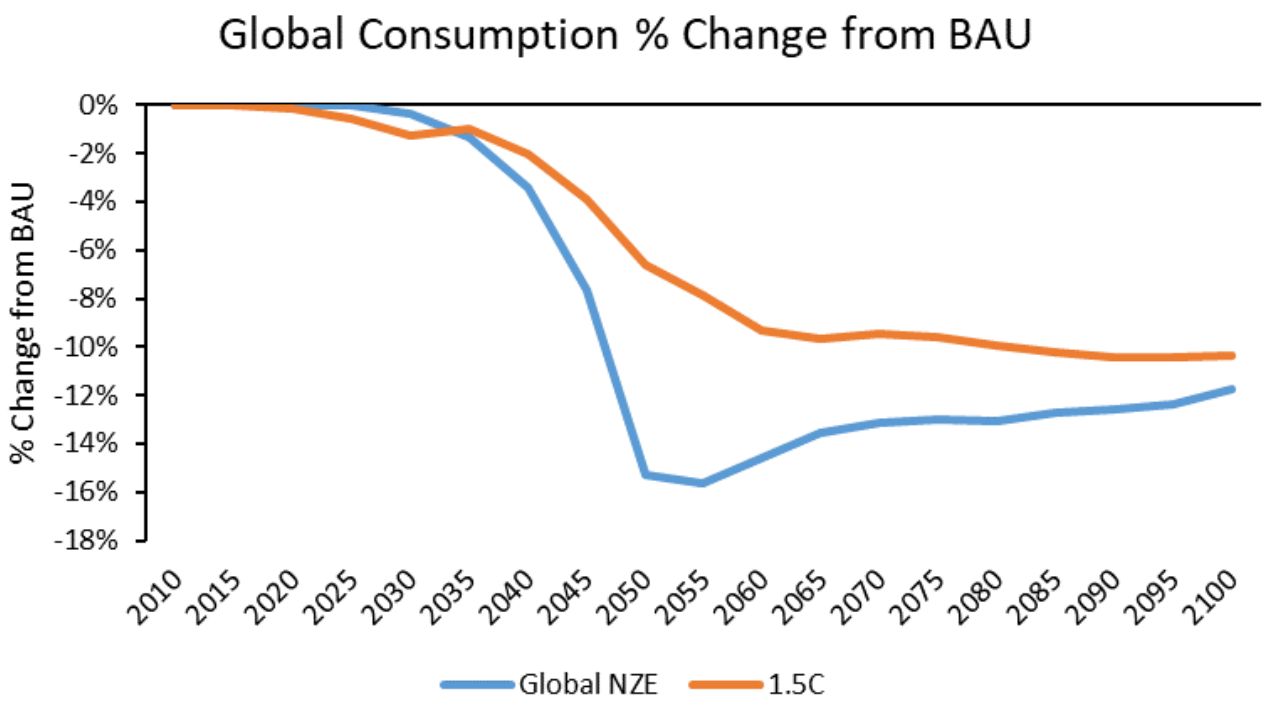


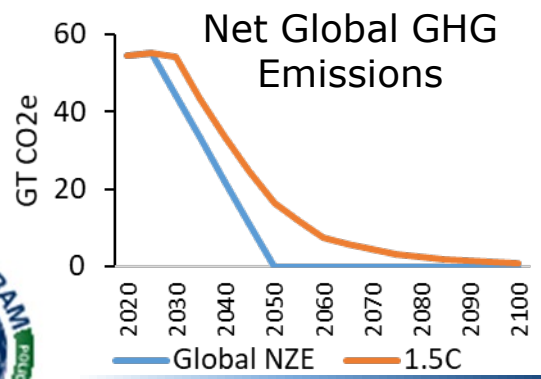
Current Trends: **Insufficient action** on GHG emissions mitigation , especially in emerging markets.

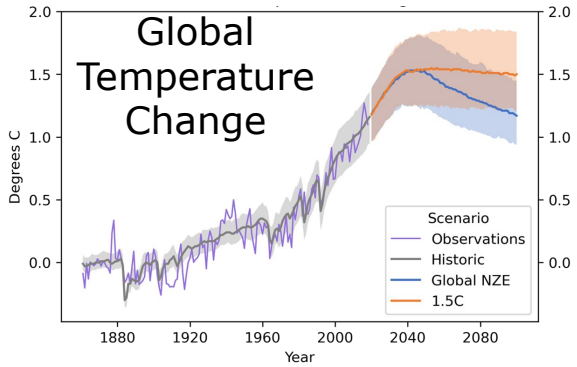
While recent policies show some progress (in 2100, global emissions total 49 Gt CO_2e vs. 69 Gt CO_2e in the 2018 Outlook), the world is still not on track to achieve long-term climate stabilization.

Ultimately, robust government policies will be **needed** for **more aggressive** GHG emissions mitigation.

Achieving Net Zero by 2050







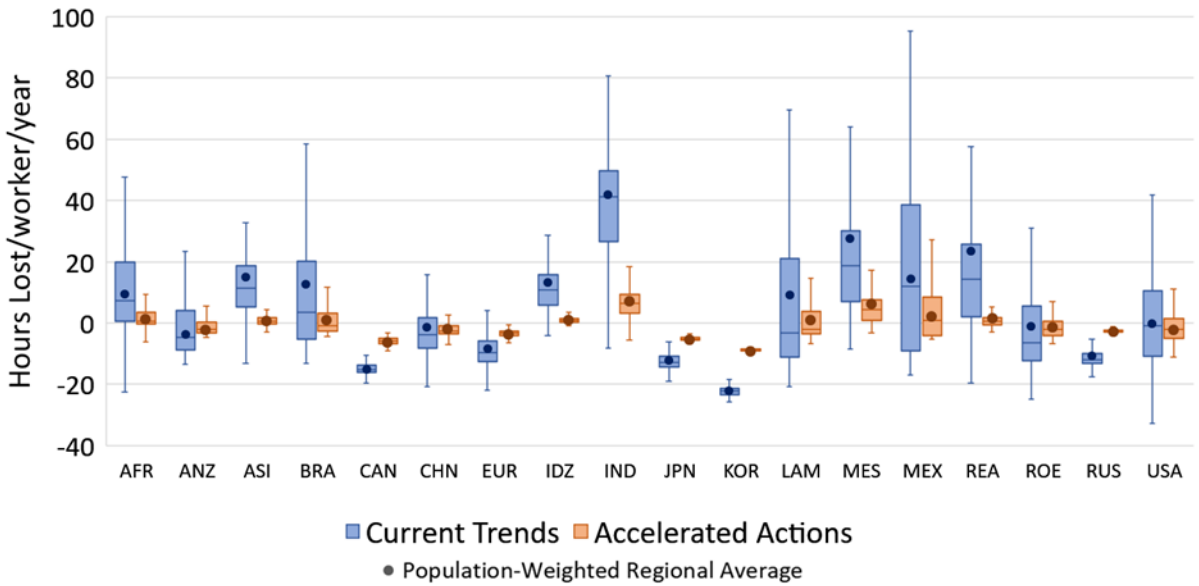
A tradeoff between policy costs and ensuring that global warming does not exceed 1.5°C.

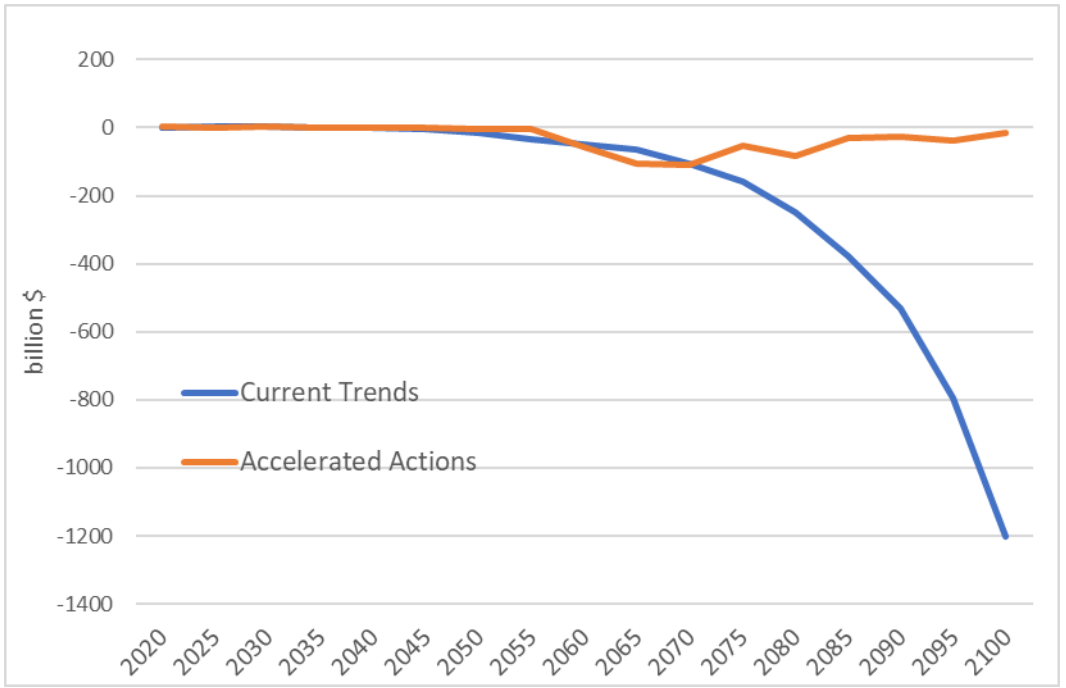
Achieving global net-zero emissions by 2050 is not necessarily required in order to keep global warming at or below 1.5°C, and would add considerable policy costs, especially at mid-century.

