Network for Greening the Financial System

Workstream on Scenario Design and Analysis

NGFS long-term scenarios for central banks and supervisors

November 2024

NGFS

Central Banks and Supervisors
Network for Greening the Financial System

Joint foreword

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Chair of NGFS

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Chair of the workstream on "Scenario Design and Analysis"

In the fifth vintage we further develop the NGFS scenarios to ensure they facilitate meaningful analyses for the financial system well into the future. Like previous vintages, the scenarios have been updated to reflect the evolving landscape of global climate commitments. As countries around the world refine their climate policy targets and strategies, the NGFS modelling framework remains responsive to these developments. In doing so, we make sure that the scenarios accurately reflect the trajectory of global climate policy. Moreover, the fifth vintage provides new insights into the macroeconomic consequences of less ambitious climate policy implementation.

At the core of this release is the application of a new damage function. Based on the latest advances in climate science, the damage function offers a thorough assessment of the impacts of physical risk on the economy. Consequently, the NGFS scenarios now more accurately reflect current reality, where the adverse consequences of climate change are becoming increasingly apparent, affecting more regions, and causing more severe losses. Thanks to this new damage function, the NGFS scenarios also account for the recent record increases in temperatures across the world.

This NGFS scenario vintage reaffirms our commitment to providing the financial community with the tools to navigate the complexities of climate change. We are confident that the latest enhancements will help our users better understand and manage the risks ahead, contributing to a more resilient and sustainable financial system. We trust this release will provide invaluable insights and support in our collective endeavour to create a future where the green transition and financial stability go hand in hand and reinforce each other.

Acknowledgements

The Network for Greening the Financial System (NGFS) is a group of 141 central banks and supervisors and 21 observers (as of 29 May, 2024) committed to sharing best practices, contributing to the development of climate and environment-related risk management in the financial sector and mobilising mainstream finance to support the transition toward a sustainable economy.

The fifth vintage of the NGFS Scenarios is a collaborative effort of the members of the Workstream on Scenarios Design and Analysis and was prepared under the auspices of Livio Stracca (European Central Bank), Chair of the Workstream with support from the NGFS Secretariat. The NGFS Workstream on Scenarios Design and Analysis has been working in partnership with an academic consortium from the Potsdam Institute for Climate Impact Research (PIK), International Institute for Applied Systems Analysis (IIASA), University of Maryland (UMD), Climate Analytics (CA) and the National Institute of Economic and Social Research (NIESR).

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Key messages

What is new in the NGFS scenarios?

- **The NGFS scenarios have been brought up to date with new economic and climate data, policy commitments, and model versions:** the scenarios use the latest release – i.e. version 3.0 – of the Shared-Socioeconomic Pathways (SSPs). In addition, the NGFS scenarios account for the most recent country-level commitments announced by March 2024.

- **A new damage function has been applied to enhance physical risk modelling.** The new damage function incorporates the latest climate science findings, and it is calibrated using state-of-the-art climate datasets. Consequently, it captures climate change impacts in a comprehensive manner beyond increases in mean temperature and assesses their persistence effects on the economy. The new damage function helps better prepare the financial system for the economic impacts of global warming.

Main results of the NGFS scenarios

- **Limiting the temperature increase to 1.5 °C above pre-industrial levels in an orderly fashion is within reach but it requires substantially more intensive efforts than delineated in previous vintages.** While economic impacts differ significantly across countries, regions and economic sectors, almost all countries will benefit from keeping global warming levels close to the 1.5 °C threshold. Early and coordinated policy action will yield the highest long-run returns. The scale of the adjustment grows disproportionately, if action is delayed.

- **A substantial economic transformation affecting all sectors of the economy is required to achieve global net zero CO_2 emissions by 2050.** Slow progress in implementing climate policies so far necessitates more ambitious approach going forward. It also means higher emissions in the near term and a more disruptive transition than previously anticipated fostered by a higher (shadow) carbon price.

- **In all scenarios, the impact of physical risk rapidly outweighs the impact of transition efforts.** The expected economic impact of unabated climate change has significantly increased. Due to the implementation of the new damage function, the projected physical risk impact has quadrupled by 2050 in some scenarios. These strong negative impacts on GDP could be mitigated by timely transition efforts.

Contents

NGFS scenarios Overview

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What are the NGFS scenarios?

A shared understanding of how climate change affects the economy can be the basis for global action. The NGFS developed climate scenarios to inform analysis and guide policy worldwide.

The NGFS **long-term climate scenarios** map out how economies might evolve under different assumptions, answering the questions:

What can happen? E.g., if policy ambition diverges and climate change is not mitigated.

What should happen? E.g. to shed light on the benefits of a timely green transition from a macro-financial perspective.

- **The NGFS scenarios have been created to provide a common starting point for analysing the impact of climate risks on the economy and financial system.** They map out **different futures**, depending on how climate change (physical risk), transition policies, technological developments and changes in preferences (transition risk) evolve.

- **The NGFS scenarios explore a range of plausible outcomes.** To reflect the uncertainty inherent to the modelling of climate-related macroeconomic and financial risks (e.g. due to uncertainty of climate change and the transition), the NGFS scenarios use **different models**, and explore **a wide range of scenarios across regions and sectors**.

- **The NGFS scenarios are not forecasts.** They are intended to explore the **range of plausible futures** (neither the most probable nor the most desirable) for the assessment of financial risk and to prepare the financial system for the shocks that may arise.

- **The NGFS scenarios present unique features that make them particularly suitable for a wide range of applications.** They produce **internally consistent results** that combine **transition and physical risks and macro-financial developments**, are applicable at the **global level**, and are **freely accessible** through an online public platform.

- **While the NGFS scenarios are constantly improved, the uncertainty and limitations of climate and economic modelling remain high.** For instance, tipping points are not represented in the NGFS scenarios.

