Report on FY2023 Commissioned Research

Study of the Use of the Network for Greening the Financial Systems (NGFS) Scenario

-tentative English translation-

Central Research Institute of Electric Power Industry (CRIEPI)
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Executive Summary

- This study had two purposes: (1) to investigate the frameworks, methodologies, and assumptions of the fourth vintage of climate scenarios, along with features of key variables, and to summarize points updated since the third vintage, in order to provide scenario analysts working for financial authorities and financial institutions with a deeper understanding; and (2) to examine ways in which financial institutions can use the NGFS scenarios in climate risk analysis.
- To fulfill (1), we analyzed and examined transition risks, physical risks, and macroeconomic impacts.

  Transition risks: The Phase IV scenarios show an overall rise in transition risks, in the form of a higher shadow carbon price in the Net Zero 2050 scenario than in Phase III, due to an increase in current emissions triggered by the post-covid economic recovery, among other factors, and also to the conservative revision of figures for the future availability of carbon dioxide removal technologies. At the same time, in the Low Demand scenario, which is a new addition to Phase IV, the rise in transition risks has been minimized by envisaging reduced demand due to behavioral changes. However, there would appear to be room for improvement here, as the impact of reduced demand has not been appropriately reflected.

  Physical risks: As in the third vintage, the impact of chronic physical risks on GDP has been estimated on the basis of a damage function driven by the range of temperature rises. With regard to acute physical risks, the Phase IV scenarios use a new methodology to provide probabilistic estimates by country of the impact on GDP of droughts, heatwaves, floods, and cyclones.

  Macroeconomic impacts: The impact of physical risks on GDP is higher in the Current Policies and Fragmented World scenarios than in other scenarios, but differences in the estimated temperature rises input into the damage functions would appear to contribute substantially to this. While transition risk leads to a short-term fall in GDP, followed by recovery in the medium to long term in the Net Zero 2050 scenario, this is likely due to the recycling of government revenue from carbon pricing. Either way, this stems from the fact that the settings used to calculate macroeconomic impact differ from one scenario to another and should be borne in mind when interpreting results.
- With regard to purpose (2) of this study, a case study of the examples of the use of climate scenarios by financial institutions led us to conclude that they could be used in medium- to long-term risk analysis based on quantitative analysis of financial impacts on an entire portfolio. Even if not accompanied by a quantitative financial analysis, consideration of such matters as the whereabouts, scale, and impact of medium- to long-term transition and physical risks based on the NGFS scenarios appears likely to be useful for qualitative risk analysis and investee engagement. At the same time, the NGFS scenarios still seem to have some issues in terms of the granularity of sectoral information and the assessment of physical risks, as well as the size and timing of envisaged stresses. As NGFS plans to continue developing and improving its scenarios, it is expected that methodologies and data will be enhanced going forward, in order to expand the scenarios' use by financial institutions.

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This report presents the findings from the Study of the Use of the Network for Greening the Financial Systems (NGFS) Scenario, which the Central Research Institute of Electric Power Industry was commissioned to conduct by the Financial Services Agency.

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1. Introduction

Background to this study

Publication of the fourth vintage of scenarios by the Network for Greening the Financial Systems (NGFS)

- The Financial Services Agency (FSA) compiled summaries of the Phase II (published June 2021) and Phase III (published September 2022) NGFS scenarios and, after analyzing the detailed features of key variables, proposed revisions to the scenarios and points to bear in mind with a view to climate risk analysis in Japan.
- NGFS published the fourth vintage of scenarios in November 2023. The Phase IV scenarios included revised assumptions, namely (1) increased current emissions due to post-covid economic recovery and the Ukraine crisis; and (2) revised availability of carbon dioxide removal technologies.[*1]
- As the NGFS scenarios will likely continue to serve as a point of reference in climate risk analysis, a summary of the features of the fourth vintage would appear useful for financial institutions.

Advances in climate scenario analysis by financial authorities and the importance of the role of the NGFS scenarios

- Awareness of the fundamentals of the NGFS scenarios is also growing within Japan, and efforts to undertake financial risk analysis that includes partially adapted NGFS scenarios is getting underway both within Japan and overseas. The NGFS scenarios have been developed and enhanced with a view to climate-related financial risk analysis conducted by financial authorities (climate stress tests), but in recent years, they have increasingly been used by commercial financial institutions and the like for a variety of purposes, including scenario analysis, the formulation of Net Zero targets and strategies (transition planning), and engagement with investees.
- In "Principles for the effective management and supervision of climate-related financial risks," published in June 2022, the Basel Committee on Banking Supervision (BCBS) requested that financial institutions use scenarios in climate risk analysis.
- Accordingly, due to the anticipated use of the NGFS scenarios in climate risk analysis by Japanese financial institutions, it is crucial to provide those financial institutions with a summary of knowledge concerning scenario analysis by financial institutions currently using the NGFS scenarios.
- At the same time, it would appear useful to facilitate more advanced risk analysis activities by financial institutions, by examining examples of the use of the NGFS scenarios and considering NGFS scenario usage.

*1 NGFS (2023b) pp. 24-25.

Purposes and overview of this study

- This study has the following two purposes.
  - To investigate the frameworks, methodologies, and assumptions of the fourth vintage of climate scenarios, along with features of key variables, and to summarize points updated since the third vintage, in order to provide scenario analysts working for financial authorities and financial institutions with a deeper understanding.
  - To examine ways in which financial institutions can use the NGFS scenarios in climate risk analysis.

Sections and overview of this report

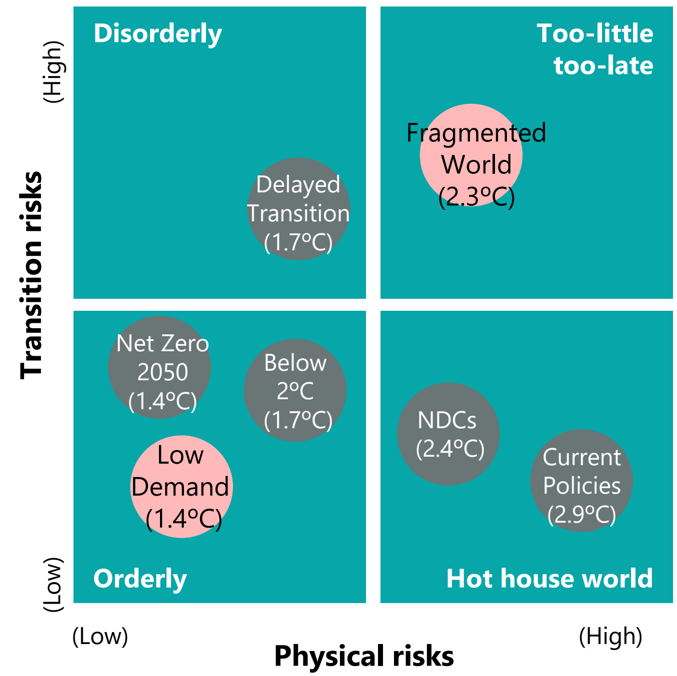
2. Outline of the Integrated Assessment Models for Transition Risks	• Summary of the features of the seven scenarios that make up the fourth vintage, with a focus on key variables, namely the volume of CO_2 emissions and removal, energy-related variables, and carbon costs. • Summary of the features of the fourth vintage based on a comparison with the third vintage, with a focus on three scenarios: Net Zero 2050, Delayed Transition, and Current Policies. • Summary of the features of the Low Demand and Fragmented World scenarios, which have been newly added in Phase IV.
3. Methodologies and Data Concerning Physical Risks	• Explanation of the methodologies for assessing chronic risks and acute risks, given the substantial enhancement of the latter in Phase IV, and also a broad overview of each risk factor's impact on GDP. • Broad overview of data available from the database of physical risk factors provided in the fourth vintage.
4. Assessments of Macroeconomic Impacts	• Broad overview of methodologies for assessing macroeconomic impacts. • Summary of the impact of physical risk (chronic risk) and transition risk factors on key macroeconomic variables, namely GDP and the inflation rate.
5. Use of NGFS Scenarios by Financial Institutions	• Case study of examples of the use of climate scenarios by financial institutions. • Examination of the ways in which the Phase IV NGFS scenarios are used by financial institutions and associated issues, taking into account the results of section 2 to 4.

NGFS scenarios framework in Phase IV

- The composition of the scenarios has been changed from the Phase III scenarios, with two new scenarios added in Phase IV.
- The Orderly quadrant now consists of three scenarios, following the addition of Low Demand to the existing two scenarios of Net Zero 2050 and Below 2°C. Low Demand is categorized in the quadrant with the lowest transition and physical risks, because the scenario is based on a low level of temperature rise at the end of the century, along with conservative settings for carbon dioxide removal.
- Envisaging substantial divergence between regions, the Fragmented World scenario has been established in the Too-little-too-late quadrant, which had no scenarios in previous vintages.
- The Divergent Net Zero scenario categorized in the Disorderly quadrant in previous vintages has been deleted in the fourth vintage.

NGFS scenarios framework in Phase IV*1

Quadrant	Scenario	Temperature rise*2	Policy reaction	Technology change	Carbon dioxide removal	Regional policy variation
Orderly	**Low Demand**	1.4°C	Immediate and smooth	Fast change	Medium use	Medium variation
	Net Zero 2050	1.4°C	Immediate and smooth	Fast change	Medium-high use	Medium variation
	Below 2°C	1.7°C	Immediate and smooth	Moderate change	Medium use	Low variation
Disorderly	**Delayed Transition**	1.7°C	Delayed	Slow/Fast change	Low-medium use	High variation
Hot house world	**Nationally Determined Contributions (NDCs)**	2.4°C	NDCs	Slow change	Low-medium use	Medium variation
	Current Policies	2.9°C	None – current policies	Slow change	Low use	Low variation
Too-little too-late	**Fragmented World**	2.3°C	Delayed and Fragmented	Slow/Fragmented change	Low-medium use	High variation



: Added in the Phase IV scenarios

*1 Compiled from NGFS (2023b); *2 End of century warming – model average.

The seven NGFTS scenario narratives in Phase IV

- Low Demand could be described as a scenario that assumes greater mitigation of economic impacts than Net Zero 2050, by means of not only reduced emissions and the introduction of technology, but also reduced demand through behavioral changes on the energy demand side.
- Fragmented World assumes that countries with net zero targets fail to achieve them (achieving 80% of the target), while the other countries do not achieve reductions greater than those in current policies.

NGFS scenario narratives in Phase IV*1

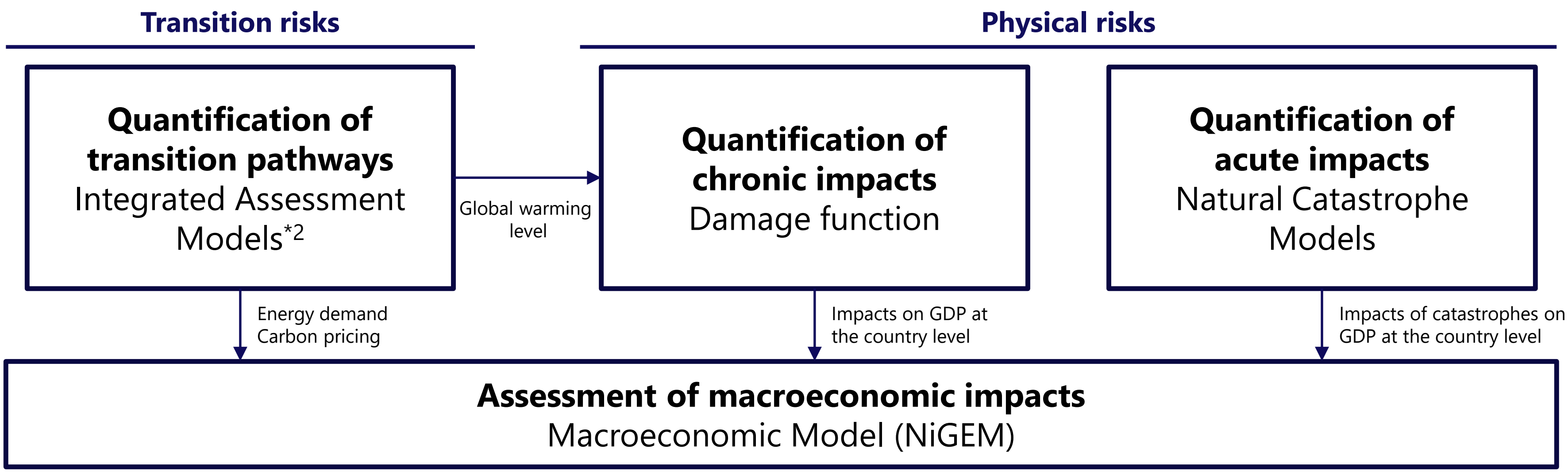
Quadrant	Scenario	Narrative
Orderly	**Low Demand**	Assumes that significant behavioral changes—reducing energy demand—in addition to (shadow) carbon price and technology induced efforts, would mitigate pressure on the economic system to reach global net zero CO_2 emissions around 2050.
	Net Zero 2050	Limits global warming to 1.5°C through stringent climate policies and innovation, reaching global net zero CO_2 emissions around 2050. Some jurisdictions, such as the U.S., EU, U.K., Canada, Australia, and Japan, reach net zero for all GHGs in addition to CO_2.
	Below 2°C	Gradually increases the stringency of climate policies, giving a 67% chance of limiting global warming to below 2°C.
Disorderly	**Delayed Transition**	Assumes annual emissions do not decrease until 2030. Strong policies are needed to limit warming to below 2°C. Negative emissions are limited.
Hot house world	**Nationally Determined Contributions (NDCs)**	Includes all pledged targets*2 even if not yet backed up by implemented effective policies.
	Current Policies	Assumes that only currently implemented policies are preserved, leading to high physical risks.
Too-little too-late	**Fragmented World**	Assumes a delayed and divergent climate policy response among countries globally, leading to high physical and transition risks. Countries with net zero targets achieve them only partially (80% of the target), while the other countries follow current policies.

*1 Compiled from NGFS (2023a,b); *2 Shown on the UNFCCC website until March 2023.

NGFS modeling framework in Phase IV

- The Phase IV NGFS scenarios quantitatively assess various climate risks via a coherently aligned set of models with differing objectives.
- By means of alignment with the level of temperature rise, the results from the Integrated Assessment Models (IAMs) for assessing transition risks are linked to the models for assessing physical risks. Both sets of results are linked to the macroeconomic model, thereby providing a coherent assessment of the impacts of transition risks and (chronic) physical risks under each scenario.

NGFS modeling framework in Phase IV*1



*1 Compiled by CRIEPI with reference to NGFS (2023a,b).

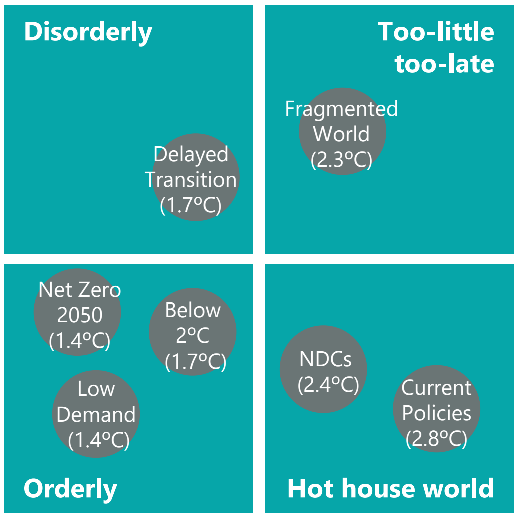
*2 In the NGFS scenarios, the range of uncertainty inherent to modeling the future is reflected by using three different IAMs (REMIND-MAgPIE 3.2-4.6, MESSAGEix-GLOBIOM 1.1-M-R12, and GCAM 6.0 NGFS) to quantify each of the narratives.

2. Outline of the Integrated Assessment Models for Transition Risks

Features of the IAMs relating to transition risks

- This part summarizes the features of the key variables in the IAMs principally relating to the transition risks of the NGFS Phase IV scenarios.

2.1 Summary of features of key variables

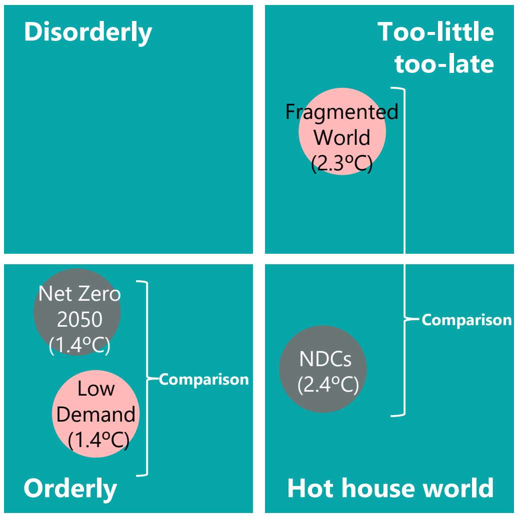


Summarizes the features of the key variables (CO_2 emissions/removal, energy supply/consumption, energy cost, and carbon price) in the seven Phase IV scenarios

2.2 Comparison with Phase III

Undertakes a comparison with the Phase III scenarios, focusing on the three scenarios most commonly used in climate scenario analysis by authorities and financial institutions, and identifies points that have been updated

2.3 Summary of features of new scenarios



Compares the two scenarios newly introduced in Phase IV with similar existing scenarios and summarizes the features of the new scenarios

2. Outline of the Integrated Assessment Models for Transition Risks

2.1 Features of key variables in the Phase IV scenarios
2.2 Features of the Phase IV scenarios based on comparison with Phase III
2.3 Features of scenarios added in Phase IV

Summary of features of key variables

- All the IAMs employed in the Phase IV NGFS scenarios quantify future developments under a set of assumptions and constraints on CO_2 emissions and the like, with a primary focus on energy systems. This section summarizes the features of key variables in the seven Phase IV scenarios, centering on energy system developments and CO_2 emissions.

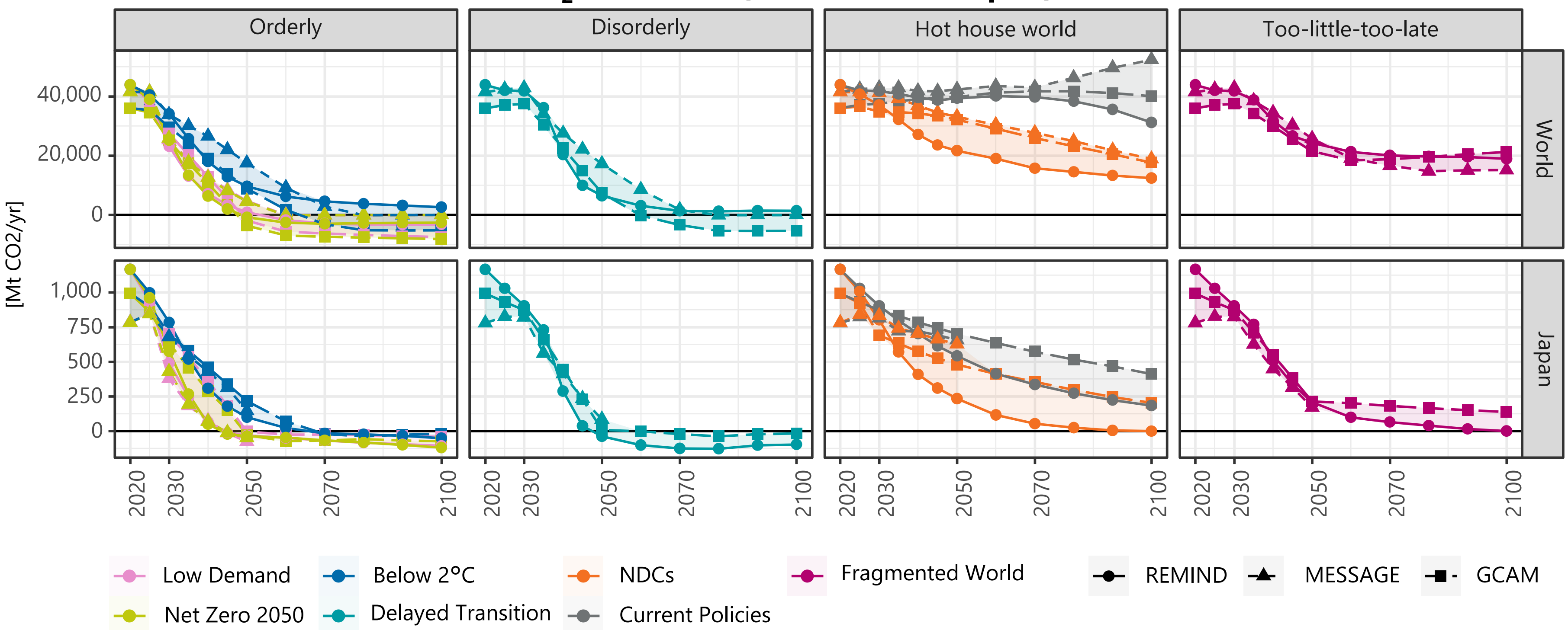
Variable category	Outline	Variables highlighted in this section
① CO_2 emissions /removal	We summarize for each scenario the volume of emissions and quantity removed, along with a breakdown of each, with a primary focus on CO_2, which accounts for the majority of GHGs.	• CO_2 emissions • CO_2 removal
② Energy supply /consumption	Focusing on energy systems, which account for the majority of CO_2 emissions, we summarize for each scenario the composition of primary energy supply (fossil fuels and biomass), secondary energy supply (electricity, etc.), and final energy consumption.	• Primary energy supply • Secondary energy supply (electricity) • Final energy consumption
③ Energy costs	Changes in energy systems lead to differences in energy costs, which impact the economy. Focusing on electricity systems, for which detailed information is available, we summarize changes in the monetary value of electricity-related investment and the breakdown thereof.	• Investment (electricity)
④ Policy costs	Costs relating to emissions reduction policies are calculated within models in the form of (shadow) carbon prices. Here we examine carbon price fluctuations arising from changes in the volume of emissions, and also consider the extent of impacts on the economy.	• (Shadow) carbon prices

Items ①–④ are explained in the following pages

CO_2 emissions

- Both the Net Zero 2050 and Low Demand scenarios assume end of century warming below 1.5°C. In both these scenarios, worldwide CO_2 emissions reached net zero by 2050, with zero to negative emissions subsequently achieved by 2100. The volume of CO_2 emissions was about the same in both scenarios.
- Of the scenarios that assume warming above 1.5°C, Delayed Transition saw Japan achieving net zero CO_2 emissions by 2050, unlike the world as a whole.
- In the Fragmented World scenario, worldwide CO_2 emissions roughly halved by 2050. In Japan, the situation was close to the Below 2°C scenario until 2050, when it reached near zero to 200MtCO_2e, but unlike the Below 2°C scenario, some level of emissions continued after 2050.

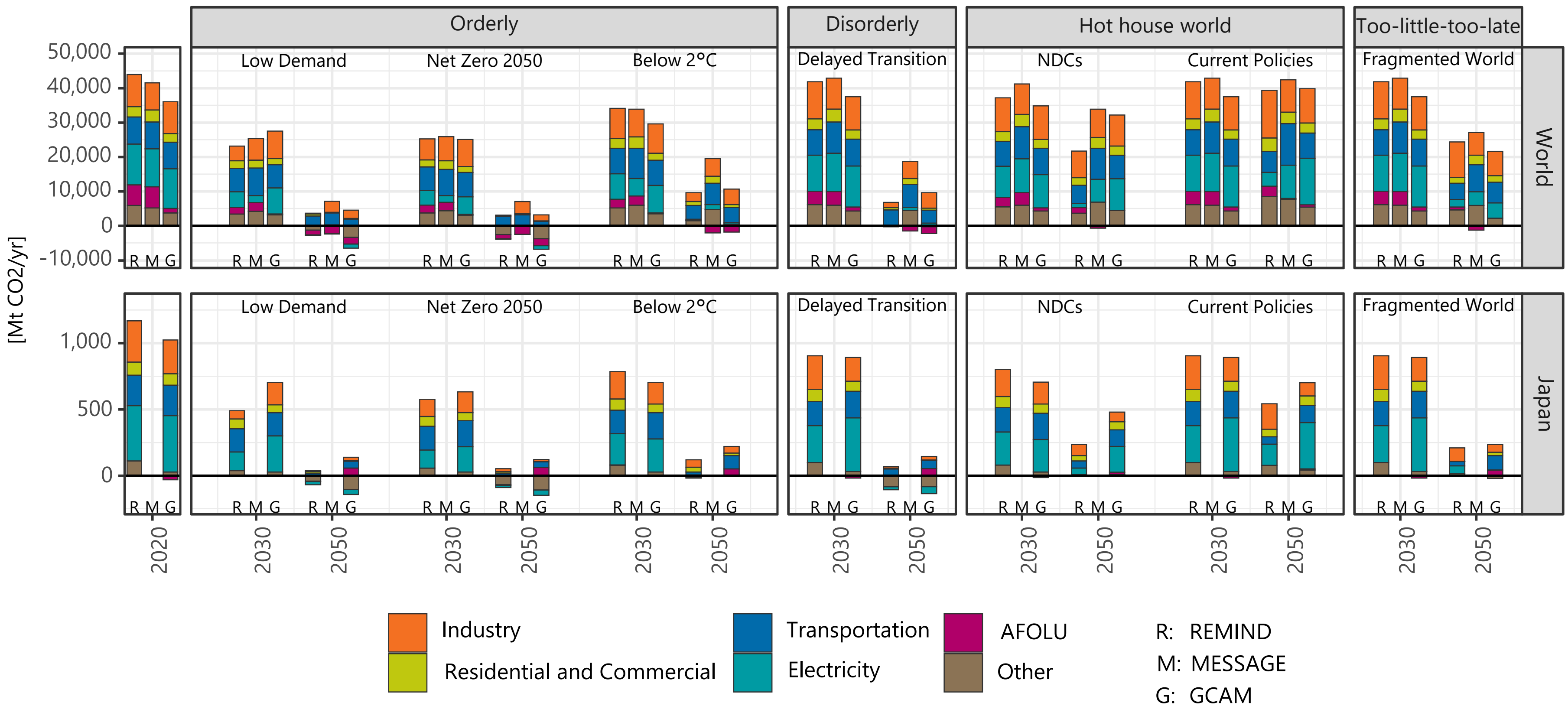
CO_2 emissions (worldwide & Japan)



CO_2 emissions (sectoral)

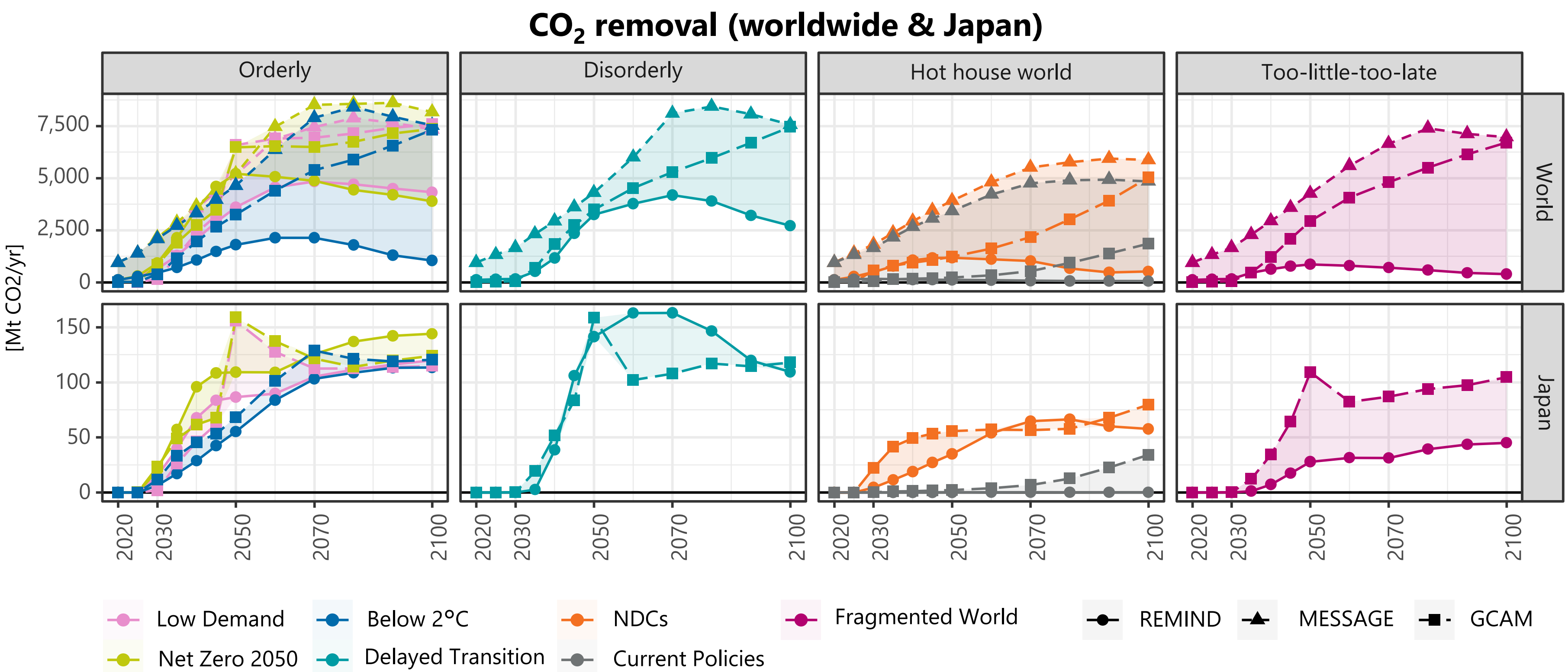
- Electricity accounts for the largest share of emissions by sector in 2020. In both transition quadrants (orderly and disorderly), the Electricity sector was found to reach zero to negative emissions in 2050, while the Transportation and Industry sectors had residual emissions.
- Comparing the Low Demand and Net Zero 2050 scenarios, no major differences in emissions by sector in 2050 could be identified.

CO_2 emissions (sectoral, worldwide & Japan)



CO_2 removal (BECCS+afforestation)*1

- CO_2 removal was higher in the transition quadrants (orderly and disorderly) than in the hot house world quadrant, confirming that CO_2 removal has a role to play in emission reduction targets both worldwide and in Japan.
- In most scenarios and IAMs, CO_2 removal demonstrated an upward trend beyond 2050, suggesting that CO_2 removal will continue to be required in the latter half of this century under the given temperature targets.
- However, in some REMIND scenarios, CO_2 removal was found to peak around the middle of this century, followed by a gradually declining trend toward 2100. In MESSAGE, a constant level of CO_2 removal was confirmed, regardless of the global warming level.

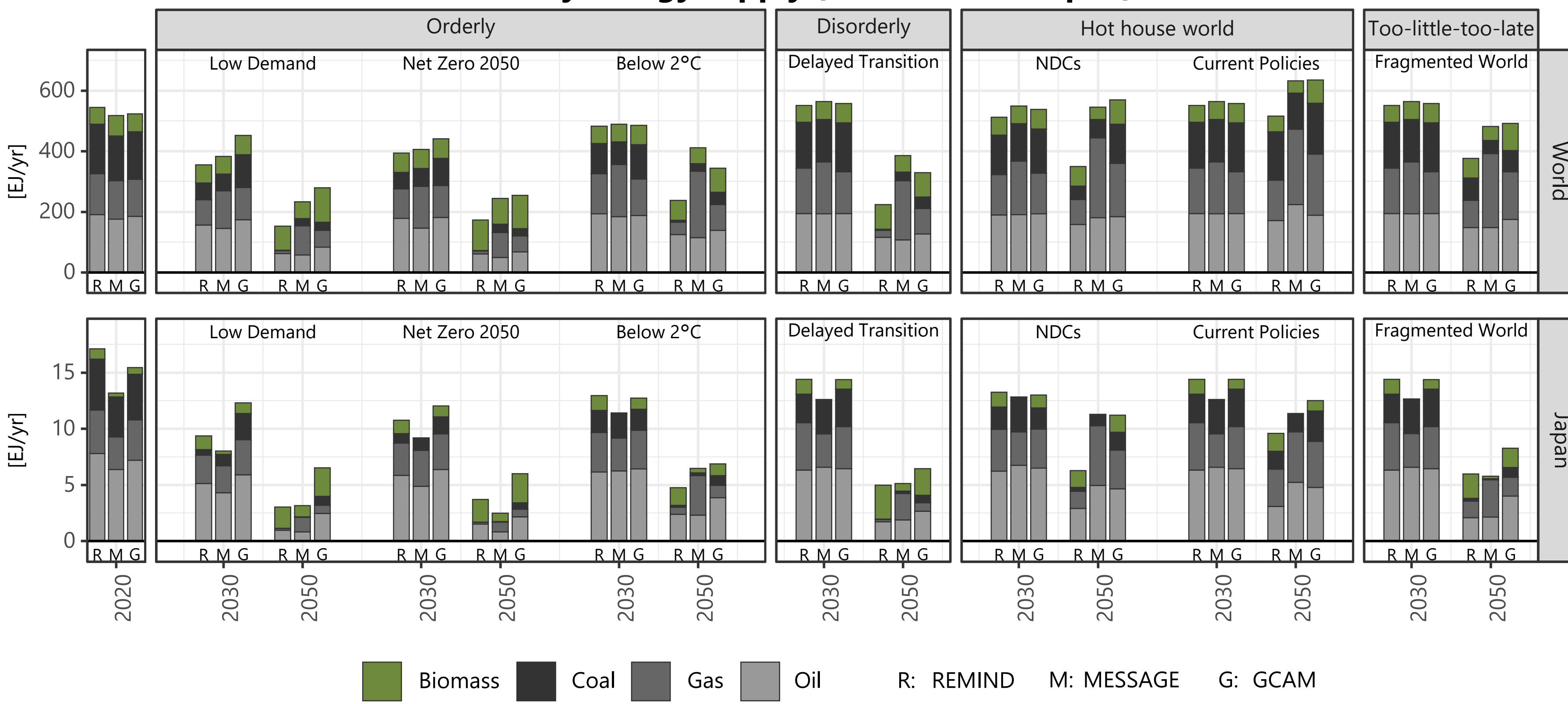


*1 IPCC (2021) defines carbon dioxide removal as "anthropogenic activities removing CO_2 from the atmosphere and durably storing it in geological, terrestrial, or ocean reservoirs, or in products." Here, the total for BECCS (bioenergy + CCS) and afforestation is used.

Primary energy supply

- Bigger decreases in primary energy supply (fossil fuels and biomass) both worldwide and in Japan were seen in scenarios with greater progress in reducing emissions. In the transition quadrants (orderly and disorderly), coal declined virtually to zero by 2050. At the same time, the extent of the decrease in natural gas and oil was smaller and a certain amount of supply was found to remain in 2050, even in scenarios in which net zero emissions were achieved.
- An upward trend in the volume of biomass supply through to 2050 was observed.