However, meeting the 2050 deadline—ideally utilizing international emissions trading to reduce policy costs—would essentially guarantee the achievement of the 1.5°C target.

Climate Feedbacks on the Economy (changes in GDP due to labor impacts)

Direct impact of climate on labor in 2100 in terms of hours of labor lost by region (positive values = hours lost; negative values = hours gained). Box and whisker plots reflect the variation across the administrative units within an EPPA region. Points reflect the population-weighted average hours lost for an EPPA region.





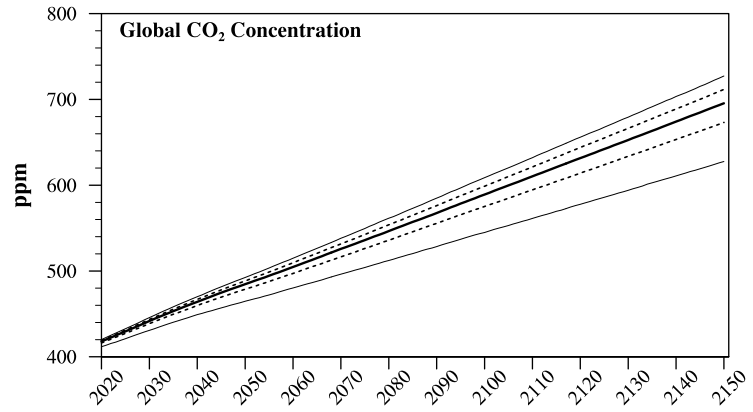
Global changes in GDP due to climate impacts on labor (in billion USD)

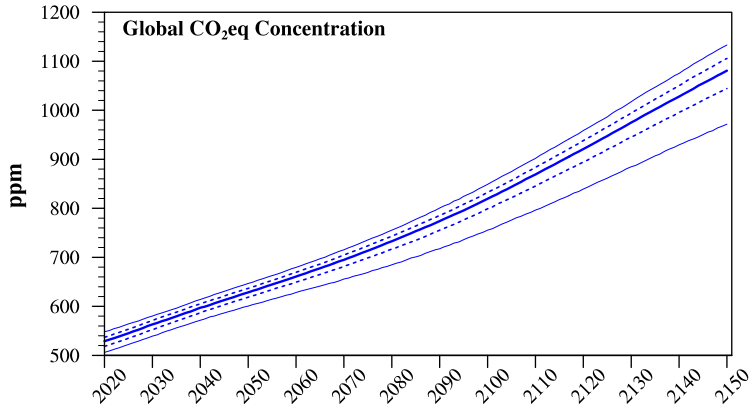
Varies significantly by region

USA in 2100: $50 billion losses (EPA FrEDI estimates of $51 billion)

CO_2 and Equivalent "Greenhouse Gas" Concentrations

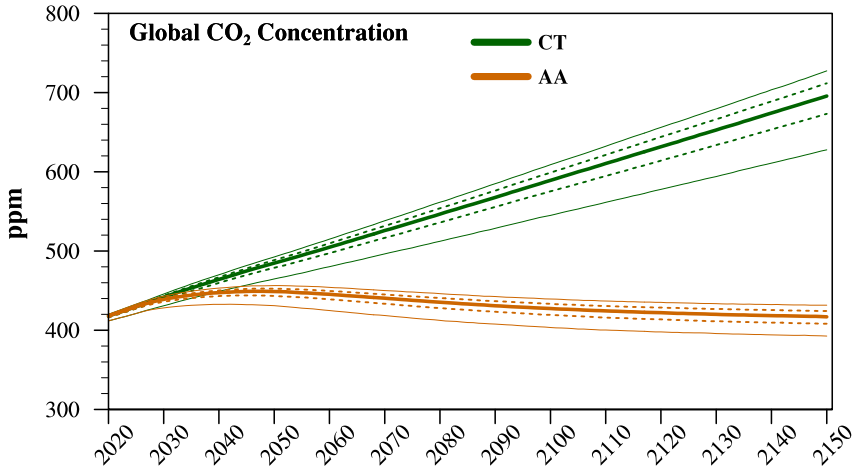
Current Trends (CT) Scenario

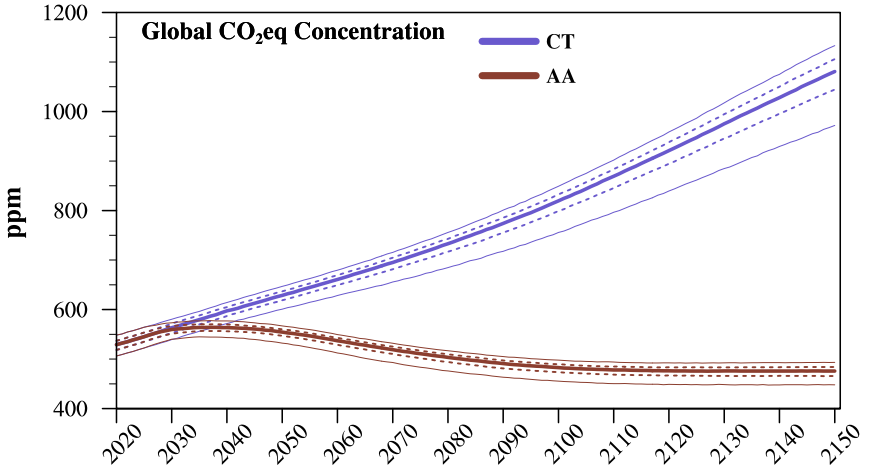




CO_2 (and equivalent) concentrations continue to rise throughout (and after) the 21st century.

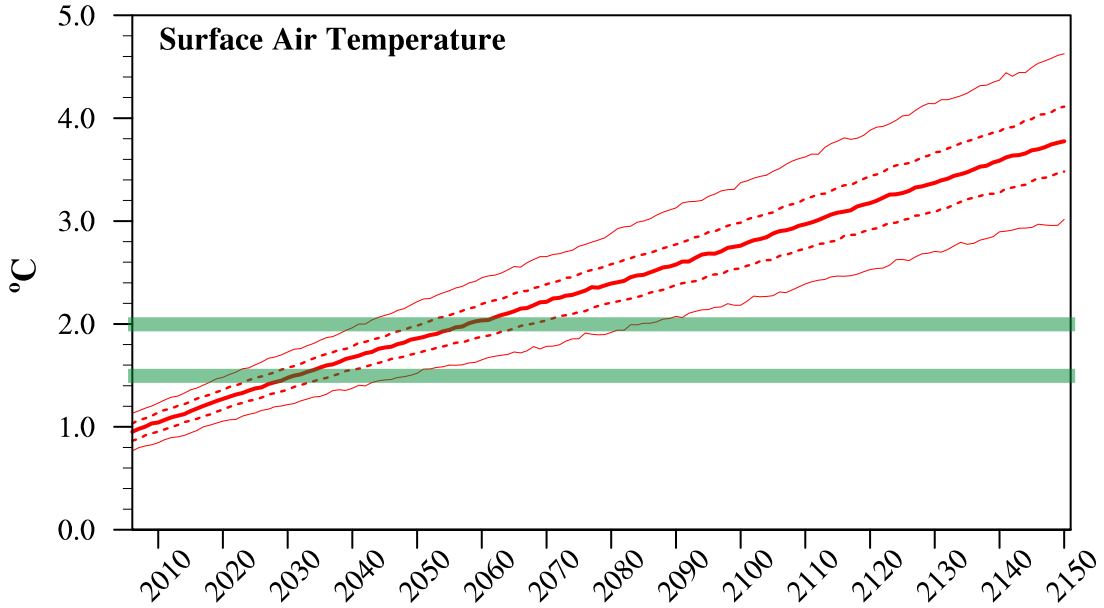
Starting in the 2040s, the climate mitigation through *Accelerate Actions* (AA) diverge distinctly.





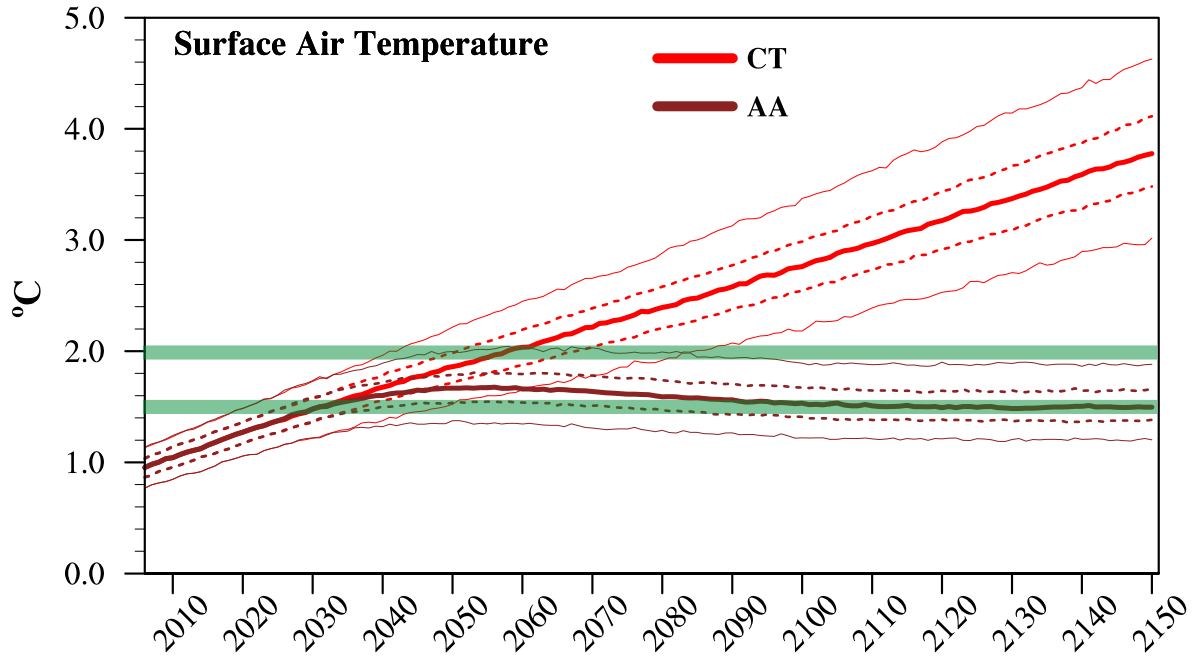
Global Average Surface-Air Temperature Changes

Current Trends (CT) Scenario



By 2060, more than half of the IGSM ensemble's Paris Forever projections exceed 2°C global climate warming, a figure that rises to more than 75% by early 2070s and more than 95% by 2085.