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Objectives and framework

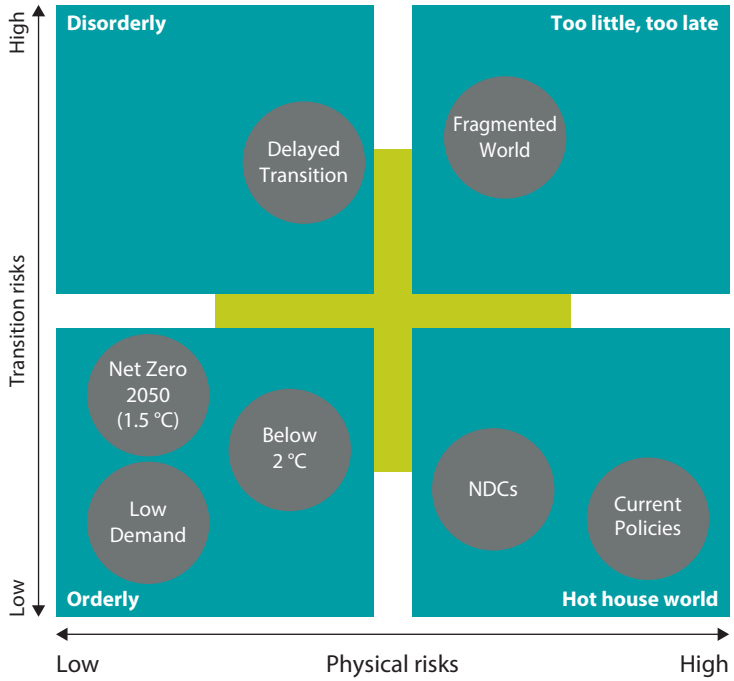
The NGFS scenarios explore the impacts of climate change and the transition with the aim of providing a common reference framework.

The NGFS scenarios explore a set of **seven scenarios** which are consistent with the NGFS framework published in the First NGFS Comprehensive Report covering the following dimensions:

- **Orderly** scenarios assume climate policies are introduced early and become gradually more stringent. Both physical and transition risks are relatively subdued.
- **Disorderly** scenarios explore higher transition risks due to policies being delayed or divergent across countries and sectors. For example, (shadow) carbon prices* are typically higher for a given temperature outcome.
- **Hot house world** scenarios assume that some climate policies are implemented in some jurisdictions, but globally efforts are insufficient to halt significant global warming. The scenarios result in severe physical risk including irreversible impacts.
- **Too-little-too-late** scenarios assume that a late and uncoordinated transition fails to limit physical risks.

(*) Shadow carbon prices are defined as the marginal abatement cost of an incremental ton of greenhouse gas emissions. Prices are influenced by the stringency of policy as well as how technology costs will evolve.

NGFS scenarios framework in Phase V



Positioning of scenarios is approximate, based on an assessment of physical and transition risks out to 2100.

Scenario narratives

Each NGFS scenario explores a different set of assumptions for how climate policies, emissions, temperatures and physical risk impacts evolve.

Disorderly

Delayed Transition assumes no additional climate policies are implemented until 2030. Strong policies are then needed to limit warming to below 2 °C. Negative emissions are limited.

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 these only partially (80% of the target), while the other countries follow current policies.

Orderly

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.

Below 2 °C gradually increases the stringency of climate policies, giving a 67% chance of limiting global warming to below 2 °C.

Low Demand assumes that significant behavioural changes – reducing energy demand – in addition to (shadow) carbon price and technology induced efforts, would mitigate pressure on the economy to reach global net zero CO_2 emissions around 2050.*

Hot house world

Nationally Determined Contributions (NDCs) includes all pledged targets 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.

* In these scenarios, some jurisdictions such as the US, EU, UK, Canada, Australia and Japan reach net zero for all GHGs.

Scenarios at a glance (1/2)

Scenarios are characterised by their overall level of physical and transition risk. This is driven by the level of policy ambition, policy timing, coordination and technology levers.

		Physical risk	Transition risk			
Quadrant	**Scenario**	**End of century (peak) warming** *(model averages)*	**Policy reaction**	**Technology change**	**Carbon dioxide removal** -	**Regional policy variation** +
Orderly	Low Demand	1.1 °C (1.6 °C)	Immediate	Fast change	Medium use	Medium variation
	Net Zero 2050	1.4 °C (1.7 °C)	Immediate	Fast change	Medium-high use	Medium variation
	Below 2 °C	1.8 °C (1.8 °C)	Immediate and smooth	Moderate change	Medium use	Low variation
Disorderly	Delayed Transition	1.7 °C (1.8 °C)	Delayed	Slow/Fast change	Medium use	High variation
Hot house world	Nationally Determined Contributions (NDCs)	2.3 °C (2.3 °C)	NDCs	Slow change	Low use	Medium variation
	Current Policies	3.0 °C (3.0 °C)	None – current policies	Slow change	Low use	Low variation
Too-little-too-late	Fragmented World	2.4 °C (2.4 °C)	Delayed and Fragmented	Slow/Fragmented change	Low-medium use	High variation

Colour coding indicates whether the characteristic makes the scenario more or less severe from a macro-financial risk perspective ^

- Lower risk
- Moderate risk
- Higher risk

- The impact of CDR on transition risk is twofold: on the one hand, low levels of CDR imply an increase in transition costs, as reductions in gross emissions should be obtained in a different way; on the other hand, high reliance on CDR is also a risk if the technology does not become more widely available in the coming years.

+ Risks will be higher in the countries and regions that have stronger policy. For example, in Net Zero 2050, various countries and regions reach net zero GHG by 2050, while many others have emission of several Gt of CO_2eq.

^ This assessment is based on expert judgment based on how changing this assumption affects key drivers of physical and transition risk. For example, higher temperatures are correlated with higher impacts on physical assets and the economy. On the transition side economic and financial impacts increase with a) strong, sudden and/or divergent policy, b) fast technological change even if shadow carbon price changes are modest, c) limited availability of carbon dioxide removal meaning the transition must be more abrupt in other parts of the economy, and d) stronger policy in those countries and/or regions.

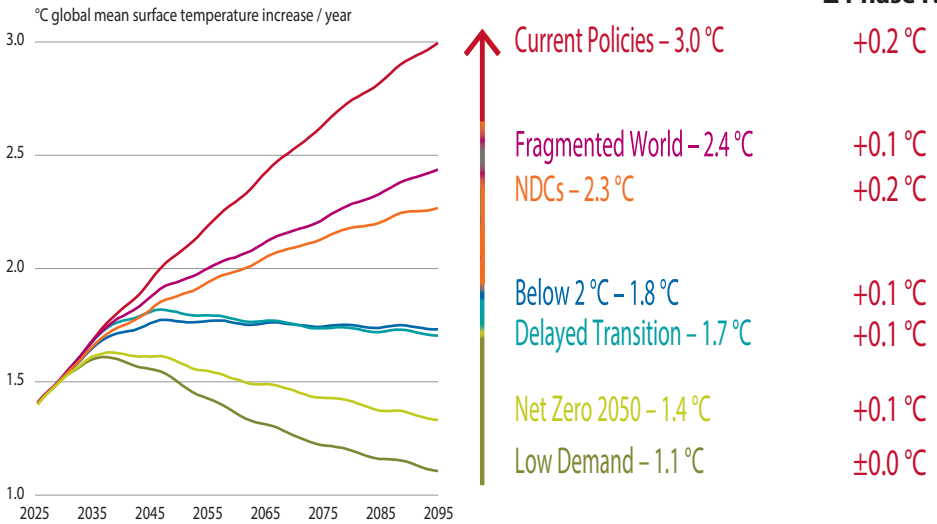
Scenarios at a glance (2/2)

Differences in assumptions across scenarios result in different temperature pathways, which correspond to varying carbon emission and (shadow) carbon price trajectories.