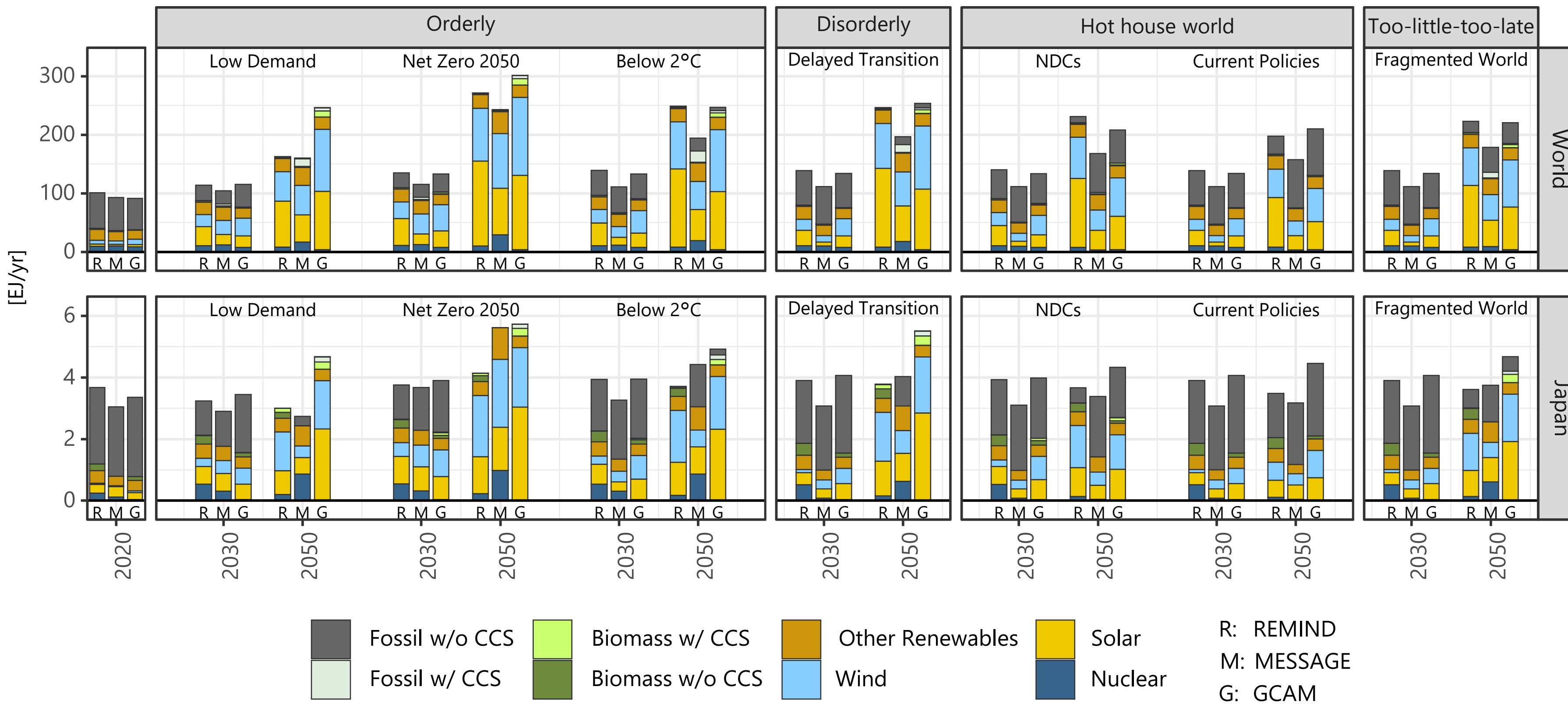
Primary energy supply (worldwide & Japan)



Secondary energy supply (electricity)

- Electricity supply increased through to 2050 both worldwide and in Japan in all scenarios. In addition to declining fossil fuel use, the proportion of renewable energy rose, principally from wind and solar.*1 This trend is more pronounced in scenarios with greater progress in reducing emissions, with wind and solar accounting for the majority of electricity supply in the Net Zero 2050 scenario.

Secondary energy supply (electricity, worldwide & Japan)

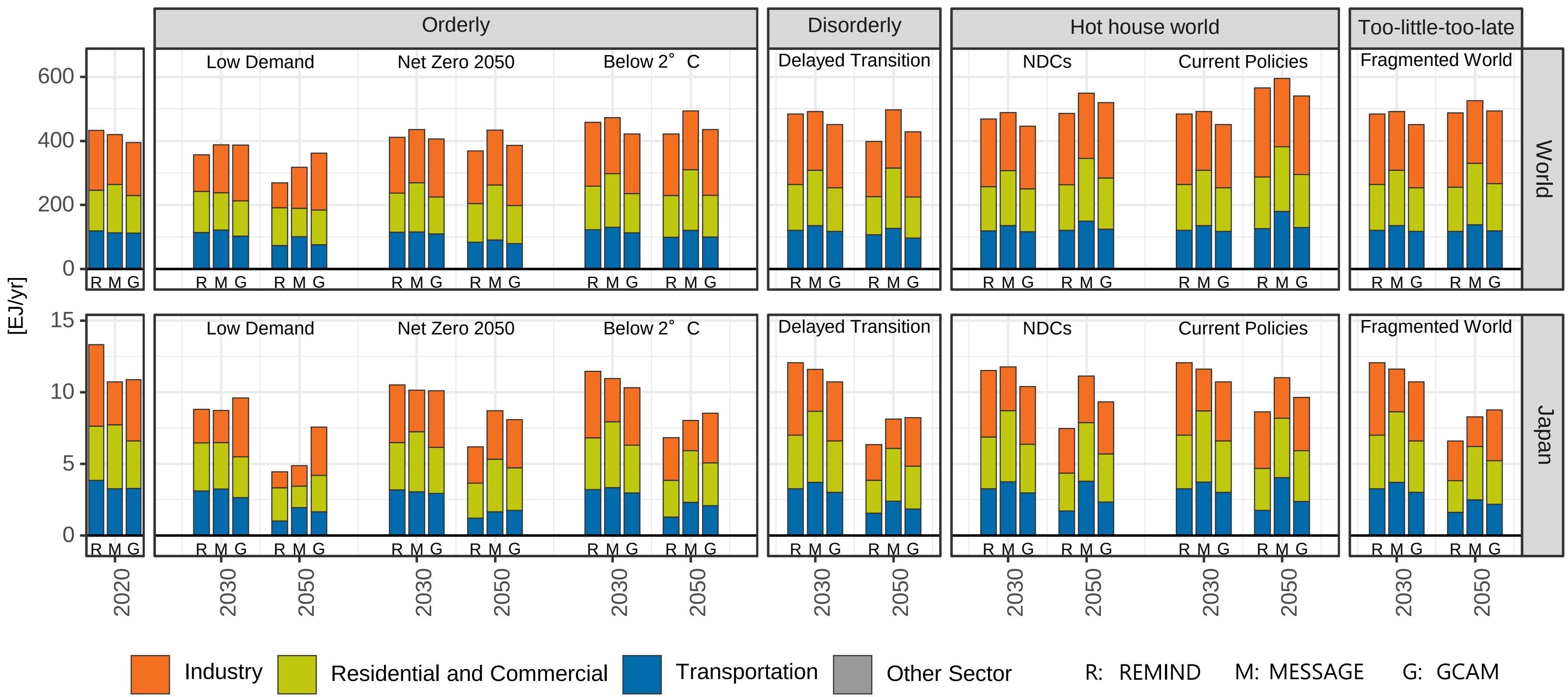


*1 While solar includes both solar photovoltaic power (PV) and concentrated solar power (CSP), PV accounts for the majority of solar in REMIND and MESSAGE. In GCAM, on the other hand, CSP accounts for the majority both worldwide and in Japan, but as there is limited potential for the introduction of CSP in Japan, the amount of renewable energy supply would appear to have been overestimated (see Financial Services Agency 2022, 2023).

Final energy consumption (sectoral)

- Low Demand, Net Zero, and Below 2°C had somewhat lower final energy consumption than NDCs and Current Policies, both worldwide and in Japan, suggesting that energy efficiency improves throughout the economy as emissions are reduced.

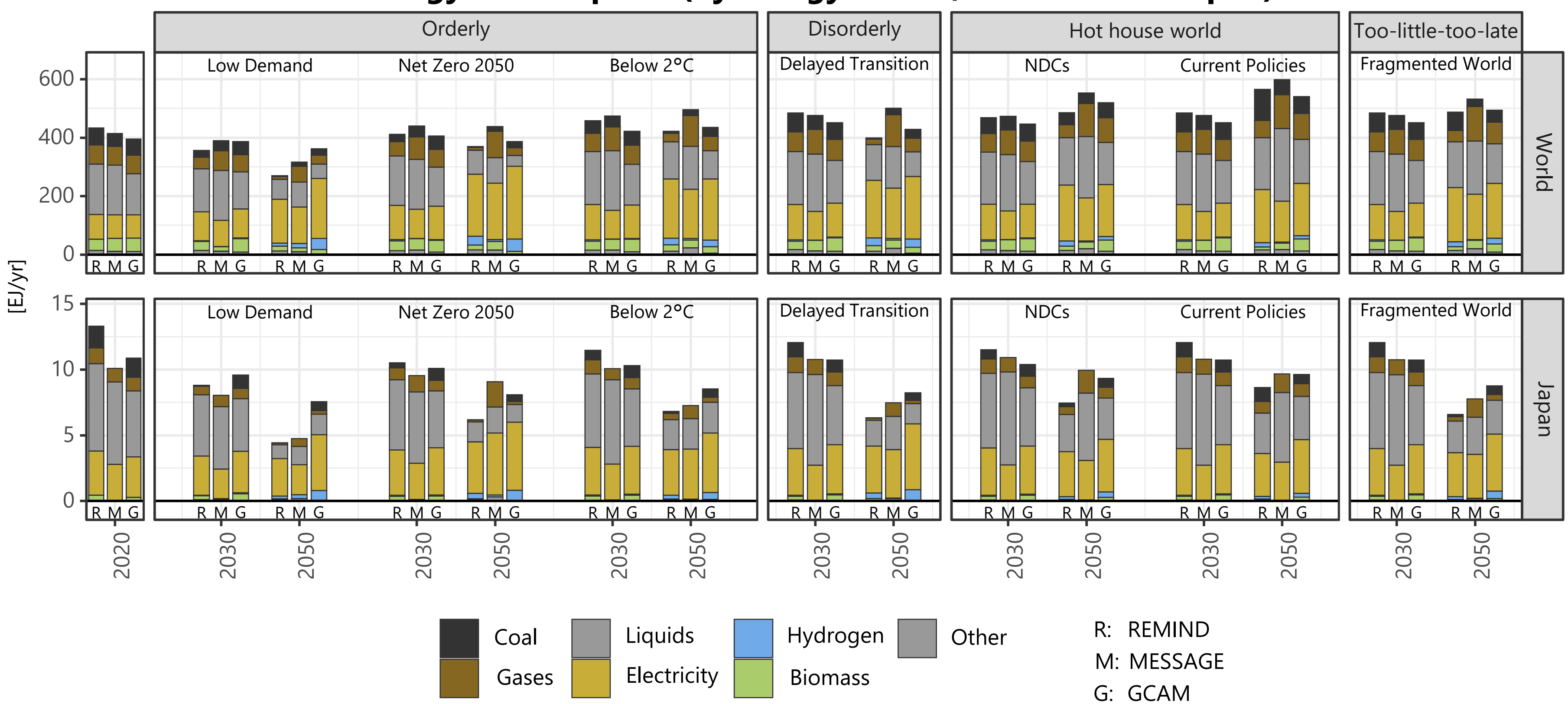
Final energy consumption (sectoral, worldwide & Japan)



Final energy consumption (by energy source)

- Scenarios with greater progress in reducing emissions had lower final energy consumption than NDCs and Current Policies, both worldwide and in Japan, demonstrating that the proportion of electricity is increasing. This suggested that reductions in energy-related emissions progress due to simultaneous advances in the decarbonization of electricity (p. 18) and the electrification of final energy demand.

Final energy consumption (by energy source, worldwide & Japan)*1

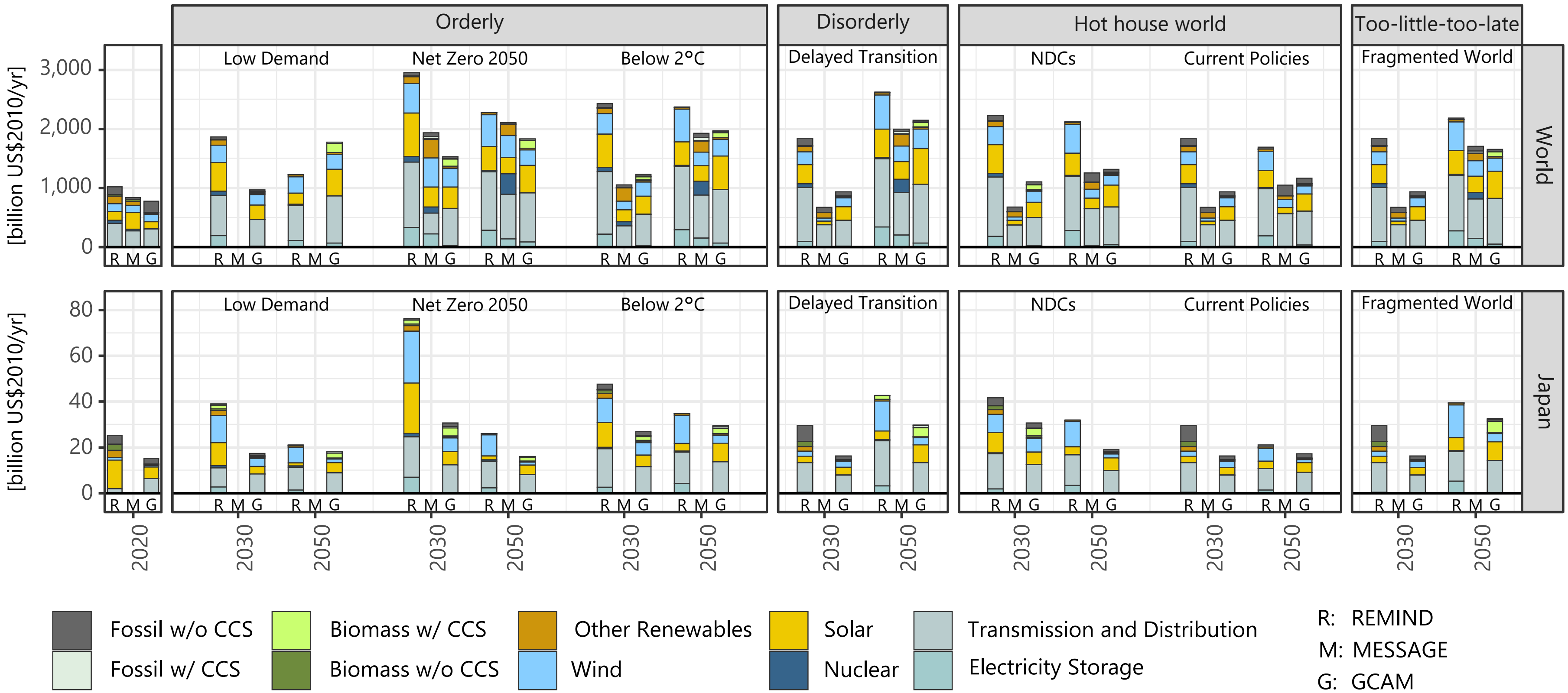


*1 In MESSAGE, figures for some years have not been reported, so total figures do not match the previous page in some cases.

Investment (electricity)

- Irrespective of the scenario or IAM, electricity distribution tended to account for a high share of investment, both worldwide and in Japan. Within power generation, wind and solar accounted for the majority of investment.
- While there was a tendency for investment in electric power supply to be higher in scenarios with greater progress in reducing emissions, the sums invested and the timing of the increase in investment differed from one IAM to another. REMIND stands out from the other IAMs in terms of the value of investment in 2030 in the Net Zero 2050 scenario, with prominent impacts from rapid transition in the Electricity sector compared with other scenarios.

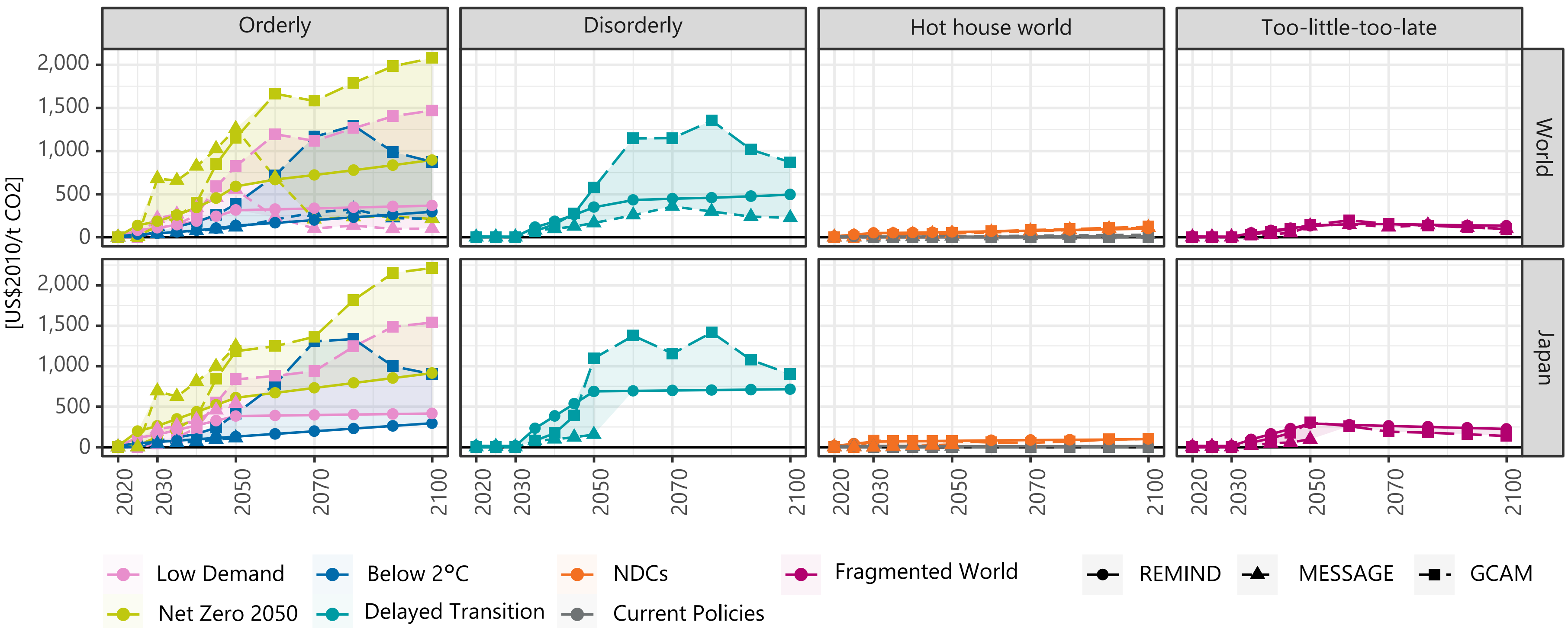
Energy-related investment (electricity, worldwide & Japan)



(Shadow) carbon prices

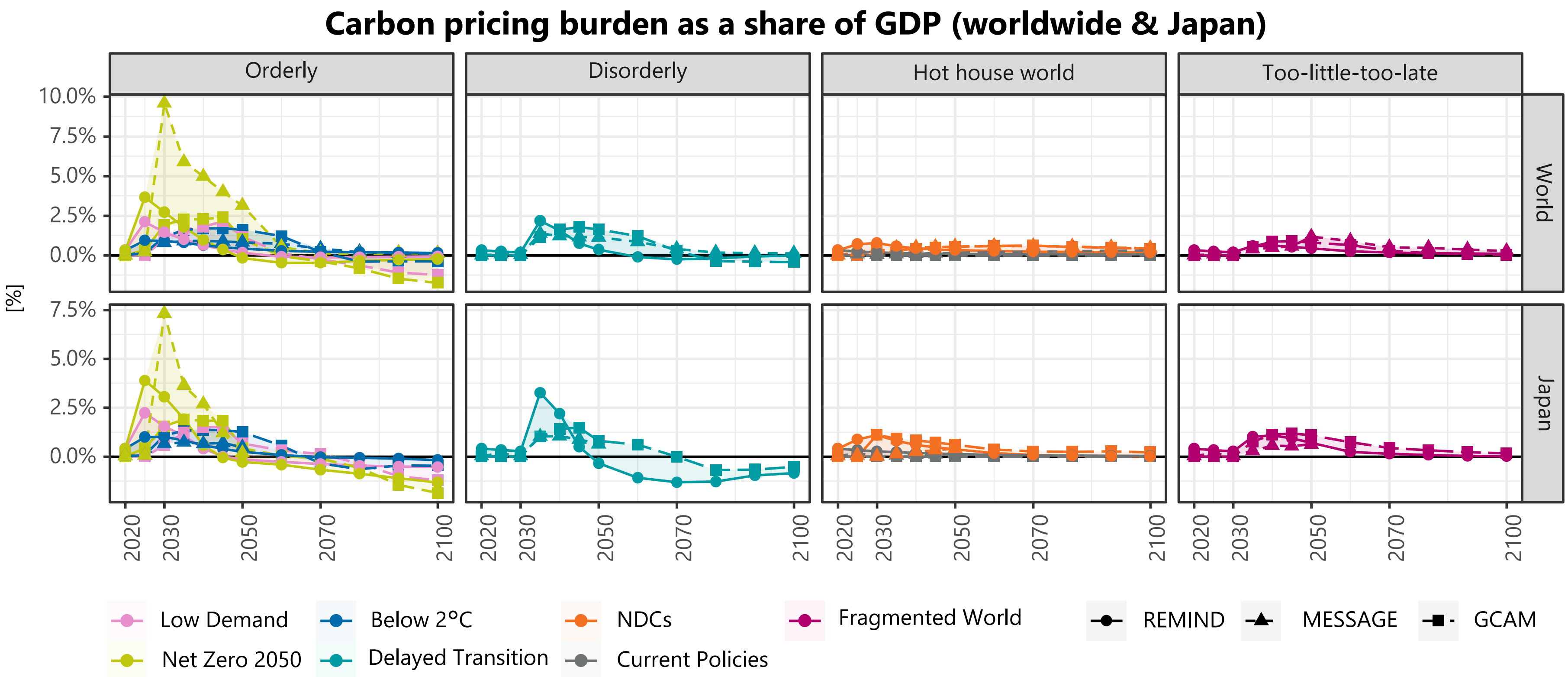
- The carbon prices reported in the Phase IV NGFS scenarios have been calculated after the fact using IAMs, in the form of shadow carbon prices that express the cost of measures to reduce GHG emissions.
- There was a tendency for the carbon price to be higher in scenarios with lower end of century warming; in scenarios in which the temperature rise was kept to below 1.5°C (Net Zero 2050 and Low Demand), the carbon price rose to US$300–1,200 by 2050 and to a maximum of at least US$2,000 by 2100, both worldwide and in Japan. However, there are considerable differences between IAMs, which shows that there is a great deal of uncertainty in forecasting carbon price levels.

Shadow carbon prices (worldwide & Japan)



Carbon pricing burden as a share of GDP

- When carbon pricing was imposed at the level of the (shadow) carbon prices on the previous page, the share of GDP for which it accounted increased between 2025 and 2030 in REMIND and MESSAGE under the Net Zero 2050 scenario, both worldwide and in Japan. From 2030, the burden of carbon pricing showed a tendency to contract across the economy as a whole, even when the carbon price level was raised, because the volume of emissions fell toward zero by 2050.*1
- In the Below 2°C and Delayed Transition scenarios, in which emissions reductions are delayed, the impact on carbon pricing as a share of GDP tended to be sustained for a comparatively long period.



*1 In some scenarios, the burden as a share of GDP is negative from 2050, because the volume of emissions is negative. This impact emerges in the macroeconomic assessment in the subsequent stage, in the form of government investment becoming slightly negative against the baseline in the Orderly quadrant scenarios (where half of government revenue from carbon pricing is recycled in the form of government investment) (pp. 77, 82).

Features of the Phase IV NGFS scenarios

1 CO_2 emissions /removal	• Both the Low Demand and Net Zero 2050 scenarios assume end of century warming below 1.5°C. In both these scenarios, worldwide and Japanese CO_2 emissions reached net zero by 2050, with zero to negative emissions thereafter. In 2050, residual emissions were observed in the Transportation and Industry sectors, while the Electricity and Land Use sectors reached negative emissions. • In the Fragmented World scenario, which assumes variation between regions, worldwide CO_2 emissions halved by 2050, whereas Japanese emissions reached a level close to zero by 2050. • Although CO_2 removal expanded through to 2100 in all scenarios in the transition quadrants, there were considerable differences between IAMs, suggesting a great deal of uncertainty in assumptions concerning removal technology.
2 Energy supply /consumption	• Although primary energy supply decreased more in scenarios with greater progress in reducing emissions, the extent of the decline in natural gas and oil was comparatively small, suggesting difficulty in finding alternatives. • Electricity (secondary energy) supply increased in all scenarios, with Net Zero 2050 in particular showing wind and solar accounting for the majority of this. • Final energy consumption was smaller in scenarios with greater progress in reducing emissions, suggesting that energy efficiency throughout the economy improves as emissions are reduced.
3 Energy costs	• While investment in electricity was higher in scenarios with greater progress in reducing emissions, the timing of the expansion of investment and the monetary value of investment differed from one IAM to another. In all scenarios, electricity distribution accounted for the highest share of investment.
4 Policy costs	• (Shadow) carbon prices showed a larger increase in scenarios with greater progress in reducing emissions. • In the Net Zero 2050 scenario, the burden of carbon pricing as a share of GDP increased between 2025 and 2030, then declined as reductions in emissions progressed thereafter.

2. Outline of the Integrated Assessment Models for Transition Risks

2.1 Features of key variables in the Phase IV scenarios

2.2 Features of the Phase IV scenarios based on comparison with Phase III

2.3 Features of scenarios added in Phase IV

Comparison with Phase III

- In addition to reflecting the latest economic situation since the Phase III scenarios were published, the Phase IV NGFS scenarios contain revised assumptions concerning the availability of carbon dioxide removal technologies[*1]. This section compares the Phase IV scenarios against the Phase III ones, centering on variables relevant to these matters.

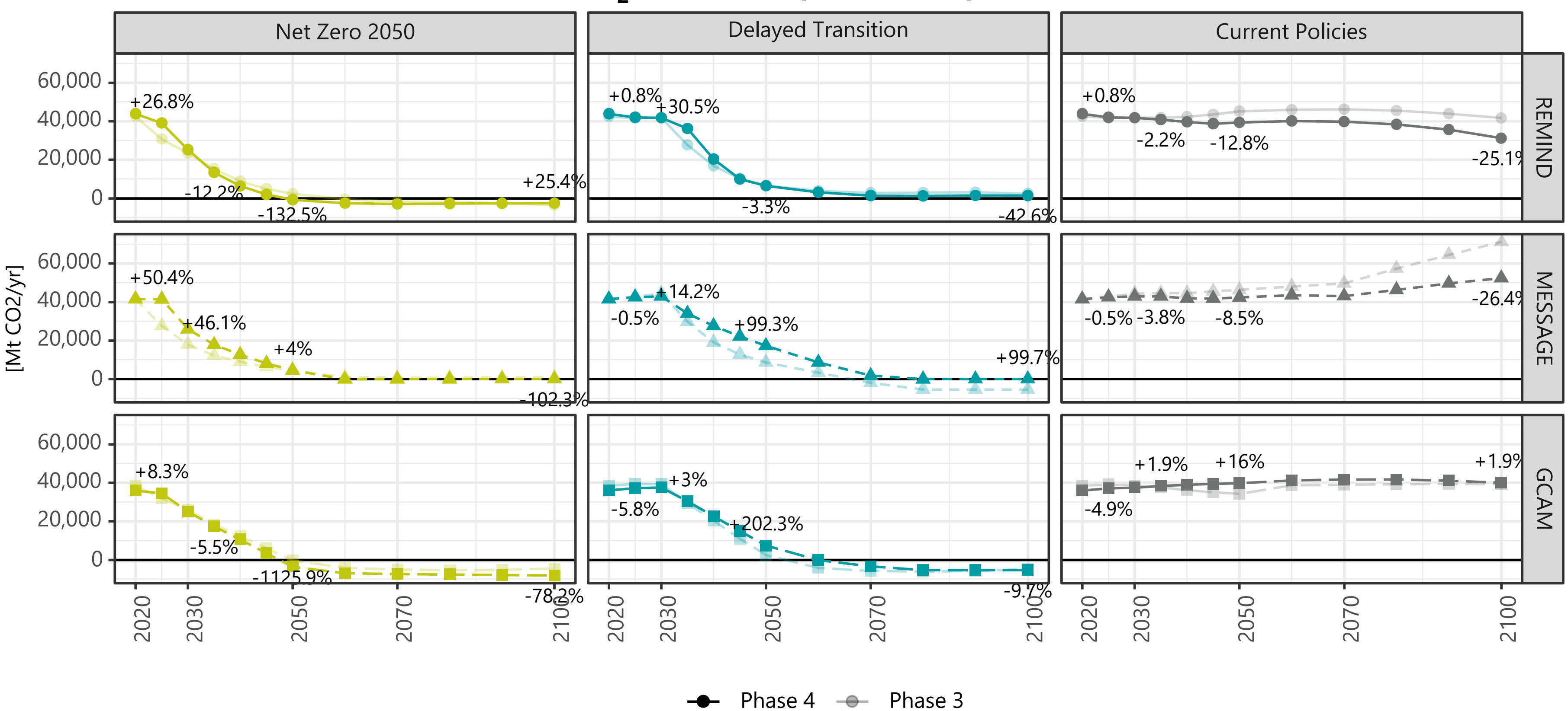
Factors contributing to change	Outline	Variables highlighted in this section
1 Reflection of the latest situation	Due to the post-pandemic economic recovery, CO_2 emissions from fossil fuels recovered to 2019 levels in 2022, so current emissions have risen. At the same time, energy supply worldwide has fallen, as the Ukraine crisis has caused constraints on the supply of Russian natural gas to Europe.	• CO_2 emissions
2 Revision of assumptions regarding carbon dioxide removal technologies	The fourth vintage explicitly limits availability of bioenergy with carbon capture and storage (BECCS) and does not consider direct air capture with carbon storage (DACCS) technologies.	• CO_2 removal
3 Impact on variables arising from revised assumptions	Due to the increase in current emissions, greater emissions reduction efforts will be required in order to keep temperature rises below a certain level.	• Carbon prices

*1 NGFS (2023b).

CO_2 emissions

- As stated in the Technical Documentation, CO_2 emissions were observed to be trending higher than in Phase III in REMIND and MESSAGE from 2025 to 2050 or thereabouts, due to the post-pandemic economic recovery.
- Conversely, in Current Policies, medium- to long-term emissions were observed to be trending lower than in Phase III, due to the reflection of the latest policies through to March 2023.

CO_2 emissions (worldwide)*1

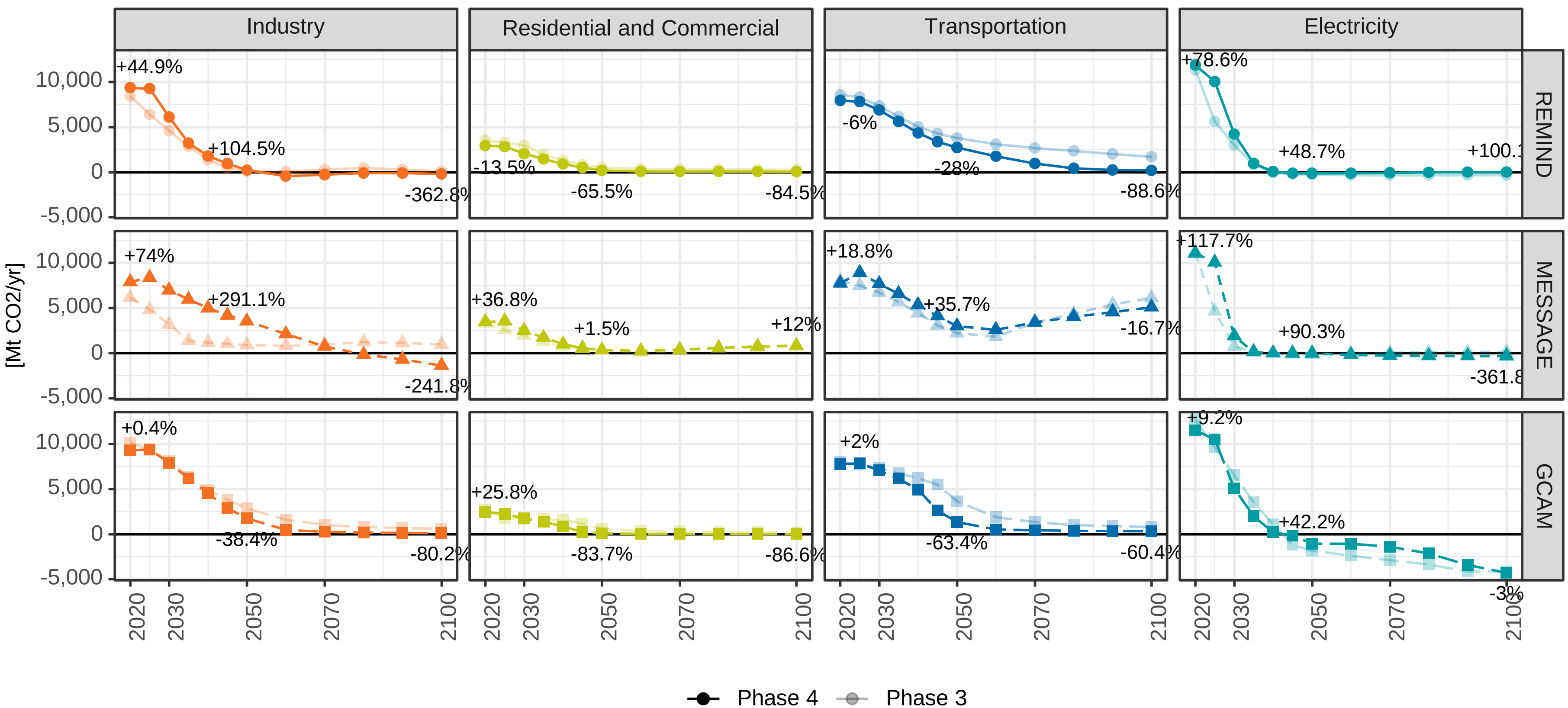


*1 Figures in the graphs indicate percentage change from Phase III to Phase IV.

CO_2 emissions (Net Zero 2050, sectoral)

- We examined on a sectoral basis the differences in CO_2 emissions between the third and fourth vintages identified on the previous page.
- In REMIND and MESSAGE, emissions in 2025 in the Industry and Electricity sectors had increased substantially. In these sectors, emissions were confirmed to have been revised on the basis of the current situation.
- In the Transportation sector, emissions in REMIND and GCAM had declined.