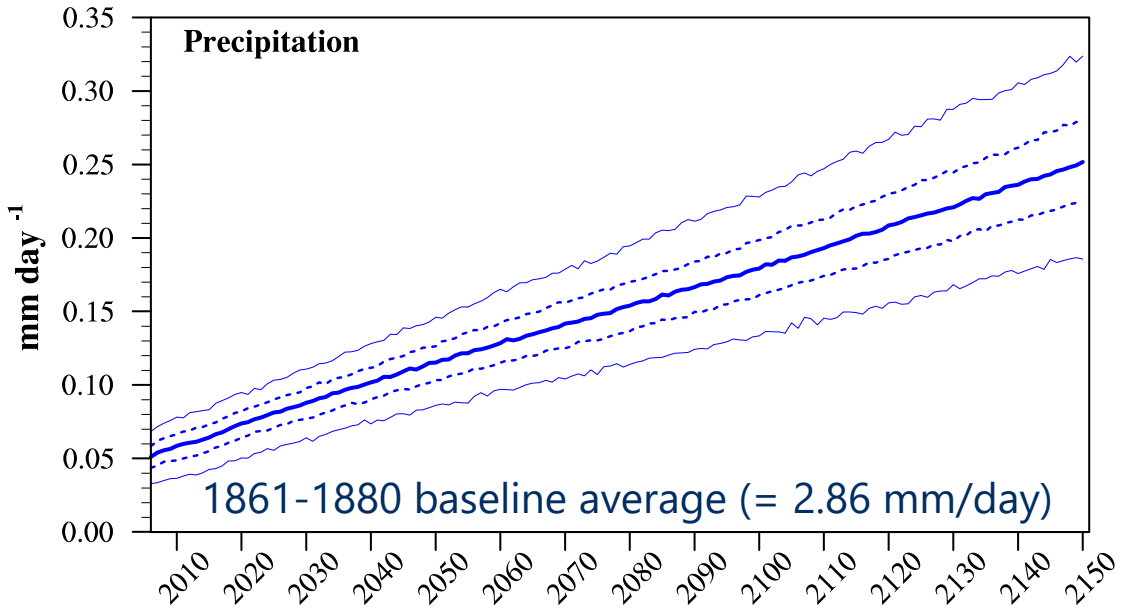
Accelerated Actions (AA) Scenario



Under *Accelerated Actions*, by midcentury global temperature rise will cease and decline slightly before stabilizing through the latter half of the century and into the 22nd century (to just below 1.5°C median warming).

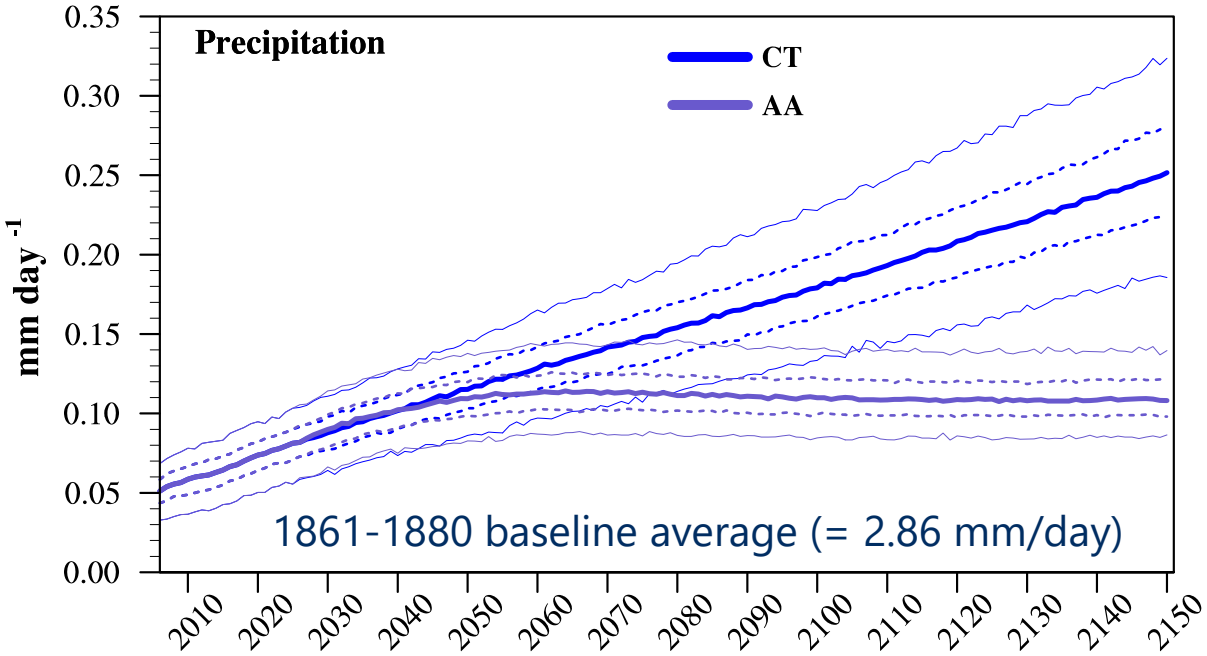
Global Precipitation Changes

Current Trends (CT)



Global precipitation between present and midcentury grows by 0.05 mm/day (median result), approximately an additional 9,300 km^3 or 2.5 quadrillion gallons of water that will precipitate each year. In a recent assessment of the global "water footprint," it is estimated that humans' global impact on water resources is 9,100 km3 per year.

Results from *Accelerated Actions* (AA)

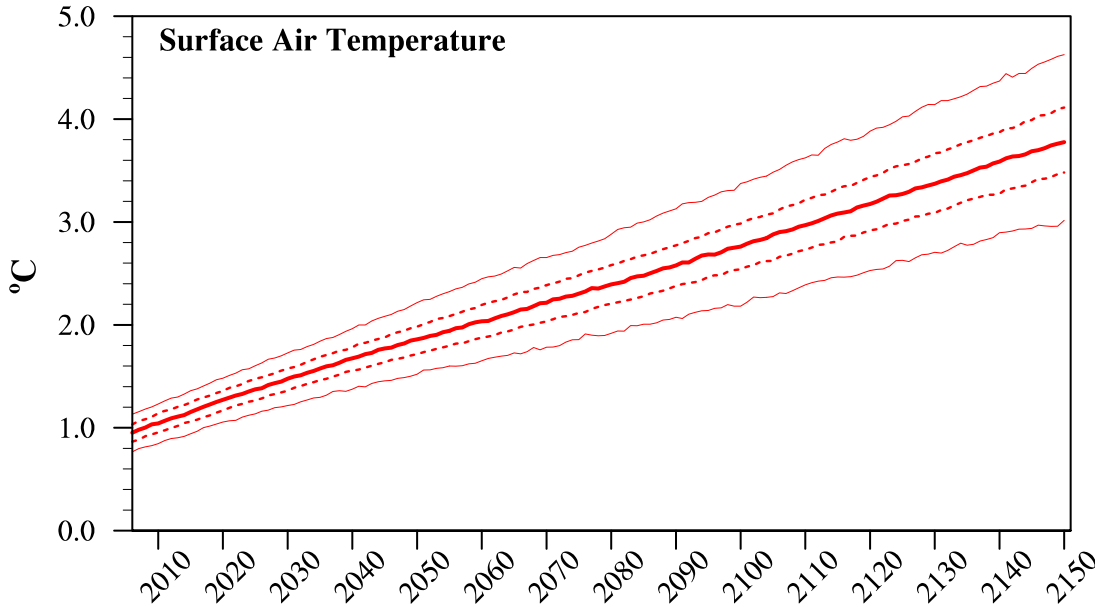


Accelerated Actions reduces the magnitude and potential range of increases. *Paris 2°C* cuts the increases by half and *Paris 1.5°C* reduces them to almost a third of the *Paris Forever* precipitation changes.

Note: A rainfall rate of 1 mm/day is approximately 375,000 gallons/year of water falling over an acre of land.