In the NGFS scenarios, the main policy lever driving the transition is a **(shadow) carbon price** that (i) represents the marginal cost of abatement of carbon emissions and (ii) is a **proxy for overall climate policy ambition and effectiveness**, accounting for a variety of real-world climate policies (carbon tax, subsidies, environmental standards, etc.).

Temperature Evolution by Scenario

AR6 Surface Temperature (GSAT) increase (50th), MAGICC with REMIND-MAgPIE emission inputs

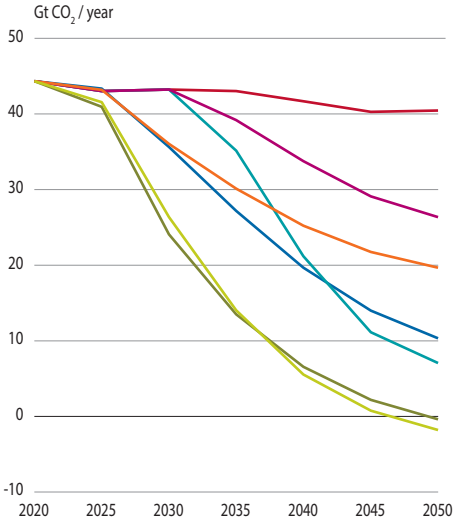


	Δ Phase IV
Current Policies – 3.0 °C	+0.2 °C
Fragmented World – 2.4 °C	+0.1 °C
NDCs – 2.3 °C	+0.2 °C
Below 2 °C – 1.8 °C	+0.1 °C
Delayed Transition – 1.7 °C	+0.1 °C
Net Zero 2050 – 1.4 °C	+0.1 °C
Low Demand – 1.1 °C	±0.0 °C

Sources: IIASA NGFS Climate Scenarios Database, MAGICC model (with REMIND emissions inputs). MAGICC provides a range of temperature increase compared to the pre-industrial levels. The temperature paths displayed here follow the 50th percentile.

Global Yearly CO_2 Emissions

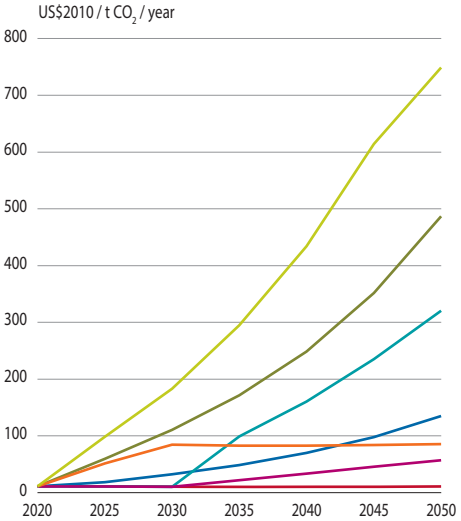
REMIND



Source: IIASA NGFS Climate Scenarios Database, REMIND model. World aggregates mask strong differences across sectors and jurisdictions. Regionally and sectorally granular information is available in the IIASA Portal.
End of century warming outcomes shown. 5-year time interval data.

Shadow Carbon Price

REMIND



Source: IIASA NGFS Climate Scenarios Database, REMIND model.
Shadow carbon prices are weighted global. Regionally and sectorally granular information is available in the IIASA Portal. End of century warming outcomes shown.
5-year time interval data.

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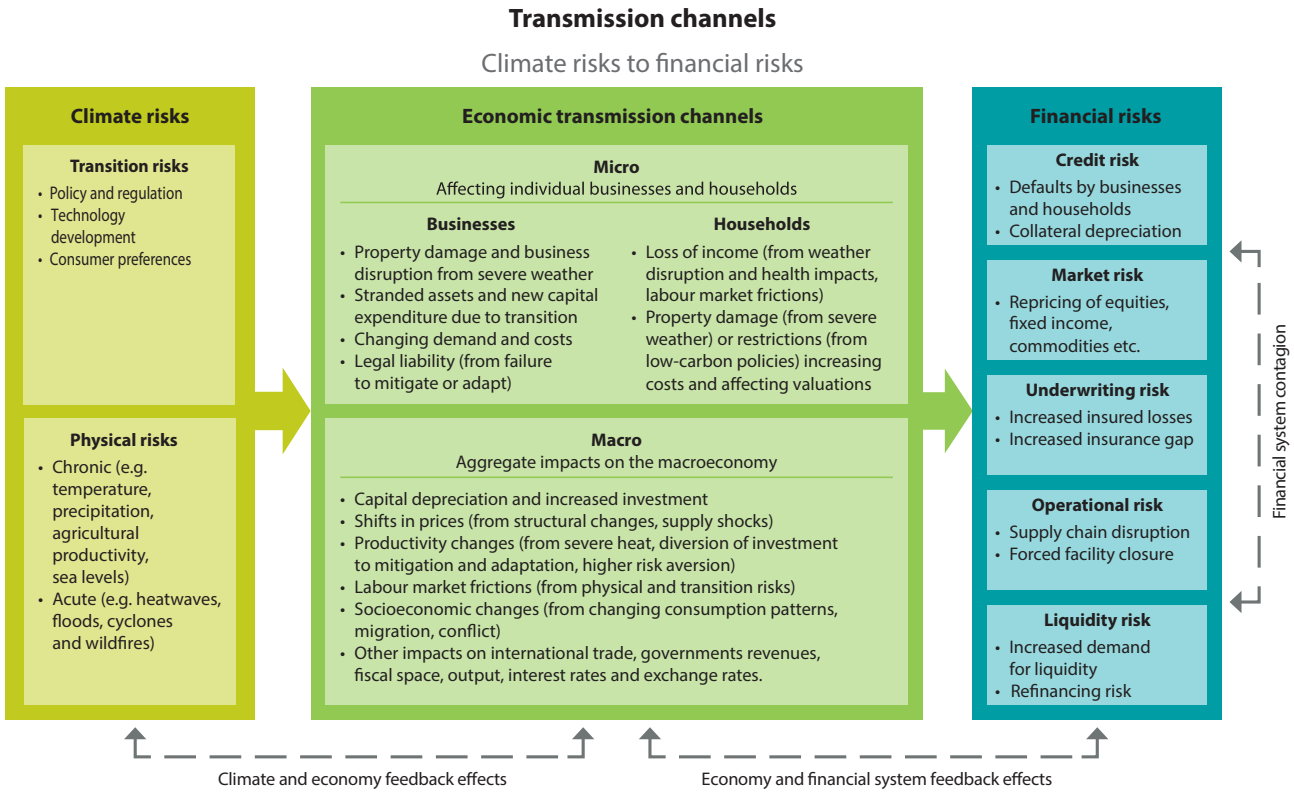
Climate risks

Climate risks could affect the economy and financial system through a range of transmission channels.