CO_2 emissions (Net Zero 2050, sectoral, worldwide)*1



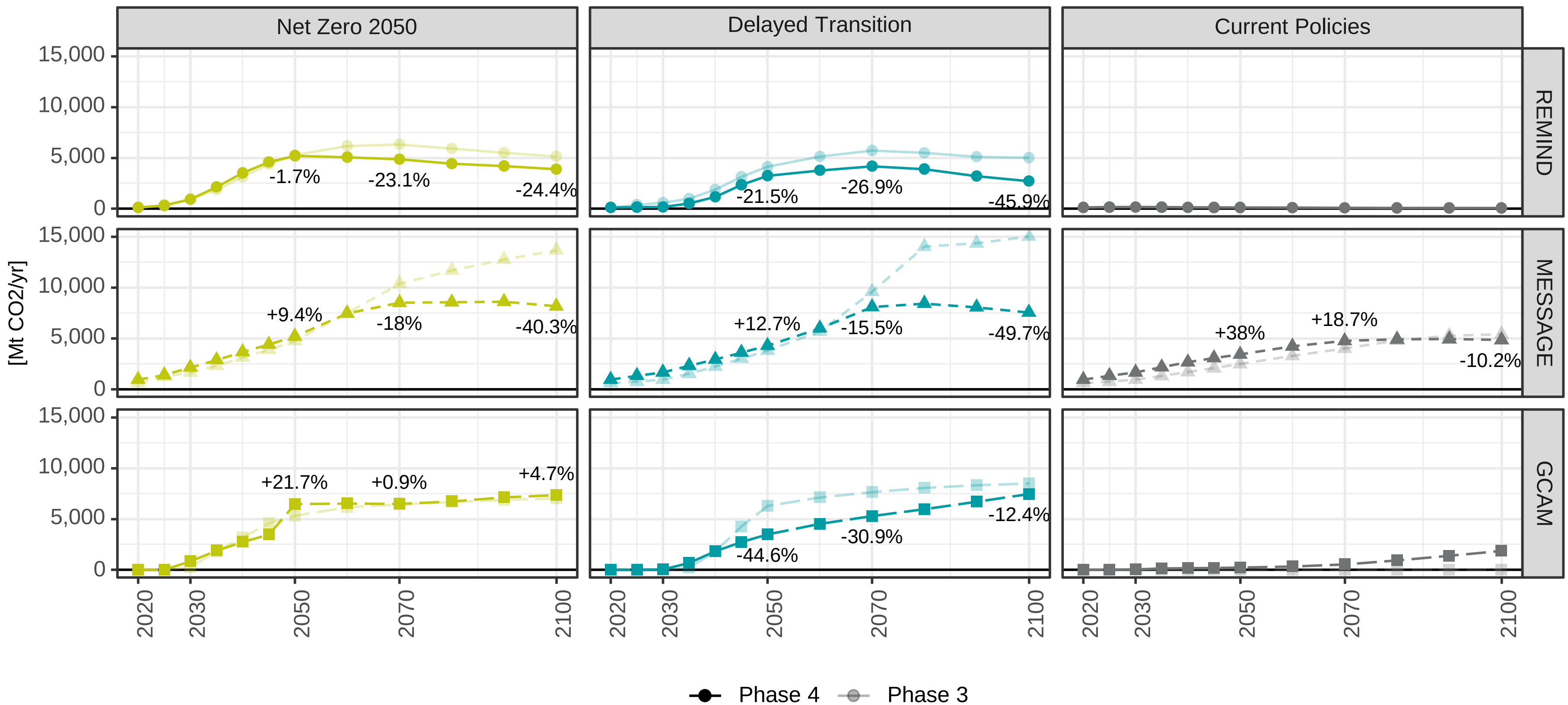
*1 Figures in the graphs indicate percentage change from Phase III to Phase IV.

CO_2 removal

- The Technical Documentation states that the availability of CO_2 removal technology has been revised in the Phase IV scenarios.

  The volume of CO_2 removed was confirmed to have actually fallen from Phase III in both REMIND and MESSAGE. In addition, the extent of the fall in CO_2 removal was greater in 2100 than in 2050, in both REMIND and MESSAGE.

CO_2 removal (worldwide)*1

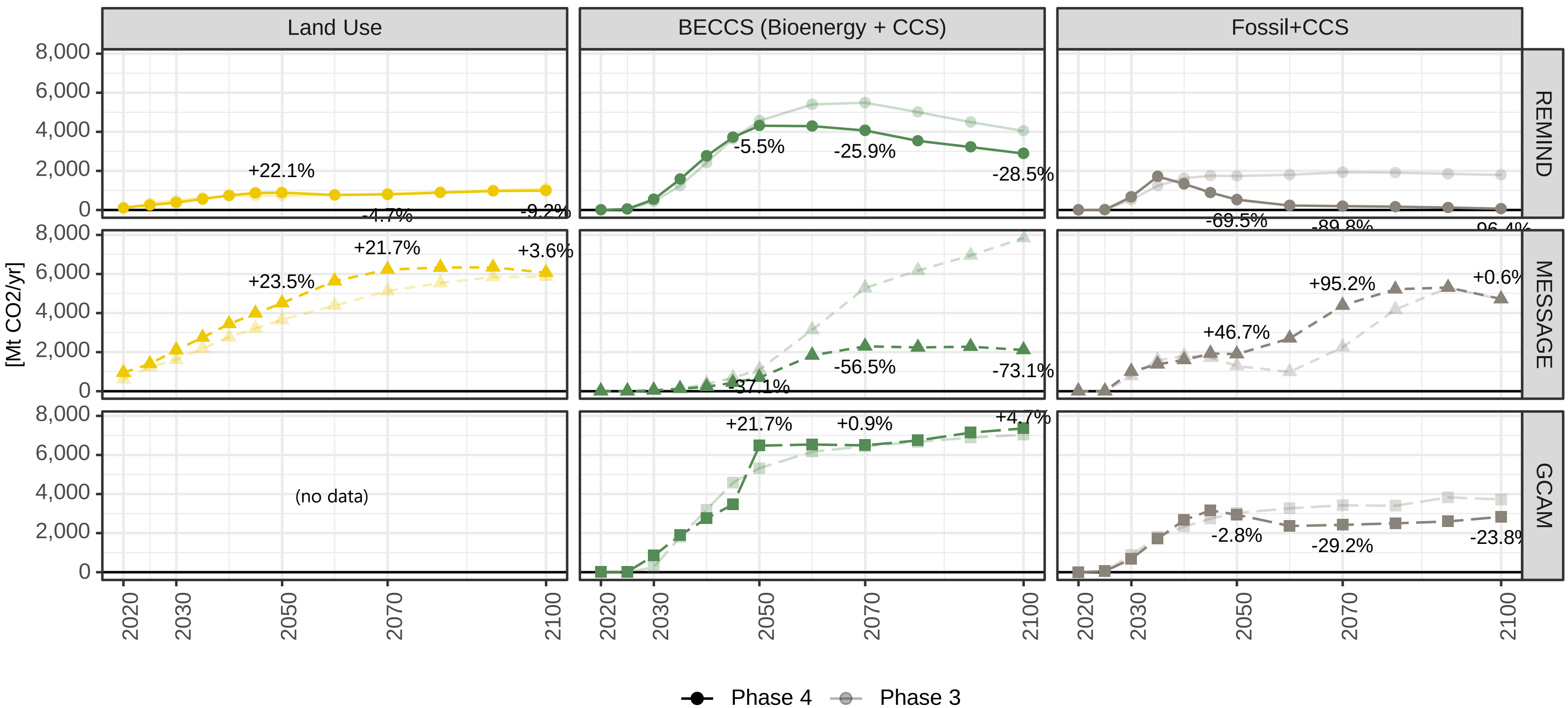


*1 Figures in the graphs indicate percentage change from Phase III to Phase IV.

CO_2 removal (Net Zero 2050, sectoral)

- Compared with Phase III, CO_2 removal declined substantially in Phase IV.
- The assumptions regarding CO_2 removal technology, including fossil fuels + CCS, were confirmed to be more conservative in the fourth vintage.

CO_2 removal (Net Zero 2050, sectoral, worldwide)*1

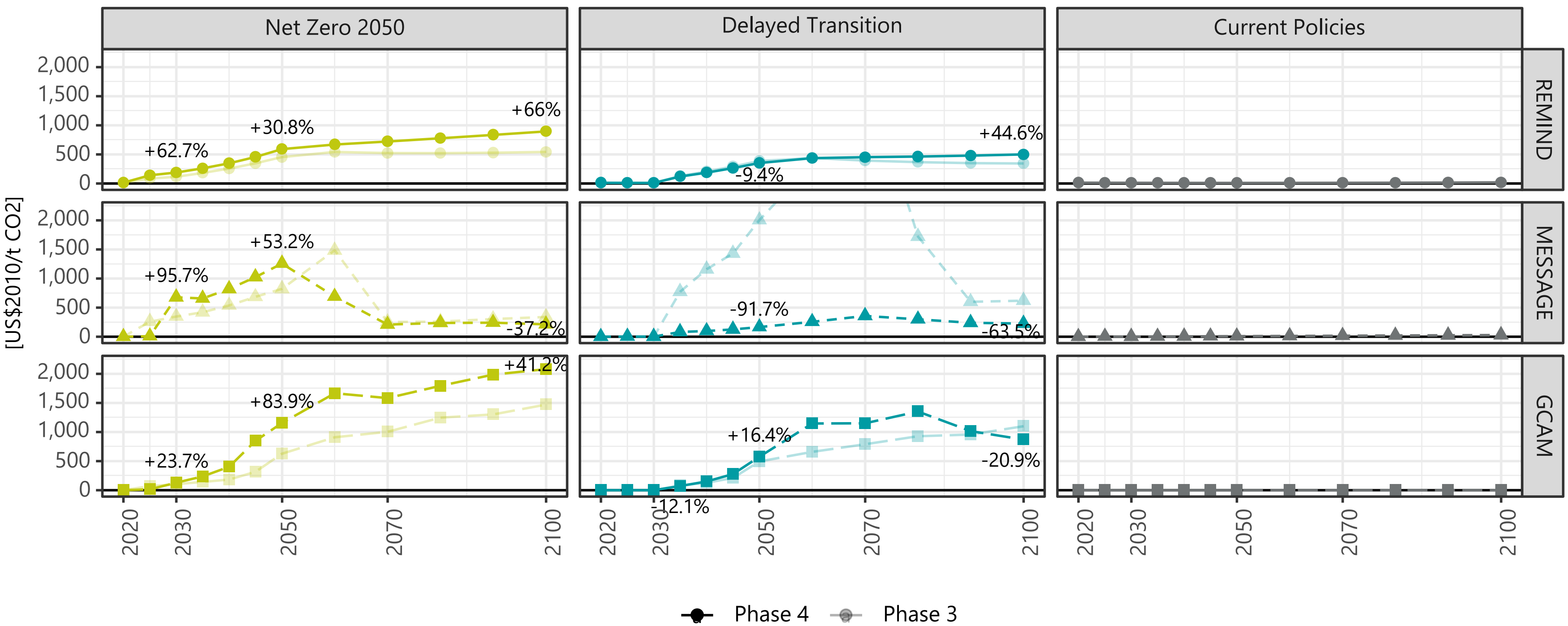


*1 Figures in the graphs indicate percentage change from Phase III to Phase IV.

(Shadow) carbon prices

- In the scenarios with greater progress in reducing emissions (Net Zero 2050 and Delayed Transition), the carbon price tended to be higher in the fourth vintage more or less consistently in both REMIND and GCAM. The increase in current emissions from Phase III to Phase IV is thought to reflect the rise in emissions reduction costs due to reduced availability of carbon dioxide removal technologies.
- On the other hand, in MESSAGE, the maximum carbon price was lower in Phase IV. Overall, the extent of uncertainty regarding future carbon price assumptions (numerical range between IAMs) can be assessed to have diminished somewhat in Phase IV, compared with Phase III.

Shadow carbon prices (worldwide)[*1]

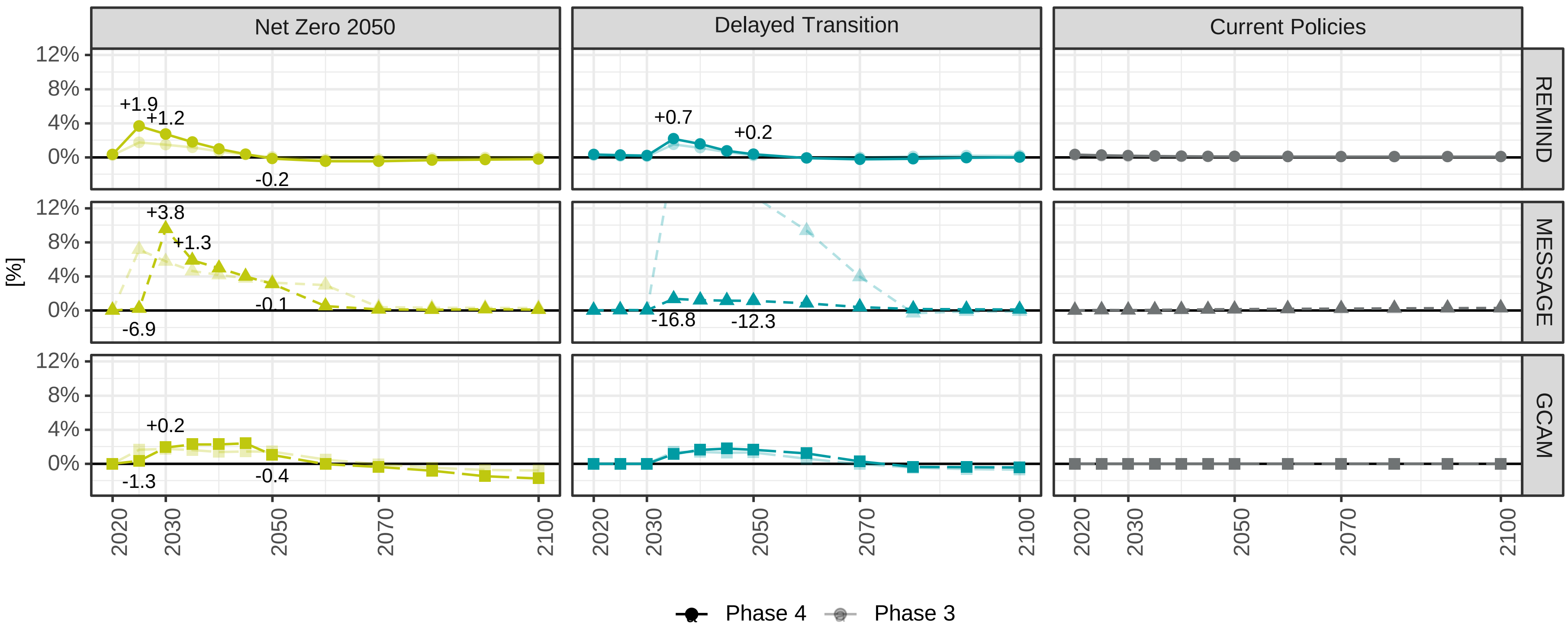


*1 Figures in the graphs indicate percentage change from Phase III to Phase IV.

Carbon pricing burden as a share of GDP

- When carbon pricing was imposed on carbon emissions at the level of the (shadow) carbon prices, the carbon pricing burden as a share of GDP was higher at the 2025–2030 peak in the Phase IV Net Zero 2050 scenario. This reflects the impact of delays in current emissions reductions, suggesting that the short-term shock caused by carbon pricing is greater in the fourth vintage.

Carbon pricing burden as a share of GDP (worldwide)*1

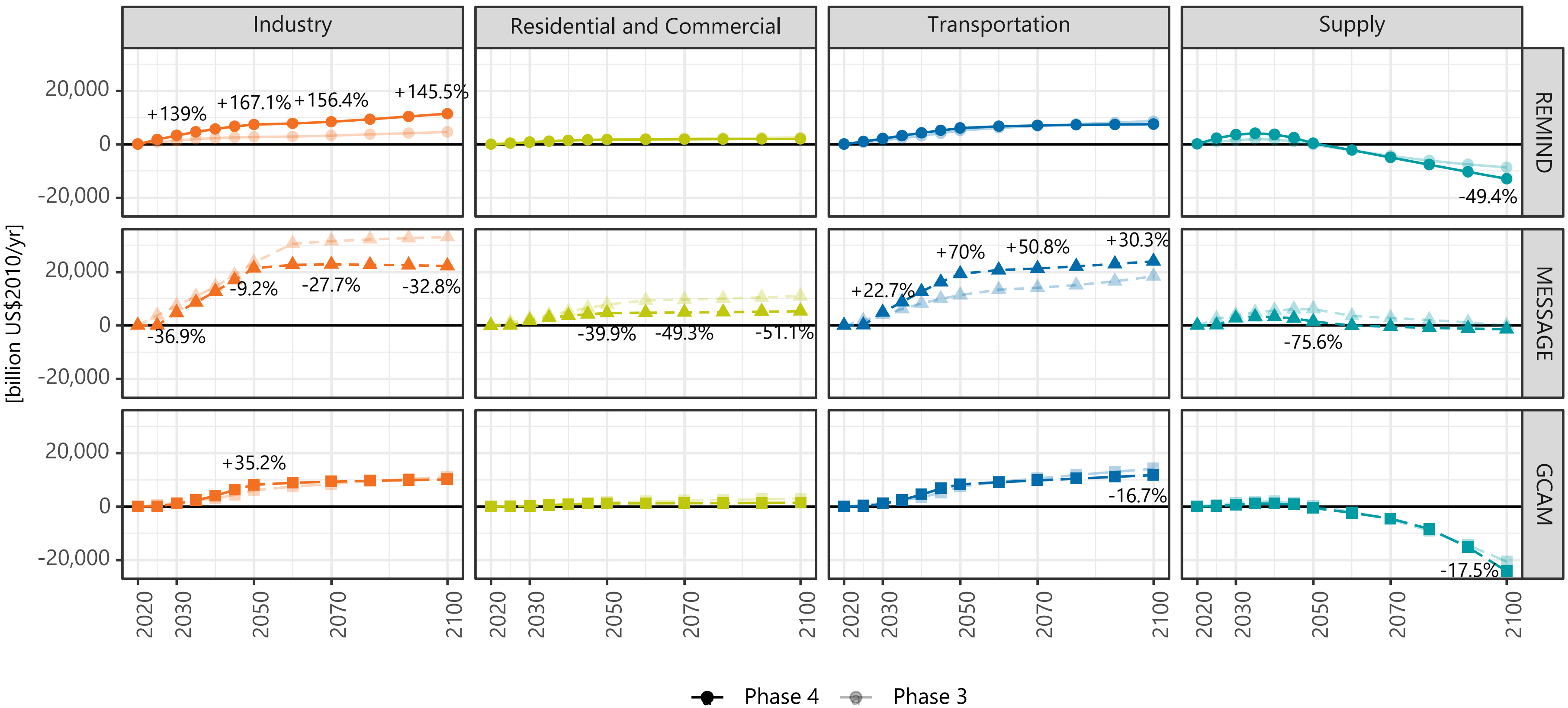


*1 Figures in the graphs indicate amount of change from Phase III to Phase IV.

Sectoral carbon pricing burden (Net Zero 2050)

- While the sectoral carbon pricing burden varied from one scenario to another, a tendency for the total value of the burden to increase through to the latter half of this century was observed in Industry and Transportation, which are regarded as sectors in which reductions are difficult to achieve.
- There was no definite trend in the scale of sectoral burdens or differences from Phase III; whereas the burden in the Industry sector was greater in Phase IV in the case of REMIND, the burden in that sector was lower in MESSAGE, while the burden in the Transportation sector increased.

Sectoral carbon pricing burden (Net Zero 2050, worldwide)*1



*1 Figures in the graphs indicate percentage change from Phase III to Phase IV.

Features of the Phase IV scenarios based on comparison with Phase III

1 Reflection of the latest situation	• Due to the revision of current emissions reductions, emissions in 2025–2030 in the Net Zero 2050 scenario have increased from the third vintage. Conversely, emissions in the Current Policies scenario showed a long-term decline, due to the reflection of countries' latest policies through to March 2023. • Particularly notable increases in emissions arising from the revision of current emissions reductions were observed in the Industry and Electricity sectors.
2 Revision of assumptions regarding carbon dioxide removal technologies	• Carbon dioxide removal technologies have been revised from Phase III levels in Phase IV. However, there was a pronounced decline in CO_2 removal from 2050. In Net Zero 2050, CO_2 emissions reach net zero by 2050, but carbon dioxide removal was not thought to have a great impact on net emissions in 2050. • Not only NECCS, but also fossil fuels + CCS saw substantial declines. Overall, CO_2 storage potential was confirmed to have been conservatively revised.
3 Impact on variables arising from revised assumptions	• A rise in (shadow) carbon prices from the third to fourth vintages was confirmed. In addition to increased current emissions and delayed emissions reductions, the envisaged cost of emissions reductions was confirmed to have risen in the medium to long term, due to the revision of future carbon dioxide removal technology availability. • The carbon pricing burden as a share of GDP saw a particular increase from the third vintage in the Net Zero 2050 scenario. This suggested that the difficulty of achieving net zero in 2050 has increased throughout the economy from Phase III to Phase IV. *1

*1 NGFS (2023a) states that in the fourth vintage, "[t]he NGFS orderly scenarios are now more disorderly, reflecting climate policy delays and the energy crisis following the war in Ukraine."

2. Outline of the Integrated Assessment Models for Transition Risks

2.1 Features of key variables in the Phase IV scenarios
2.2 Features of the Phase IV scenarios based on comparison with Phase III
2.3 Features of scenarios added in Phase IV

Summary of features of new scenarios

- Two new scenarios have been introduced in the Phase IV NGFS scenarios. This section highlights the features of these new scenarios based on a comparison with existing scenarios where CO_2 emissions are close.

Considerations	Outline	Variables highlighted in this section
1 Low Demand scenario considerations	While the Low Demand scenario has more or less the same level of CO_2 emissions as Net Zero 2050, carbon prices remain at a low level. We consider sectors in which demand is reduced and the impact of reductions in demand.	• CO_2 emissions (sectoral) • Final energy consumption (sectoral) • Volume of production (Industry sector)
2 Fragmented World scenario considerations	We consider the impacts resulting from regional variation in the level of policy implementation. Countries that have set net zero targets and year set for achieving the target*1 (Year of achievement is 2050 unless otherwise specified) • EU • UK • Russia (2060) • U.S. • Canada • Japan • South Korea • China (2060) • India (2070) • Indonesia (2060) • Australia • New Zealand • Argentina • Brazil • Colombia • South Africa	• CO_2 emissions (sectoral) • Carbon prices (by region)

*1 NGFS (2023b) Table 38.

CO_2 emissions (sectoral)

- While no major differences between the two scenarios were identified in terms of sectoral CO_2 emissions, differences between the IAMs were identified. For example, Industry sector emissions in 2030 were low in REMIND, whereas MESSAGE showed ongoing residual emissions in the Industry sector beyond 2050, but low emissions from the Transportation sector.

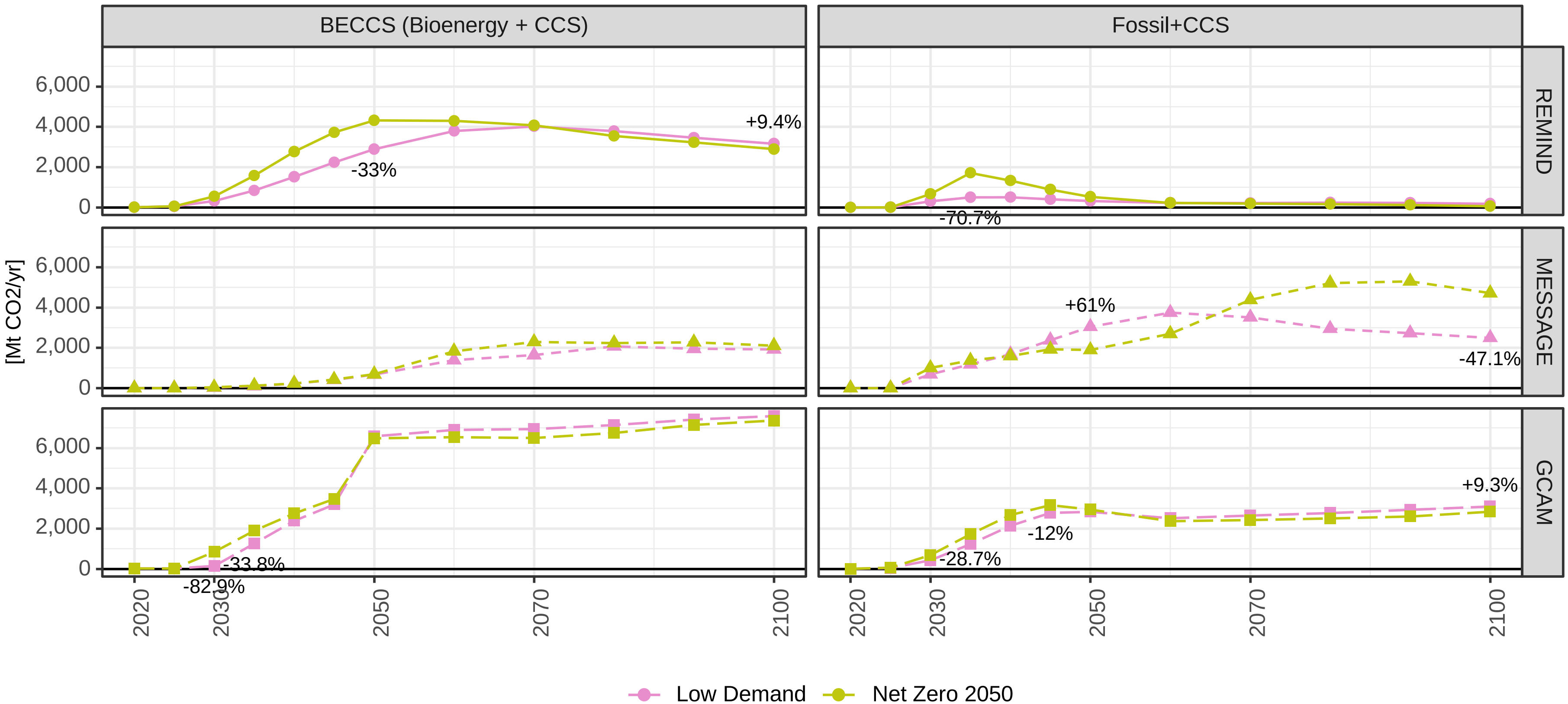
CO_2 emissions (sectoral, worldwide)*1

*1 Figures in the graphs indicate percentage change in Low Demand compared with Net Zero 2050.

CO_2 removal

- In REMIND, CO_2 removal due to bioenergy + CCS (BECCS) and fossil fuels + CCS were found to show a marked decline in the Low Demand scenario. On the other hand, there was virtually no change in BECCS in MESSAGE, while fossil fuels + CCS was higher in the Low Demand scenario in 2050.

CO_2 removal (by technology, worldwide)*1

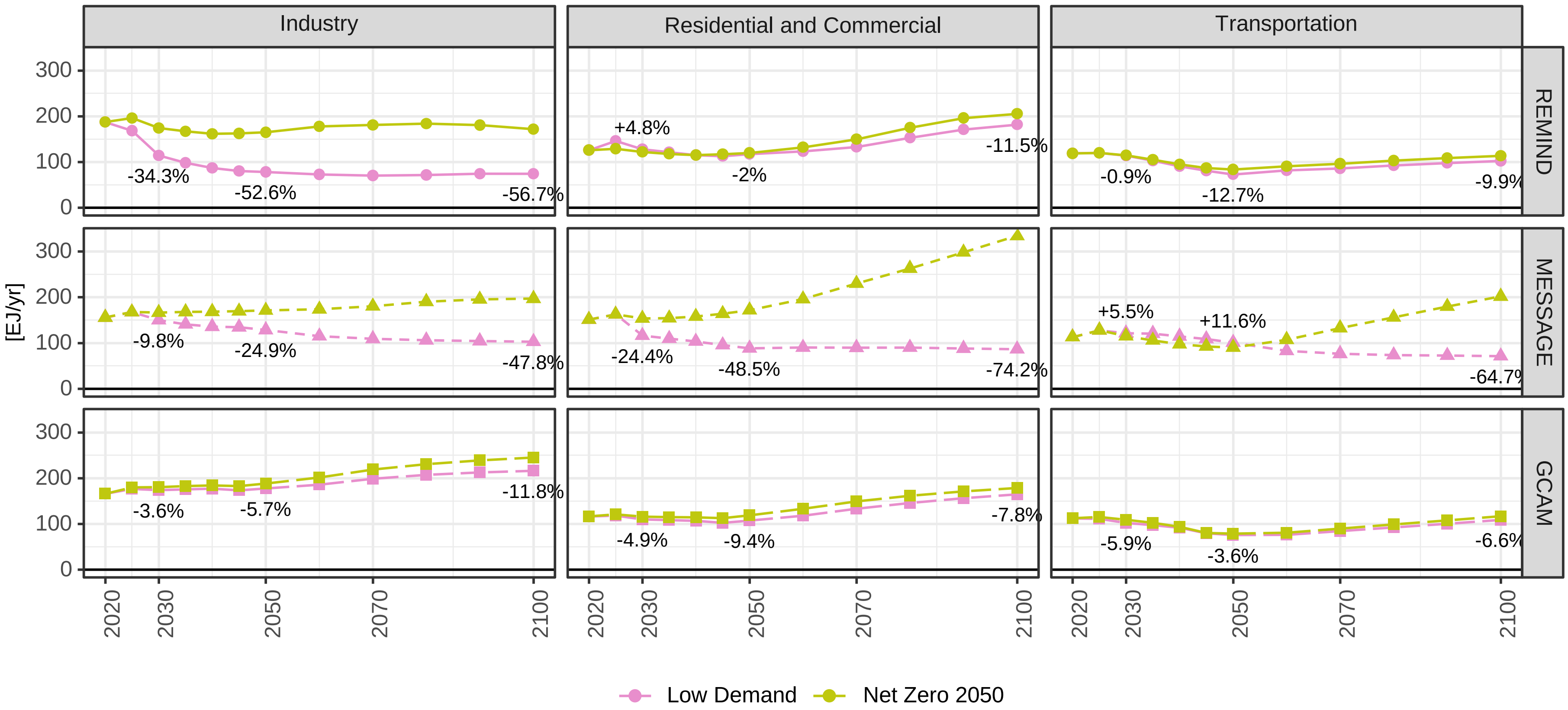


*1 Figures in the graphs indicate percentage change in Low Demand compared with Net Zero 2050.

Final energy consumption (sectoral)

- Final energy consumption was found to show a decline in the Low Demand scenario.
- REMIND showed a marked fall in energy consumption in the Industry sector, while in MESSAGE, the decreases were pronounced in the Industry, Residential and Commercial, and Transportation sectors.

Final energy consumption (sectoral, worldwide)*1

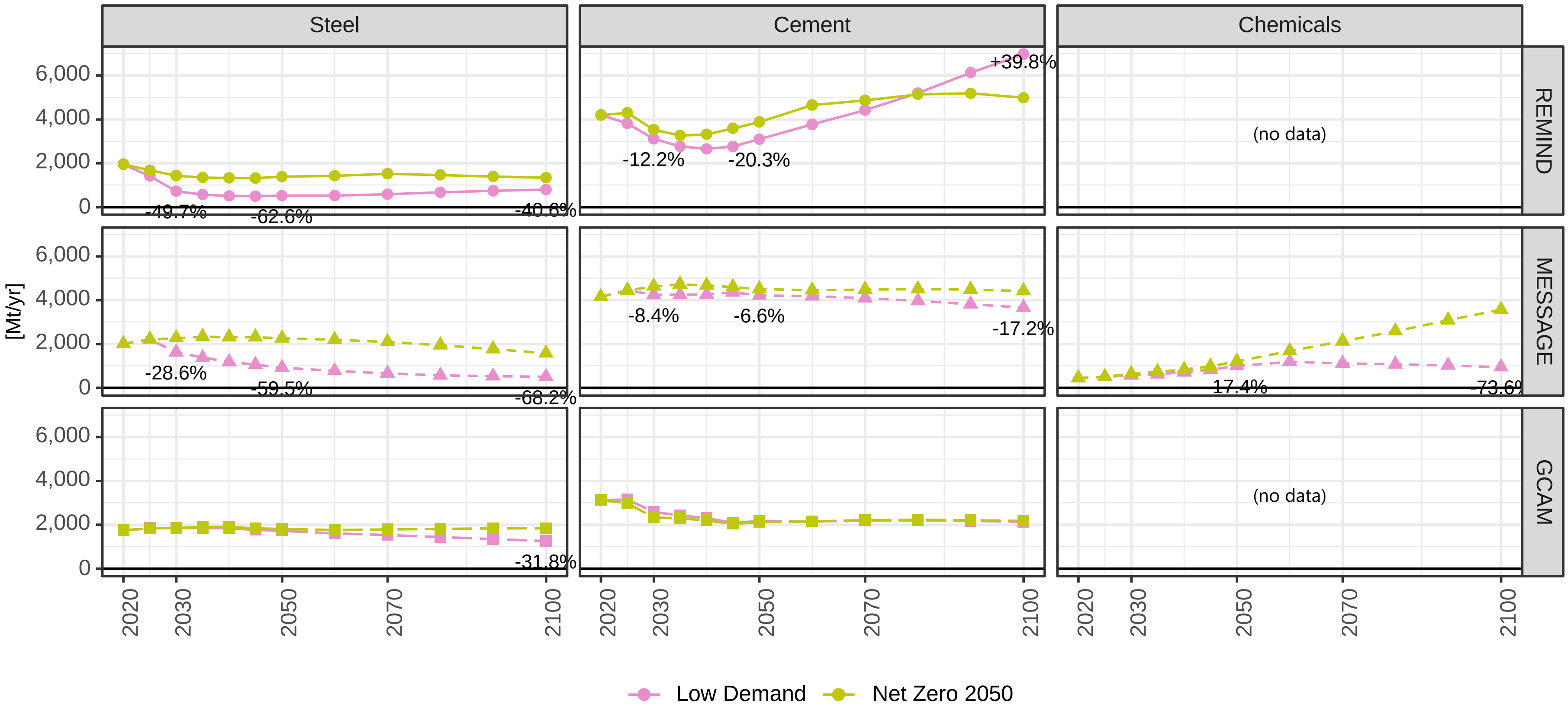


*1 Figures in the graphs indicate percentage change in Low Demand compared with Net Zero 2050.

Volume of production (Industry sector)

- A marked decline in the volume of production in the Industry sector was found in both REMIND and MESSAGE.

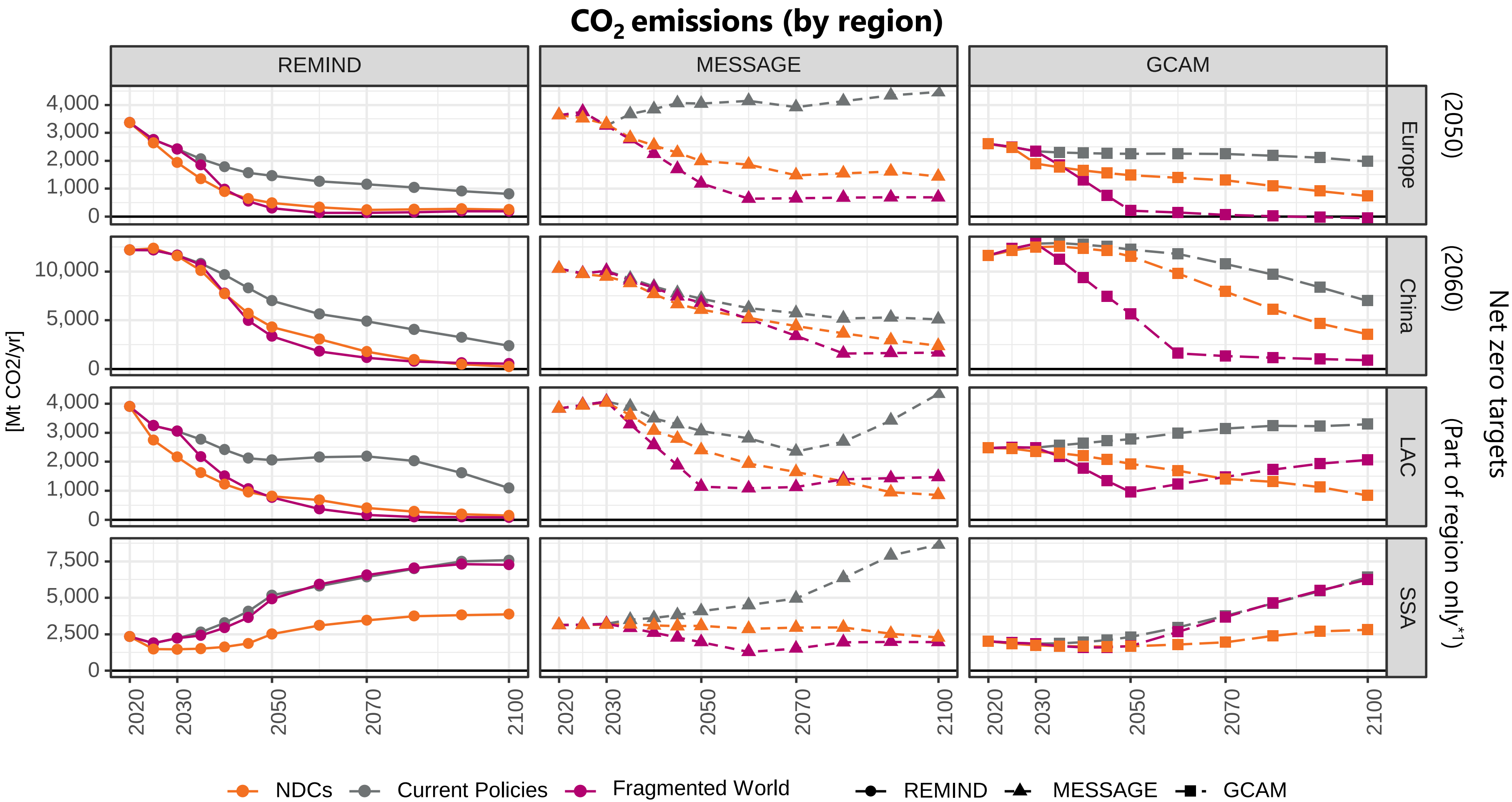
Volume of production in the Industry sector (worldwide)*1



*1 Figures in the graphs indicate percentage change in Low Demand compared with Net Zero 2050.