Downscaling of Global Climate Response

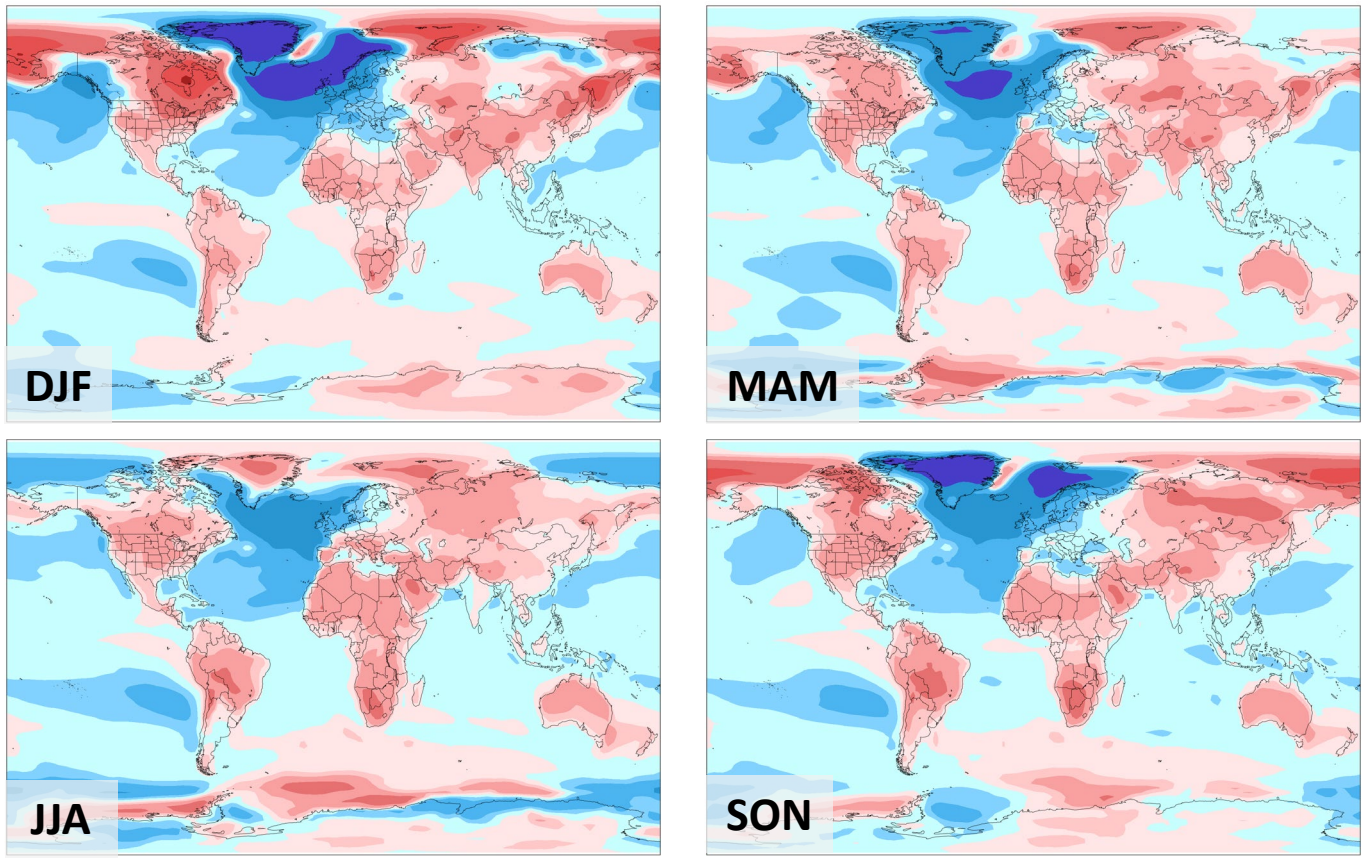
***Current Trends* Ensemble**



Combines the global-scale distribution of human-forced climate change with more spatially-resolved climate-response patterns from the Coupled Model Intercomparison Project (CMIP).

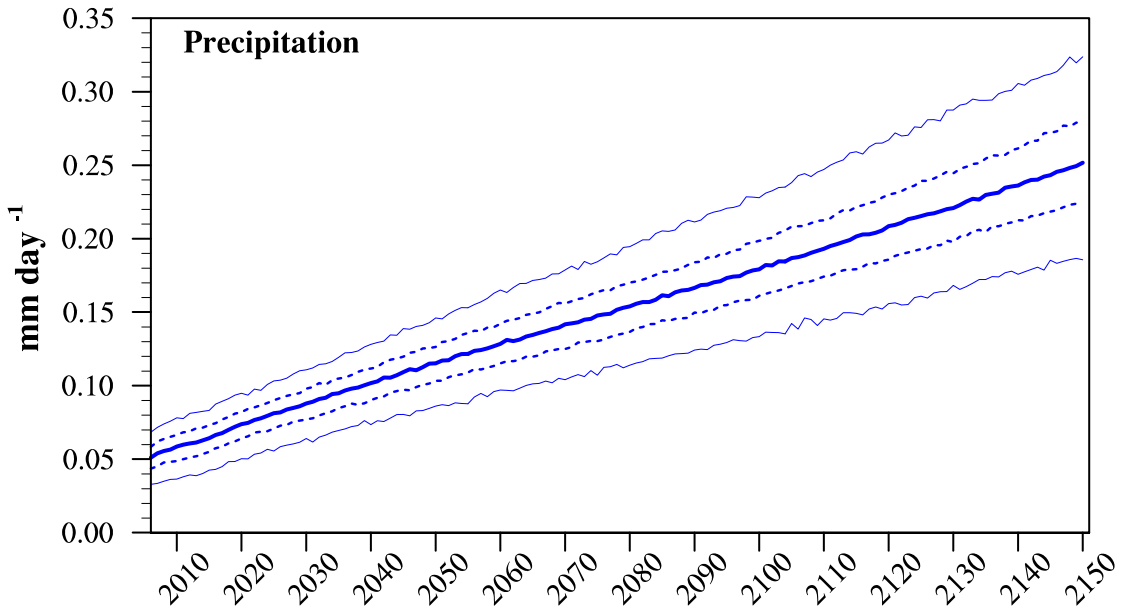
Other variables include: precipitation; max. and min. daily temperature; near-surface winds; radiation; humidity; and surface-air pressure

CMIP6-based model-mean relative response patterns of temperature change



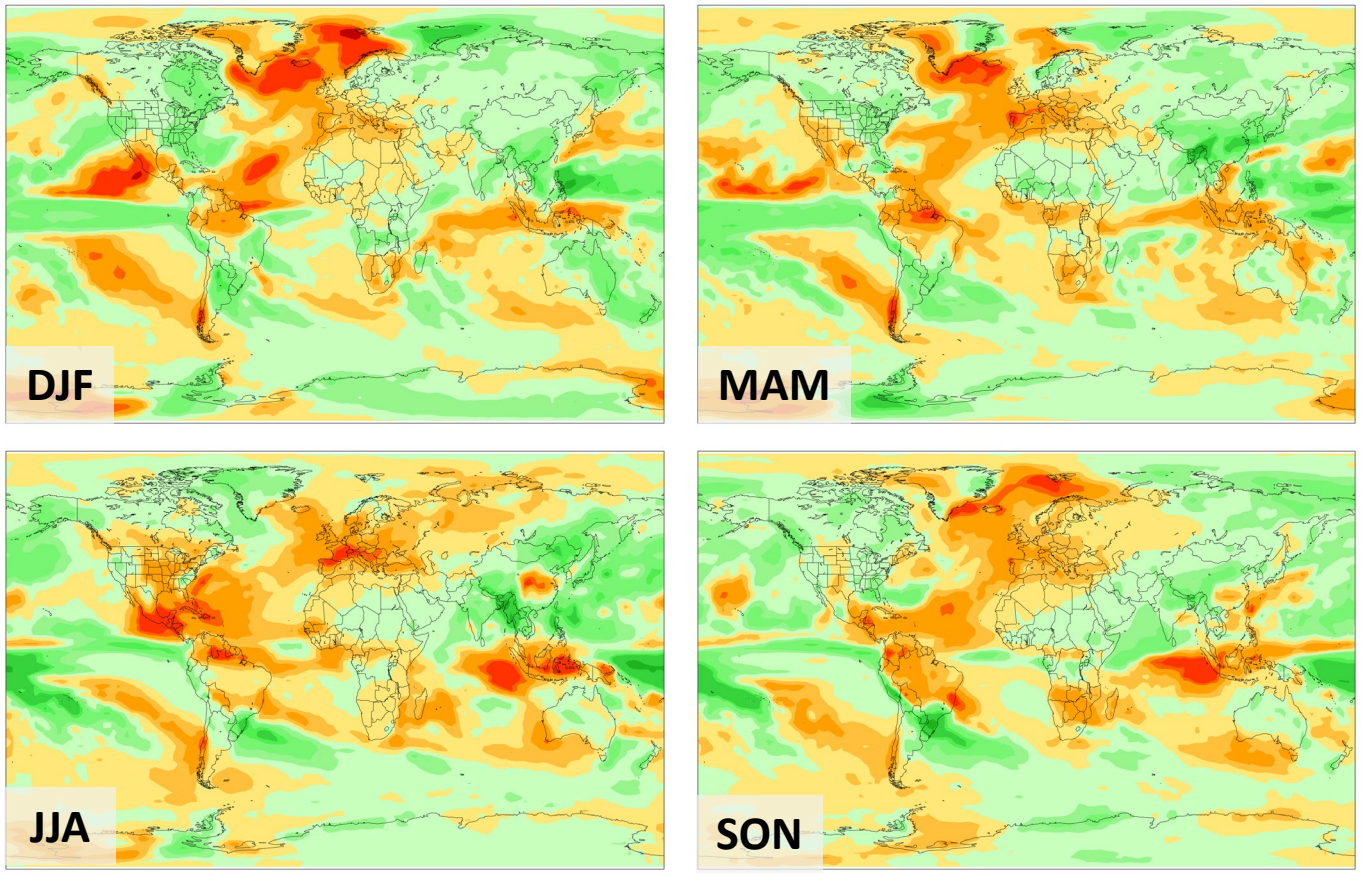
Downscaling of Global Climate Response

***Current Trends* Ensemble**



Combines the global-scale distribution of human-forced climate change with more spatially-resolved climate-response patterns.