Transition risks will affect the profitability of businesses and wealth of households, creating financial risks for lenders and investors. They will also affect the broader economy through investment, productivity and relative price channels, particularly if the transition leads to stranded assets.

Physical risks affect the economy in two ways.

- **Chronic impacts**, particularly from increased temperatures, a rise in sea levels and precipitation changes, which may affect labour, capital, land and natural capital in specific areas. These changes will require a significant level of investment and adaptation from companies, households and governments.
- **Acute impacts**, from extreme weather events, can lead to business disruption and damages to property, reduction of agricultural yields and/or of labour productivity. There is some evidence that with increased warming acute impacts could also lead to persistent longer-term impacts on the economy. These events can increase underwriting risks for insurers, possibly leading to lower insurance coverage in some regions, and impair asset values.

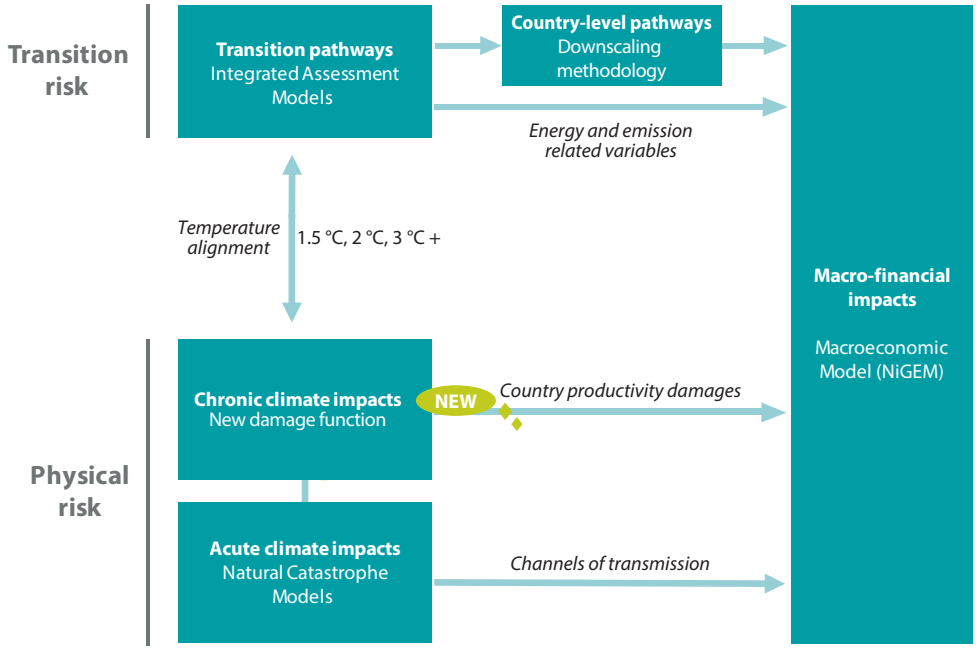


NGFS modelling framework

The NGFS scenarios provide a range of data on transition risks, physical risks and economic impacts, produced by a suite of models aligned in a coherent way.

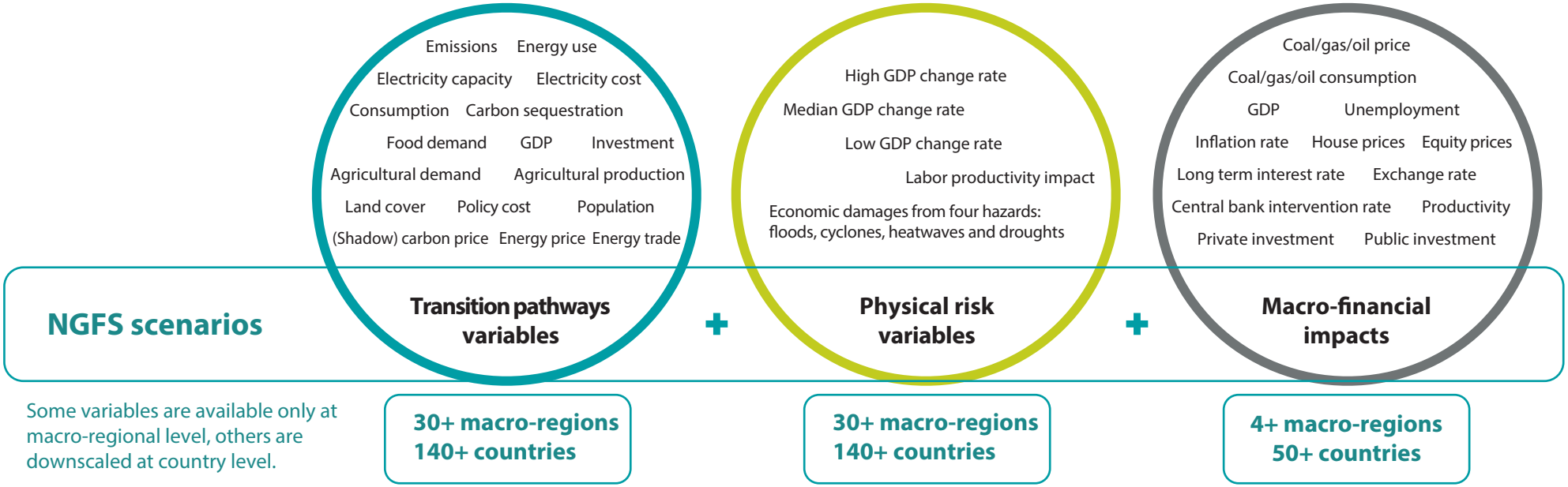
- **Transition risk models** include three Integrated Assessment Models (IAMs), specifically REMIND-MAgPIE, GCAM and MESSAGEix-GLOBIOM, that derive the impacts of different policy ambitions on the energy and transition-relevant sectors (transportation, buildings, industry etc.), emissions, and land use.
- **Country-level downscaling** is applied to IAMs world regions to provide more granular information on the implications of the NGFS scenarios for 144 countries.
- **Physical risk models** include acute and chronic physical risk models. Acute physical risk is assessed for four hazards at country level with various channels of transmission. Chronic physical risk is assessed with **a new damage function**. Both sets of models project physical risk based on the Global Temperature Paths measured in Global Mean Temperatures (GMTs).
- **The macroeconomic modelling** relies on the NiGEM model (a version specifically modified for the purpose of producing the NGFS scenarios), to understand the consequences of transition and physical risk on the key macro-financial fundamentals.