CO_2 emissions (by region)

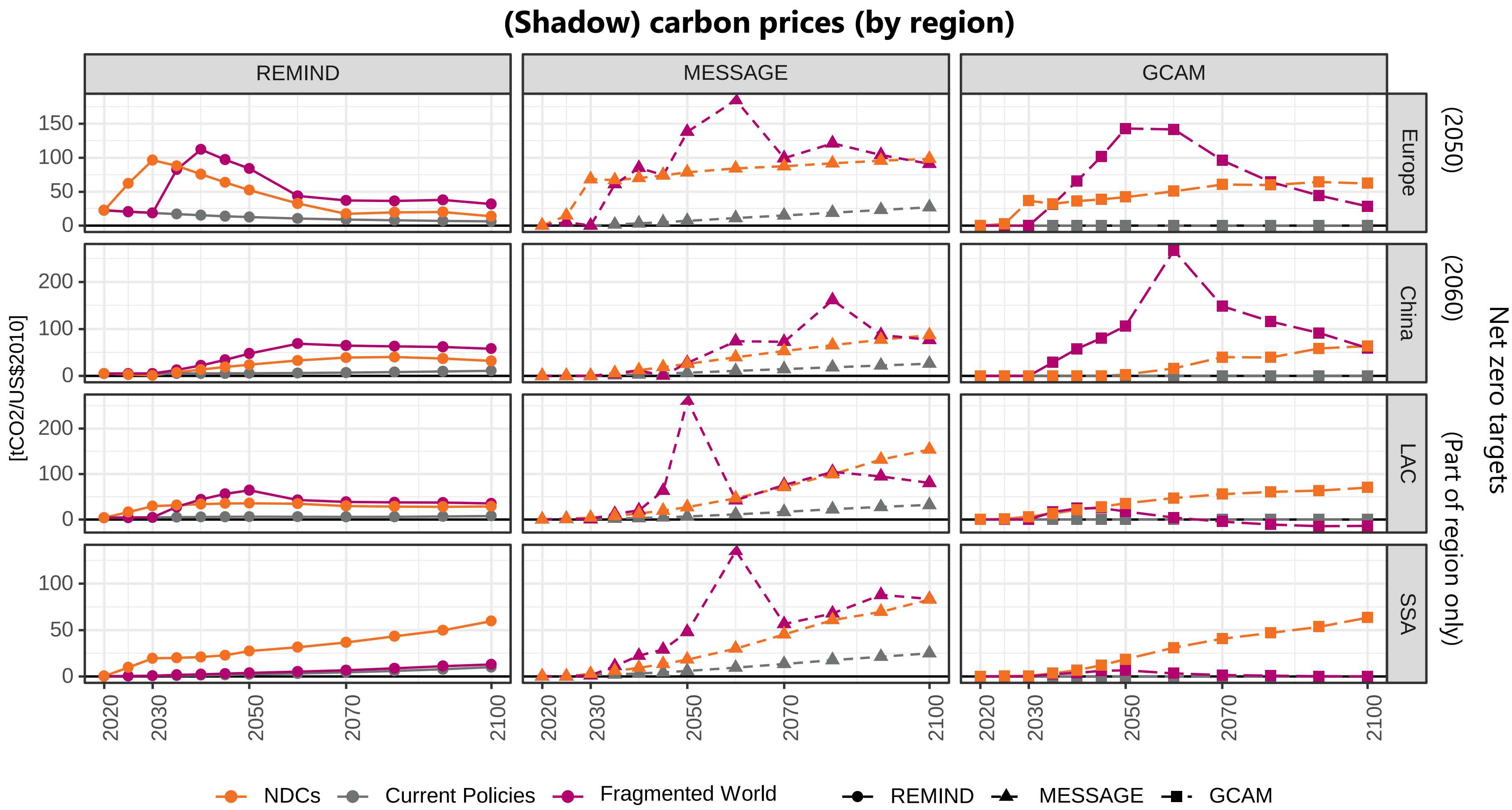
- In the Fragmented World scenario, different emission pathways have been set for regions that have declared a target of achieving net zero and regions that have not.
- In regions that have declared a net zero target, reductions in emissions progress at a level equivalent to or greater than their NDCs, but in regions where only part of the region has declared net zero targets, the degree of progress in reducing emissions differs according to the IAM.



*1 LAC (Latin America and the Caribbean): Argentina, Brazil, Colombia (2050); SSA (Sub-Saharan Africa): South Africa (2050).

(Shadow) carbon prices

- As with CO_2 emissions, (shadow) carbon prices are set at a level equivalent to or greater than NDCs in regions that have declared a net zero target, but in regions where only part of the region has declared net zero targets, levels differ according to the IAM.



*1 LAC: Argentina, Brazil, Colombia (all 2050); SSA: South Africa (2050).

Features of scenarios added in Phase IV

1 Validity of the Low Demand scenario	• While the rise in temperature is higher than in Net Zero 2050, reduced demand due to behavioral changes keeps (shadow) carbon prices at a low level as well. Looking at the situation by sector, emissions were low in the Industry sector in REMIND, and in the Transportation sector in MESSAGE. • The degree of reduction in energy demand was particularly large in the Industry sector, suggesting that it stems from a decrease in the volume of production in the high-emitting Steel and Chemical subsectors. Low Demand can be interpreted as a scenario that achieves emissions reductions in excess of Net Zero 2050 through reduced demand in some high-emitting subsectors. • Although the overall carbon price level is kept low in Low Demand, the impact of reduced demand on specific sectors is not reflected in carbon prices, so there is thought to be room for improvement (data for Low Demand have not been provided in the assessment of macroeconomic impacts in the subsequent stage).
2 Impact of the Fragmented World scenario	• Differences in emissions and carbon price levels were observed between regions that have declared net zero targets and other regions. • Regions that have not declared net zero targets are deemed to continue with existing policies, but emissions and carbon price levels differ according to the IAM. In the IAMs, except for major countries, multiple countries are modeled as a single region, with regions that have declared net zero targets mixed together with regions that have not. In such regions, there would appear to be differences between IAMs in terms of the target levels set.

3. Methodologies and Data Concerning Physical Risks

Products relating to physical risks and updates in the Phase IV scenarios

- This part summarizes the features of methodologies and data relating to the assessment of the impacts of physical risks in the Phase IV scenarios.

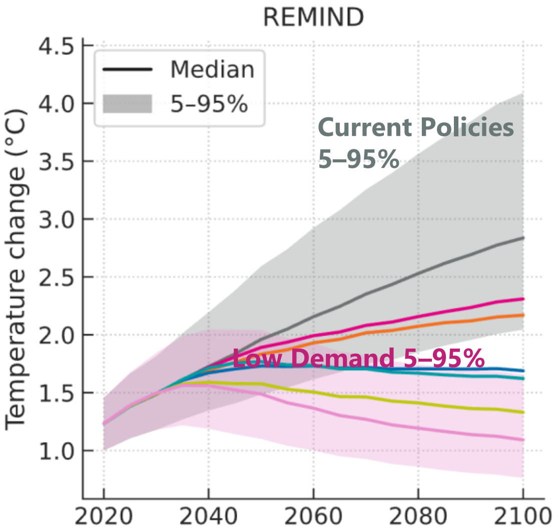
3.1 Methodologies concerning the assessment of physical risks	❶ Assessment of chronic risk impacts	• In the Phase IV scenarios, as in Phase III, assessment of chronic risk impacts is carried out by means of a reduced complexity earth system model (MAGICC) and damage functions. - Calculation of the global warming level (global average temperature change against the 1850–1900 baseline) in each scenario by means of the reduced complexity earth system model. - Calculation of country-level temperature change based on scaling of the global warming level, and calculation of country-level GDP impacts using damage functions.
	❷ Assessment of acute risk impacts	• Methodologies and data relating to the macroeconomic impacts of acute risks have been enhanced in the Phase IV scenarios. - New methodologies have been used to estimate the impacts of four hazards (physical risk factors). - In addition to floods and cyclones, which were included in Phase III, two more hazards are included in the Phase IV modeling: heatwaves and droughts. For each of these hazards, channels of transmission thought to be most strongly connected have been used to build the models. - In Phase IV, results of country-level impact assessments are provided (Phase III provided results only at the worldwide level).
3.2 Data provided in Phase IV	❸ Data on climate and economic indicators	• As in Phase III, the Phase IV scenarios provide data on various climate and economic indicators using Earth system models and climate impact models. - 33 chronic and acute risk variables linked to the global warming level are provided at the country level.

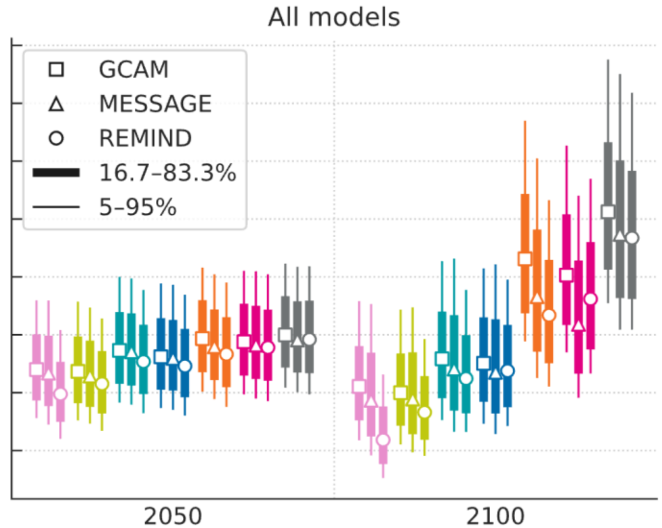
3. Methodologies and Data Concerning Physical Risks

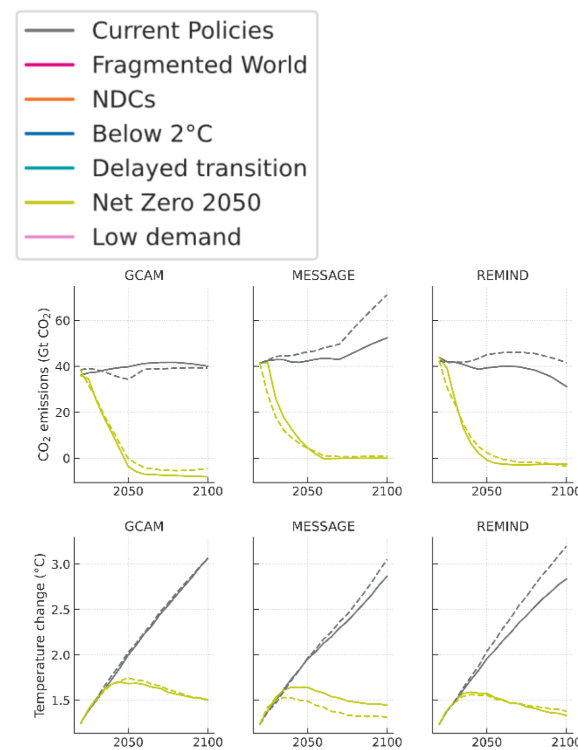
3.1 Methodologies concerning the assessment of physical risks
3.2 Data provided in Phase IV

Chronic risk assessment procedure 1/4: IAM emissions ⇒ Global warming level

- The method is the same as in Phase III. Updates in Phase IV relate solely to the composition of IAM scenarios and the level of emissions therein.
  - While the Low Demand scenario is close to Net Zero 2050, the global warming level is positioned lower in REMIND.
  - Variance in temperature due to differences in emissions also emerges in the scenarios that the fourth vintage has in common with Phase III (graphs bottom right).
- Global warming levels are calculated probabilistically from IAM emissions using a reduced complexity earth system model (MAGICC).
  - There are no conspicuous differences between the scenarios in terms of the range of uncertainty in climate forecasts for the first half of this century.







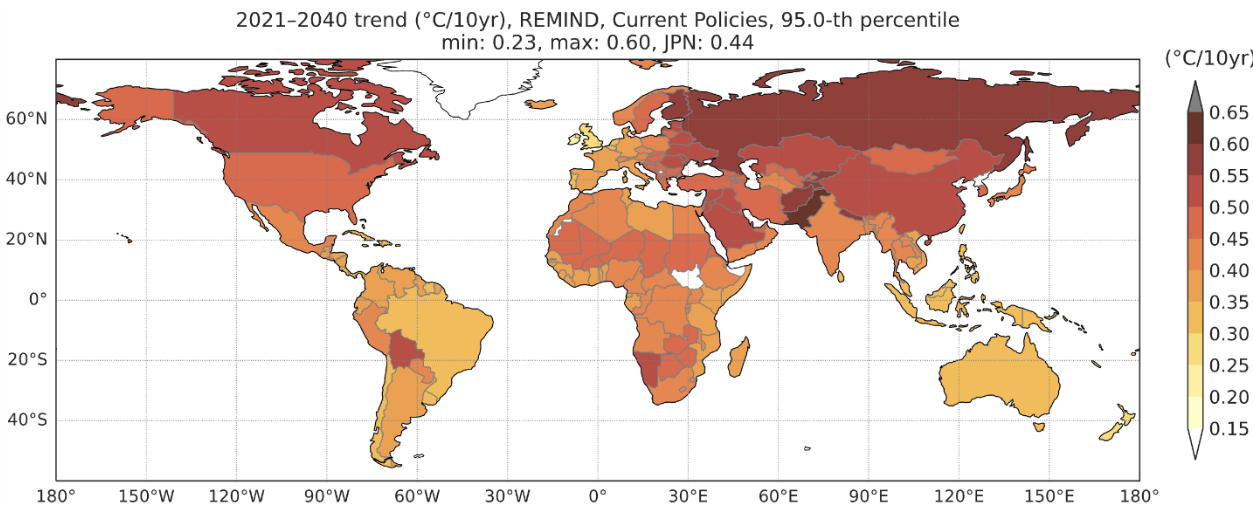
Top left: Change over time (median and 5th to 95th percentiles for some scenarios, in the case of REMIND).

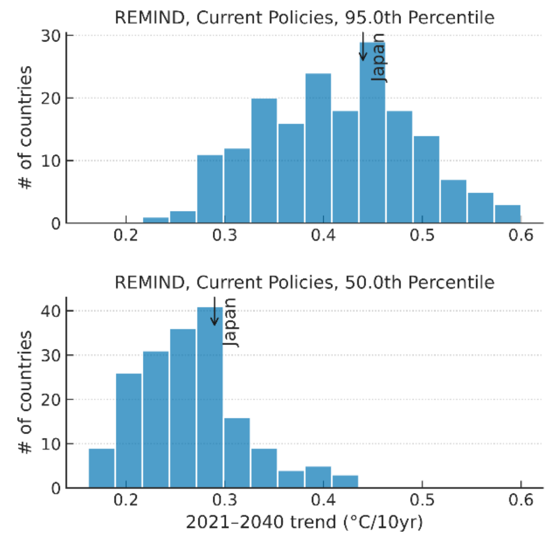
Top right: Median and range of uncertainty in each IAM for 2050 and 2100.

Bottom right: Comparison of changes in CO_2 emissions and global warming levels over time in each IAM in Phase IV (solid line) and Phase III (dotted line). Current Policies and Net Zero 2050 scenarios only.

Chronic risk assessment procedure 2/4: Global warming level ⇒ Country-level temperature

- The method is the same as in Phase III. Global warming levels have been downscaled to temperatures for 180 countries around the world.
  - Using observed temperatures in 2005 as a baseline, each country's temperature is calculated by multiplying the global warming level by a country-specific coefficient obtained from complex climate model calculations.
  - The 5th, 50th, and 95th percentiles (median for the 50th) are used for global warming levels.
- The tendency toward a large temperature rise in high latitudes of the northern hemisphere and in landlocked countries is reflected by means of the country-specific coefficient (left-hand diagram).
  - Japan is positioned slightly higher than the center of the distribution (right-hand diagram).





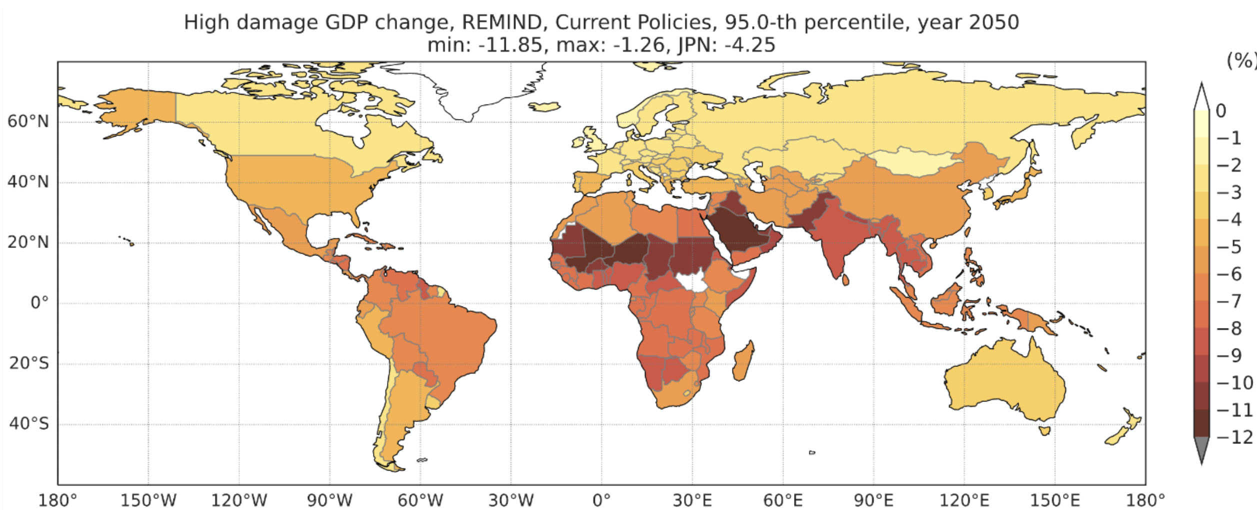
As a typical example of temperature changes in each country, the results of calculating the linear trend for 2020–2040 from the Current Policies scenario in REMIND are shown as changes per decade.

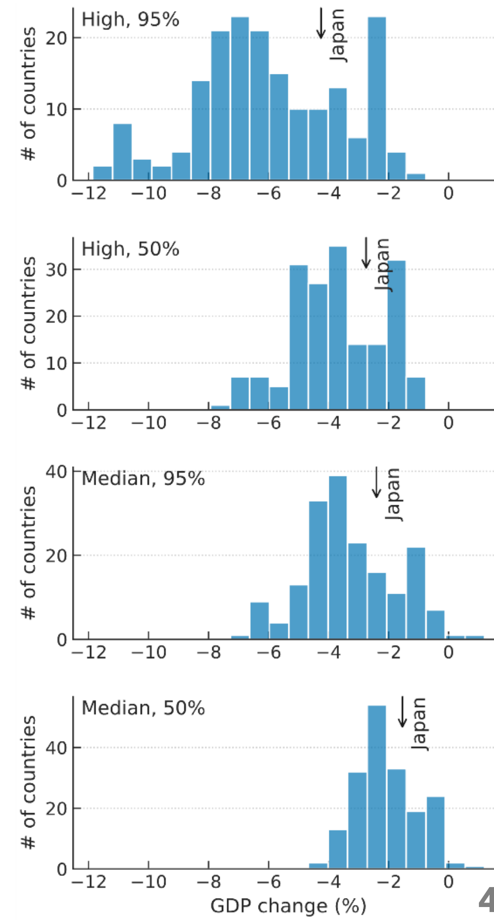
Left: Spatial distribution of the 95th percentile.

Right: Histograms for the 95th and 50th percentiles. Arrows indicate Japan's position.

Chronic risk assessment procedure 3/4: Country-level temperature ⇒ GDP change

- The method is the same as in Phase III. Changes in GDP have been estimated by applying a damage function to country-level temperature.
  - Two damage functions are presented: median damage and high damage (using the median and the 95th percentile estimates of the damage function parameters).
  - Three temperature estimates (5th, 50th, and 95th percentiles) and the two damage estimates are combined to produce six estimates.
- The damage functions used in the assessment capture labor and land productivity, and capital depreciation.
  - GDP loss is high in lower-latitude regions (left-hand diagram). Japan is positioned in the area of little change (right-hand diagram).





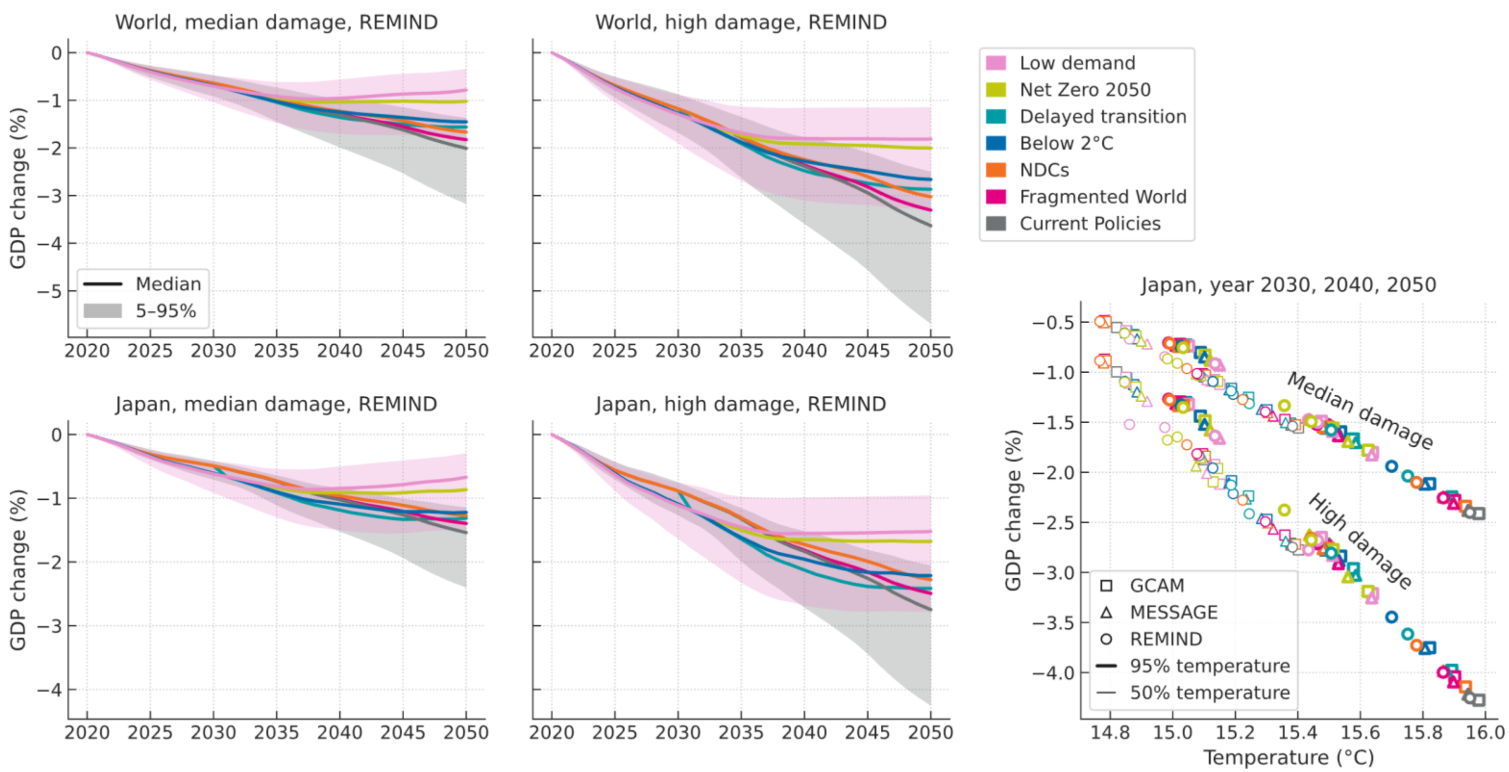
As a typical example of GDP changes in each country, the distribution for 2050 from the Current Policies scenario in REMIND is shown.

Left: Spatial distribution of the 95th temperature percentile and the high damage situation.

Right: Histograms comparing the different combinations of temperature and damage (5th temperature percentile omitted). Arrows indicate figures for Japan.

Chronic risk trends: GDP change worldwide and in Japan (damage functions)

- Change over time shows similar trends worldwide and in Japan. GDP loss estimated using the damage functions is on the smaller side in Japan's case (left and middle graphs).
  - The difference between scenarios fits within the uncertainty range (5th to 95th percentiles) for temperatures in a single scenario.
- GDP change in each country is more or less proportional to temperature[*1], with a quantitative difference between the median and high damage functions (bottom right graph).



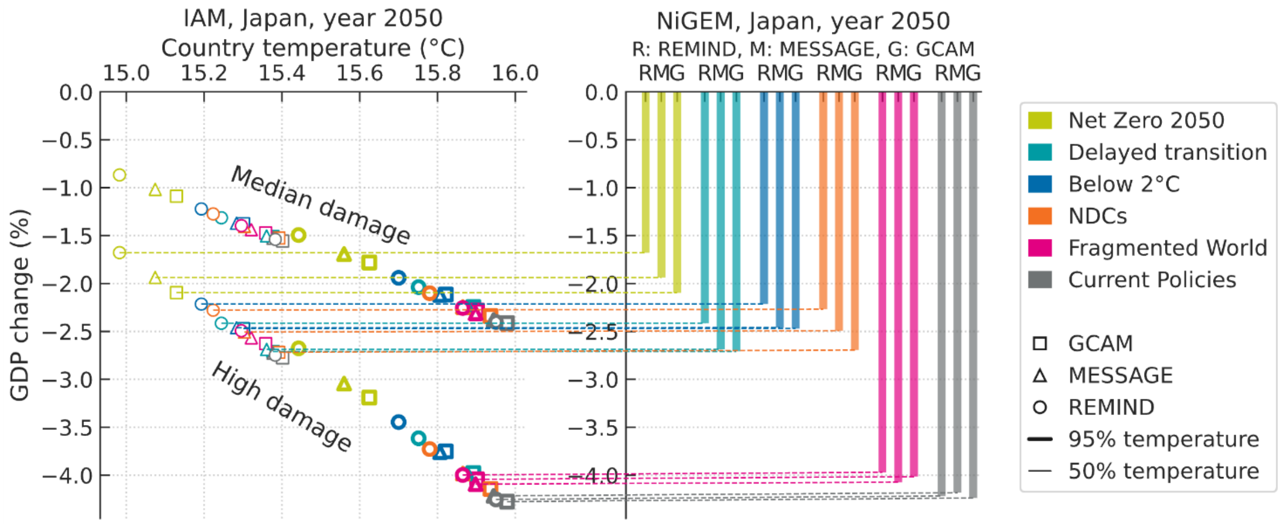
Left and middle: Change over time in the REMIND model. 50th temperature percentile for each scenario and 5th to 95th percentile range for some scenarios.

Bottom right: Relationship between GDP change and temperature in Japan. Excerpt of values for 2030, 2040, and 2050 from each IAM for the 95th and 50th temperature percentiles and median and high damage situations. Linear distribution, divided into median and high damage. The 95th and 50th temperature percentiles are indicated by differences in the thickness of the markers.

*1 The damage functions used in Phase IV (Kalkuhl and Wenz, 2020) rely solely on temperature. In future updates, it is expected that other climate variables (precipitation, temperature variability, persistence of climate impacts, etc.) will also be taken into account (NGFS, 2023a, p. 50).

Chronic risk assessment procedure 4/4: GDP change ⇒ Inputs to macroeconomic assessment

- GDP changes obtained from the IAMs via the damage functions are used as input variables into the macroeconomic model (NiGEM), and their impacts on various macroeconomic variables (including GDP, potential GDP, and prices) are quantified (p. 68).
- Of the six estimates of GDP change, the high damage estimates are uniformly input into NiGEM, using the 95th temperature percentile for the Current Policies and Fragmented World scenarios, and the 50th temperature percentile for all others*1 (graph below).
  - The high damage situations are used in order to take into account elements not captured in the damage functions, such as sea-level rise and climate-change-induced conflict.*2
  - The 95th temperature percentile is used for the Current Policies and Fragmented World scenarios in order to reflect uncertainty inherent in the modeling of macroeconomic effects of chronic physical risks.*3



GDP change in both IAM and NiGEM is provided as percentile values, but the adjustment of the original GDP for inflation differs.

NiGEM data does not include the Low Demand scenario.

Left: Relationship between GDP change and temperature in Japan. Excerpt of values for 2050 from each IAM for the 95th and 50th temperature percentiles and median and high damage situations.

Right: GDP change input into NiGEM from the different temperature and damage combinations in each IAM.

*1 While this differs from the approach explained in the source (NGFS, 2023b, p. 191, Table 24), it has been determined by the authors from the results of comparison in order to present the data on a chart.

*2 Based on the explanation in the source (NGFS, 2023b, pp. 127–128, Figure 69).

*3 Based on the explanation in the source (NGFS, 2023a, p. 33).

Assessment of acute risks

- The natural catastrophe modeling framework is based on three main components: hazards or perils; exposure; and vulnerability.
  - Hazards are extreme events or physical variables causing the damage. Whereas Phase III focused solely on floods and cyclones, **drought and heatwaves have been added** in Phase IV.
  - Exposure is expressed as a spatial map of the objects exposed to damage (e.g. assets, infrastructure, etc.).
  - Vulnerability is calculated as a function that assesses the degree of damage of the exposed objects (individual damage functions).
- While Phase III provided estimates only at the aggregate (world) level, Phase IV has been **updated with country-level estimates**.
  - The country-level estimates are positioned as a significant step toward the use of the models for stress tests or climate risk analyses (numerous points for future improvement are listed, suggesting that extensive data validation and improvements will be required).
- The risk assessment procedure is as follows.
  - (1) Estimate impacts at the country level using the principles of natural catastrophe modeling and temperature grid point data.
    - The method has been revised from the Phase III approach, which applied a future change multiplier to historical shock data.
  - (2) Forecast impacts in accordance with global warming level paths.
    - Global warming levels are handled at 0.1°C intervals within the range of 1–3.6°C. Based on forecasts for multiple models[*1] and multiple scenarios, impacts are estimated as a distribution of 84 samples[*2] (21 years × 4 models).
  - (3) Convert impact forecasts into supply and demand shocks in NiGEM and assess the country-level macroeconomic impacts.
    - International connections through trade are isolated and only domestic impacts are assessed (as in the case of chronic risks).
    - The modeling in Phase IV has been **updated to use the most strongly connected channels of transmission** for each hazard.

*1 The modeling of the impacts of warming uses the same basic data from the database relating to physical risks, which is explained on a later page.

*2 Natural variability from one year to another and variation between models are reflected. The handling of uncertainty differs from that relating to chronic risks, which combines high and median damage situations with the 5th to 95th temperature percentiles.

Assessment of acute risks: Hazard-specific approach

	Risk focus (indicator)	Inputs into NiGEM	Channels of transmission in NiGEM
Drought	Reduced crop yields (SPEI-12)	Damage to yields	Productivity, exports, prices
Heatwaves	Human health (Wet bulb temperature)	Population affected by heatwaves	Population
Floods	River floods	Capital stock damage	Capital stock
Cyclones	Extreme winds	Capital stock damage	Capital stock

Used as a drought indicator, the standardized precipitation evaporation index over 12 months (SPEI-12) is based on variables such as precipitation and evaporation, and includes the current and 11 preceding months. SPEI-12 is relevant to the possibility that crops may be exposed to a serious drought.

Used as a heatwave indicator, wet bulb temperature is defined as the temperature of a parcel of air when it reaches saturation (100% humidity) as a result of the evaporation of water vapor (removal of heat). Wet bulb temperature indicates the degree of humid heat, which is harmful to human health, and is used as the major factor in the heat indicators provided on the Ministry of the Environment's Heat Illness Prevention Information website, among others. Extreme value distribution parameters fitted to 84 samples have been input into NiGEM.

The risk focus and estimation for both floods and cyclones are basically the same as in Phase III.

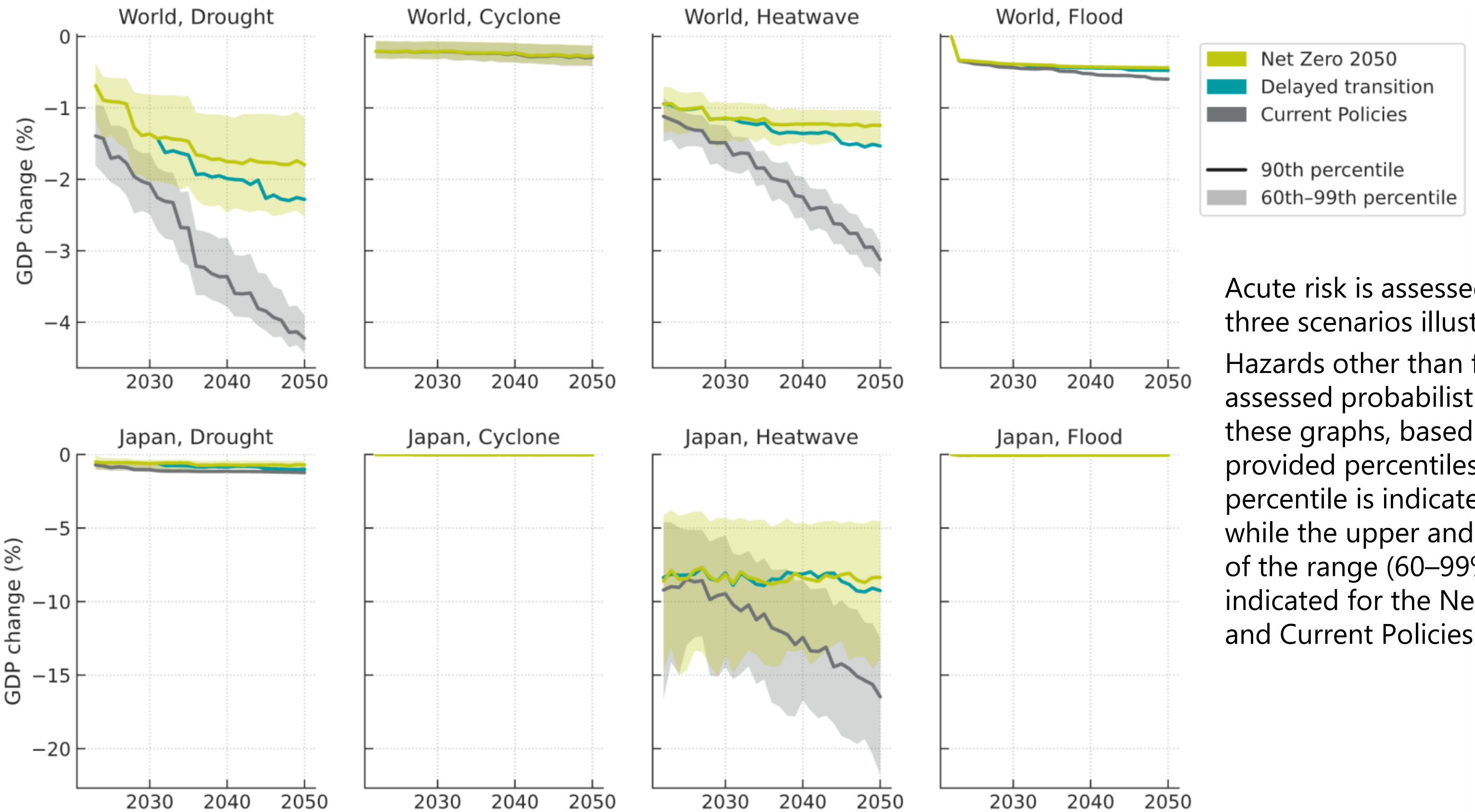
Floods focus solely on river floods, with coastal flooding from storm surges and pluvial flooding identified as issues for the future. Flood data input into NiGEM are the average yearly damage and are treated as a single shock (hazards other than floods are treated as repeated random shocks conforming to a probability distribution).