CMIP6-based model-mean relative response patterns of precipitation change



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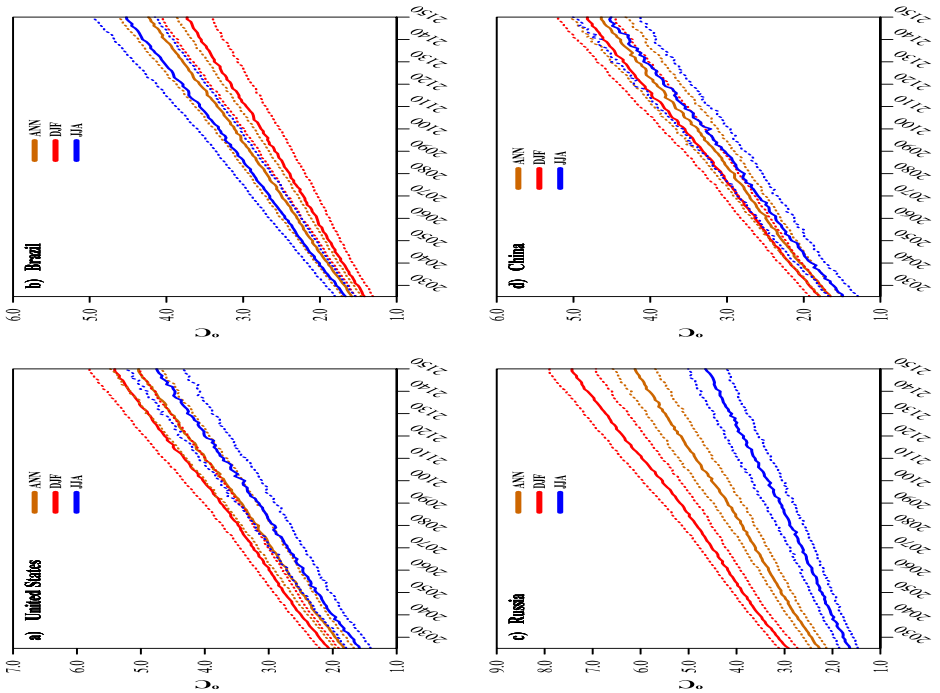
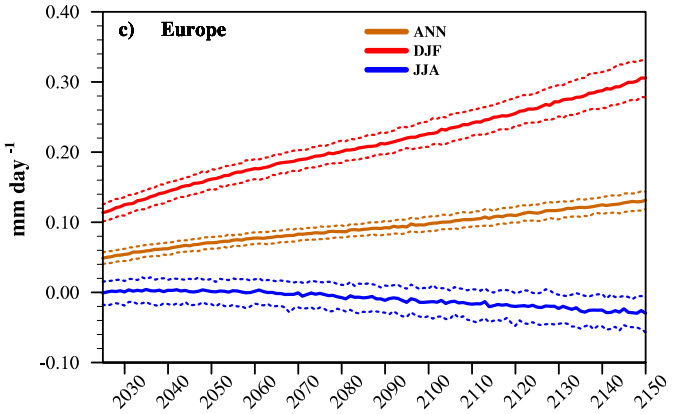
Regional Distributions of Climate Change



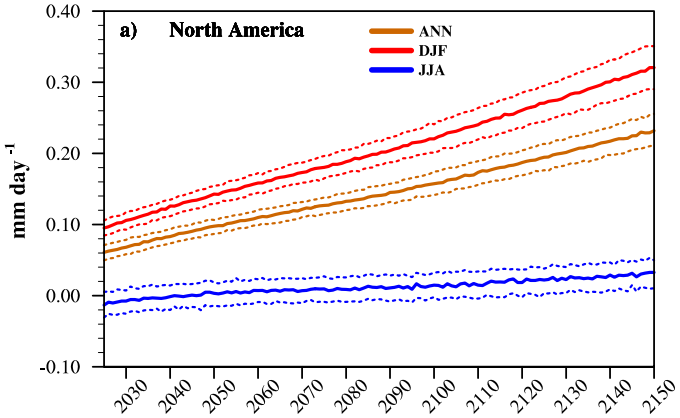
Under *Current Trends* (national pledges fulfilled/maintained in perpetuity) and long-term (global warming below 2°C) climate targets, most major continents will have passed 1.5°C of warming by mid-century, even when considering the lowest 5th percentile of our ensemble results



Across some continental regions, wetter-winter/drier-summer risk evolves through the latter half of the century

Threat of more flood-prone conditions in colder seasons

Compounding risk of enhanced heat-stressed and drought-prone prevailing conditions during warm seasons. Under *Accelerated Actions* risk is eliminated.



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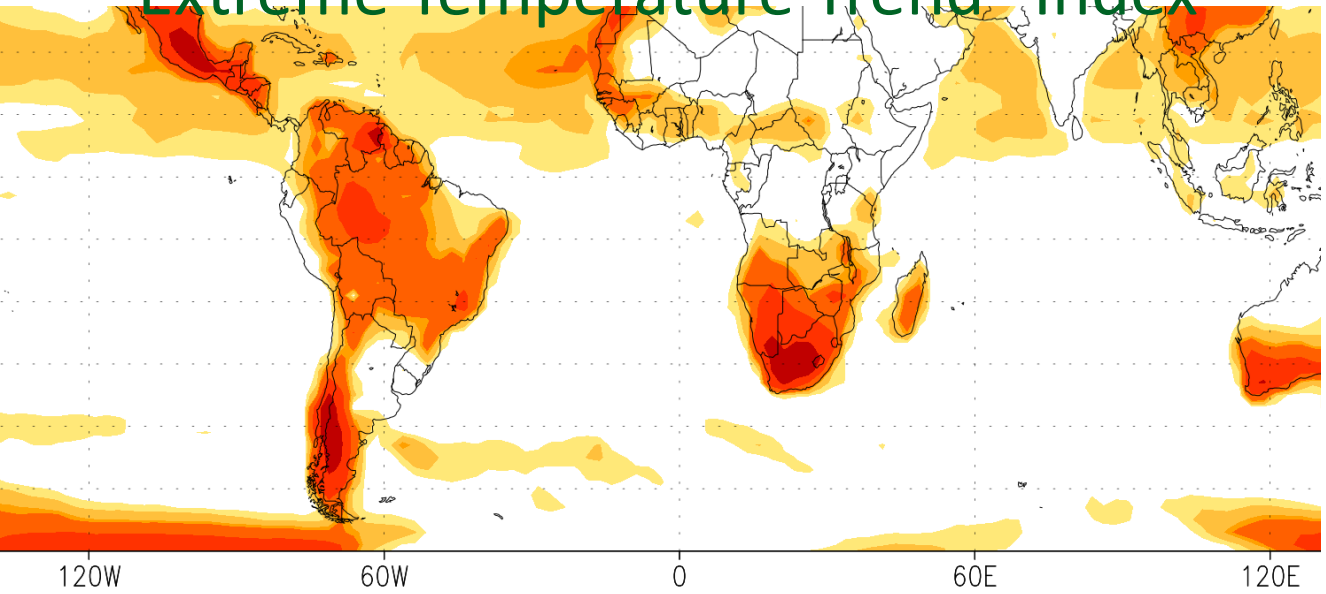
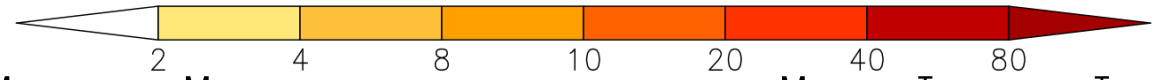
Evolving Patterns of Extreme Temperature Outbreaks

"Extreme Temperature Trend" Index





Maximum and Mean Temperature Trends Likely at Same Pace

Maximum Temperature Trend Likely to Outpace Mean Temperature Trend

- Indicates the relative degree and consensus to which the trend in daily maximum temperature outpaces the mean temperature change in response to human-forced climate warming.
- Based on the aggregate climate-model response from the Coupled Model Intercomparison Project Phase 6 (CMIP6), which forms the basis of our "hybrid" downscaling of the IGSM global scenarios (presented in this section).
- Darkest shades of red indicate regions where the relative increase of daily temperature maximum is more likely to outpace the rate of mean warming and are more likely experience more pronounced "unprecedented" extreme-temperature events as human-forced climate warming intensifies.