NGFS suite of models approach



NGFS modelling framework

The NGFS scenarios consist of a set of climate-related and macro-financial variables available for each model, scenario and geography.



This slide does not contain the full list of variables and is for illustrative purposes only. The names of the variables do not necessarily correspond to the ones used in the IIASA Portal. The number of countries/regions available varies significantly depending on the variable. Downscaled climate-related and macro-financial variables are available for 180+ and 50+ countries, respectively.

What's new in Phase V of the NGFS scenarios

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Physical risk: new damage function

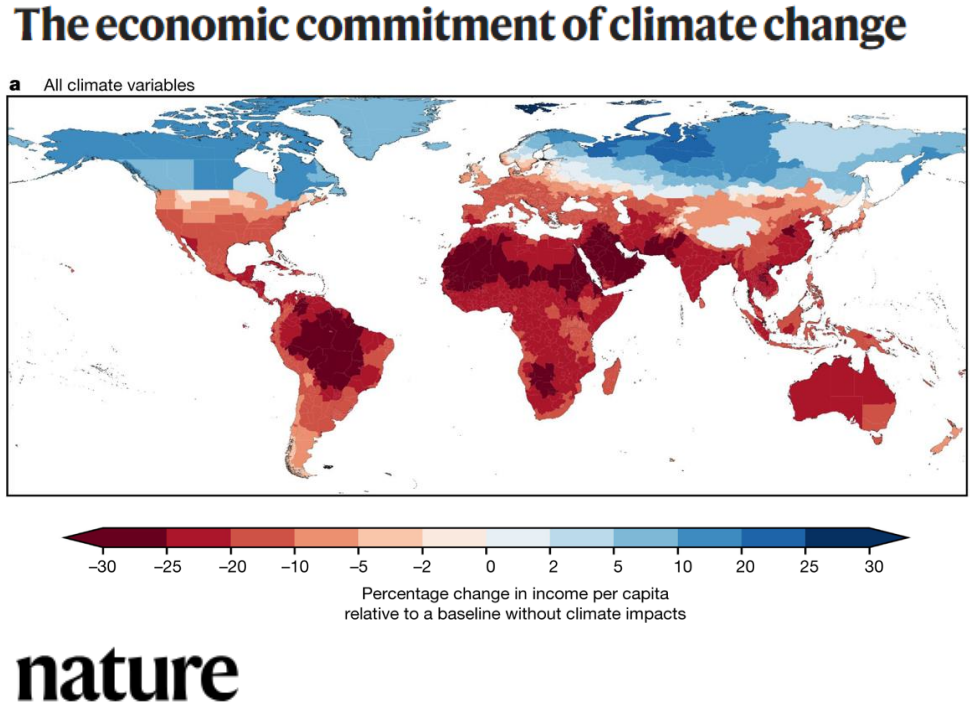
A new damage function, which presents a novel approach to capture physical risk impacts on the economy, has been applied.

- In Phase V **a new damage function** has been applied to capture physical risk impacts on the economy based on Kotz *et al.* (2024)*. The new damage function integrates the latest scientific evidence about the economic impacts of a warming climate.

- **The new damage function has been calibrated using the newest state-of-the-art climate datasets and models.** Both climate data and economic data were used on a highly granular (sub-national) level for a period spanning between 1979 and 2019.

- In contrast to the previous damage function, the new function encompasses the **effects of climate change** much more comprehensively. It **extends beyond increases in mean temperature** previously applied in the NGFS scenarios. The variables included in the model are average annual temperature, daily temperature variability, total annual precipitation, number of wet days, and extreme daily rainfall.

- In addition, the new damage function captures **lagged effects of climate shocks on economic output**. The impact of climate shocks persists up to 10 years after the occurrence in this model.



*Kotz, M., Levermann, A. & Wenz, L. The economic commitment of climate change. *Nature* **628**, 551–557 (2024). https://doi.org/10.1038/s41586-024-07219-0.

An updated version of the SSPs

In Phase V, the NGFS scenarios rely on the assumptions from the latest release of the Shared Socioeconomic Pathways (SSP2, version 3.0).

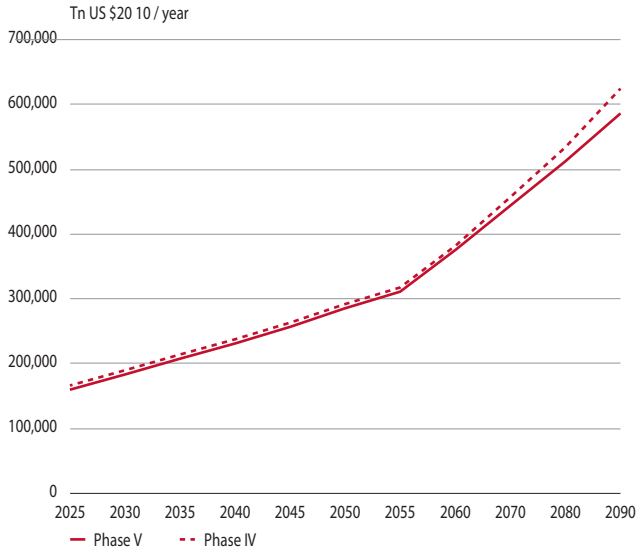
- **All NGFS scenarios share the same underlying assumptions from the SSP2**, a "middle of the road" scenario which follows historical patterns of population and economic trends. The IAMs used by the NGFS are calibrated based on the SSP2 GDP and population pathways, and compute GDP semi-endogenously.

- In **Phase IV, the NGFS scenarios use the updated data of the SSP 3.0 data** released in January 2024. This implies changes in both the **GDP projections** and **population forecasts**.

- With respect to Phase IV, which employed the old SSP 2.0, **the world baseline GDP is lower**. The world economy grows on average by 3.4% per year by mid-century (REMIND data). The **population numbers** are higher in Phase V. At the mid of the century, REMIND data based on SSP 3.0 projects a larger world population by almost 200 million, implying population growth from 8.2 billion today to 9.6 billion in 2050.