Cyclone risk focuses solely on wind. While storm surges due to strong winds are considered indirectly, torrential rain and landslides are excluded from consideration.

The assessment results for each hazard are provided as NiGEM outputs (GDP change). Although input information is not provided, relevant data can be obtained from the Climate Impact Explorer as referred to on the following pages.

Acute risk trends: GDP change worldwide and in Japan

- Of the four hazards, drought and heatwaves have the biggest impact worldwide.
  - Cyclones and floods have a relatively small impact, because the areas affected by them are limited, and it is also likely that differences arise according to the assessment method.*1
- The substantial impact of heatwaves in Japan features prominently.



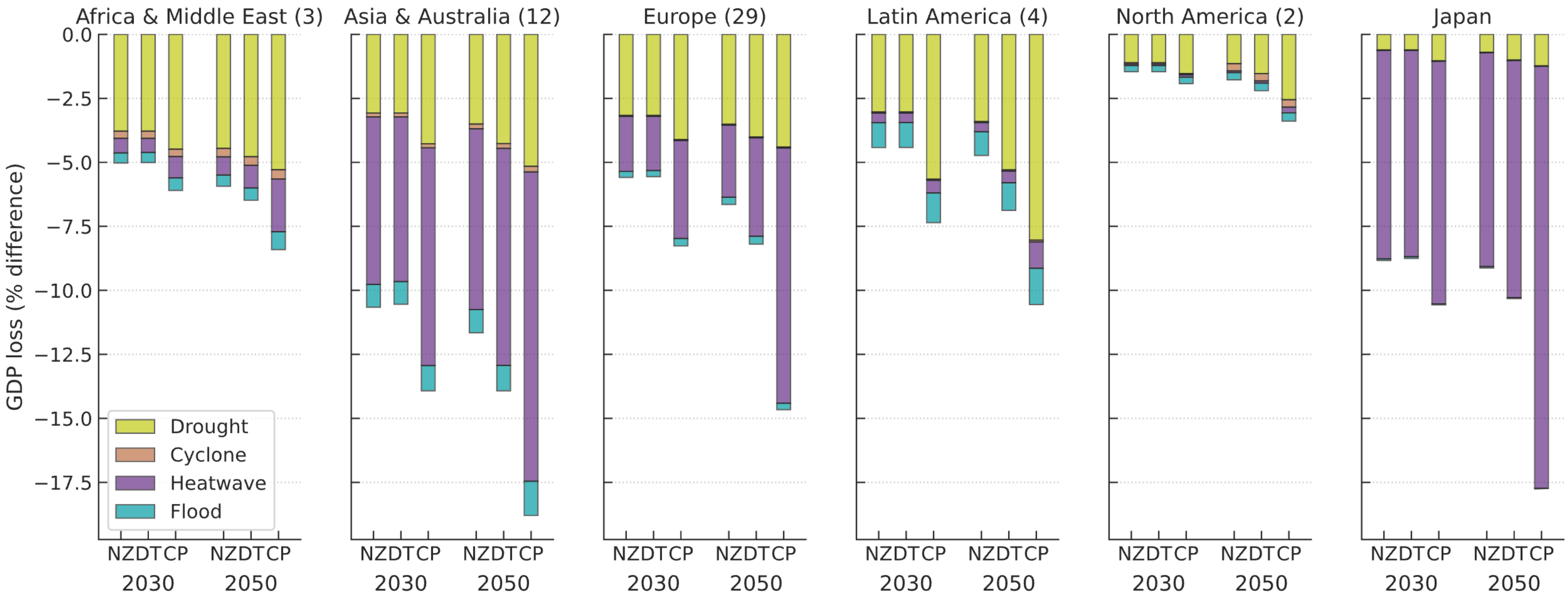
Acute risk is assessed only in the three scenarios illustrated here.

Hazards other than floods are assessed probabilistically. In these graphs, based on the provided percentiles, the 90th percentile is indicated by a line, while the upper and lower limits of the range (60–99%) are indicated for the Net Zero 2050 and Current Policies scenarios.

*1 Based on the explanation in the source (NGFS, 2023a, p. 35).

Acute risk trends: Comparisons of 2030 and 2050 by continent and for Japan

- Drought is a risk factor in many regions. Heatwaves show a comparatively large regional skew.
  - As wet bulb temperature is used as the indicator of heatwaves, there is a major impact on regions with high humid heat.
- Japan's risk factors for cyclones and floods are extremely low.
  - Authors' opinion: Our impression is that this differs from the assessment of water-related disasters in the Assessment of Climate Change Impacts (Ministry of the Environment, 2020). Caution is required in regard to the fact that assessment of cyclone risk is limited to extreme winds.



Continent-level totals have been calculated by averaging out the 50 individually modeled countries by continent, following the usage example in the NGFS Data EnTry Tool.

https://colab.research.google.com/drive/1iM6dEmthZE9DCZjDH1rwYpZI0eV3etEx?usp=sharing

Figures in parentheses in the titles of each chart indicate the number of countries in that region. We referred to the 90th percentile for drought, cyclones, and heatwaves, which were assessed probabilistically.

3. Methodologies and Data Concerning Physical Risks

3.1 Methodologies concerning the assessment of physical risks
3.2 Data provided in Phase IV

Database of physical risks – List of variables

- Data concerning physical risks can be obtained from Climate Impact Explorer. In Phase IV, one additional variable is available (maximum 5-day rainfall). The categorization of indicators has also been clarified.

List of indicators available in Climate Impact Explorer*1

	Indicator (variable name)	Category, etc.	
1	Mean air temperature (tasAdjust)	<Chronic> <<Climate>> Annual/seasonal, weighted average by area/population/GDP	
2	Daily maximum air temperature (tasmaxAdjust)		
3	Daily minimum air temperature (tasminAdjust)		
4	Relative humidity (hursAdjust)		
5	Specific humidity (hussAdjust)		
6	Precipitation (prAdjust)		
7	Snowfall (prsnAdjust)		
8	Atmospheric pressure (surface) (psAdjust)		
9	Atmospheric pressure (adjusted to sea-level) (pslAdjust)		
10	Downwelling longwave radiation (rldsAdjust)		
11	Wind speed (sfcWindAdjust)		
12	Surface runoff (qs)	<Chronic> <<Freshwater>> Annual/seasonal, weighted average by area/population/GDP	
13	River discharge (dis)		
14	Maximum of daily river discharge (maxdis)		
15	Minimum of daily river discharge (mindis)		
16	Soil moisture (soilmoist)	<Chronic> <<Agriculture>>	Annual/seasonal, weighted average by area/population/GDP

	Indicator (variable name)	Category, etc.	
17	Annual mean maize yield (yield_maize_co2)	<Chronic> <<Agriculture>>	Annual, weighted average by area/population/GDP
18	Annual mean rice yield (yield_rice_co2)		
19	Annual mean soy yield (yield_soy_co2)		
20	Annual mean wheat yield (yield_wheat_co2)		
21	Land fraction annually exposed to river floods (fldfrc)	<Acute> <<Peril-specific hazards>>	Annual, weighted average by area
22	Annual maximum river flood depth (flddph)		Annual, weighted average by area/population/GDP
23	Land fraction annually exposed to crop failures (lec)		Annual, weighted average by area
24	Fraction of population annually exposed to crop failures (pec)		Annual, weighted average by population
25	Land fraction annually exposed to wildfires (lew)		Annual, weighted average by area
26	Fraction of population annually exposed to wildfires (pew)		Annual, weighted average by population
27	Land fraction annually exposed to heatwaves (leh)		Annual, weighted average by area
28	Fraction of population annually exposed to heatwaves (peh)		Annual, weighted average by population
29	Labour productivity due to heat stress (ec1)	<Chronic> <<Labour productivity>> Annual, weighted average by area/population/GDP	
30	Annual expected damage from river floods (ec2)	<Acute> <<Economic damage>> Annual, total	
31	Annual expected damage from tropical cyclones (ec3)		
32	1-in-100-year expected damage from tropical cyclones (ec4)		
33	Extreme 5-day rainfall (rx5day)	<Chronic> <<Climate>> Annual, weighted average by area/population/GDP	

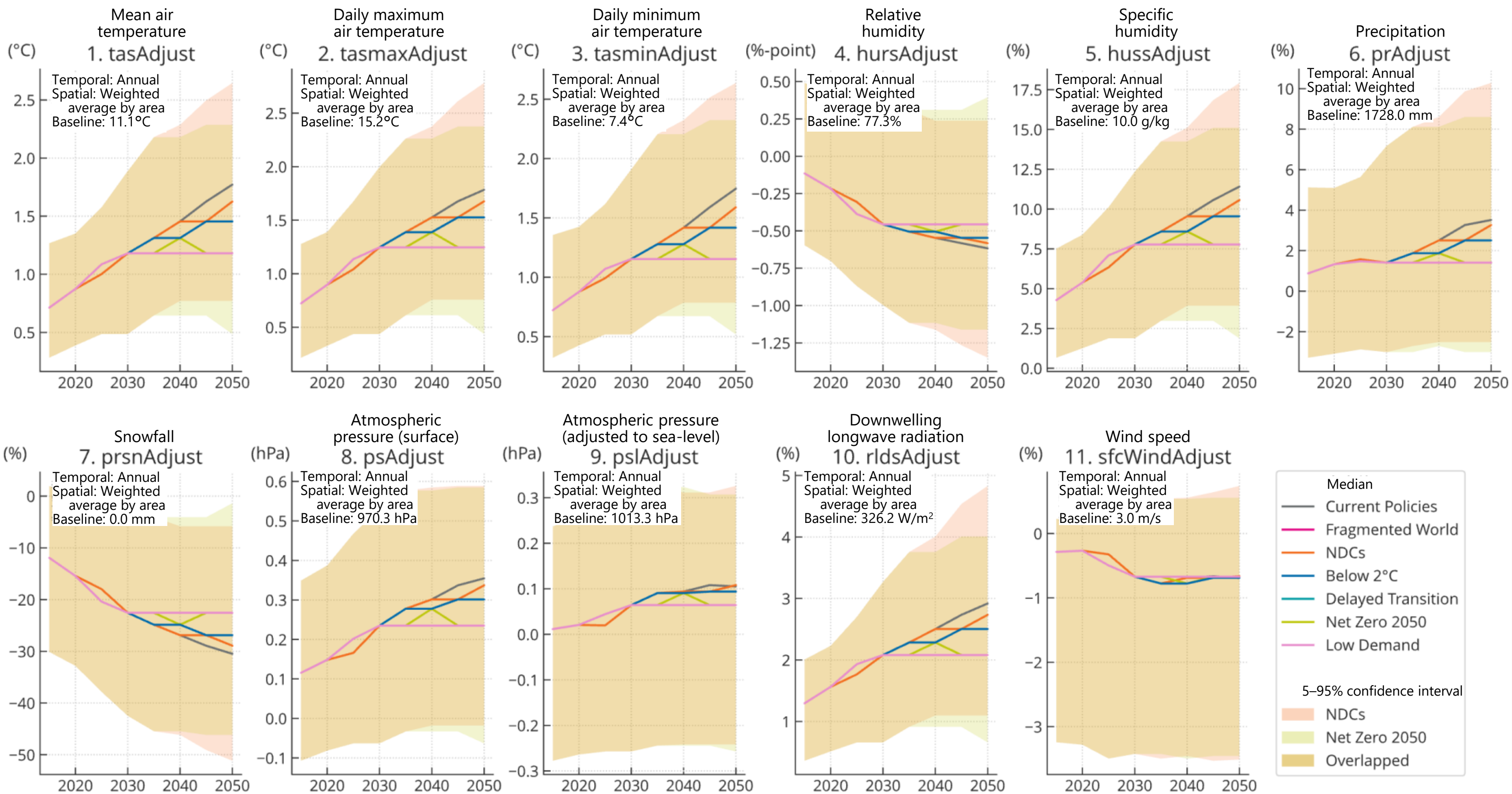
*1 The category column shows the main and sub-classification of each indicator (terms in single and double angle brackets), along with the options for temporal average and spatial aggregation method.

Data provider's disclaimer on the indicators

- While the data have been obtained using reputable models, they do not depict changes in the focus of assessment in their entirety.
  - Models used: Climate models (1–11, 27–29, 33); land surface, river, and hydrological models (12–16, 21–22, 30); crop models (17–20, 23–24); vegetation models (25–26)
  - Crop models have not been calibrated for every country. While the CO_2 fertilization effect is considered, there is considerable uncertainty regarding its impact on future yield.
- The prerequisites for assessing impact are assumed to remain constant in the future.
  - Land use and irrigation patterns (13–15, 21–26), water use for human activities (13–15, 21–22), crop cultivation locations, irrigation and rain-fed region categories (17–20), flood control standards (21–22), farm management practices (23–24), wildfire management practices (25–26)
- With regard to crop failure (23–24), a crop failure year is defined as a year in which yields fall to extremely low values, which appear on average 2–3 times in a century under preindustrial climate conditions. The data do not capture less drastic events whose impacts can already be felt.
- Heatwaves (27–28) are defined as events in which both air temperature and the combined indicator of air temperature and relative humidity reach exceptionally high values. **The risk from dry heatwaves is not fully captured.**
- Labour productivity (29) quantifies heat stress using five exposure response functions relating to wet bulb temperature. As these are derived from field studies of specific tasks and locations, there is substantial uncertainty around their applicability at global scale.
- For typhoons and other tropical cyclones (31–32), paths are generated probabilistically on the basis of past events, while future changes in frequency and strength are derived from estimates based on reference literature. **Future paths cannot be considered in regions with few historical events.**
- To convert changes in the focus of assessment into damage, time-independent damage functions are applied (30–32). As such, country-specific vulnerabilities and their future changes are not accounted for.
- As the number of simulations is limited, short-term fluctuations may reflect natural climate variability.
  - In the case of snowfall (7), small-scale features (locally large increases or decreases) may also reflect the influence of natural climate variability.
- Due to the small number of model simulations, confidence in the results is low for high warming levels (2.5-3°C).

Indicator trends and quality: Climate (1–11) indicators for Japan*1

- The difference between scenarios progressively widens from 2030, but there is a larger degree of uncertainty within individual scenarios.
- The upward trends in air temperature (1–3), specific humidity (5), precipitation (6), and downwelling longwave radiation (10) are comparatively clear, as are the downward trends in relative humidity (4) and snowfall (7).

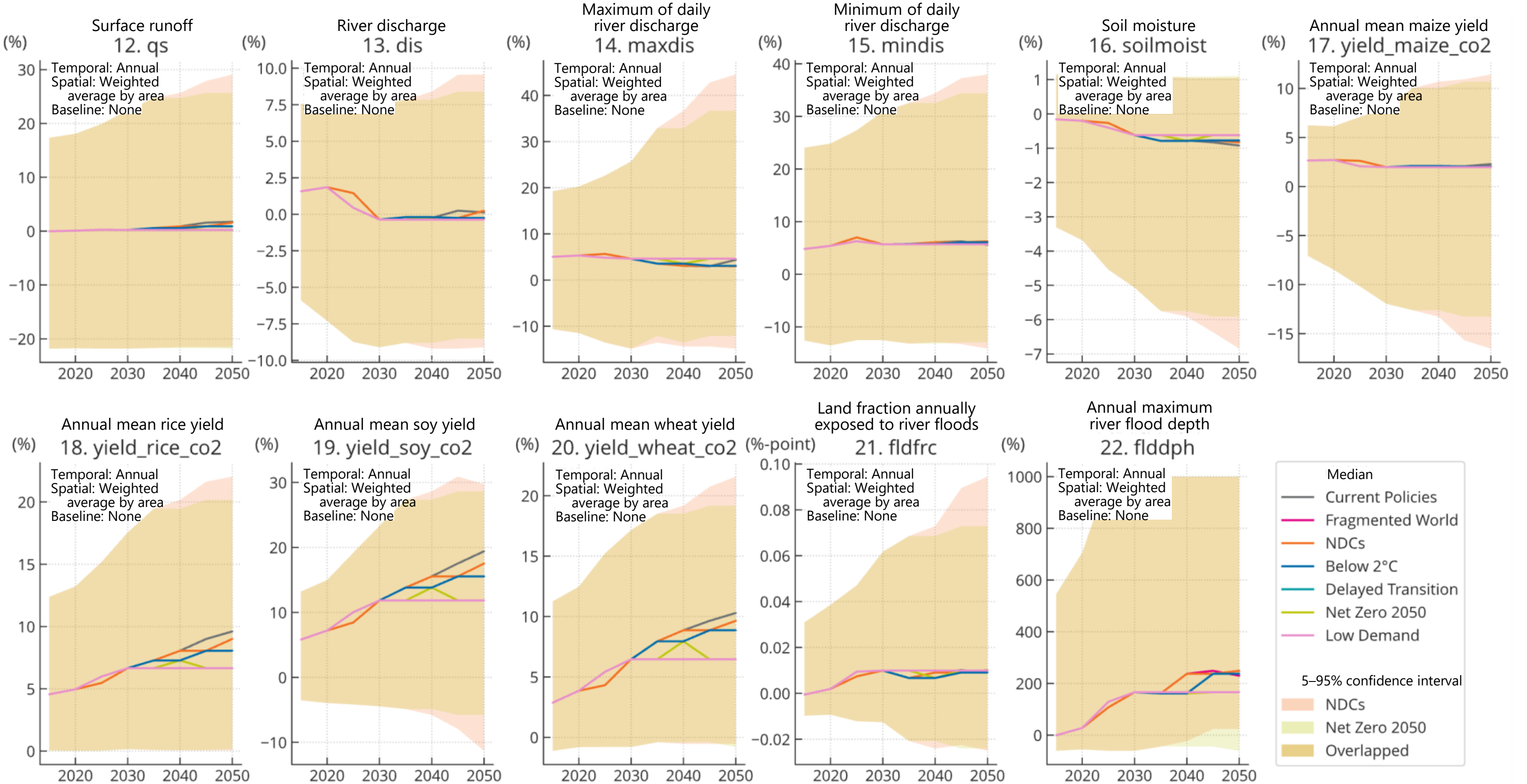


*1 Graphs show median values for each scenario and the 5–95% confidence interval for two selected scenarios. Values for each indicator are difference from the baseline (1986–2006 average) or rate of change against the baseline (%). %-point refers to the difference from the baseline value where the indicator is originally a percentage value.

Indicator trends and quality*1:

Freshwater (12–15), agriculture (16–20), and flood (21–22) indicators for Japan

- While upward trends in crop yields (excluding maize, 18–20), and in flooded area and flood depth (21–22) can be observed, along with a downward trend in soil moisture, there is substantial uncertainty.

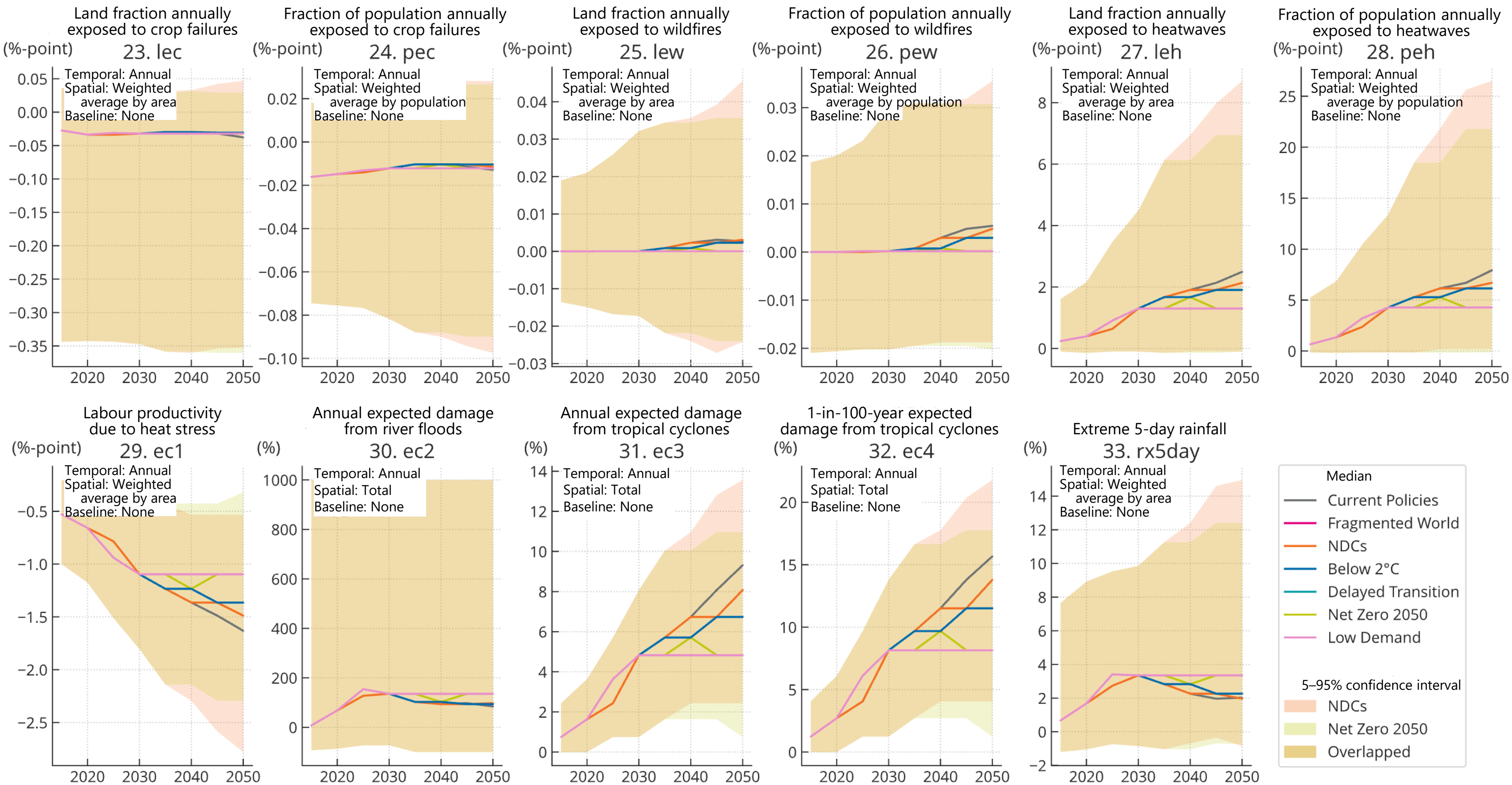


*1 Baseline values for 1986–2006 are not provided. This is because bias adjustment and validation of relevant model results have not been completed for all locations, due to the quality of historical data (the same applies to indicators 23–33 on the next page). Values for flood depth (22) are very high, suggesting that there are challenges with the underlying data (the graph is not displayed on internet browsers, but we have used data downloaded via the API to prepare the graph shown here) (disclaimer from the data provider).

Indicator trends and quality[*1]:

Crop failure (23–24), wildfire (25–26), heatwave (27–28), labour productivity (29), economic damage (30–32), and extreme rainfall (33) indicators for Japan

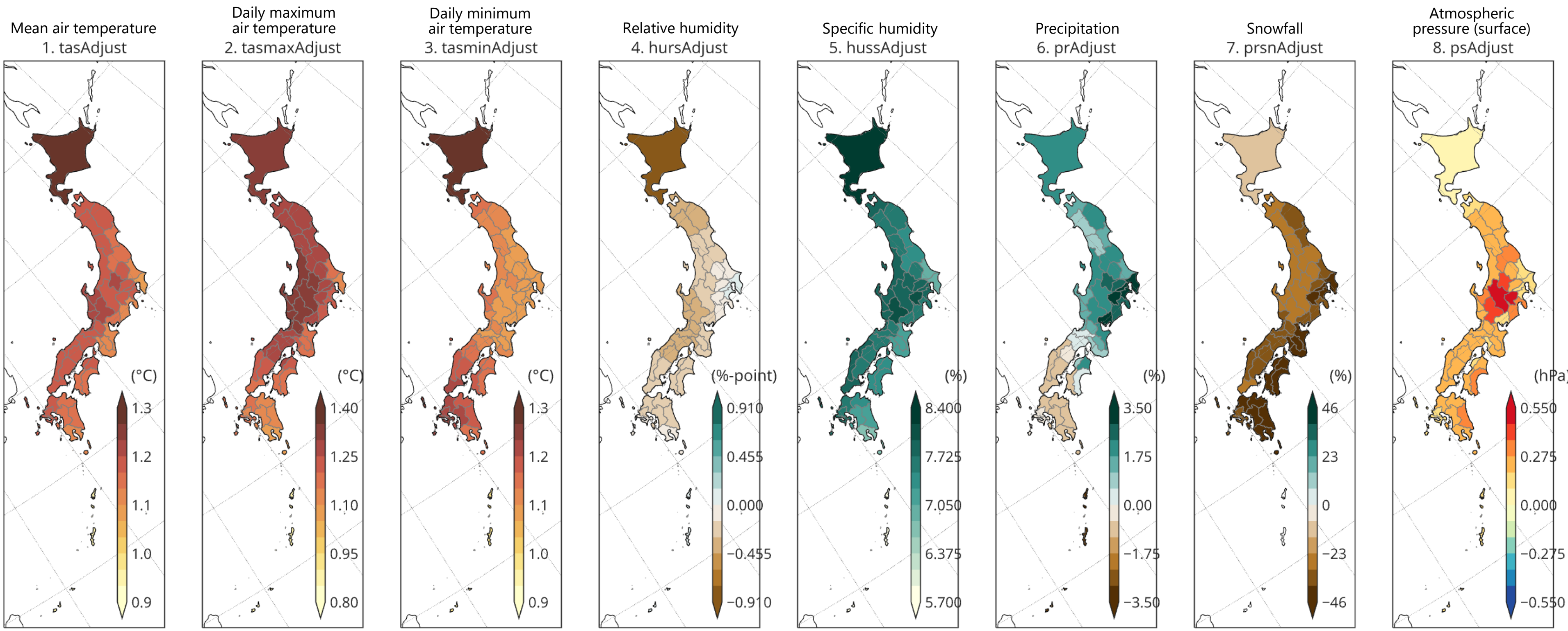
- The upward trends in economic damage due to heatwaves (27–28) and cyclones (31–32) are comparatively clear, as is the downward trend in labour productivity (29).
- Extreme rainfall (33) increases toward 2030, then declines or remains flat on average thereafter.



*1 Values for the fractions of land and population exposed to wildfires (25–26) are small, due to the fraction applying to the entire area/population of the country or region. The same applies to the land fraction exposed to river floods (21) on the previous page. In the case of annual expected damage from river floods (ec2), relative changes result in extremely high values in locations where flood events are rare occurrences (disclaimer from the data provider).

Prefectural figures for indicators 1–8*1: Current policies, 2030, median values

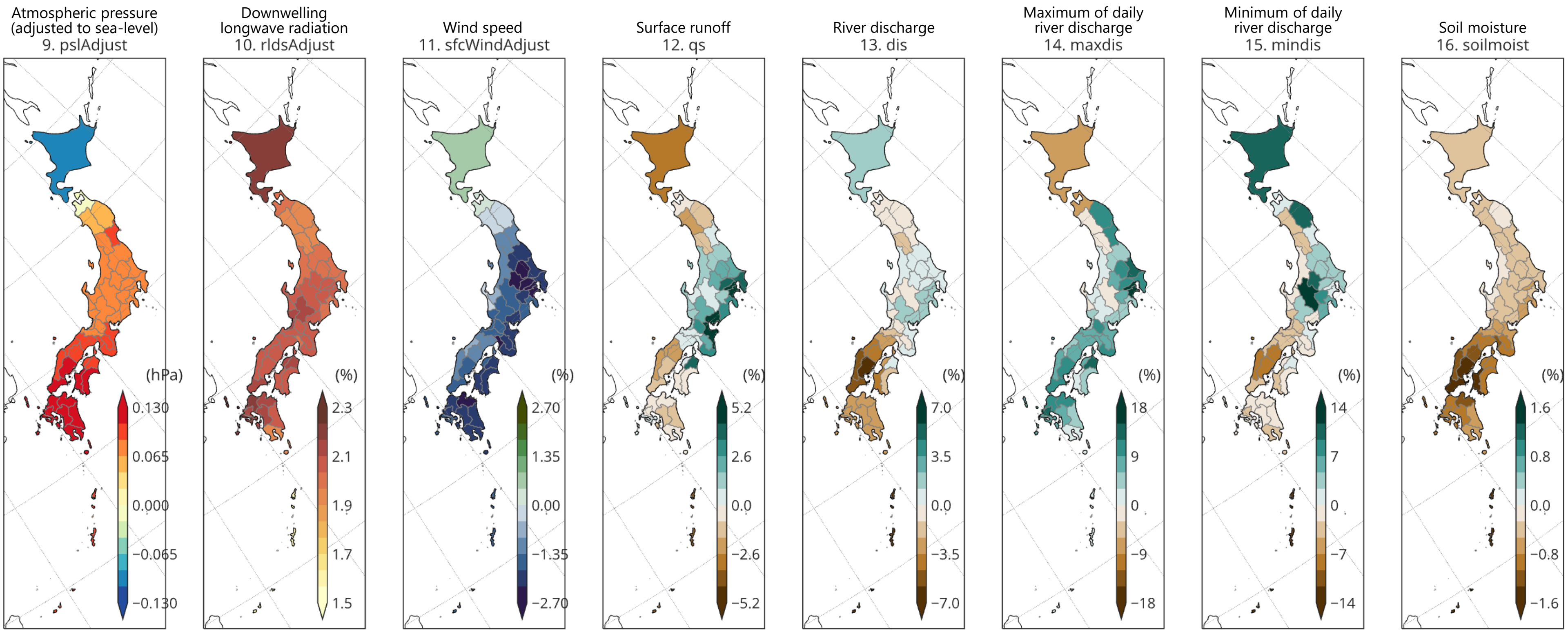
- Differences in scenario and year are essentially based on scaling of the global warming level (the same applies to other indicators).
  - The distribution is the same in other scenarios and years.
- The biggest temperature change is in Hokkaido. Large changes are also seen in maximum temperature in regions such as Chubu, and in minimum temperature in West Japan.
- Precipitation falls in West Japan but increases elsewhere. Although specific humidity (water evaporation) increases, relative humidity falls.



*1 Seasonal averages and spatial aggregation methods for each indicator are the same as those shown for annual change in previous pages. There are no data concerning snowfall (7) for Okinawa Prefecture (treated as being unavailable, due to excessively high values). In general, caution is required concerning patterns of change in precipitation, as there is a great deal of uncertainty compared with patterns of temperature change.

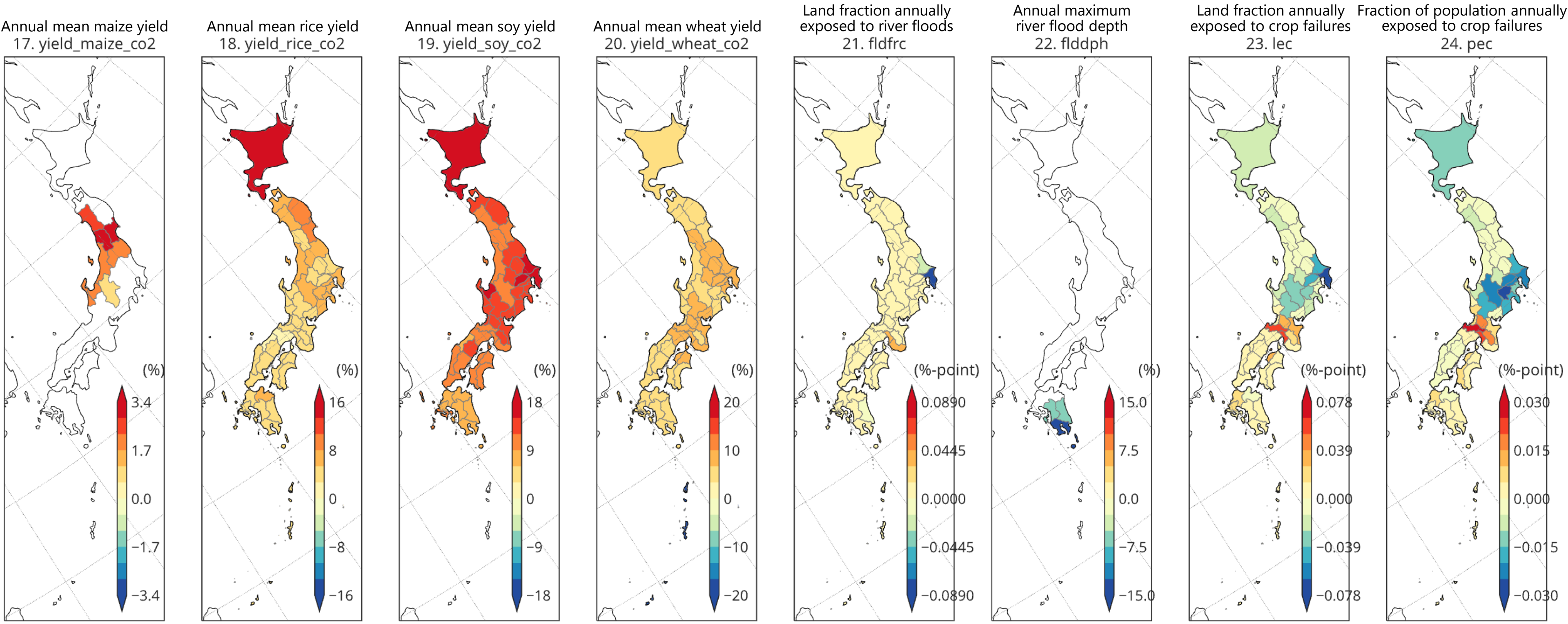
Prefectural figures for indicators 9–16: Current policies, 2030, median values

- There is a clear contrast between north and south with regard to atmospheric pressure adjusted to sea-level and wind speed.
- In West Japan, annual river discharge falls (consistent with precipitation levels). However, maximum daily discharge increases.
    - Reverse change trends between maximum and minimum daily discharge can be seen in some regions.