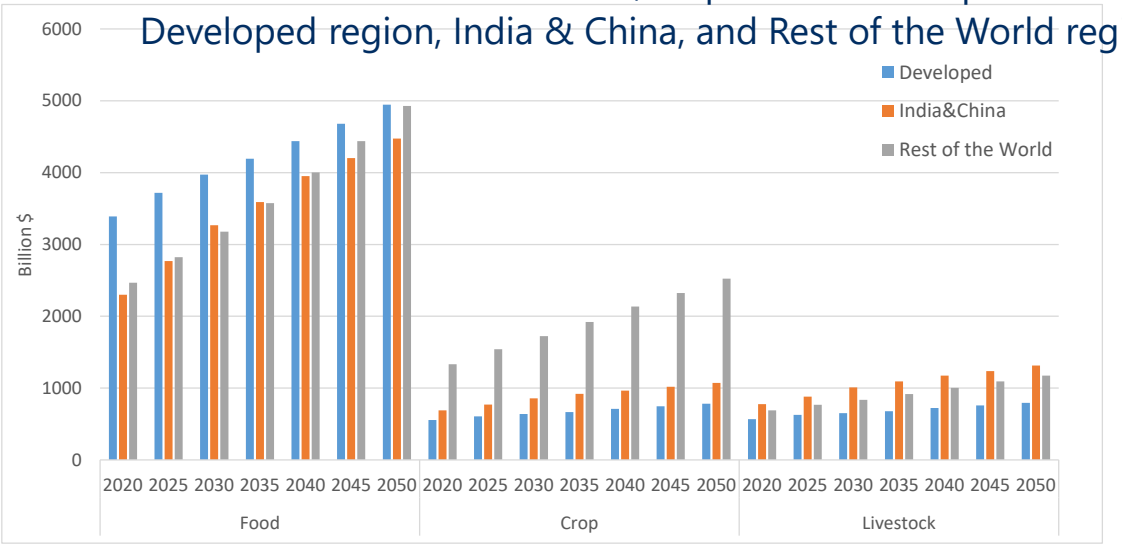
Global Food Production

Under the *Current Trends* scenario, From 2020 to 2050, agricultural output grows by 71% from crops and 62% from livestock. Population trends are a key driver behind such increases.

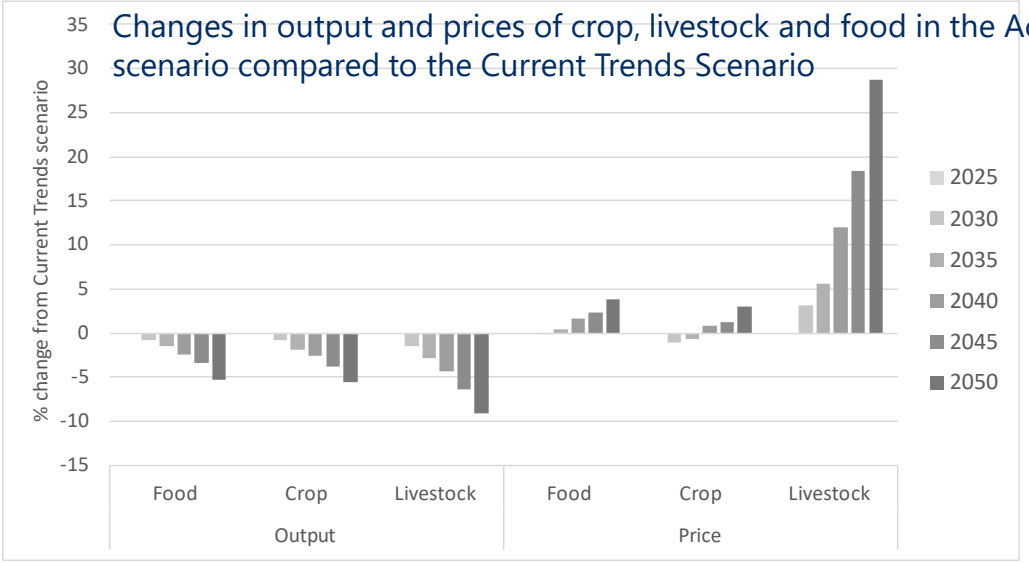
Different world regions experience diverse trends in agriculture and food production, due to important emerging structural changes.

Under the *Accelerated Actions*, less agricultural and food output and higher prices evolve compared to *Current Trends*.

Current Trends Scenario: Food, crop and livestock production in Developed region, India & China, and Rest of the World region



Changes in output and prices of crop, livestock and food in the Accelerated Actions scenario compared to the Current Trends Scenario



Land Use

In *Current Trends* scenario - productivity and yield gains prevent substantial agricultural area expansion. Natural forest areas decrease by 1.4% and natural grasslands by 3%.

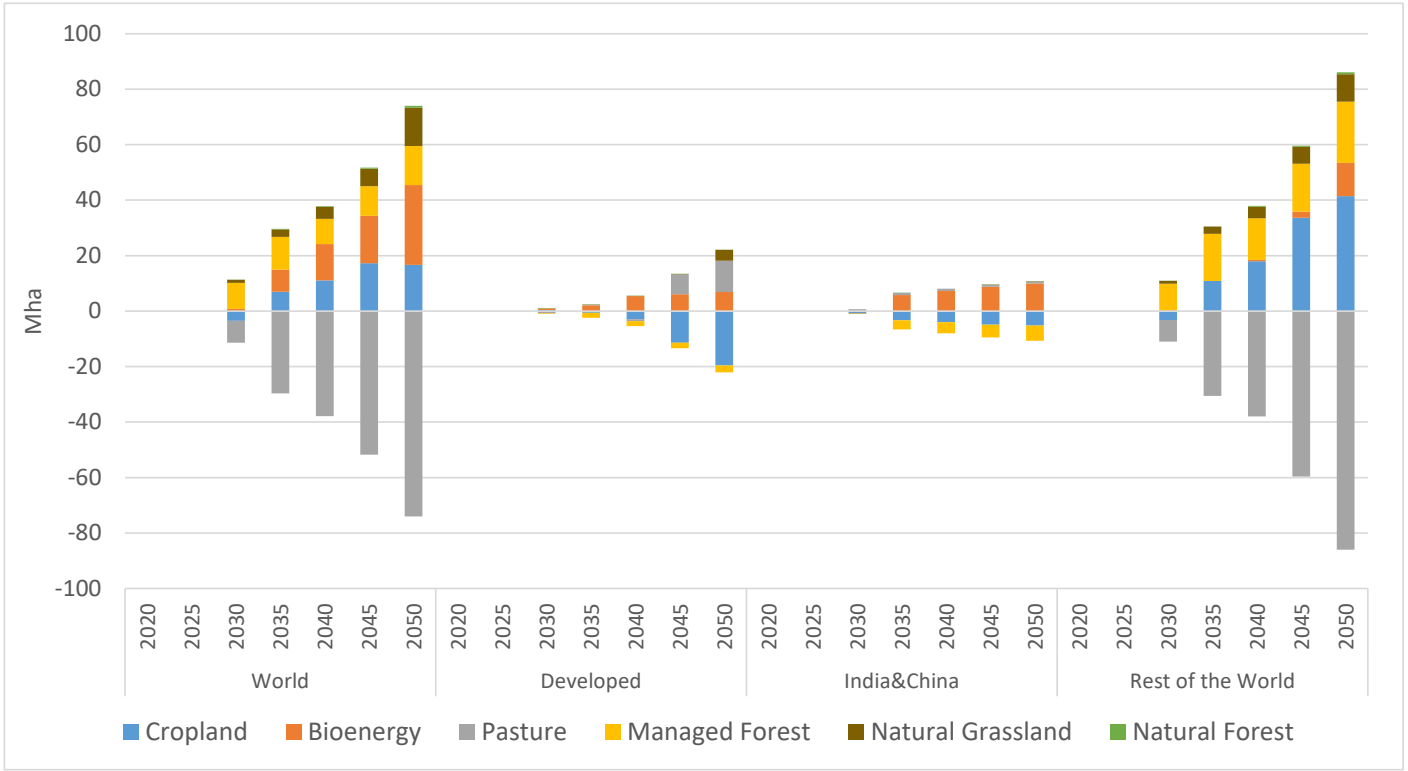
Accelerated Actions scenario requires larger use of land for crops in the Rest of the World and bioenergy everywhere.

Some intensification in livestock production and sharp contraction in pasture areas.

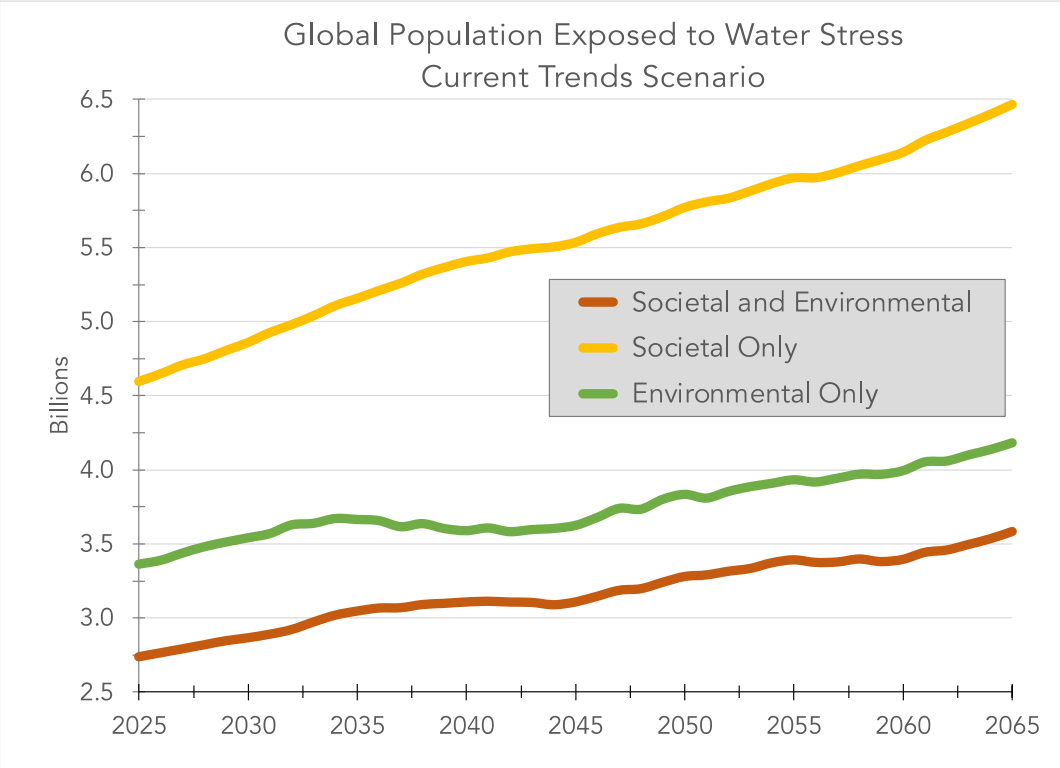
Accelerated Actions prevent the loss of 13.5Mha of natural areas and represents 15% less deforestation relative to the 89.8Mha natural vegetation loss in *Current Trends*.