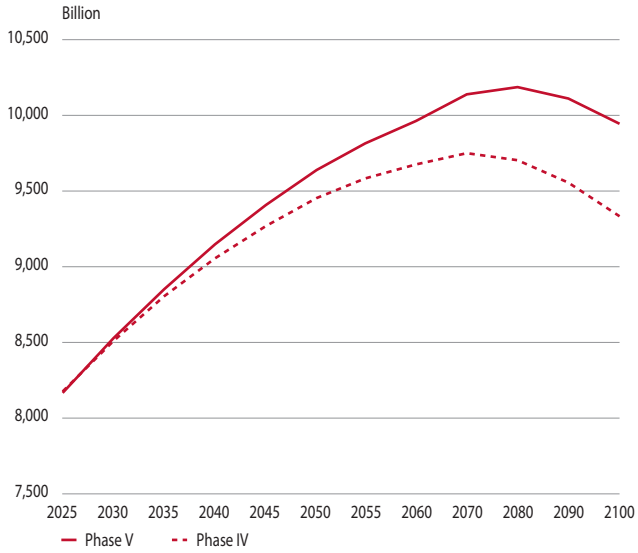
GDP|PPP

REMIND, Current Policies



Population

REMIND, Current Policies



New models and updated policy commitments

The NGFS scenarios are regularly updated and enhanced in line with evolving expectations, models, and policy commitments.

The scenarios account for targets and pledged policies published by the UNFCCC until **end of March** 2024. In Phase V, a total of 36 new submissions were considered from countries including Brazil, Azerbaijan, United Arab Emirates, Kazakhstan and Egypt, and the EU.

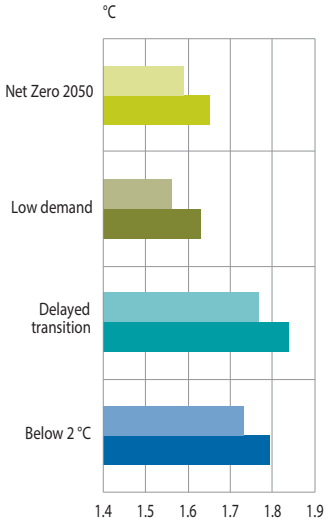
Similarly to the previous vintage, in Phase V the **use of carbon dioxide removal (CDR) technologies** is refined based on current trends.

Two IAM models have undergone structural updates. The REMIND-MAgPIE new version 3.3-4.8 and MESSAGEix-GLOBIOM 2.0-M-R12 are applied. More details can be found in the Technical documentation.

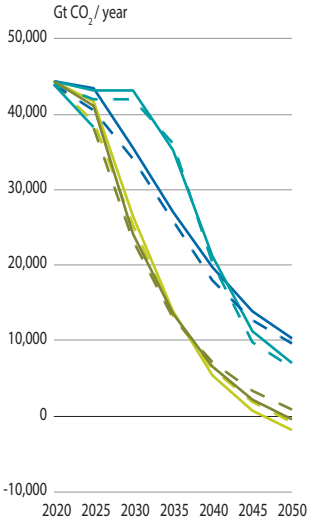
Higher peak temperatures

Higher emissions in the near-term cause higher peak warming levels and result in higher (shadow) carbon prices.

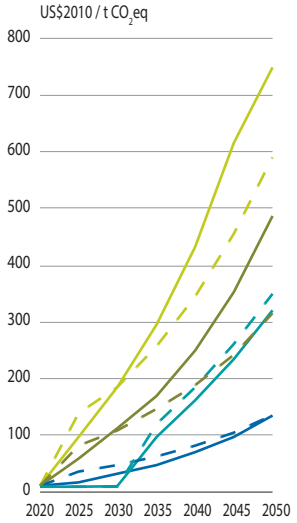
Peak temperature
REMIND, World
Phase IV in transparent



CO_2 Emissions
REMIND, World
Phase IV in dotted



(Shadow) Carbon Price
REMIND, World
Phase IV in dotted



- The slow implementation of climate policies has led to higher emissions in the near-term. Therefore, in the *orderly* scenarios (Net Zero 2050, Low Demand and Below 2 °C) and in the Delayed Transition the **peak temperatures reached in Phase V are higher** compared to Phase IV. Now reaching a peak temperature of 1,7 °C, the Net Zero 2050 scenario cannot be labelled as a 'Low Overshoot' (< 0,1 °C) scenario anymore.
- This means that the orderly scenarios have become more *disorderly*.
- The higher emissions in the short-term require an imposition of **higher carbon** prices compared to Phase IV.

Main results of the NGFS scenarios

Transition risk

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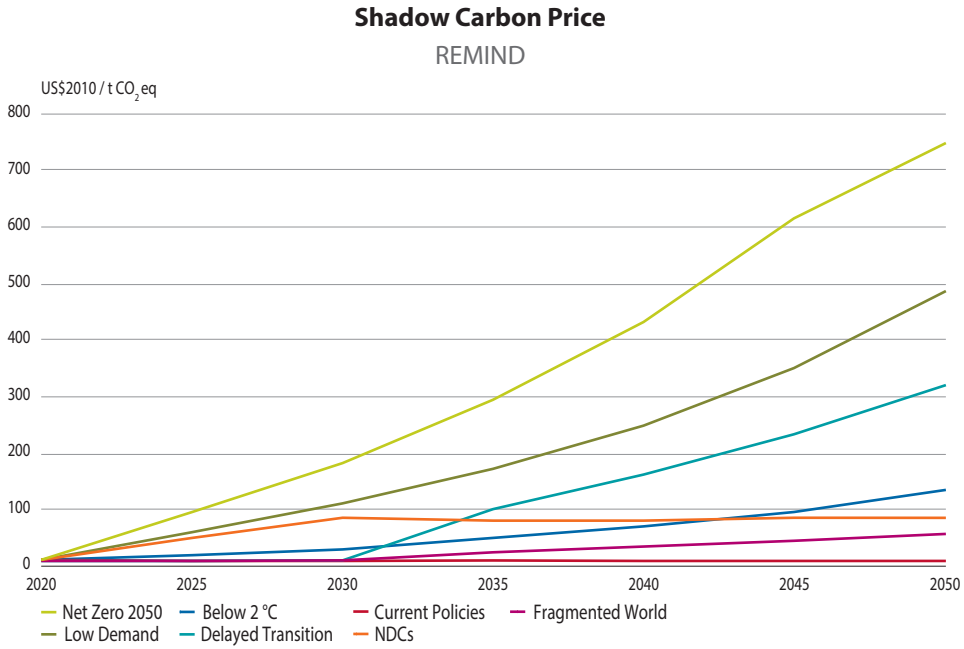
Carbon prices

Reducing carbon emissions will require implementing ambitious policies affecting all sectors. The transition thus poses transition risks for the economy and financial system if not anticipated. A key indicator of the level of transition risk is the (shadow) carbon price, a proxy for government policy intensity and changes in technology and consumer preferences. Compared to Phase IV, reaching net zero by 2050 will require more intensive efforts and a higher (shadow) carbon price.