Prefectural figures for indicators 17–24[*1]: Current policies, 2030, median values

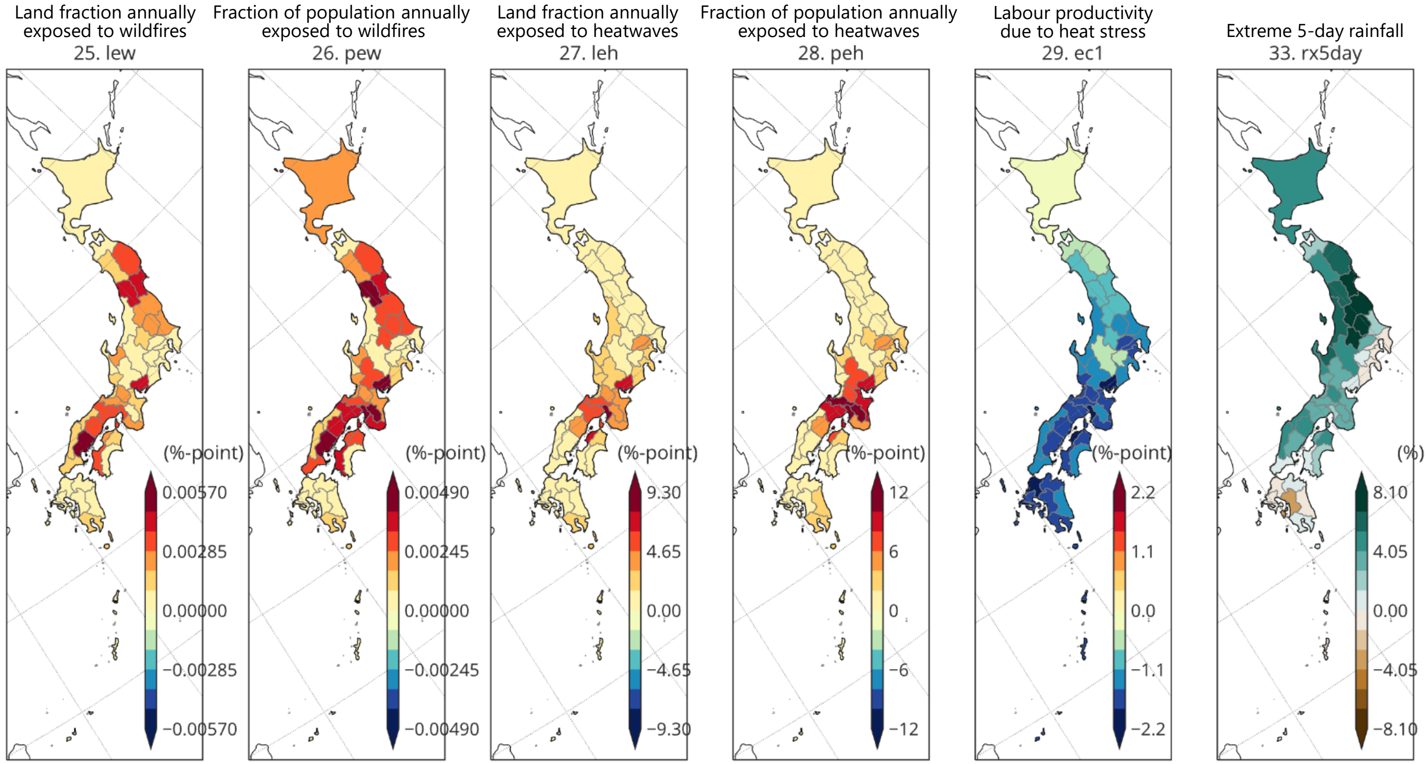
- Crop yields show an upward trend overall.
  - The exception to this is wheat yields in Okinawa Prefecture, which show a downward trend.
- Acute risks (floods and crop failure) show comparatively large fluctuations in specific regions.
  - Extreme events are generally difficult to model. It is necessary to assess the origin of fluctuations.



*1 Data for annual mean maize yield (17) are available for only 8 regions, while no data for annual mean soy yield (19) are available for Okinawa Prefecture. Crop yield indicators cover areas where the crop in question was cultivated as of 2010. Data for annual maximum river flood depth (22) are available for only 3 regions, with other regions treated as being unavailable, due to excessively high values.

Prefectural figures for indicators 25–33*1: Current policies, 2030, median values

- Acute risks (wildfires and heatwaves) show comparatively large increases in specific regions.
  - Extreme events are generally difficult to model. It is necessary to assess the origin of fluctuations.
- Labour productivity demonstrates a downward trend. Changes are comparatively large from the Kanto to Kyushu regions.
- Five-day extreme rainfall shows comparatively large changes in parts of southern Tohoku and northern Kanto.



*1 Prefectural data are not provided for indicators 30–32 (annual expected damage from river floods and tropical cyclones, and 1-in-100-year expected damage from tropical cyclones).

4. Assessments of Macroeconomic Impacts

4.1 Methodologies for assessing macroeconomic impacts

4.2 Assessments of transition risks and physical risks (chronic impacts)

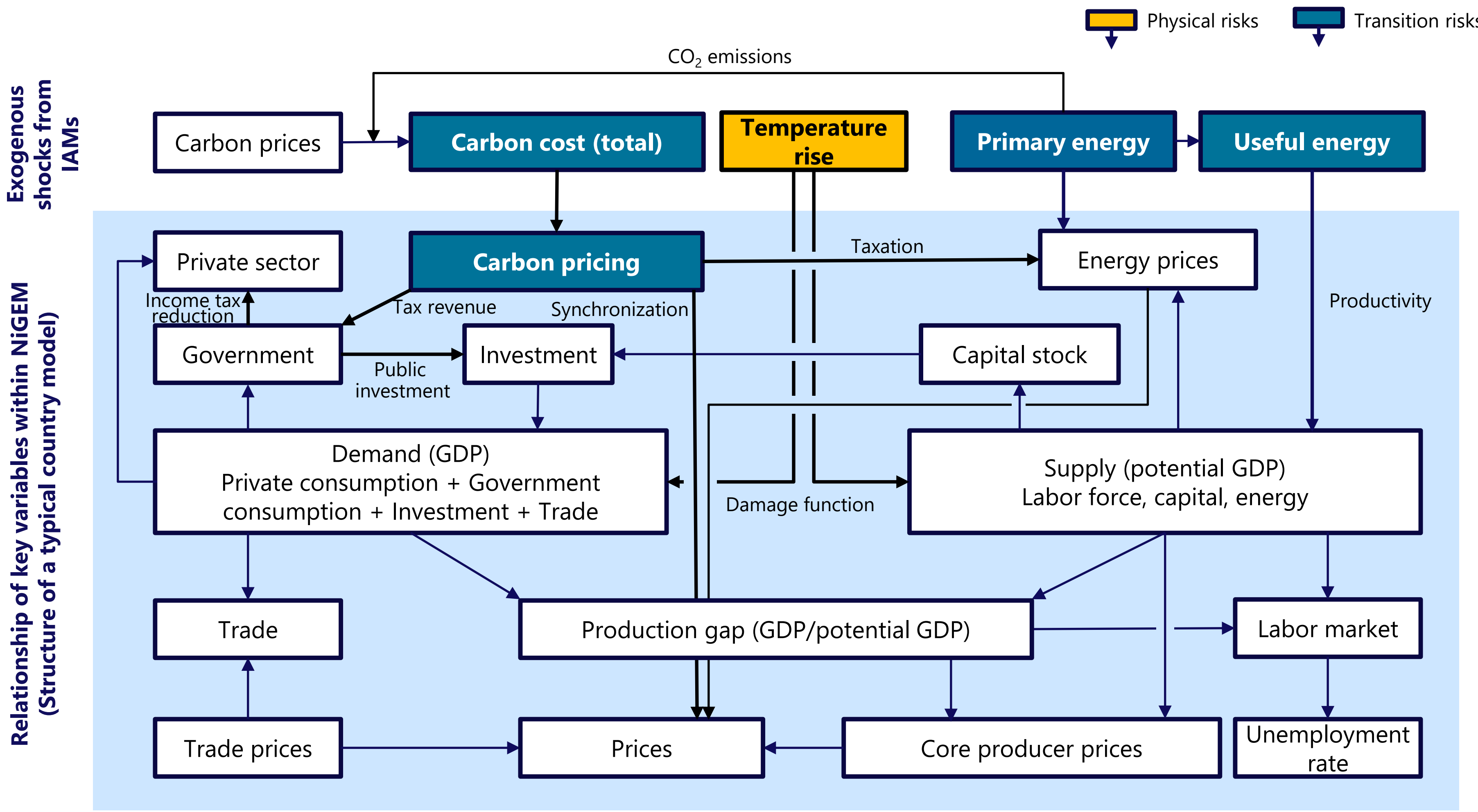
Methodologies for assessing macroeconomic impacts

- In the Phase IV scenarios, macroeconomic impacts are assessed quantitatively by means of the computable general equilibrium model (NiGEM). While the methodology has not undergone major changes since Phase III, parts of the model and the data have been expanded.

NiGEM features	• A closed model consisting of individual country models for major economies, plus other regional blocks (Africa, Middle East, Latin America, Developing Europe, and East Asia). • Models climate change policy impacts through the implementation of energy transition and physical climate shocks. Transition risk impacts for a baseline forecast and climate change risk scenarios are taken from IAMs, while GDP damage due to chronic physical risk is provided by the Potsdam Institute (PIK) and the impact of acute physical risks by Climate Analytics. • Key model outputs: Major macroeconomic and financial variables for the NGFS scenarios, including GDP, inflation rates, unemployment rates, consumption, investment, exports, imports, and interest rates.
Structure of individual country models	• Composed of determinants of domestic demand, trade volumes, prices, current accounts, and asset holdings. • Individual country models are linked together through trade in goods and services, and integrated capital markets. Accordingly, an economic slowdown in a given country would impact other countries and blocks through lower exports of goods and shifts in asset prices. • The individual country models are divided into full country models—which have a more disaggregated description of domestic demand and incorporate greater detail on the labor market and the government sector—and reduced country models. Full country models are available for 24 countries, including the U.S., Japan, and China, while reduced country models are available for another 27, including South Korea, Russia, and Brazil, along with five regional blocks.
Updates to the Phase IV NGFS scenarios	• Country models have been added (Malaysia, Croatia) or expanded from a reduced country model to a full country model (Romania, South Africa). • Trade matrices and commodity equation data have been updated from 2017 to 2019 trade figures. • The modeling of acute physical risks has been expanded (see Section 3.1 (pp. 52-55)).

Structure of the macroeconomic model (NiGEM) and connection to IAMs

- The macroeconomic impacts of climate change are assessed by applying exogenous shocks from IAMs against a baseline adjusted to conform to the Current Policies scenario.



Compiled with reference to NIESR (2023) and NGFS (2023b).

4. Assessments of Macroeconomic Impacts

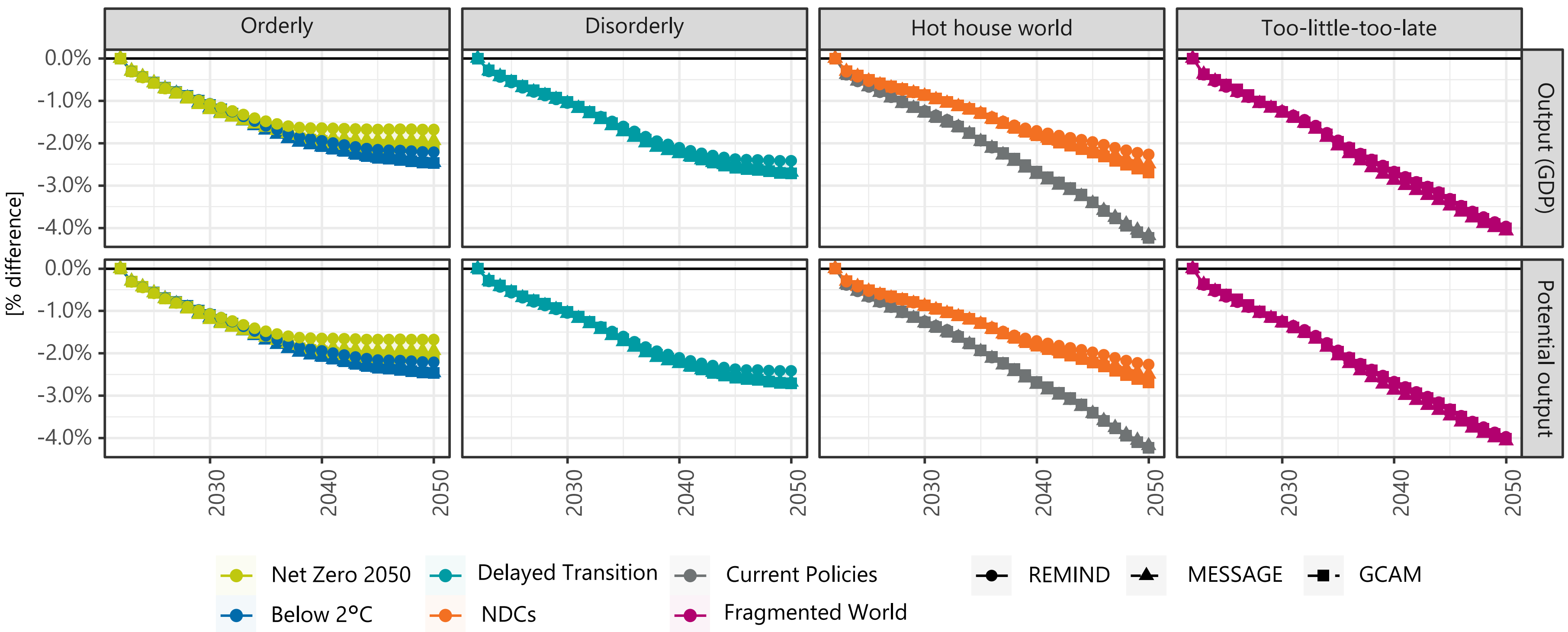
4.1 Methodologies for assessing macroeconomic impacts

4.2 Assessments of transition risks and physical risks (chronic impacts)

Impact on GDP/potential GDP

- Damage functions are used to model the impact of chronic physical risks associated with increases in temperature, in the form of both demand- and supply-side shocks. The graphs show that both GDP (upper row) and potential GDP (lower row) decline by about the same degree.
- The range of the fall from the baseline is greater in the Current Policies and Fragmented World scenarios than in the other scenarios. These results are affected by the fact that, in addition to a high global warming level, a high estimated temperature rise is used for the former and a medium rise for the latter (p. 51).

Physical risk impacts on GDP (upper row) and potential GDP (lower row) (Japan, against the baseline*1)



*1 Baseline scenario calculated on the assumption that there are no impacts from physical risk under the Current Policies scenario (the same applies hereinafter).

Input variables and major channels of transmission for transition risk factors

- Shocks associated with transition risks are applied as exogenous variables from the IAMs.
- The shocks have three main channels of transmission: (1) the effects of reductions in energy usage (useful energy) and the introduction of carbon pricing in raising short-term prices and depressing production; (2) the ripple effect across the economy and prices as a whole of the complex interactions brought about by recycling carbon pricing revenue into the economy; and (3) the effect of reductions in fossil fuel demand and prices in depressing prices as a whole.

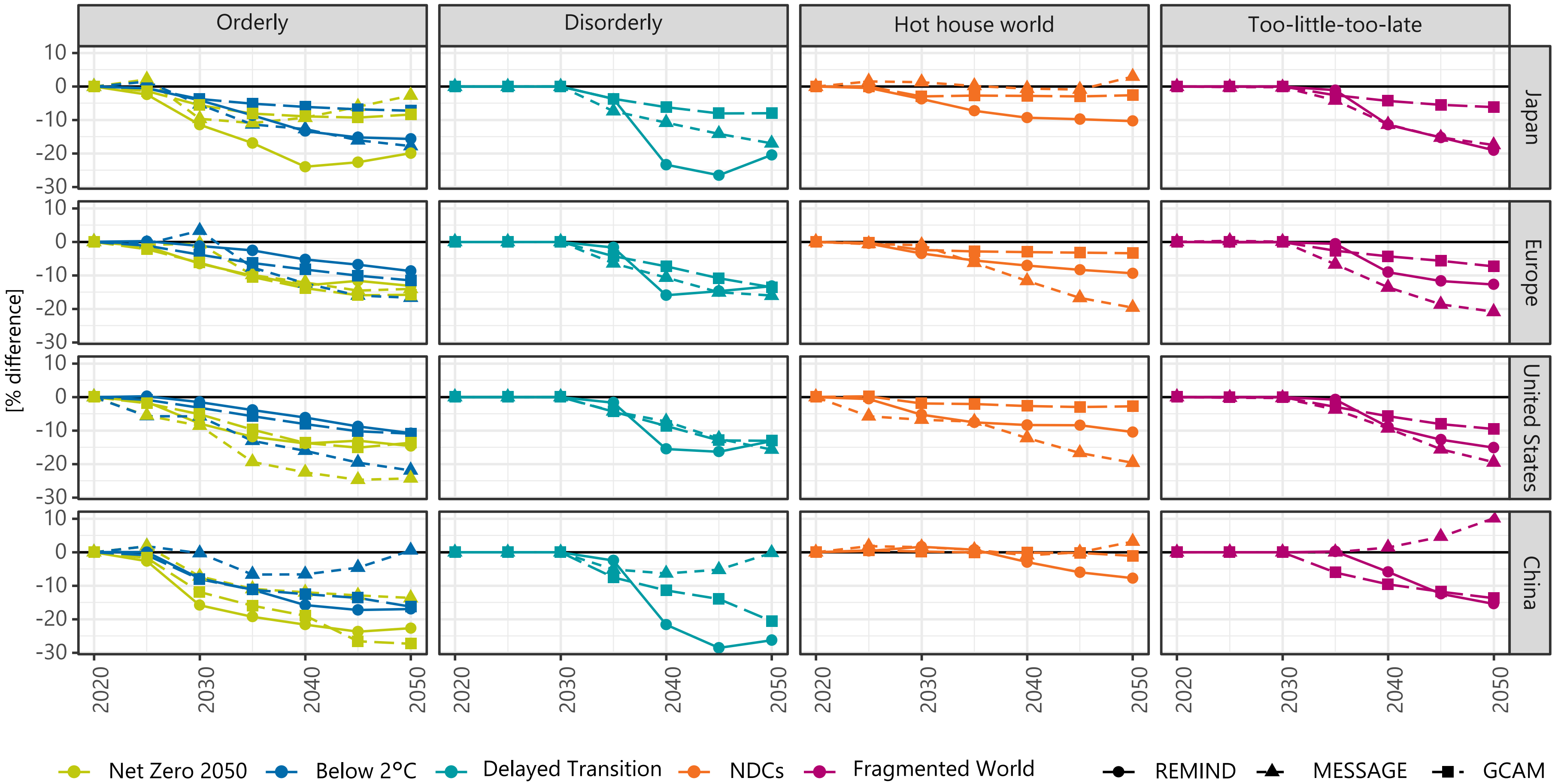
1 Useful energy*1	• Reduced energy demand arising from emissions reductions becomes a factor depressing the volume of production in the short term. • In the Phase IV scenarios, the final energy demand is converted into useful energy.
2 Carbon pricing (government revenue)	• The introduction of carbon pricing depresses GDP and raises prices as a whole by increasing production costs in the short term. • Government revenue generated from the introduction of carbon pricing improves the government's fiscal balance and provides financial leeway for fiscal policy. In the Orderly scenarios, half of government revenue is recycled into the economy as government investment, while in the other scenarios, the whole sum is recycled into the economy in the form of resources to fund tax reductions, thereby becoming a factor that helps to boost GDP in the medium to long term. • In the Phase IV scenarios, the total value of government revenue generated by the introduction of carbon pricing is applied, rather than (shadow) carbon prices.
3 Primary energy demand	• The reduction in primary energy demand becomes a factor in depressing prices as a whole through falling fossil fuel prices. • In the Phase IV scenarios, changes in primary energy demand are applied as exogenous variables from the IAMs, which are then used to calculate energy prices.

*1 Useful energy is energy associated with levels of energy services (e.g., passenger-km, ton-km) as a direct input to GDP formation, and is calculated by applying conversion factors specific to each energy source and sector to the final energy variable (NGFS 2022).

Useful energy

- While useful energy declines in the short term during the phase in which global warming policies are strengthened, there are cases in which it recovers in the long term (such as Japan's Net Zero 2050 and Delayed Transition scenarios).
- The long-term recovery in useful energy serves as a factor that boosts potential GDP.

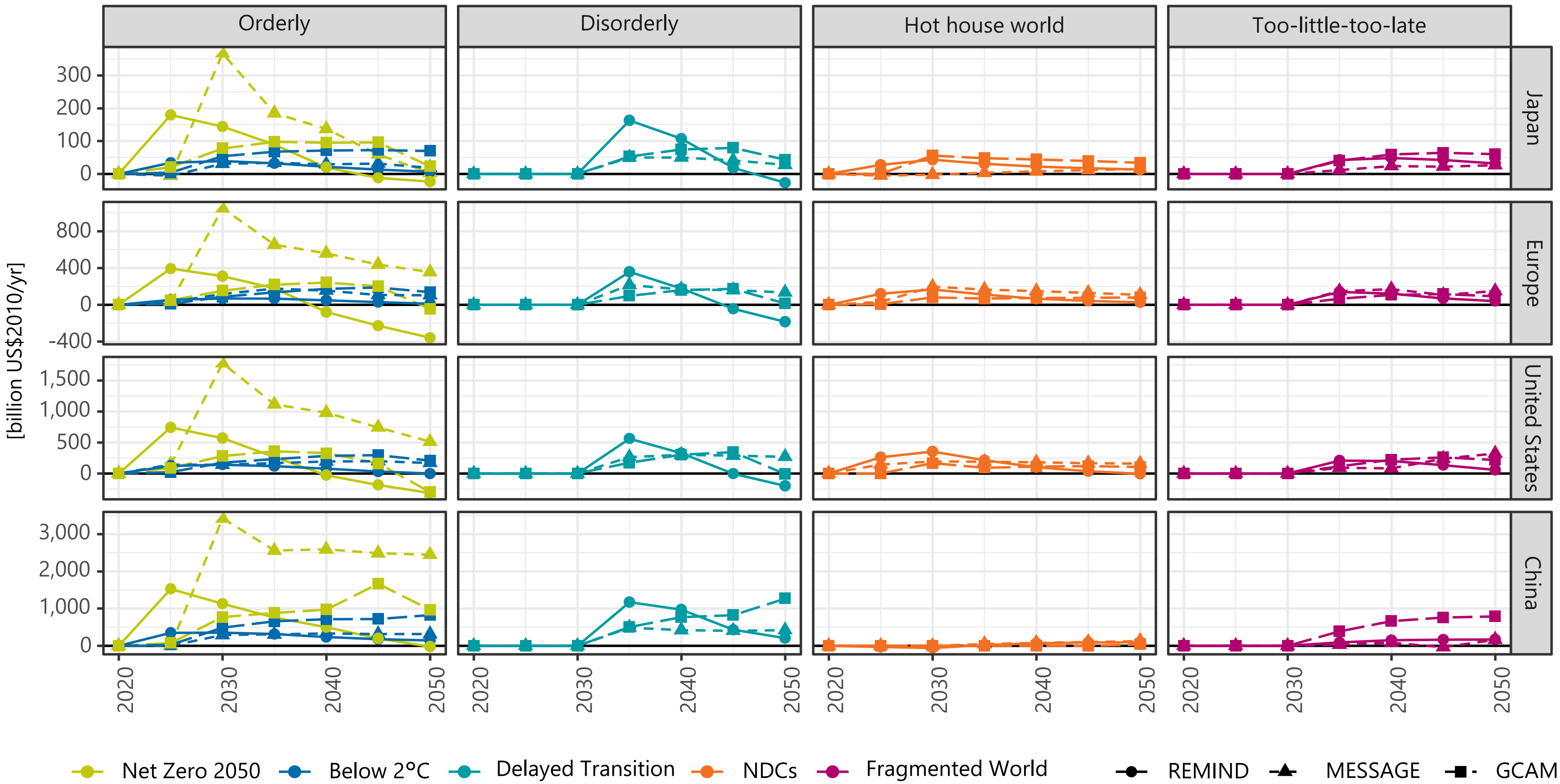
Useful energy (by region, against the baseline)



Carbon revenue

- Carbon taxes cause overall price rises (inflation) via production costs.
- Carbon revenue generated at the same time improves the government's fiscal balance and provides financial leeway for fiscal policy.
- In the Orderly scenarios, half of government revenue is recycled into the economy as government investment, while in the other scenarios, the whole sum is recycled into the economy in the form of resources to fund tax reductions, thereby boosting GDP.

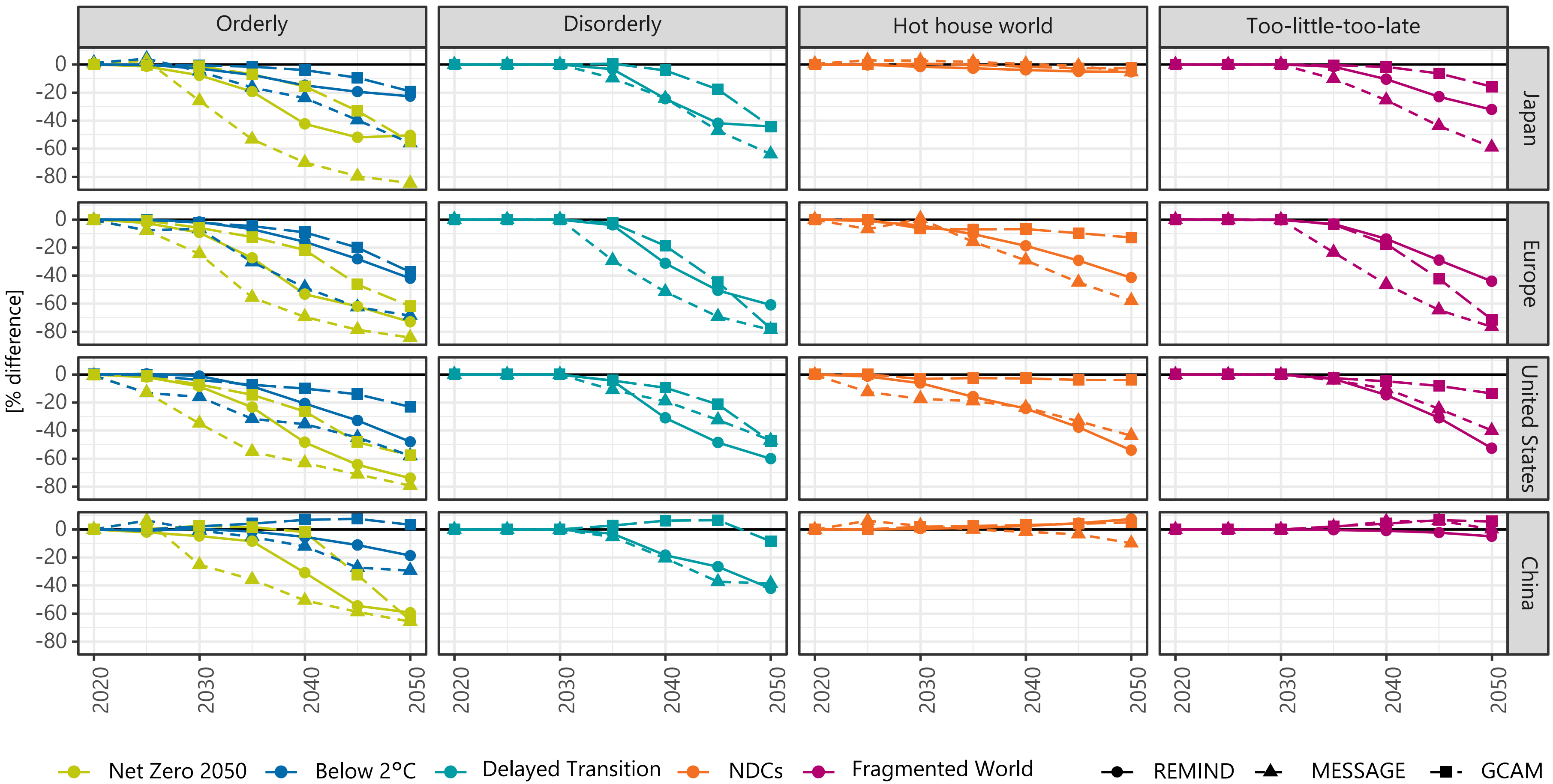
Carbon revenue (by region)



Primary energy demand (oil)

- During the phase in which global warming policies are strengthened, primary energy demand declines and fuel prices fall.
- This acts as a deflationary factor via falling import prices.

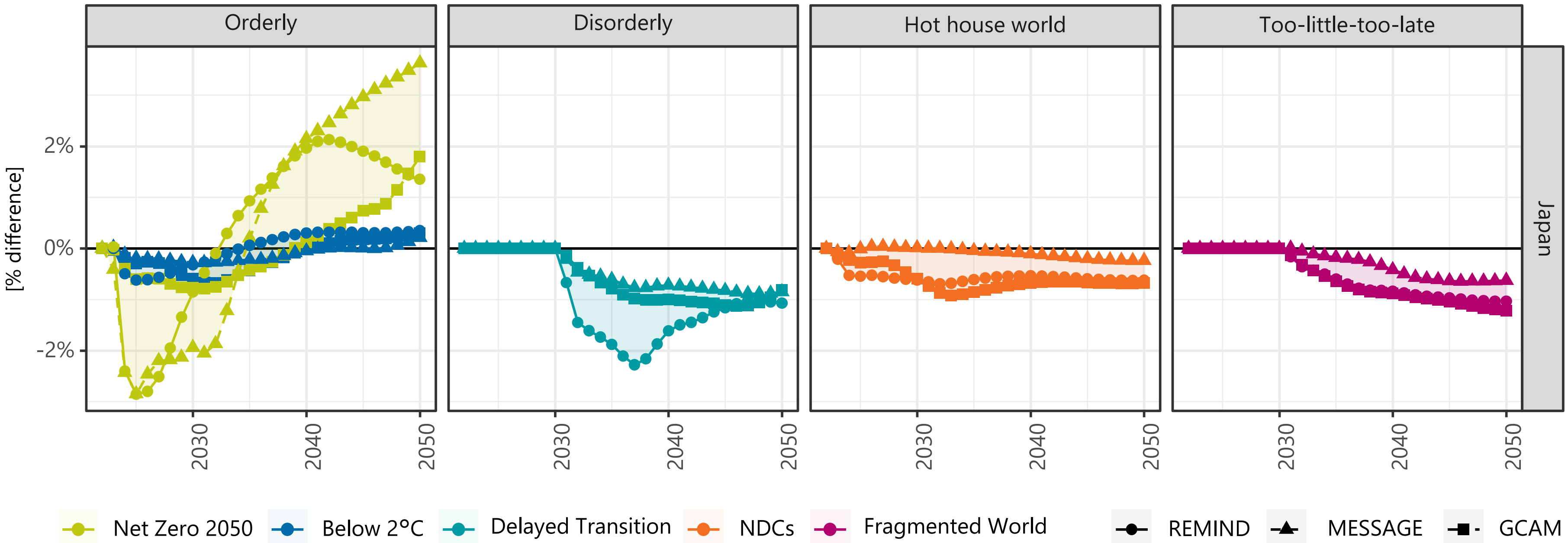
Volume of primary energy (by region, against the baseline)



GDP (Japan)

- While GDP decreases immediately after the implementation of policies such as carbon pricing, some scenarios/models show a recovery trend thereafter.
- In the Net Zero 2050 scenario, although GDP falls in the short term, improved energy efficiency and other positive effects surpass the negative effects in the long run.

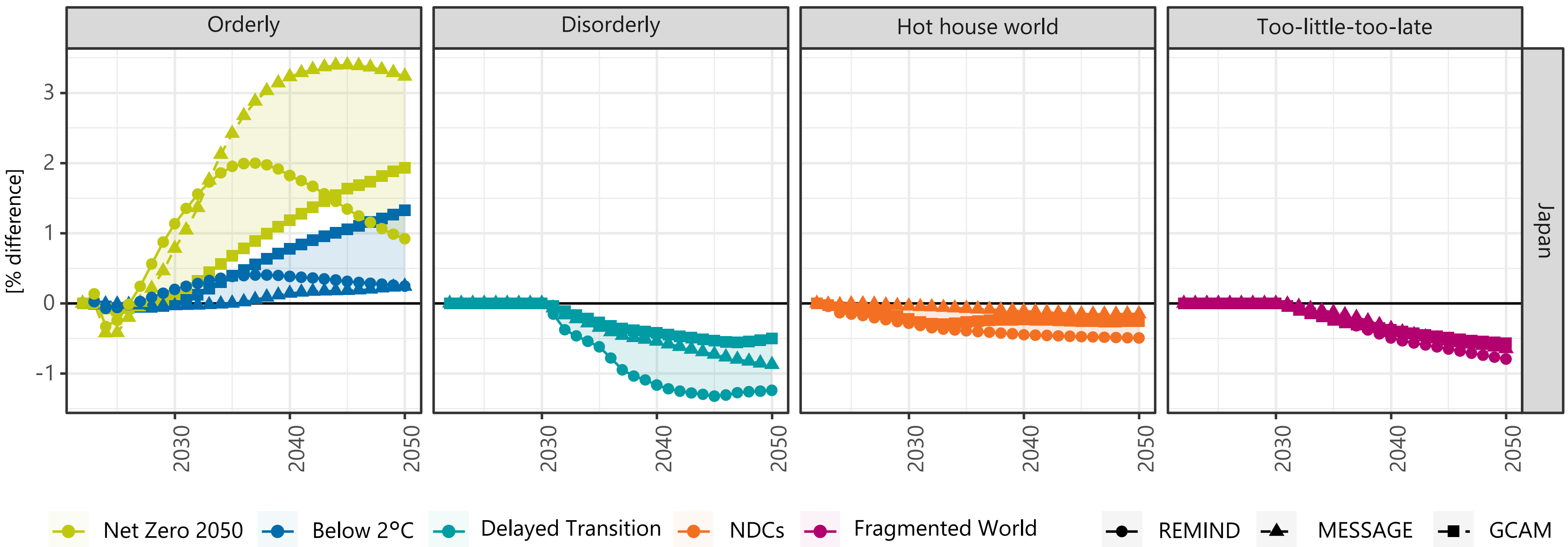
Transition risk impacts on GDP (Japan, against the baseline)



Potential GDP (Japan)

- In the Net Zero 2050 scenario, although potential GDP sees a temporary fall due to the introduction of carbon pricing, it subsequently recovers rapidly, with greater potential GDP growth and productivity rises than in the base case (however, it should be noted that there is substantial divergence between the IAMs).
- A variety of factors could possibly have had an effect on potential GDP growth, including the recovery in useful energy and the accumulation of capital due to government investment.