Expansion in biomass production in *Accelerated Actions* scenario is in part due to improvements in crop yields

Differences in land use between the Accelerated Actions scenario and the Current Trends scenario in major regions and the World



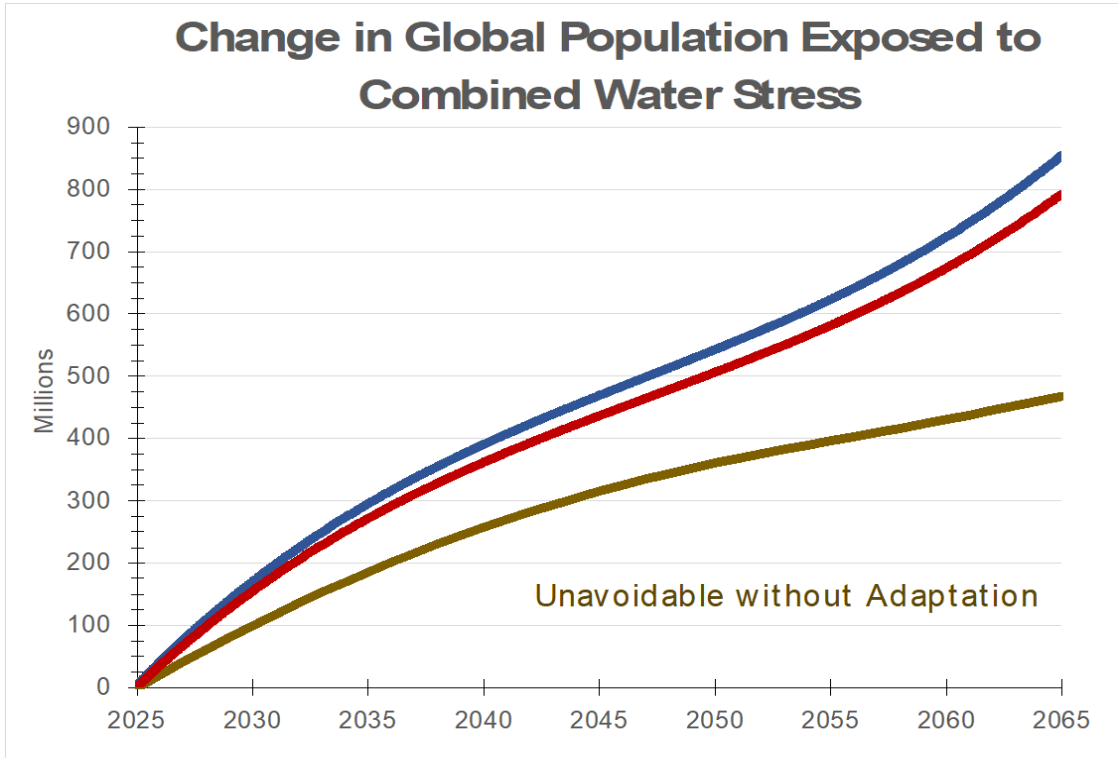
Global Water Stress



By midcentury 5.8 billion people worldwide will be exposed to shortfalls in water supply (societal stress) across the major river basins where they reside.

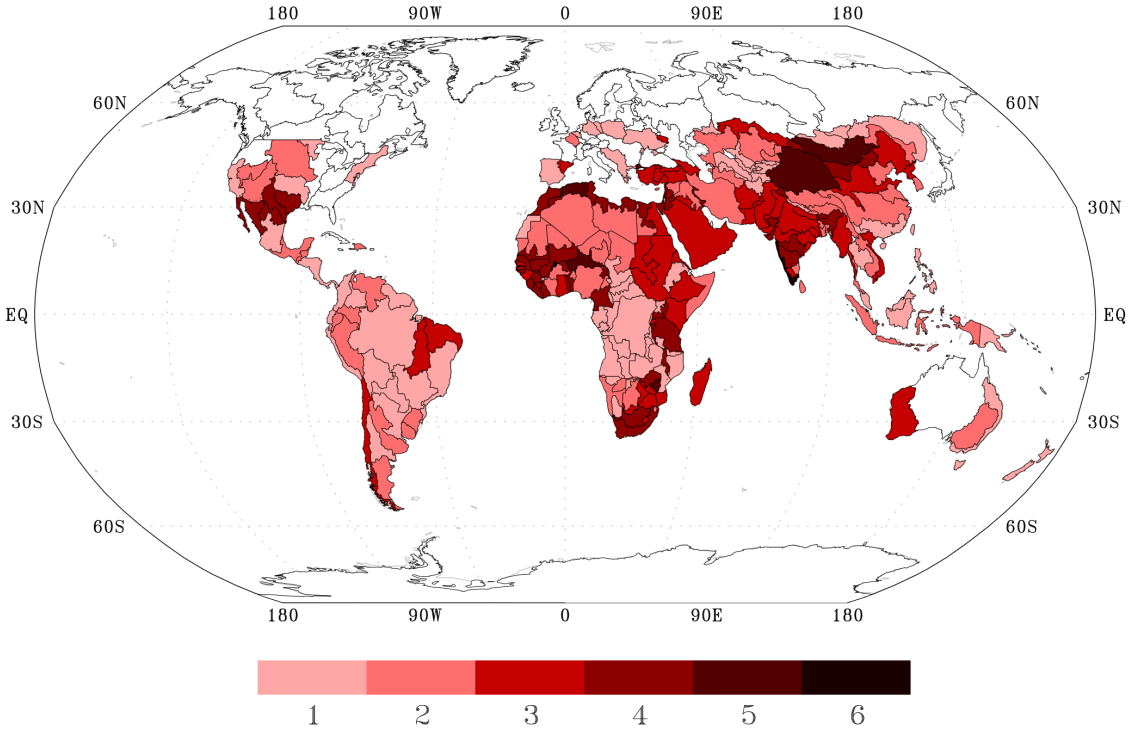
1) **"Environmental water-stress"** index: basin use of water has exceeded one-third of its natural replenishment

2) **"Societal water-stress"** index: basin where 15% (or higher) of the basin's annual water demands cannot be met



The most aggressive climate mitigation could reduce midcentury population under combined water stress by ~10%.

Overall Water Stress Threats by Mid-Century



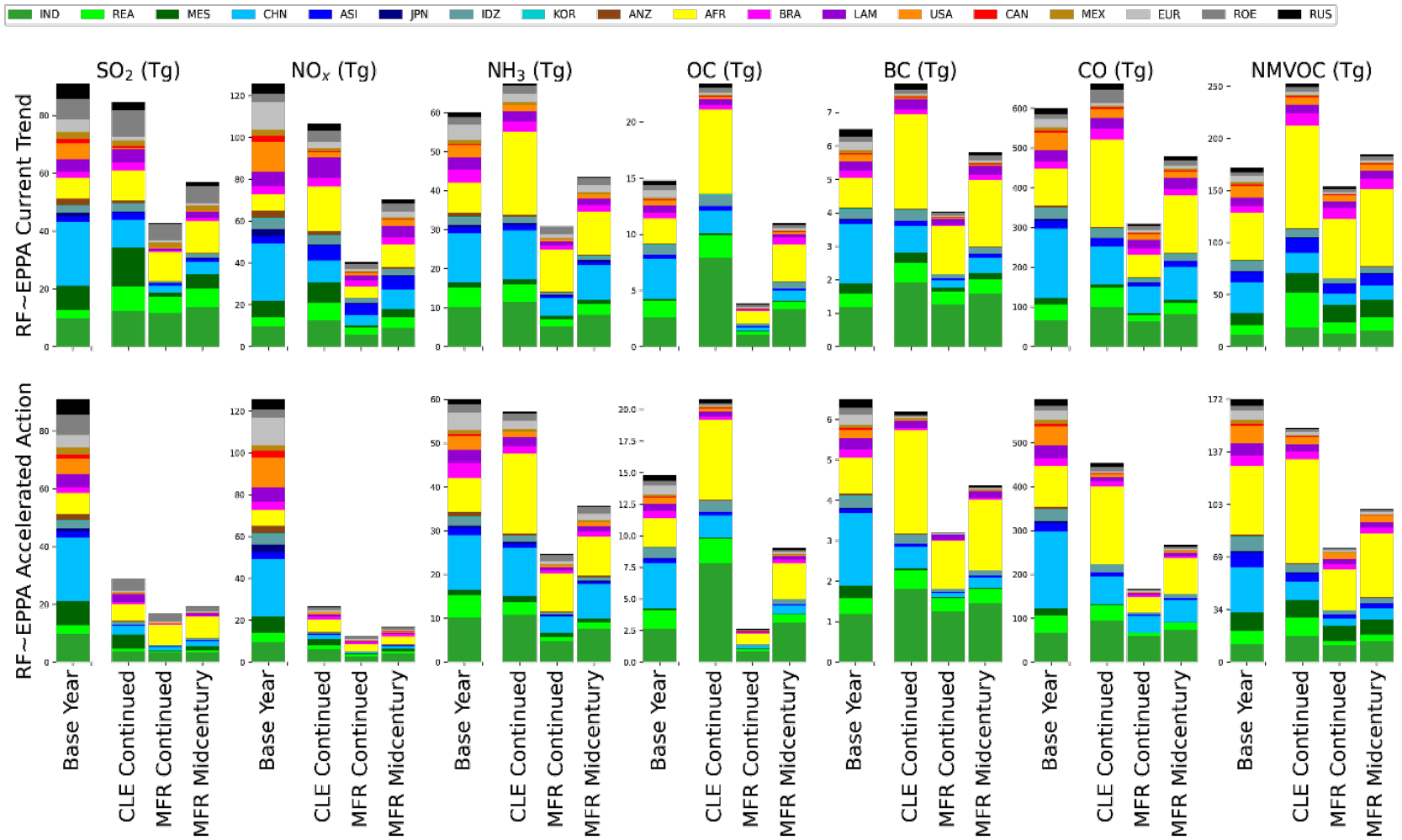
Aggregate water-stress indicator: Shows whether three conditions are met in both water stress indices: 1) a positive trend through midcentury; 2) water-stress conditions occur for more than half of the period between 2021-2059; and 3) stressed conditions emerge by 2050-2059.