- **Transitioning away from fossil fuels and carbon-intensive production and consumption requires a significant shift towards emissions-neutral alternatives in all sectors.** Policymakers can induce this transition by increasing the implicit cost of emissions. As it takes time to develop and deploy alternative technologies, climate policies may lead to higher costs in the interim.
- **In the IAMs a higher (shadow) carbon price(*) is a proxy for more stringent climate policies.** The shadow carbon price encompasses all types of climate mitigation actions including taxation and regulation.
- **A shadow carbon price of around \$300/tCO_2 would be needed by 2035 to incentivize a transition towards net zero by 2050.** This means an increase from \$98/tCO_2 to \$294/tCO_2 within ten years. The 2035 level is also around \$50/tCO_2 higher when compared to the results from Phase IV reflecting slower than previously expected progress in implementing climate policies across the world.



(*) Prices tend to be lower in emerging economies as policy stringency is lower and there tends to be a greater number of low-cost abatement options still available.

Source: IIASA NGFS Climate Scenarios Database, REMIND model.
Shadow carbon prices are weighted global. Regionally and sectorally granular information is available in the IIASA Portal.

Emissions and primary energy consumption

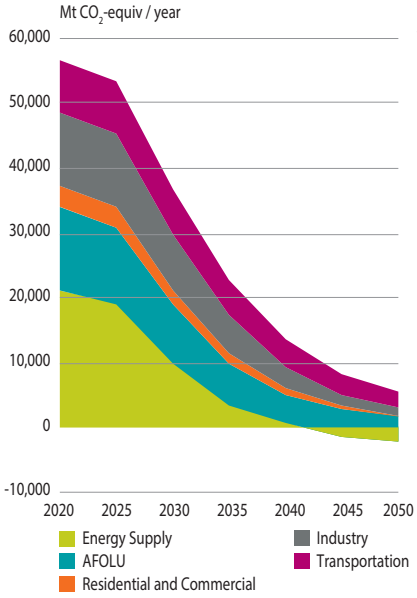
A substantial economic transformation is required to achieve Net Zero with heterogenous impact across sectors. Most of the global emissions reduction under the Net Zero 2050 scenario is driven by large decreases in the Energy Supply and the Industry sector. Substantial changes in the global supply of primary energy are key, both in terms of overall production levels as well as the composition of the energy source.

- **Imposition of steep (shadow) carbon prices raises costs of polluting energies at the source.** Most of the global emissions reduction under the Net Zero 2050 scenario is driven by large decreases in the Energy Supply and the Industry sector.
- **Sectors for which transition from fossil fuels is more challenging will remain amongst the higher emitters.** By 2050, the largest emitter of CO_2 is the Transportation sector where, based on current technologies, moving away from fossil fuels is most challenging.
- **To achieve emissions reduction, primary energy supply needs to shift from carbon intensive to renewable sources.** Compared with today (i.e. 2025 levels), global primary energy supply needs to decline by around 19% by 2050 in the Net Zero 2050 scenario. The decline in primary energy supply can result from lower energy demand and improvements such as increased energy efficiency.
- **By 2050, renewables and biomass would deliver almost 80% of global primary energy needs in the Net Zero 2050 scenario.** Reliance on fossil fuels declines by around 16 pp between 2025 and 2050 under the Current Policies scenario, reaching ca. 67% of total primary energy supply in 2050. In an ambitious Net Zero scenario, the share of energy production from fossil fuels would need to drop drastically to around 20% in 2050.
- **The structural transformation requires significant investment flows to be directed towards greener sources of energy production in the coming decades.** In the Net Zero 2050 scenario global energy investments need to be on average $3.8 trillion/year, with more than one-third going to renewables mostly for the generation and storage of renewable electricity.

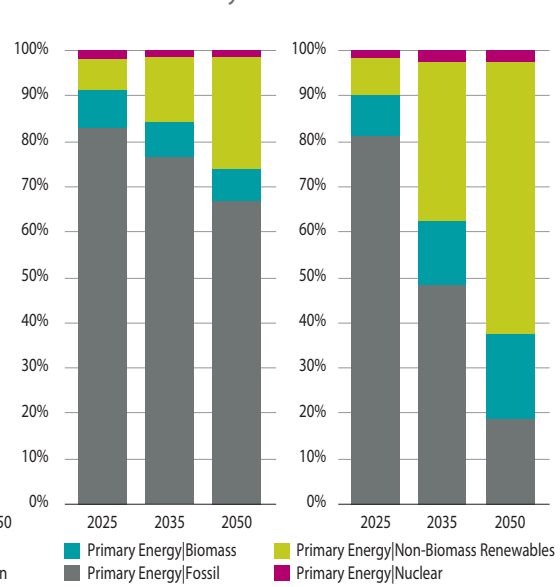
(*) Prices tend to be lower in emerging economies as policy stringency is lower and there tends to be a greater number of low-cost abatement options still available.
AFOLU stands for Agriculture, Forestry, and Other Land Uses

Global Sectoral Kyoto Gases Emissions

Net Zero 2050, REMIND



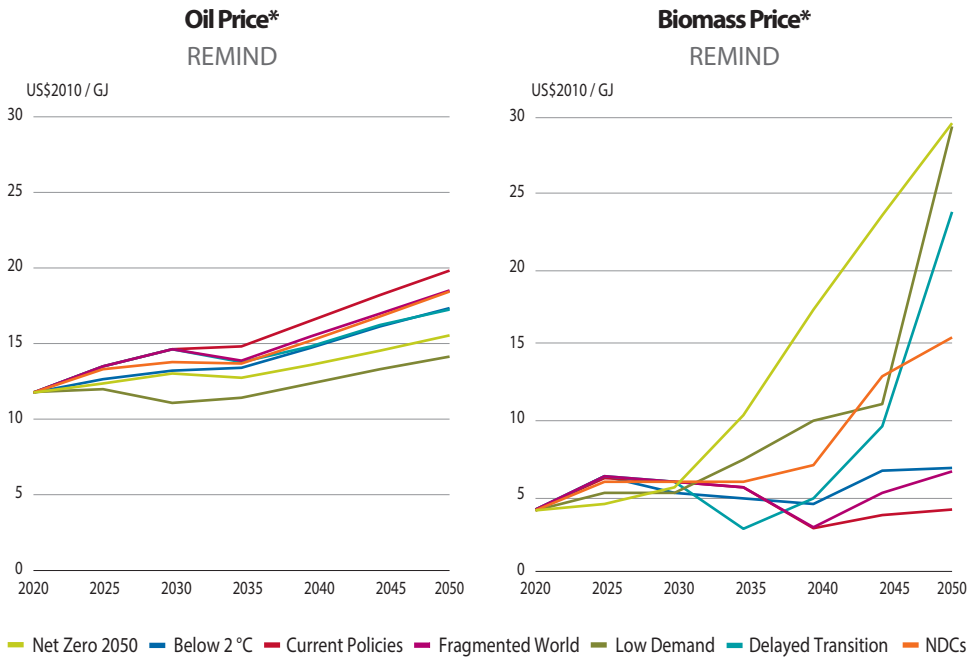
Global Primary Energy Mix (based on REMIND outputs)



Energy prices

Changes in carbon prices impact the relative price between green and polluting energies, shifting the energy demand towards renewables and biomass. These dynamics generate price effects on primary energy prices (i.e. before including carbon prices, taxes, and transport). The impact on individual countries depends on the structure of their economies, in particular their reliance on import and export of the different types of energy sources.