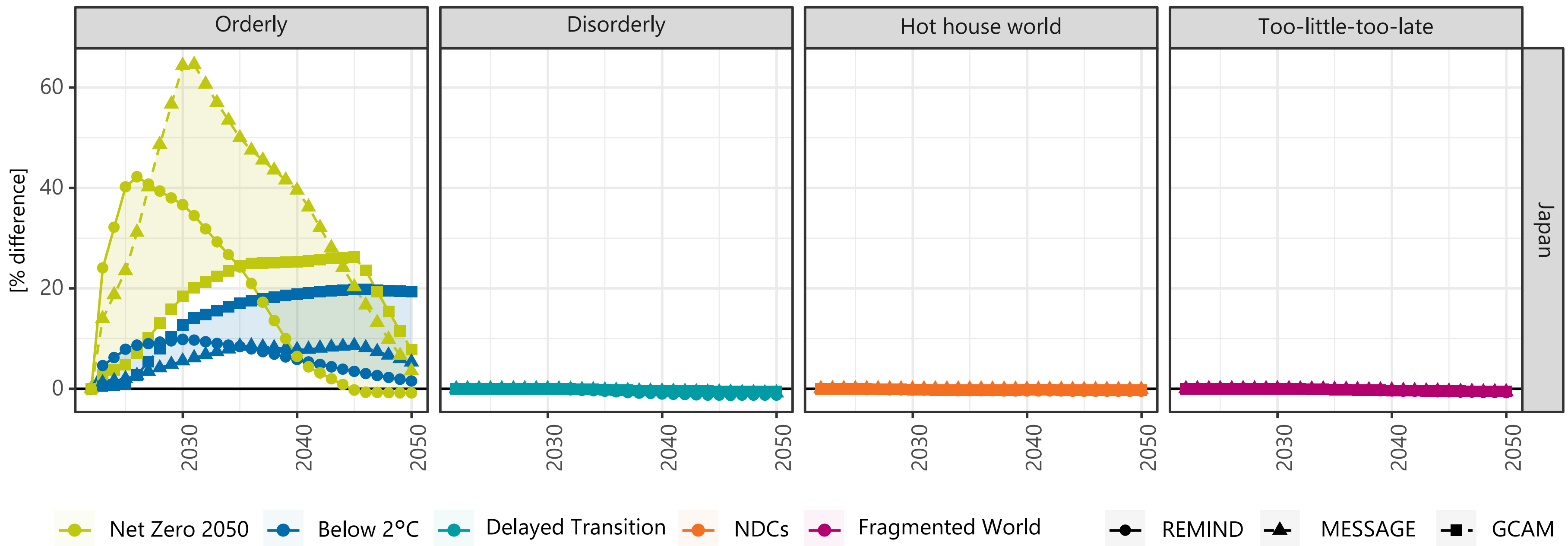
Transition risk impacts on potential GDP (Japan, against the baseline)



Government investment (Japan)

- In the Orderly scenarios (Net Zero 2050 and Below 2°C), half of carbon revenue is recycled into the economy as government investment (in the other scenarios, it is recycled as tax reductions). This recycled revenue contributes to the recovery of potential GDP in the medium to long term via the accumulation of capital, etc.

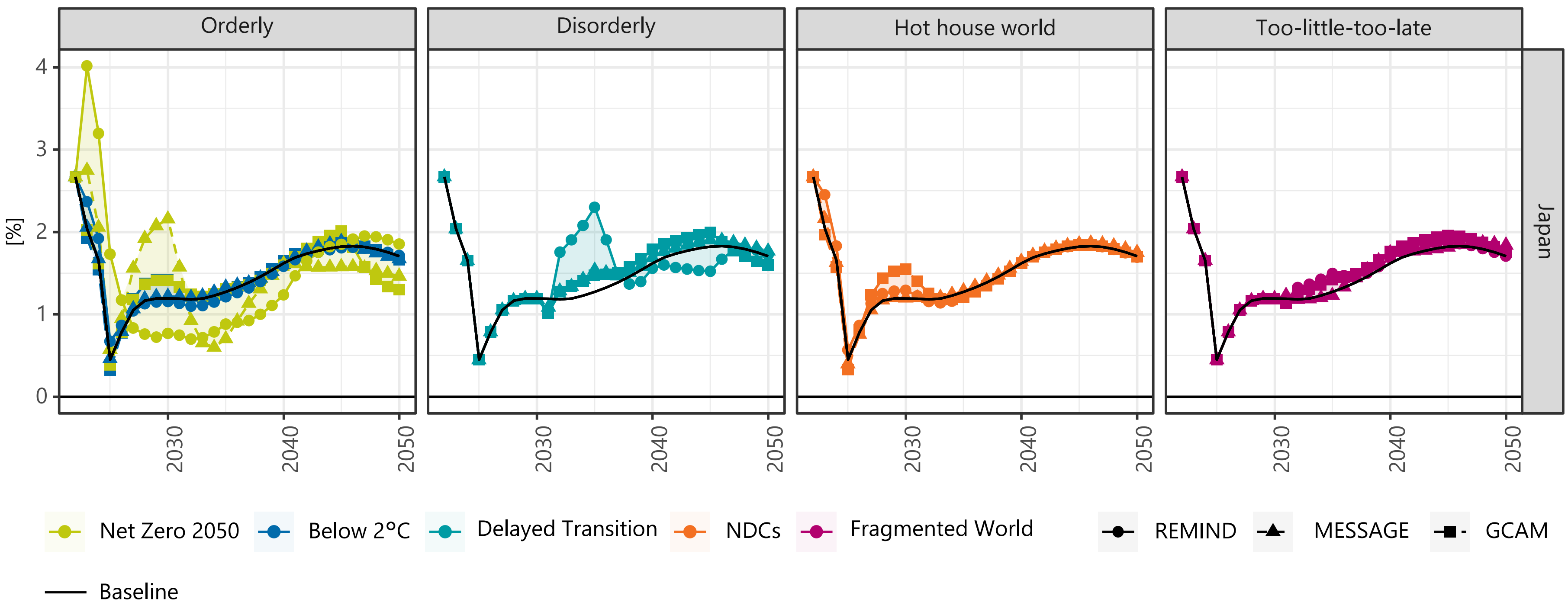
Transition risk impacts on government investment (Japan, against the baseline)



Inflation rate (Japan)

- The inflation rate rises in the short term immediately after the introduction of the carbon pricing policy.
- In scenarios with greater progress in reducing emissions, useful energy demand (an input variable from IAMs) decreases, causing energy's contribution to factors of production to fall (as energy efficiency improves), and inflation therefore settles down in the long term.
- In addition, in scenarios with greater progress in reducing emissions, the decline in fossil fuel demand (an input variable from IAMs) causes fossil fuel (oil, natural gas, and coal) prices to fall, which becomes a factor depressing prices as a whole.

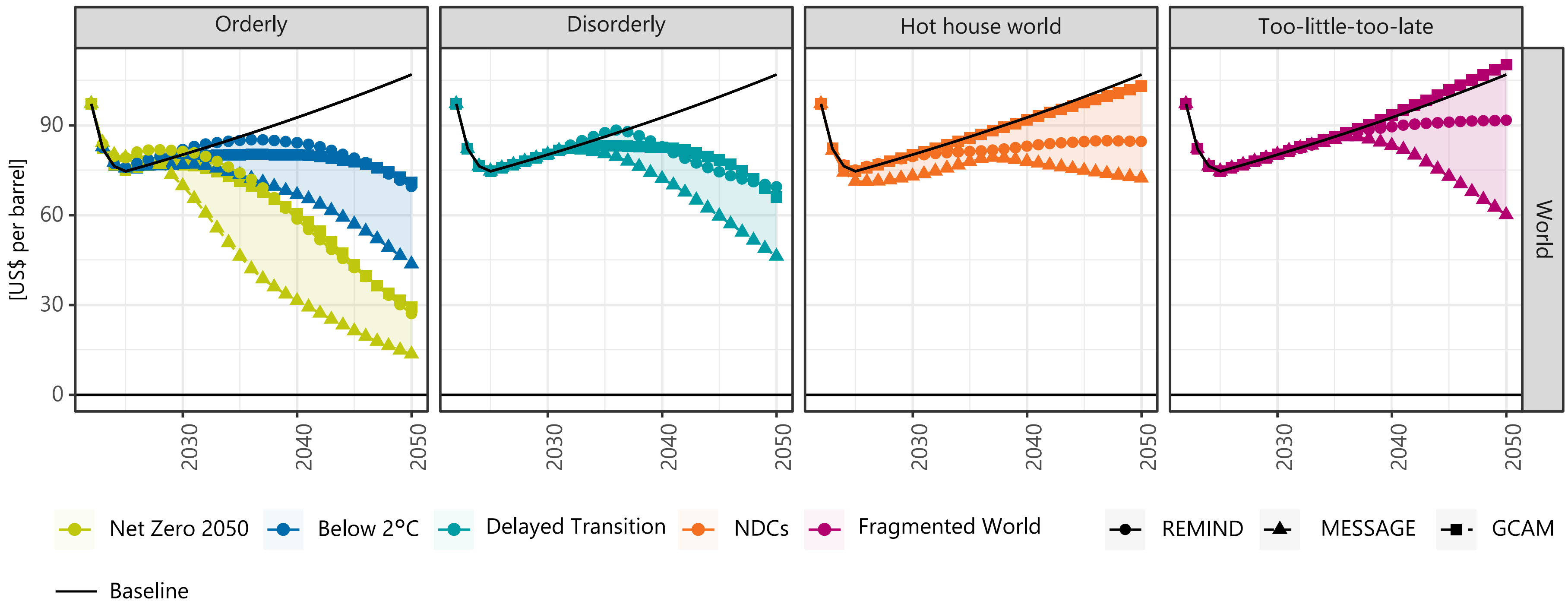
Transition risk impacts on the inflation rate (Japan)



Primary energy prices (oil)

- Due to declining energy demand as emissions reductions progress, primary energy prices also fall worldwide.
- The medium- to long-term fall in primary energy prices contributes to a decline in the rate of inflation.

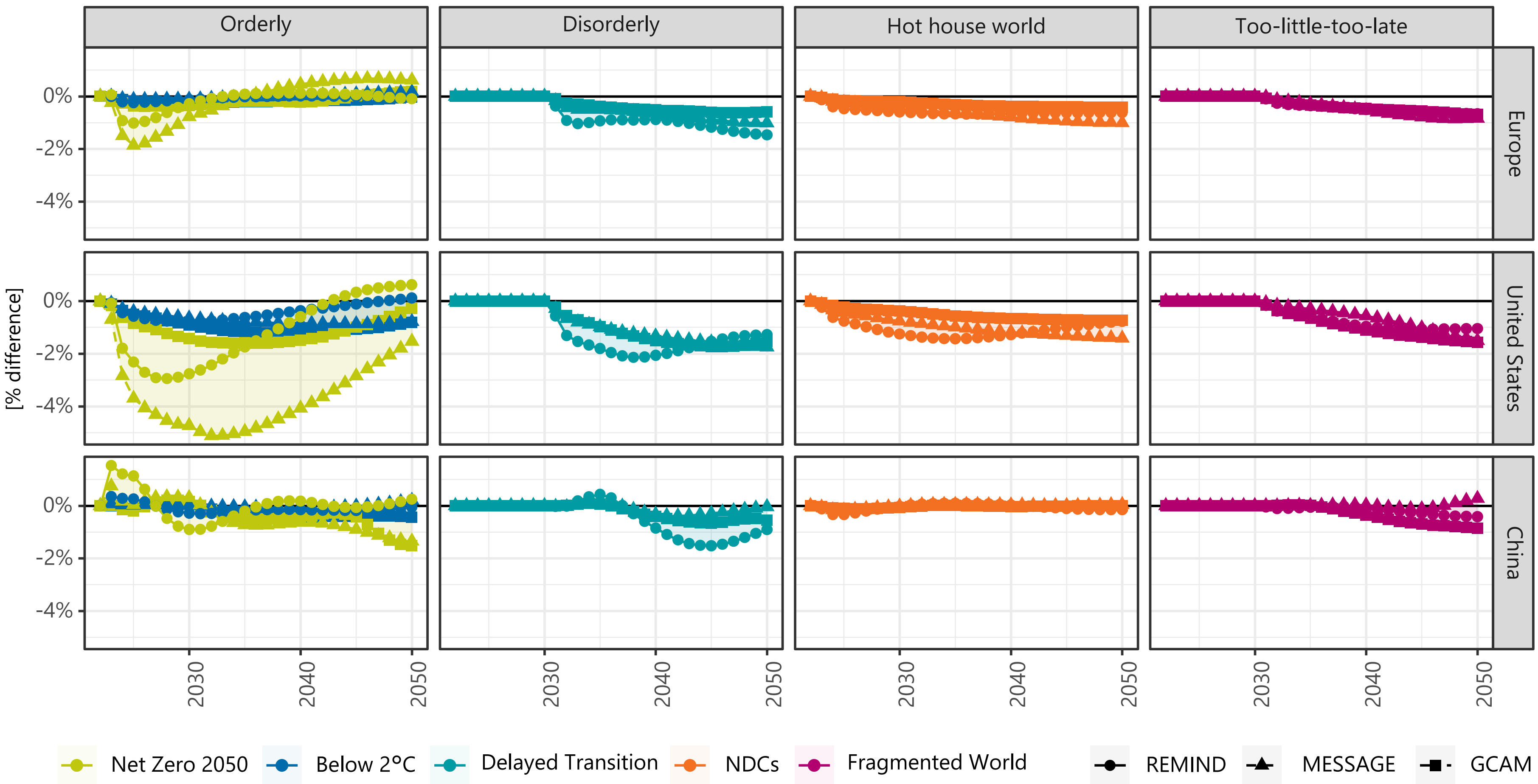
Transition risk impacts on primary energy prices (oil, worldwide)



GDP (Europe, U.S., and China)

- The pace of recovery from the fall in GDP caused by policy implementation is weaker than in Japan.

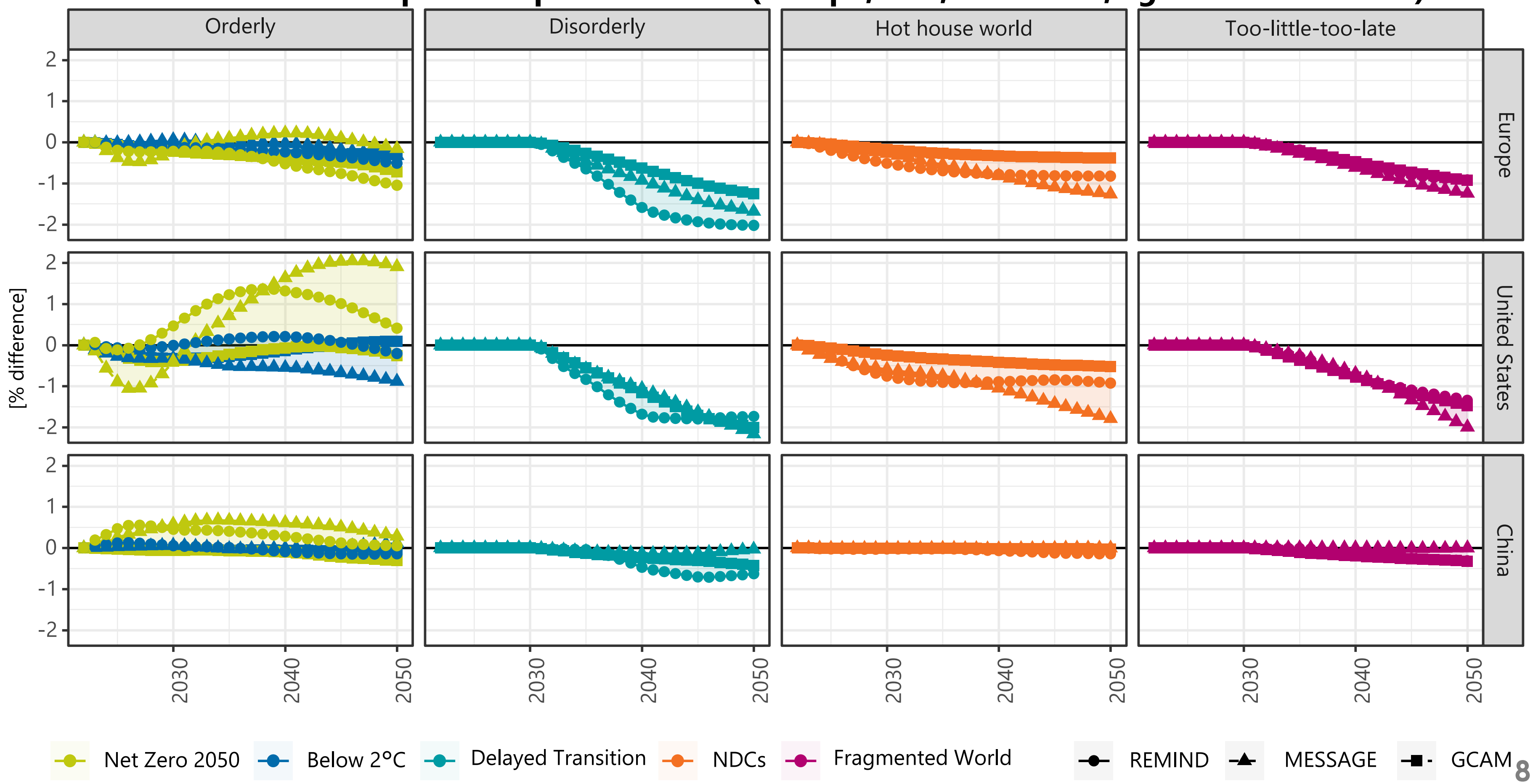
Transition risk impacts on GDP (Europe, U.S., and China, against the baseline)



Potential GDP (Europe, U.S., and China)

- In the Net Zero 2050 scenario, although potential GDP sees a temporary fall due to the introduction of carbon pricing, it subsequently recovers rapidly, with greater potential GDP growth and productivity rises than in the base case (however, it should be noted that there is substantial divergence between the IAMs).
- A variety of factors could possibly have had an effect on potential GDP growth, including the recovery in useful energy and the accumulation of capital due to government investment.

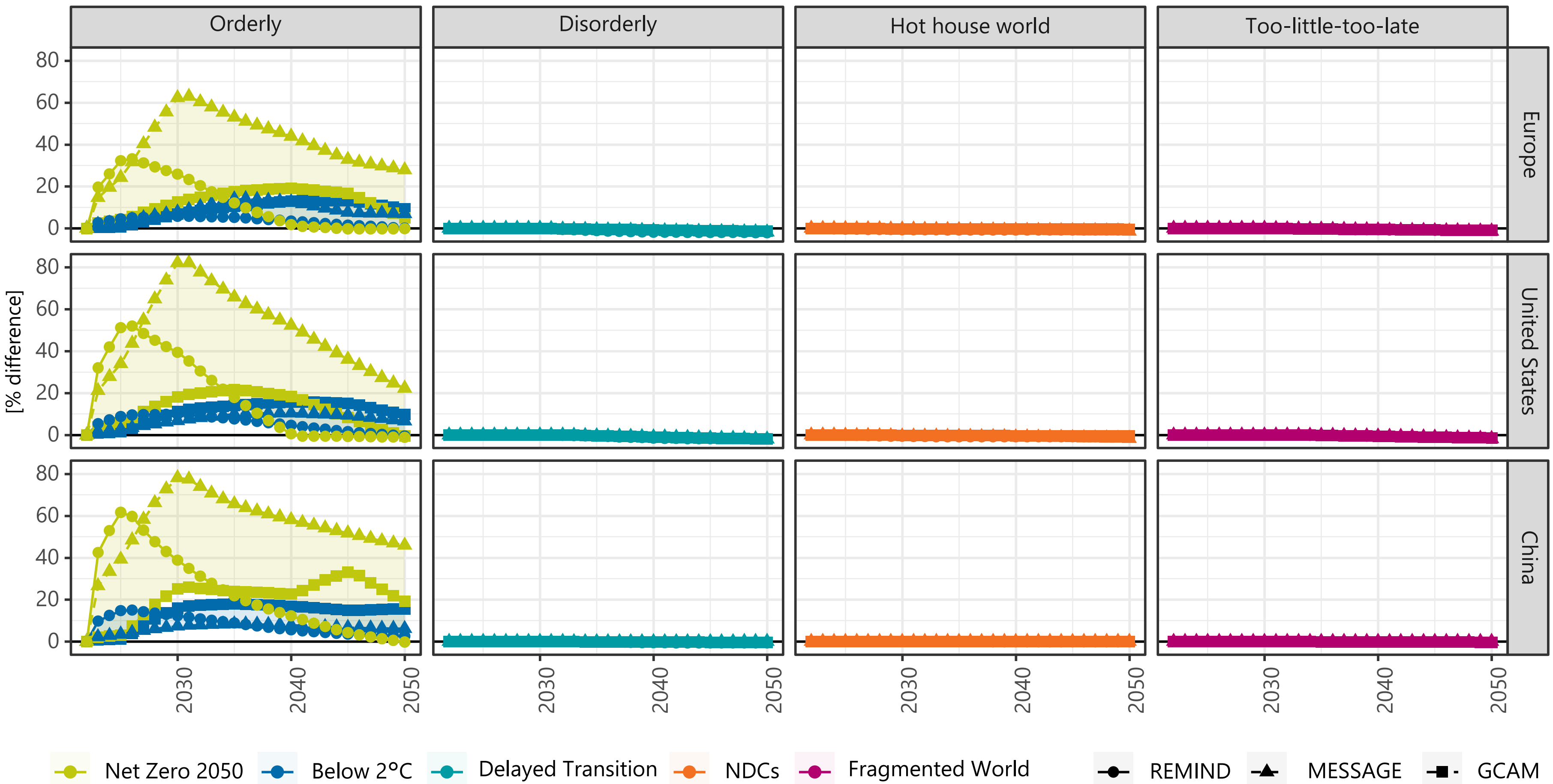
Transition risk impacts on potential GDP (Europe, U.S., and China, against the baseline)



Government investment (Europe, U.S., and China)

- In the Orderly scenarios (Net Zero 2050 and Below 2°C), half of carbon revenue is recycled into the economy as government investment. There is no change in government investment in the other scenarios, where carbon revenue is recycled as tax reductions.

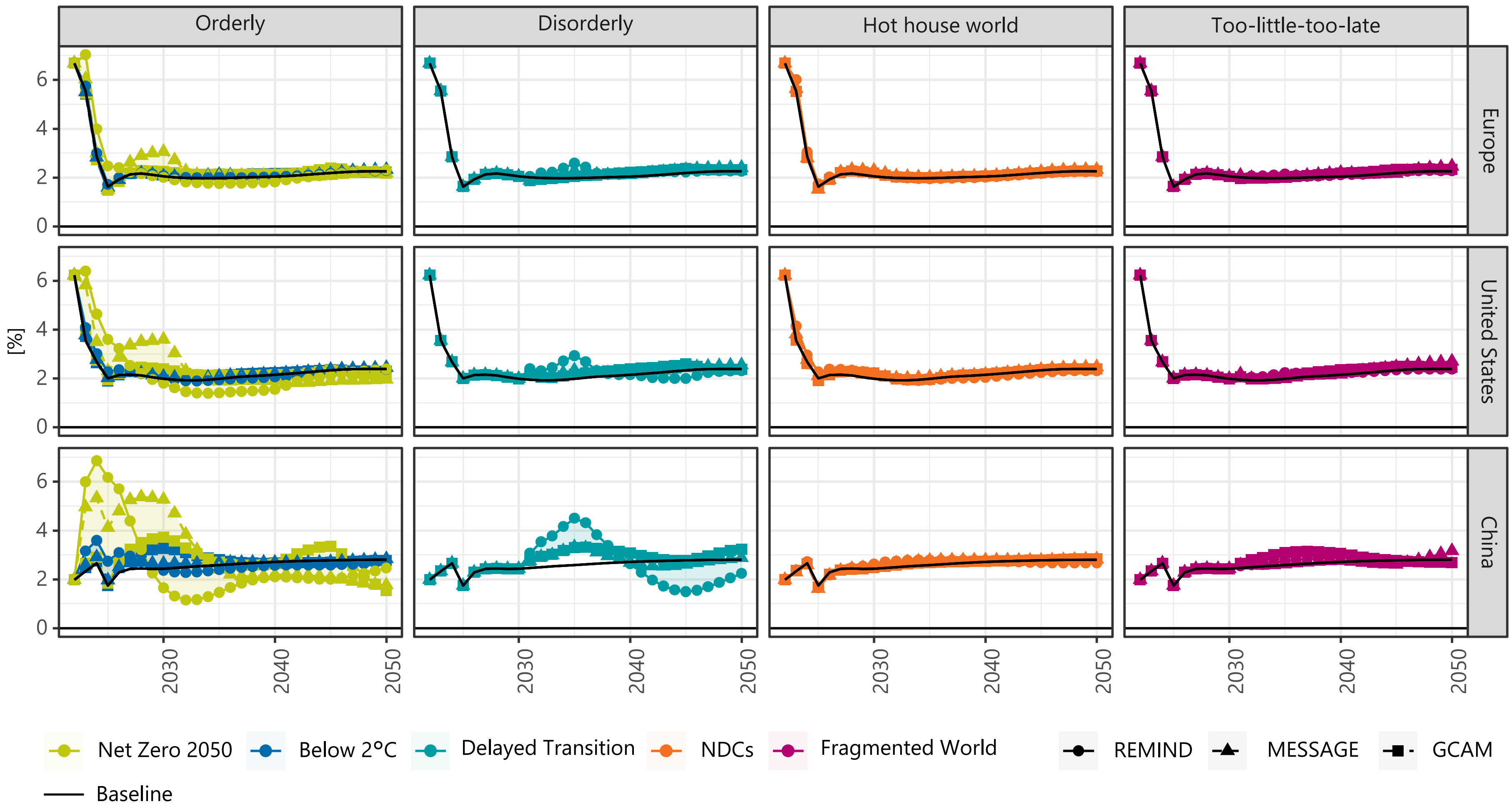
Transition risk impacts on government investment (Europe, U.S., and China, against the baseline)



Inflation rate (key regions)

- High inflation against the baseline was seen in the Net Zero 2050 scenario for China. This is thought to be because, in addition to the impacts of carbon pricing, increased effective demand arising from government investment also accelerated inflation.

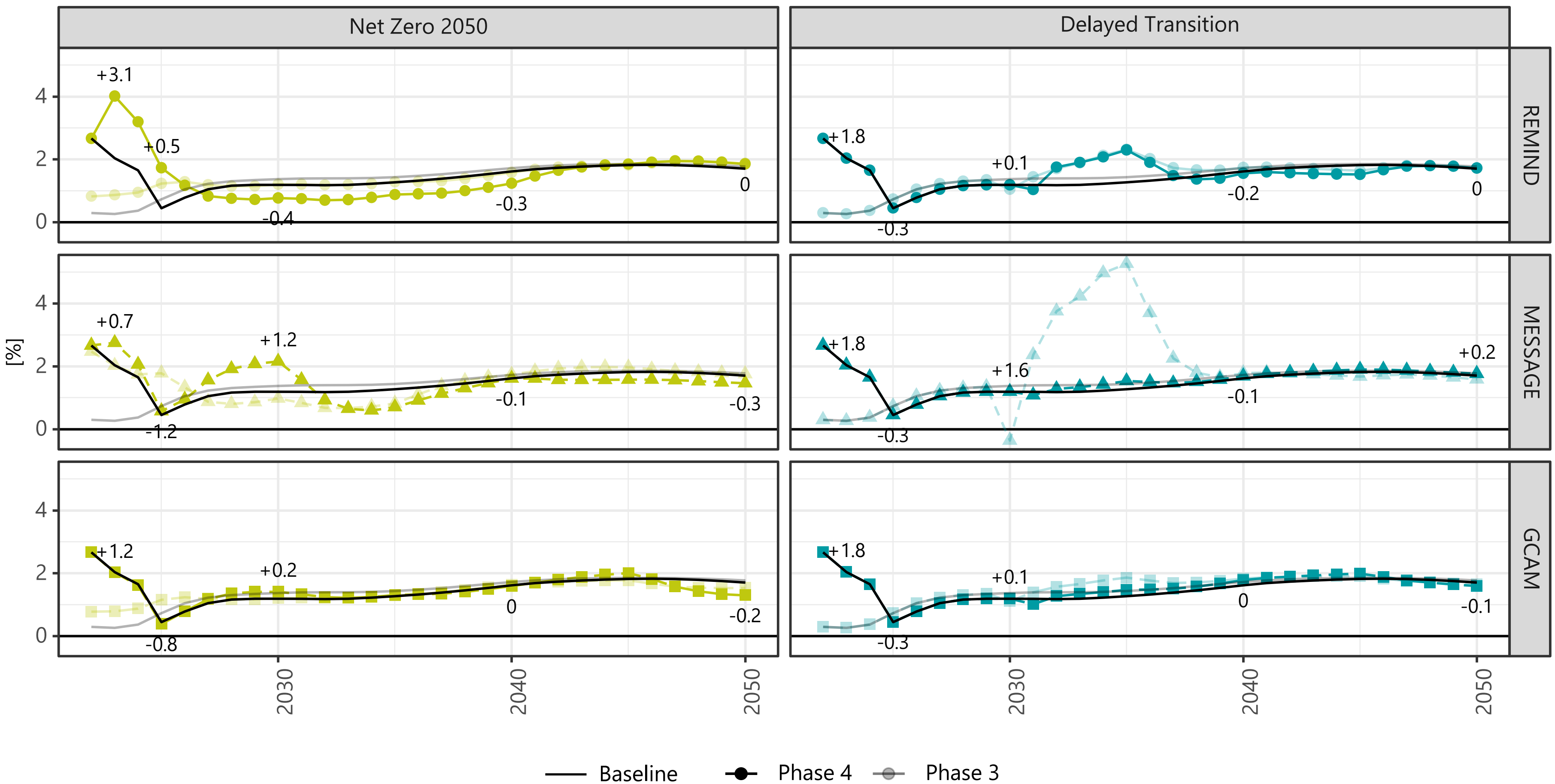
Transition risk impacts on the inflation rate (Europe, U.S., and China)



Inflation rate (Japan, comparison with Phase III)

- The Phase IV scenarios reflect current price rises.
- While rapid inflation was observed immediately after policy implementation in MESSAGE in the Delayed Transition scenario in Phase III, this has been revised in Phase IV.

Transition risk impacts on the inflation rate (Japan, comparison with Phase III scenarios)



Assessment of macroeconomic impacts and points to bear in mind

Macro-economic impacts associated with physical risk factors	• As in the Phase III scenarios, both GDP and potential GDP decline due to temperature rises. • The range of the fall in GDP and potential GDP is greater in the Current Policies and Fragmented World scenarios than in the other scenarios. This is due to differences in the temperature estimates applied to the damage functions (p. 51). This point must be kept in mind when interpreting the results.
Macro-economic impacts associated with transition risk factors	• In the Net Zero 2050 scenario, a short-term fall in GDP and a rise in inflation were observed as a result of carbon pricing, but in Net Zero 2050, GDP sees a medium- to long-term recovery that takes it above the Delayed Transition scenario. • Recycling half of carbon revenue as government investment has a substantial effect in this regard in the Net Zero 2050 scenario. It must be borne in mind that the difference between the results of these two scenarios stems from differences in the method of recycling carbon revenue.
Updates from the Phase III NGFS scenarios	• The basic framework for assessing macroeconomic impacts is the same as in Phase III. • The Phase IV scenarios appear to reflect recent price rises in current inflation rates and the like.
Other points to bear in mind	• Although not dealt with in this report, among the variables provided regarding macroeconomic impacts, carbon pricing has seen a rise to an extremely high level compared with the IAM values, which also affects domestic energy prices (such as oil prices). The reason for this is unclear, but because energy consumption as a proportion of overall GDP falls through to 2050, the impact on the key macroeconomic variables of GDP and the inflation rate is thought to be limited.

5. Use of NGFS Scenarios by Financial Institutions

Role and positioning of the NGFS scenarios

- An international network of central banks and financial supervisory authorities, NGFS encourages a proactive approach to the integration of future climate-related risks into financial stability monitoring and prudential supervision. In June 2020, as part of these efforts, NGFS published a guide to climate scenario analysis and a set of climate scenarios for central banks and supervisors (the NGFS scenarios).[*1,2]
- The NGFS scenarios were developed for use by such authorities in conducting risk analysis of financial systems and individual financial institutions (stress testing), and in analyzing the impacts of climate change on entire economies.[*1] Accordingly, unlike other scenarios, the NGFS scenarios are characterized by the fact that the future development of transition risks, physical risks, and macroeconomic impacts is coherently quantified on the basis of various emission pathways.
- At the same time, areas for improvement have been pointed out, given the scenarios' initially envisaged purpose of being used in risk assessment (stress testing) by authorities (see p. 108 for a summary). As such, NGFS continues to refine the scenarios based on the results of an ongoing process of scenario improvement and enhancement in collaboration with various national authorities, market participants, and external research institutions.
- In addition, the NGFS scenarios are used by organizations including financial institutions and research institutions for a variety of objectives beyond their original purpose of use in risk analysis by central banks and supervisors.[*3]

*1 NGFS (2020a); *2 NGFS (2020b); *3 NGFS (2023b).

Types of climate scenario use by financial institutions

- The NGFS scenarios are used for various objectives that go beyond their originally envisaged purpose of use in risk analysis (stress testing) by central banks and supervisors.

Use of NGFS Scenarios by Financial Institutions[*1]

A Risk analysis by financial institutions	1 Climate scenario analysis	Quantitative and qualitative validation of the resilience of a financial institution's strategy after envisaging various future scenarios, including extreme scenarios.
	Climate stress testing	Validation of the resilience of financial systems or financial institutions after envisaging future scenarios that are extreme, but possible. Validation of capital and liquidity adequacy, when conducted by individual financial institutions.
B Use in strategy development and Implementation by financial institutions	2 Development of strategies and targets	When envisaging a transition to climate neutrality, alignment of financed emissions on a portfolio or sectoral basis with emission pathways set out in scenarios, and alignment of financial activities on a portfolio or sectoral basis, or alignment of such financial activities with technologies set out in scenarios.
	3 Engagement	Encouragement of customers responsible for particularly large impacts to implement measures to address them or to transition their business, taking into account technology development set out in scenarios for transition to climate neutrality and the progression of future physical risks indicated in warming scenarios.

- **With regard to items ①–③ above, section 5.1 presents examples of the use of climate scenarios by financial institutions, based on TCFD reports and the like.**
- **Section 5.2 summarizes the features of the Phase IV scenarios and examines the use of NGFS scenarios by financial institutions and associated issues, based on the examples of their use by financial institutions and various reference literature.**

*1 Compiled with reference to BCBS (2022) and NGFS (2023b).

5. Use of NGFS Scenarios by Financial Institutions

5.1 Examples of the use of climate scenarios by financial institutions

5.2 Proposals for the use of NGFS scenarios

Examples of the use of climate scenarios by financial institutions: Case study methodologies

- Looking at the companies that responded to the CDP Climate Change 2022 Questionnaire, we selected financial institutions as candidates for analysis of usage examples, based on the details provided by financial institutions that responded to question C3.2a regarding scenario analysis (n=321).
- We then used the latest (as of March 2024) climate-related information disclosed on the selected financial institutions' websites to check their statements regarding scenario analysis and put together an overview.

Case Study Methodologies

STEP 1
Search for relevant examples
- Using data from responses to the CDP Climate Change 2022 Questionnaire, we extracted an overview of scenario analysis by financial institutions.
- For each scenario analysis objective and approach, we used keyword searches to extract financial institutions that would serve as candidates for analysis.

STEP 2
Detailed cases of examples
- We used the latest reports and other information published on the websites of candidate financial institutions to check the details directly.
- We then put together an overview of examples that appeared particularly typical.

STEP 3
Summary of usage examples
- Based on each example, we summarized examples of scenario usage by financial institutions.
- We then examined the areas for improvement in the scenarios for various uses based on reference literature and the cases.

Climate scenario analysis objectives and approaches

- After envisaging various future scenarios, financial institutions use climate scenario analysis to conduct quantitative and qualitative analysis of the resilience of their strategies.