More than half of the world's population will be exposed to stresses on its water supply by 2050, and that 3 of every 10 people will live in water basins where compounding societal and environmental pressures on water resources will be experienced.

High-priority basins or regions include: Brahmaputra, Chad, Chile, Danube, East Africa, Huang He, India, Ganges, Mediterranean (Africa), Mongolia, Niger, Nile, North Africa, Rio Grande, South Africa, Tigris, Volta, West Africa, and the Zambezi.

Climate, Air Quality, and Health

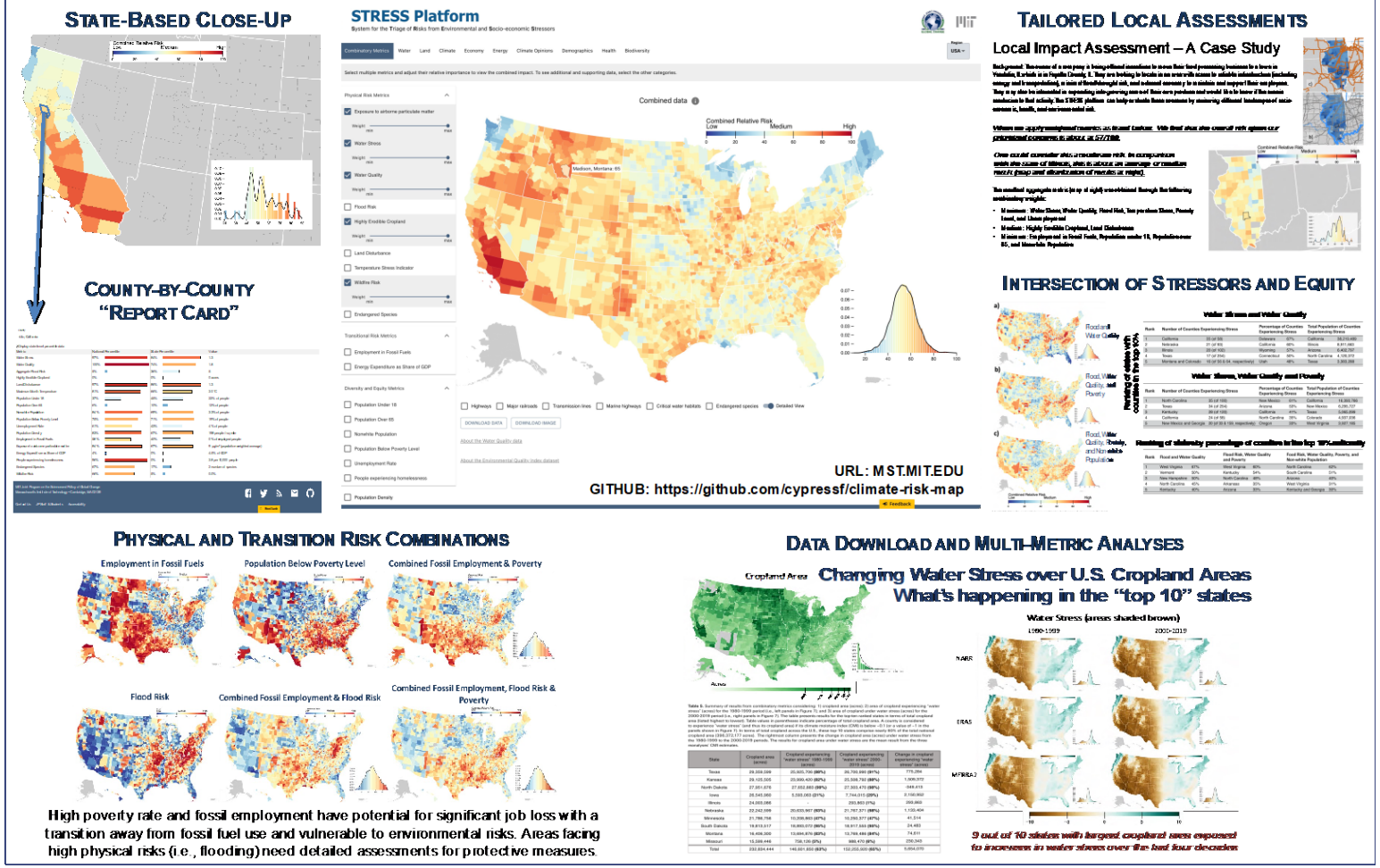
Tool for Air Pollution Scenarios (TAPS)



- Substantial co-benefits to climate mitigation actions that reduce emissions of important trace gases affecting air quality—and subsequently human health.
- However, we cannot rely purely on these co-benefits to solve air-quality problems.
- Future scenarios and policy mechanisms must be designed with more comprehensive targets that not only steer the planet to a safer climate, but also supports a cleaner environment and improved human health.

System for the Triage of Risk from Environmental and Socioeconomic Stressors (STRESS) Data-Visualization Platform (mst.mit.edu)

Examples of STRESS Platform Data-Visualization Capabilities



The STRESS platform currently provides several visual and user-inspired features:

- Growing collection of over 100 variables that convey conditions of water-land-energy resources, economics, climate, demographics, air quality, public opinions on climate change, health, mapped infrastructure overlaying highways, railways, waterways, transmission lines, critical habitats and endangered species;
- Subset of metrics across physical, socio-economic and demographic conditions allow user-inspired, interactive combinations of physical and transition risks as well as socio-demographic and equity landscapes to create aggregate metric mappings
- Risk "report card" for any selected U.S. county
- Downloadable data & maps for tailored analyses
- Open-science, open-source philosophy and design.
- **More to come!** Global maps and Outlook scenarios

Preparing for Tomorrow

The **Current Trends** in Paris Agreement pledges (made by countries for the year 2030) do not substantially decrease the share of fossil fuels in global primary energy consumption.

While we project an 8.6-fold increase in variable renewable energy (wind and solar) between 2020 and 2050, the share of **low-carbon energy sources** (wind, solar, biomass, hydro and nuclear) in primary energy consumption grows slowly, from the current 20% to about 30% in 2050.

The **Accelerated Actions** scenario squeezes out fossil fuels faster, but they are not completely eliminated by 2050. **Wind and solar** energy has the **fastest growth** in all regions in this scenario: the increase is 9-fold in the Developed region, 10-fold in India & China and 45-fold in the Rest of the World.

Additional **policy actions are needed** to speed up the energy transition towards low-carbon sources.

Electricity generation from **low-carbon sources** becomes a **dominant** source of power by 2050 in both scenarios, providing 70-90% of global power generation by midcentury.

Preparing for Tomorrow

Our projected global **climate** responses under the **Current Trends** scenario indicate with near-certainty that the world **will surpass** important GHG concentration thresholds and **climate targets** in the coming decades.

Many regions of the world are likely to experience **more pronounced "unprecedented" extreme-temperature events** as human-forced climate warming intensifies

More than half of the world's population will experience **stresses** on its **water supply** by 2050, and that at least **3 of every 10 people** will live in water basins where **compounding societal and environmental pressures** on water resources will be experienced.

Agriculture and **food production** will keep **growing**. This will increase **pressure** for **land-use** change, **water** use, and use of **energy-intensive inputs**, which will also lead to higher **GHG emissions**.

The **Accelerated Actions** scenario, however, can virtually **assure the world** of remaining below 2°C of global warming. Nevertheless, **additional policy mechanisms** must be designed with more comprehensive targets **that also supports a cleaner environment and improved and equitable human health**.

Thank you

2023 Outlook Available Online at:

https://globalchange.mit.edu/sites/default/files/newsletters/files/2023-JP-Outlook.pdf

Visualization Tool at: https://mitjointprogram.shinyapps.io/outlook2023/