Objectives of climate scenario analysis by financial institutions*1

(i) Resilience analysis	Analysis/assessment of the impacts of climate change and the transition to a low-carbon economy on the financial institution's strategy and the resilience of its business model
(ii) Risk identification	Identification of climate-related risk factors
(iii) Exposure/loss estimation	Measurement of vulnerability to climate-related risks, and estimation of exposures and potential losses
(iv) Validation of analytical challenges	Diagnosis of data and methodological limitations in the financial institution's climate risk management
(v) Validation of risk management	Validation of the adequacy of the bank's risk management framework, including risk mitigation options

Approaches to climate scenario analysis

Risk type	• Transition risks • Physical risks (chronic/acute)
Focus	• Whole portfolio • Specific industries/asset classes
Period	• Short term (several years) • Medium/long term (several decades)
Analysis results	• Quantitative • Qualitative

*1 BCBS (2022).

Risk analysis focused on the whole portfolio

Invesco Asset Management (U.S., asset manager)[*1]

- Using the Phase III NGFS scenarios, Invesco quantitatively measures long-term transition risk and physical risk, and verifies the validity of its investment strategy in high-emitting sectors.

Objectives	(i) Resilience analysis (ii) Risk identification (iii) Exposure/loss estimation
Risks	Transition risks and physical risks
Focus	Whole portfolio
Period	Long term (to 2050)
Results	Quantitative

Overview of analysis

Focus of analysis	Equities (covering 83.41% of the value of equities under management), corporate bonds (covering 39.22% of the value of corporate bonds under management), and sovereign bonds[*2]
Scenarios	• Phase III NGFS scenarios: - Orderly: Below 2°C - Disorderly: Delayed Transition - Hot house world: Current Policies • Forecast Policy Scenario (FPS) 2022 (positioned as supplementary to analysis based on the NGFS scenarios)
Risk measurement	Forecasts changes in the revenue of individual investees resulting from the risk factors below, and calculates changes in equity and corporate bond valuations through to 2050 - Transition risks: Carbon pricing, changes in product demand, cost reductions due to emissions reductions, market forces - Physical risks: Direct losses due to acute/chronic risks, cost reductions due to adaptation
Analysis results	• The negative impacts of transition risks were highest in the Disorderly quadrant, and particularly large in the Utilities, Materials, and Energy sectors. This result supported the validity of Invesco's investment strategy in high-emitting sectors. • While the impact of losses due to physical risks was low, the company mentions substantial regional variation and the possibility of undervaluation due to modeling limitations. Improving future analytical capabilities is a challenge.

*1 Invesco (2023); *2 Details concerning sovereign debt have been omitted from this summary.

Risk analysis focused on the whole portfolio

a.s.r. (Netherlands, insurer)*1

Objectives	(i) Resilience analysis (ii) Risk identification (iii) Exposure/loss estimation
Risks	Transition risks and physical risks
Focus	Whole portfolio
Period	Long term (to 2050)
Results	Quantitative

- Using external scenarios similar to the NGFS scenarios, a.s.r. measures the long-term impact of both transition risk and physical risk on assets under management and insurance reserves.

Overview of analysis

Focus of analysis	Assets under management
Scenarios	• External scenarios (Ortec Finance): - Orderly transition to the Paris Agreement (1.3-2.4°C; SSP1-2.6) - Disorderly transition to the Paris Agreement (2.1-3.5°C; SSP2-4.5) - Failed transition to the Paris Agreement (3.3-5.7°C; SSP5-8.5) - Base scenario (envisages neutral policy changes)
Risk measurement	Measures impacts based on scenarios calculated by the data provider (Ortec Finance) from the following data - Climate data: IPCC - Economic impacts: GDP shocks developed by an external data provider (Cambridge Econometrics)
Analysis results	• Compared with the base scenario, earnings from assets under management deteriorate in all scenarios, with the biggest impact seen in the Failed Transition scenario. • Under all scenarios, a.s.r. maintains the minimum Solvency Capital Requirement; the insurer attributes this to the fact that its investment portfolio is centered on Europe and also to its sustainable investment policy.

*1 a.s.r. (2023).

Risk analysis focused on the whole portfolio

Bank of America (U.S., bank)[*1]

Objectives	(ii) Risk identification (iii) Exposure/loss estimation
Risks	Transition risks
Focus	Whole portfolio
Period	Short term & long term (2052)
Results	Quantitative & qualitative

- Using the NGFS scenarios, Bank of America mainly quantitatively assesses the impact of long-term transition risk and physical risk.
- Also uses its own Instantaneous and Idiosyncratic scenarios.

Overview of analysis

Focus of analysis	Commercial loans, commercial real estate (credit risk), trading and counterparty (market risk), derivative collateral (liquidity risk)
Scenarios	NGFS scenarios: - Net Zero 2050 - Delayed Transition Other: - Instantaneous scenario (market risk only) - Idiosyncratic scenario
Risk measurement	• Credit risk: In light of the specific nature of each sector, the impacts of factors such as GHG emissions and changes in fuel prices are measured using internal models • Market risk: Constructed on the basis of narratives in long-term NGFS scenarios, a short-term scenario is used to measure impacts on the bank's trading portfolio • Liquidity risk: Impacts on derivative collateral requirements and commercial loans are measured on the basis of sudden transition shock scenarios and long-term NGFS scenarios
Analysis results	• Climate-related transition risk for the majority of the bank's lending portfolio is assessed as low or moderate.

*1 Bank of America (2023).

Risk analysis focused on the whole or part of the portfolio

Objectives	(ii) Risk identification (iii) Exposure/loss estimation
Risks	Transition risks and physical risks
Focus	Whole/partial portfolio
Period	Long term (to 2050)
Results	Quantitative & qualitative

Goldman Sachs (U.S., bank)*1

- Using its own scenarios and data, Goldman Sachs quantitatively assesses the impacts of transition risk and physical risk (in the case of physical risk, the bank assesses the severity of the risk in qualitative terms).

Overview of analysis

Focus of analysis	Transition risk: lending portfolio; physical risk: real estate property collateral
Scenarios	Transition risks: - Scenario that reaches the Paris Agreement goal (1.5°C goal) worldwide (the same scenario as NGFS Net Zero 2050, equivalent to RCP2.6 or RCP1.8) - Scenario that partially reaches the Paris Agreement goal (equivalent to RCP3.7 or RCP4.5) - Baseline (equivalent to NGFS Current Policies or RCP6.0) Physical risks: - RCP2.6, RCP6.0, RCP8.5
Risk measurement	Transition risks: - Calculates impacts on credit ratings and corporate value against the baseline, based on data relating to the emissions of sectors and individual borrowers, and also to past risk factors - Re-assesses all asset values on the balance sheet under each scenario and assesses any potential losses Physical risks: - Uses climate model data to establish a four-level index for the severity of physical risk factors at different geographic locations and assess the scale of impacts qualitatively
Analysis results	Transition risks: Impacts on asset values stemming from climate-related transition risks are low in comparison with other factors.

*1 Goldman Sachs (2023).

Risk analysis focused on part of the portfolio

Commonwealth Bank of Australia (Australia, bank)[*1]

Objectives	(i) Resilience analysis (ii) Risk identification (iii) Exposure/loss estimation
Risks	Transition risks and physical risks
Focus	Specific industries
Period	Long term (to 2050)
Results	Qualitative

- Focusing on two sectors within Australia (home loans and agricultural loans), the bank measures the exposure of each sector to transition risk and physical risk.

Overview of analysis

Focus of analysis	Home loans and agricultural loans
Scenarios	• Uses a combination of NGFS scenarios, IEA scenarios, and IPCC RCP scenarios - Delayed transition scenario: NGFS Phase III Delayed Transition + RCP4.5 - 1.5°C scenario: IEA NZE + RCP2.6 - Physical risk scenario: NGFS Phase III Current Policies + RCP8.5
Risk measurement	• Home loans: - Transition risks: Risk of default due to the decline of Australia's domestic fossil fuel industry and regional economies - Physical risks: Exposure to acute risk (cyclone, fire, and flood) and chronic risk (sea level rise) • Agricultural loans: - Modeling of environmental change in high-productivity areas (in partnership with a research institution)
Analysis results	• Home loans (as a percentage of lending exposure within Australia): - Transition risks: Assessed as high default risk, with 2.5% (delayed transition scenario) - Physical risks: Assessed as high risk, with acute risk at 4.6% and chronic risk at below 0.3% (physical risk scenario)

*1 Commonwealth Bank of Australia (2023).

Qualitative risk management with reference to climate scenarios

CaixaBank (Spain, bank)[*1]

Objectives	(ii) Risk identification (iii) Exposure/loss estimation (v) Validation of risk management
Risks	Transition risks
Focus	Whole portfolio
Period	Short to long term (2050)
Results	Qualitative

- With reference to climate scenarios, CaixaBank identifies factors that could become transition risks on a sectoral basis and prepares sectoral transition risk heat maps.

Overview of analysis

Focus of analysis	Whole portfolio (sectoral basis)
Scenarios	• NGFS scenarios: - Orderly transition (Net Zero 2050) - Disorderly transition (Delayed Transition) - Hot House World (Current Policy)
Risk measurement	• With reference to climate scenarios, identifies factors (variables) that could become major risks on a sectoral basis and the impacts thereof, and establishes risk heat maps for different time horizons (2025, 2030, 2040, and 2050)
Analysis results	• The energy, transport, iron and steel, aluminum, cement, agriculture, mining, and materials sectors have been determined to be high-risk sectors, and high-risk, high-exposure sectors have been identified.

*1 CaixaBank (2022, 2023).

Qualitative risk management with reference to climate scenarios

Lincoln National Corporation (U.S., insurer)*1

- Lincoln National Corporation validates its risk management framework using climate scenarios as a qualitative reference.

Objectives	(ii) Risk identification (iii) Exposure/loss estimation (v) Validation of risk management
Risks	Physical risks
Focus	Whole portfolio
Period	-
Results	Qualitative

Overview of analysis

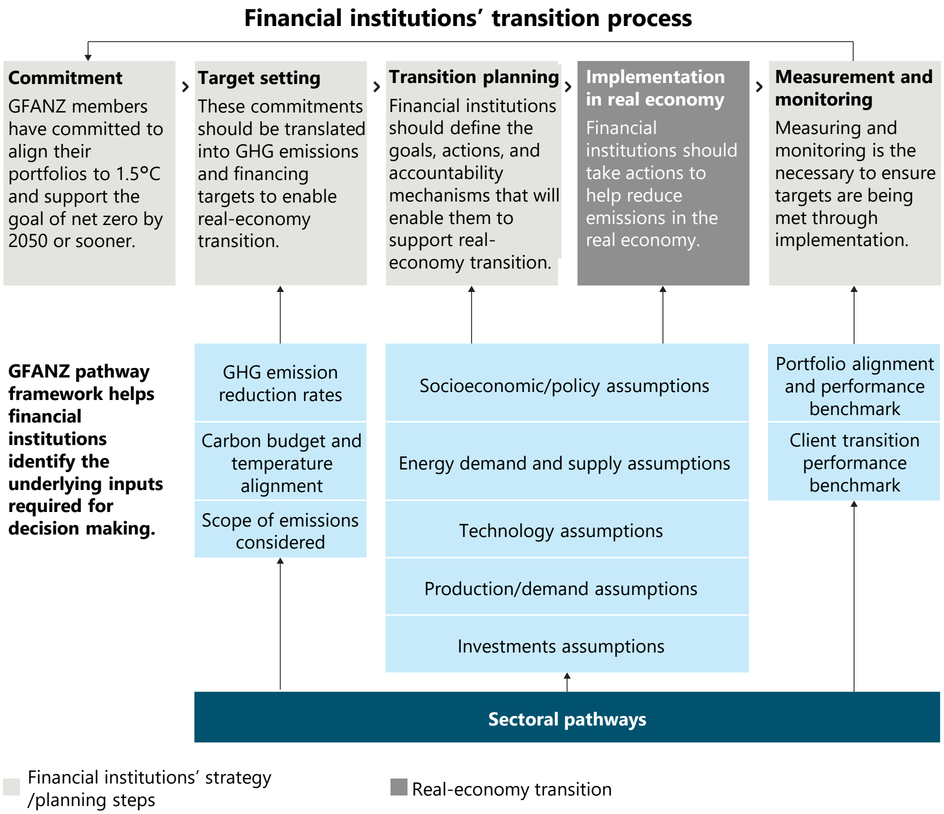
Focus of analysis	-
Scenarios	• IPCC RCP scenarios: - Baseline scenario: RCP2.6 (1.6-2.0°C) - Extreme scenario: RCP8.5 (4.1°C)
Risk measurement	• Has qualitatively identified key risk categories based on a comparison of baseline and extreme scenarios Assesses the importance of identified risk categories as part of the insurer's stress testing • Also considers the effects of risk mitigation actions in identifying risk categories
Analysis results	• All identified physical risks were assessed as falling within the insurer's risk tolerance.

*1 Lincoln National Corporation (2023).

Development of strategies and targets by financial institutions with reference to climate scenarios

- Financial institutions seek to address transition risk by setting targets for reducing their financed emissions and exposure in specific sectors.
- In technical documentation*1 on sectoral pathways published in June 2022, GFANZ lists several scenarios, including NGFS, as examples relevant to target setting and transition planning by financial institutions.

Role of sectoral pathways in a financial institution's transition process



Scenarios and assumptions used as examples by GFANZ

IEA	• Net Zero Emissions by 2050 (NZE2050)
NGFS	• Net Zero 2050 (REMIND) • Net Zero 2050 (MESSAGE) • Net Zero 2050 (GCAM)
UTS*2	• One Earth Climate Model (OECM)

Criteria for scenario selection in GFANZ (2022):
- They have detailed methodology and public access to data/assumptions.
- They provide some sector-level granularity.
- They are in line with the required level of ambition of 1.5°C.
- They are widely used/recognized (IEA and NGFS) or supported by financial institutions (UTS is backed by the Net-Zero Asset Owners Alliance).

*1 GFANZ (2022); *2 University of Technology Sydney.

Reference to scenarios in target setting 1/2

- Many financial institutions that conduct climate scenario analysis have declared the goal of achieving net zero financed emissions in their lending and insurance portfolios by 2050, and have set interim targets aligned with this goal.
- The majority of the financial institutions highlighted in section ① have used 2030 as their deadline when setting interim targets for their entire portfolio or for key sectors. While sectoral scenarios such as those developed by IEA and MPP have been referred to in setting percentage reductions from a baseline year, no institutions have referred to the NGFS scenarios when setting targets.

Interim targets set by financial institutions and scenarios referred to

Invesco Asset Management	• Whole portfolio: 50% reduction in emissions by 2030 (against 2019 baseline)	IPCC SR15 S1/P2*1
a.s.r.	• Whole portfolio: 65% reduction in scope 1 and 2 emissions intensity by 2030 (against 2015 baseline)	-
Bank of America	• Automobiles: 48% reduction in scope 1, 2, and 3 emissions intensity by 2030 (against 2019 baseline) • Cement: 32% reduction in scope 1 and 2 emissions intensity by 2030 (against 2019 baseline) • Energy: 45% reduction in scope 1 and 2 emissions intensity and 29% reduction in scope 3 emissions intensity by 2030 (against 2019 baseline) • Power generation: 70% reduction in scope 1 emissions intensity by 2030 (against 2019 baseline)	IEA NZE2050
	• Aviation: 37% reduction in scope 1 emissions intensity by 2030 (against 2019 baseline)	MPP*2
Goldman Sachs	• Automobiles: 48% reduction in emissions intensity by 2030 (against 2019 baseline) • Energy: 17–22% reduction in emissions intensity by 2030 • Power generation: 48–65% reduction in emissions intensity by 2030 (against 2019 baseline)	-

*1 IPCC (2018); *2 Mission Possible Partnership.

Reference to scenarios in target setting 2/2

Interim targets set by financial institutions and scenarios referred to

Commonwealth Bank of Australia	• Power generation: 53% reduction in scope 1 emissions intensity by 2030 (against 2020 baseline) • Oil: 27% reduction in scope 1, 2, and 3 emissions by 2030 (against 2020 baseline) • Gas: 17% reduction in scope 1, 2, and 3 emissions by 2030 (against 2020 baseline) • Coal: 100% reduction in scope 1, 2, and 3 emissions by 2030 (against 2020 baseline)	IEA NZE (2021)
	• Steel: 30% reduction in scope 1 and 2 emissions intensity by 2023 (against 2021 baseline) • Alumina: 62% reduction in scope 1 and 2 emissions intensity by 2023 (against 2021 baseline) • Aluminum: 46% reduction in scope 1 and 2 emissions intensity by 2023 (against 2021 baseline) • Cement: 23% reduction in scope 1 and 2 emissions intensity by 2023 (against 2021 baseline)	SBTi*1 & MPP
	• Housing: 60% reduction in scope 1 and 2 emissions intensity by 2030 (against 2021 baseline)	SBTi
CaixaBank	• Power generation: 30% reduction in scope 1 emissions intensity by 2030 (against 2020 baseline) • Oil and gas: 32% reduction in scope 1, 2, and 3 emissions by 2030 (against 2020 baseline)	IEA NZE (2021)
Lincoln National Corporation	-	-

*1 Science-based Targets Initiative.

Example of engagement using climate scenarios

Impax Asset Management (U.S., asset manager)[*1]

Risks	Transition risks and physical risks
Focus	Investees
Period	-
Results	Qualitative

- Based principally on qualitative scenario analysis, Impax identifies investees that represent a high risk from the perspectives of transition and physical risks.
- In engaging with investees, the asset manager not only undertakes climate risk management, but also requires the disclosure of the data needed for analysis (location data of individual assets).

Overview of analysis

Scenarios	• NGFS Net Zero 2050 scenarios (transition risks) • IPCC RCP scenarios: (details unknown) (physical risks)
Overview of analysis	• Identifies companies whose earnings would be substantially impacted by carbon prices, based on carbon prices in the NGFS Net Zero 2050 scenario and investee companies' emissions. • Considers the impact on location-level physical risks (including precipitation, extreme heat, and floods) for each asset held in its private equity and listed equity portfolios.
Use in engagement	• Undertakes engagement as part of regular dialogue with investees, focusing on climate risk management and disclosure, physical risk preparedness, and publication of location data concerning assets. • Immediately contacts investees to propose/request improvement measures where material concerns are identified. If improvements are not forthcoming, the asset manager considers such actions as approaching senior officers within the company, joint engagement with other investors, and filing shareholder resolutions.

*1 Impax Asset Management (2023).

Use of climate scenarios by financial institutions

1 Climate scenario analysis	Quantitative analysis of the whole portfolio or specific sectors/assets	• Examples of the quantitative measurement of transition and physical risk impacts across the entire portfolio or on a sectoral or individual investee basis were observed (however, detailed methodologies have not been published). • Among the financial institutions, there were also examples of the validation of impacts on capital adequacy requirements and other regulatory criteria. This would appear to indicate that such financial institutions have integrated climate-related risks into their internal stress testing. • In some cases, financial institutions used external scenarios or their own scenarios aligned with the NGFS scenarios.
	Qualitative analysis of transition risk	• Examples were seen of the qualitative analysis and consideration of the scale of sectoral risk with reference to the NGFS scenarios.
	Qualitative analysis of physical risk	• Examples were seen in which financial institutions employed physical risk variables and external data as a qualitative reference when measuring exposure and validating internal risk management.
2 Establishment of strategies and targets	• Even among financial institutions that refer to the NGFS scenarios in risk management, many referred to the IEA scenarios or other non-NGFS scenarios when setting targets.	
3 Engagement	• An example was observed in which the exposure of individual investees to physical risk was assessed qualitatively and used in engagement. This engagement included not only risk management checks, but also the acquisition of specific data.	

5. Use of NGFS Scenarios by Financial Institutions

5.1 Examples of the use of climate scenarios by financial institutions

5.2 Proposals for the use of NGFS scenarios

Use of NGFS scenarios in risk analysis and associated issues 1/2

- Among the examples of the use of climate scenarios by financial institutions, we identified cases in which the NGFS scenarios were used in risk analysis for the purpose of quantitatively assessing the impacts of transition and physical risks on a wide range of assets throughout the institutions' portfolios.
- At the same time, the NGFS scenarios as they stand at present appear to have some issues in light of their application in risk assessment. NGFS intends to continue updating the scenarios, so it is expected that these issues will be addressed and further enhancements made to information in future revisions.

Envisaged uses of the NGFS scenarios		Current issues and expected future improvements
Risk analysis focused on the whole portfolio	• It would appear that the scenarios were used in risk analysis focused on entire portfolios, because the impacts of physical risk and transition risk can be coherently quantified[*1]. • The analysis of the impacts on asset values and investment earnings of risks such as carbon price rises and GDP shocks (transition risks), and direct losses stemming from hazards (physical risks) were considered to be examples of such analysis.[*2,3] • The analysis of examples also suggested a need for financial institutions to expand their own scenarios or use external data[*2,3,4] (see also pp. 109-111).	• Some variables are not provided in the NGFS scenarios, depending on the objective of the risk analysis. As NGFS is working on such tasks as improving sectoral granularity and developing short-term scenarios, it is expected that information will be enhanced in due course. • Methodologies for assessing physical risk are still in the process of development, so it is expected that accuracy improvements and information enhancement will be forthcoming.
Internal stress testing	• The use of the scenarios in internal stress testing relating to capital adequacy requirements, as part of risk analysis.[*2]	• Matters concerning time horizons and degree of stress are among the issues that have been pointed out regarding the use of the NGFS scenarios as they stand at present (p. 108). • NGFS has begun work on short-term scenarios intended for use in stress testing.[*5]

*1 Invesco (2023); *2 a.s.r. (2023); *3 Bank of America (2023); *4 Goldman Sachs (2023); *5 NGFS (2023c).

Use of NGFS scenarios in risk analysis and associated issues 2/2

- From the examples of scenario analysis by financial institutions, it would appear that the variables provided in NGFS scenarios are used not only for quantitative risk analysis and assessment, but also for qualitative risk analysis and assessment, along with strategy resilience analysis.

	Envisaged uses of the NGFS scenarios	Current issues and expected future improvements
Qualitative analysis of transition risk	• The carbon price and energy price indicators could conceivably be used in qualitative analysis and consideration of risk relating to high-emitting sectors and companies.[*1,2,3]	• As top-down scenarios, the NGFS scenarios do not currently provide sufficient data concerning such matters as detailed technological advances. • As NGFS is also working to improve sectoral granularity, it is expected that information will be enhanced in due course.
Qualitative analysis of physical risk	• The Phase IV scenarios provide variables concerning a diverse array of acute and chronic physical risk factors. • Referring to the spatial distribution of variables associated with physical risk could make it possible to use the scenarios in qualitative analysis of exposure to risk.[*2,4]	• Methodologies for assessing physical risk are still in the process of development, so it is expected that accuracy improvements and information enhancement will be forthcoming.
Strategy resilience analysis	• The scenarios could conceivably be used in validating the resilience of medium- to long-term strategies by conducting quantitative assessments of impacts on the financial institution's portfolio or lending strategy with reference to transition scenarios (such as Net Zero 2050[*5]) aligned with the Paris Agreement or the institution's own targets.	-

*1 Goldman Sachs (2023); *2 Commonwealth Bank of Australia (2023); *3 CaixaBank (2022,2023); *4 Lincoln National Corporation (2023).

*5 In conducting strategy resilience analysis, it would appear desirable for financial institutions to select appropriate scenarios after first understanding the attributes of various transition scenarios, including the NGFS scenarios. See also section 2.2 (pp. 25-34) of this report for details of the features of the Phase IV NGFS transition scenarios.

Use in the development of strategies and targets, and in engagement

- From the analysis of examples, we identified diverse examples of use by financial institutions that were not confined to risk analysis, but also included the strategy developments and targets, and engagement.

	Envisaged uses of the NGFS scenarios	Current issues and expected future improvements
Establishment of strategies and targets	• The NGFS scenarios could conceivably be used in the development of strategies and targets.[*1] While emissions and other data could conceivably be used in the establishment of strategies and targets, the technical bottom-up scenarios published by organizations such as the IEA are currently used in most cases.[*2]	• As top-down scenarios, the NGFS scenarios do not yet provide sufficient data concerning such matters as sectoral emissions and technological trends. • As NGFS is also working to improve sectoral granularity, it is expected that information will be enhanced in due course.
Engagement based on risk assessment	• The NGFS scenarios could conceivably be used in engagement with individual investees by using the scenarios to understand the nature and scale of transition and physical risks, and to identify exposure to those risks.[*3] • Engagement is also thought likely to assist in gathering detailed information that cannot be captured by the existing NGFS scenarios alone.[*3]	• With regard to physical risk, NGFS methodologies and data are still in the process of development, so it is expected that further enhancements will be forthcoming in due course.

*1 GFANZ (2022) cites the NGFS Net Zero 2050 scenario as a scenario to which financial institutions can refer when establishing strategies and targets.

*2 While the NGFS and IEA scenarios differ in their structure and purpose, they have been assessed as being well aligned on a number of dimensions, including energy demand and emissions (NGFS, 2023a).

*3 Impax Asset Management (2023).

Reference: Use in stress testing and associated issues

- The Basel Committee on Banking Supervision requires financial institutions to consider climate-related risks in their stress testing.[*1] Some financial authorities make the same request of financial institutions.[*2]
- A number of financial institutions consider climate-related risks as part of their routine stress testing, including the internal capital adequacy assessment process (ICAAP) and own risk and solvency assessment (ORSA).[*3]
- At the same time, the following criticisms concerning the unsuitability of the existing NGFS scenarios for stress testing purposes have been voiced.

1 Incompatible time horizons	Whereas the time horizon for stress testing by financial institutions is usually short term (a few years), most climate scenarios deal with the medium to long term (between 5 years and the end of this century).
2 Assumption of extreme scenarios[*4,5]	Stress testing involves assessing a financial institution's soundness based on the assumption of various scenarios that are extreme, but possible in the future, whereas current climate scenarios do not necessarily assume extreme situations.
3 Impact of volatility[*6]	Most climate scenarios depict smooth transition pathways without any sudden changes (volatility) stemming from climate change, giving rise to the possibility that they underestimate losses.

*1 BCBS (2022); *2 OFSI (2023); *3 ECB (2020); *4 IMF (2023); *5 NGFS (2023c); *6 Aguais and Forest (2023).

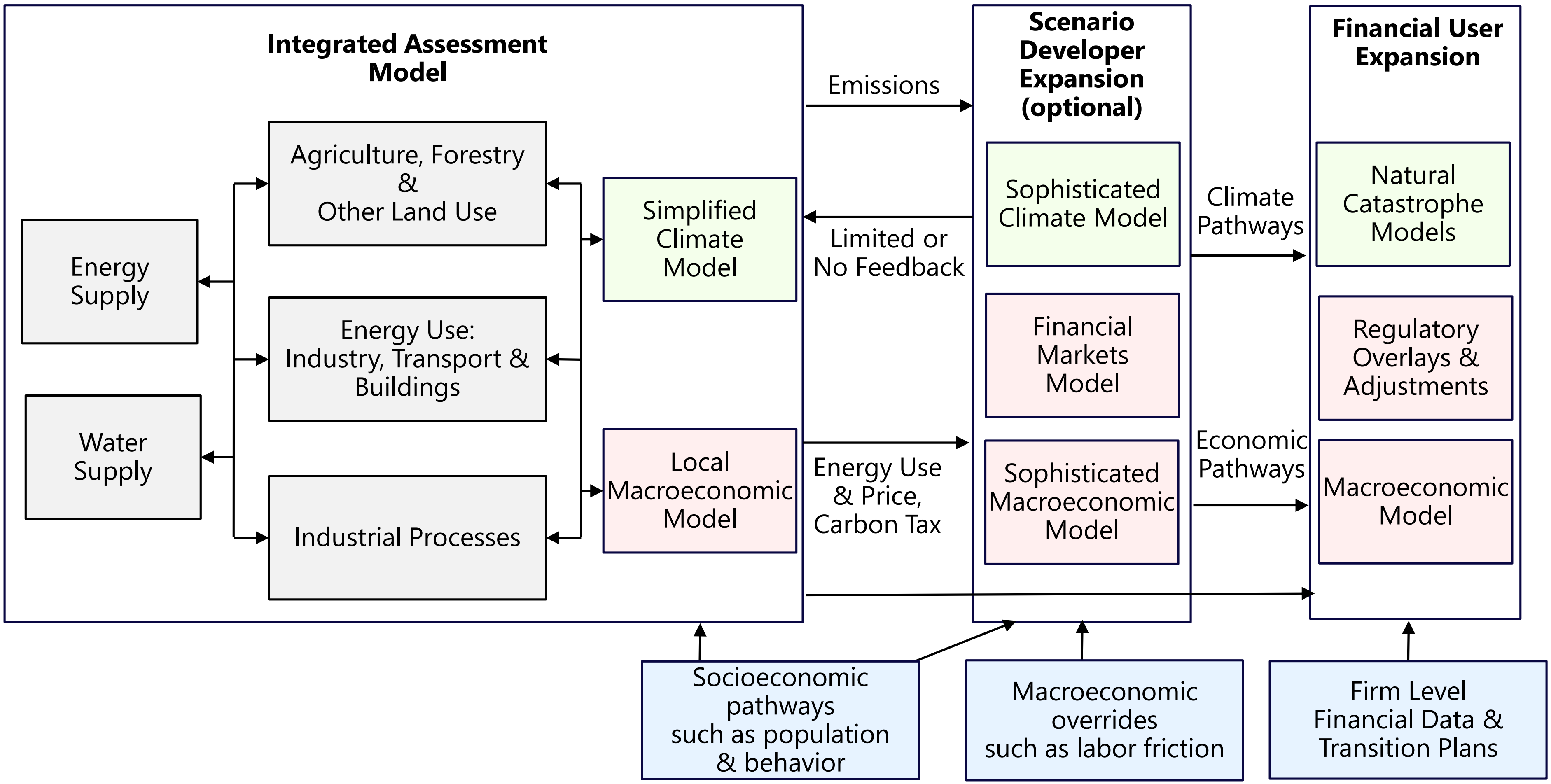
Reference:
Scenario and model characteristics according to scenario use cases

- Baer et al. (2023) states that the requirements of scenarios differ according to their use cases.
- While consideration of a financial institution's business and strategy is based on central scenarios and a broad spectrum, stress testing envisages worst-case scenarios within a reasonable range (Table: Where the scenario sits within the probability distribution).
  - The smooth trend scenarios provided by organizations such as the IEA, NGFS, and IPCC are useful in considering a financial institution's business and strategy; shocks and friction deviating from those trends could not be described as highly relevant (Table: Economic and financial friction), nor is the degree of granularity required high (Table: Scenario and model granularity).
  - In stress testing, it is necessary to reflect reasonable worst-case scenarios that sit at extremes of the distribution, so the relevance of economic and financial friction is very high. As the simplification of information pass-through channels between the models used runs the risk of information being lost, leading to an inability to capture the tail risk (Table: Information pass-through in climate modeling chain), highly granular models and scenarios are required (Table: Scenario and model granularity).

		Key scenario features			Model characteristics					Wider scenario considerations	
Institution type	Use case	Time horizon of scenarios	Where the scenario sits within the probability distribution	Scenario pathway	Transition model narrative	Economic and financial friction	Risk coverage of IAMs	Information pass-through in climate modeling chain	Scenario and model granularity	Scenario likelihood conditional on mitigation progress and policy action	Intertemporal trade-off dimensions
Financial institution	Medium term business planning	5 years	Central scenario and reasonable expectation scenario	Cost optimization and relatively smooth	Very high relevance	Medium relevance	High relevance	High relevance	Medium relevance	Medium relevance	Low relevance
	Strategic planning	5-50 years	Full spectrum broad range of long-term scenarios	Cost optimization and smooth	Very high relevance	Medium relevance	High relevance	Medium relevance	Low relevance	Very high relevance	Very high relevance
	Internal stress testing —balance sheet	Balance sheet velocity (1-3 years)	Reasonable worst-case scenario (tail-risk)	Short-term disruptions and volatility around scenario pathway	Very high relevance	Very high relevance	Very high relevance	Very high relevance	Very high relevance	Medium relevance	Medium relevance
	Internal stress testing —business model	10 years	Reasonable worst-case scenario (tail-risk)	Cost optimization and relatively smooth	Very high relevance	Very high relevance	Very high relevance	Very high relevance	Very high relevance	High relevance	Medium relevance
Central banks and supervisors	Regulatory stress testing and capital setting	0-5 years	Reasonable worst-case scenario (tail-risk)	Short-term disruptions and volatility around scenario pathway	Very high relevance	Very high relevance	Very high relevance	Very high relevance	Very high relevance	Very high relevance	High relevance
	Learning exercise stress testing (long time horizon)	0-30 years	Reasonable worst-case scenario (tail-risk)	Cost optimization and relatively smooth	Very high relevance	Very high relevance	Very high relevance	High relevance	Medium relevance	Very high relevance	Very high relevance

Reference: Need for expansion of IAMs

- Baer et al. (2023) states that, as IAMs cannot provide all the information required by financial institutions, the financial sector needs to develop additional scenario-related modeling functions, and presents the modeling chain shown in the diagram below. The article points out that although expansion is essential if the use case is (short-term) internal stress testing for a financial institution, capturing overall trends could well be sufficient for the purpose of analysis for long-term planning.



Reference: An example of guidance concerning scenario usage

- Baer et al. (2023) proposes the scenario usage shown in the diagram below, with a view to application to risk management and stress testing, while also taking into account the issues identified on the previous pages.

Stage I: High-Level Scenarios Selection	Identify key objectives of exercise and set use case	+	Assess the suitability of fundamental narrative and understand high-level scenario characteristics Understand envelope of possible pathways across relevant time horizons and range of scenarios			⇨ Select third party scenario
Stage II: Detailed Assessment of Chosen Third Party Scenario(s)	Better understand detailed assumptions of scenarios and weaknesses	+	Assess the plausibility and likelihood of the accuracy of underlying scenario assumptions: • based on where elements sit within credibility of global policy action based on level of conservativeness of the assumed impacts (both physical and transition)			⇨ Detailed understanding of chosen scenarios and identification of gaps and weaknesses to help interpretation
Stage III: Augmentation of Selected Scenario and Adjustment	Consider how good of a fit the scenario and its assumptions are for key financial exposures of financial institutions and respective use case	+	Augment or recalibrate subject to the sophistication of the user or discard	+	Reiterate and assess potential systemic interaction of recalibration with other scenario components and high-level scenario	⇨ Generation of sub-scenarios to allow for more decision-relevant scenarios (to better capture range of possible pathways and disruptions)
Stage IV: Expansion of Scenario to Financial Assessment	Establish relevant transmission channels between economic and financial layer	+	Expansion process and downscaling to financial counterparty level (either through exogenous shock creation or integrated scenario modeling)	+	Integration into financial models (complete passing through of relevant extremes and information when matching macro-micro-financial layers)	⇨ Derive financial risk estimates for business model or balance sheet based on scenarios

List of Abbreviations

AR6	IPCC Sixth Assessment Report
BECCS	Bioenergy with Carbon Capture and Storage
BCBS	Basel Committee on Banking Supervision
CCS	Carbon Capture and Storage
CO_2	Carbon Dioxide
DACCS	Direct Air Capture with Carbon Storage
FSB	Financial Stability Board
GCAM	Global Change Assessment Model
GFANZ	Glasgow Financial Alliance for Net Zero
GHG / GHGs	Green House Gas(es)
IAM	Integrated Assessment Model
IPCC	Intergovernmental Panel on Climate Change
MAGICC	Model for the Assessment of Greenhouse Gas Induced Climate Change
MESSAGE	Model for Energy Supply Strategy Alternatives and their General Environmental Impact
MPP	Mission Possible Partnership
NDCs	Nationally Determined Contributions
NGFS	Network for Greening the Financial Systems
NiGEM	National Institutes Global Econometric Model
REMIND	REgional Model of Investment and Development

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