- **Oil prices are expected to increase in all scenarios by 2050.** A steeper increase in oil prices is expected in the disorderly scenarios. In the Current Policies scenario, oil prices increase from 13.5 $2010/GJ in 2025 to 19.8 $2010/GJ in 2050.
- **Biomass prices are relatively more heterogenous across scenarios.** Biomass prices increase significantly in the Net Zero 2050 and Low Demand scenarios from around 5 US$2010/GJ in 2025 to more than 29 $2010/GJ in 2050. This is due to the higher demand caused by a more prominent use of biomass for energy production. In the Delayed Transition scenario, biomass will see a delayed but steep increase in demand, followed by an increase in prices, after the implementation of transition policies.



Main results of the NGFS Scenarios

Physical risk

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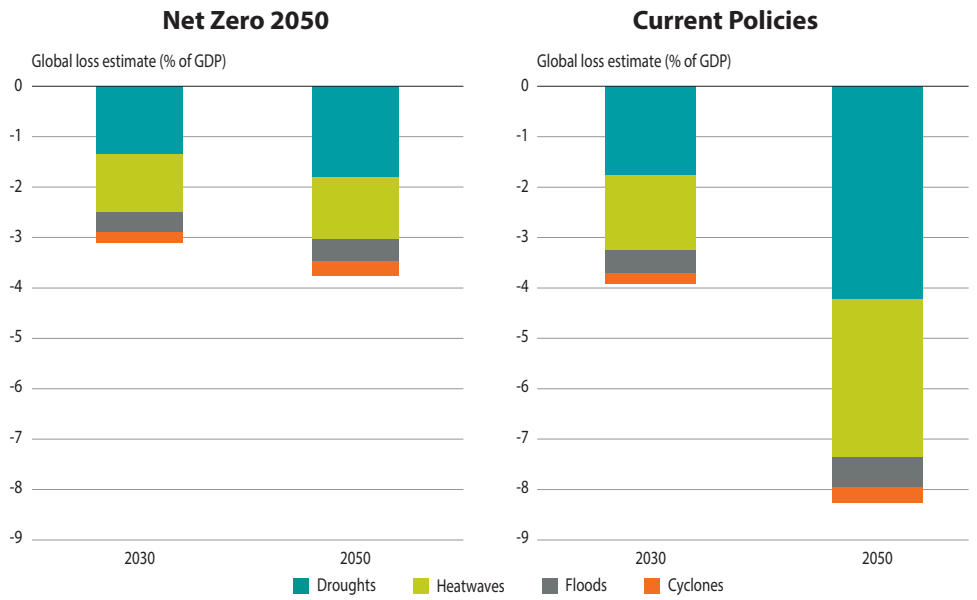
Acute physical risk: individual hazards modelling

There are no updates of individual hazards modelling in Phase V.

- **Acute physical risks are represented by four perils in the NGFS scenario framework: droughts, heatwaves, floods, and cyclones.** There have been no changes and updates in Phase V. Results from Phase IV continue to be reported.
- **Under the Current Policies scenario, losses due to these four perils exceed 8% of global GDP**, while in the Net Zero 2050 scenario, damages remain below 4% of global GDP.
- **Droughts and heatwaves account for the largest share of losses globally**, but large regional differences exist. Together they account for more than 75% of total losses from acute physical risks in the NGFS scenarios.



Note: Phase IV results for NiGEM using Climate Analytics input. Damages shown correspond to 90th damage percentile for droughts, heatwaves, and cyclones (floods are represented by a point estimate).

(Chronic) physical risk: higher impact

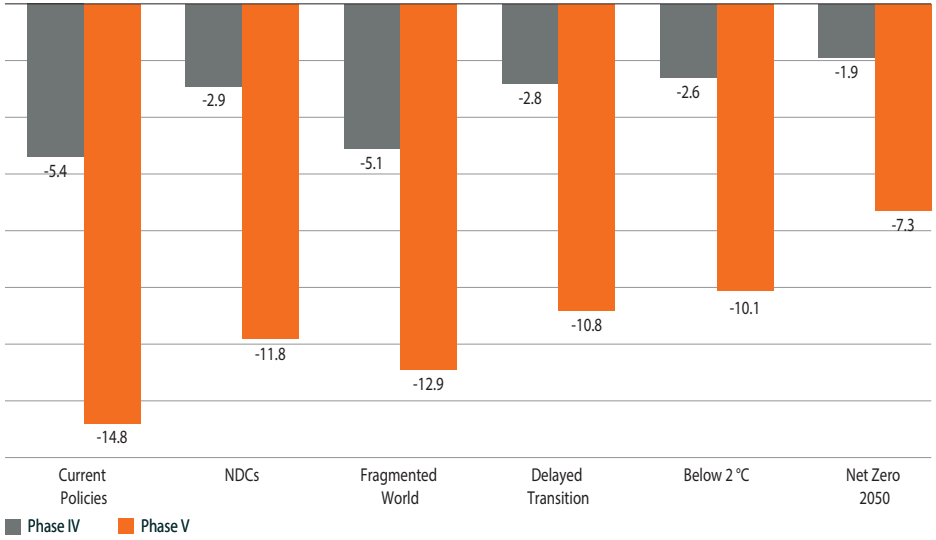
The projected (chronic) physical risk impact has significantly increased in Phase V. This increase mostly results from a change in estimation methodology, i.e., a new damage function.

- **Using the updated damage function, the NGFS Current Policies scenario foresees around 15% losses compared to a scenario without climate change by 2050.** To recall, in Phase IV, losses from chronic physical risk stood at ca. 5% in 2050.

- **The increase in damage is mostly attributable to the change of damage function.** Only 1.5 pp of the change in Current Policies damages in 2050 can be attributed to differences in projected temperature pathways*. The damages displayed also encompass changes in modelling assumptions.

Losses from (chronic) physical risk by 2050: Phase IV vs Phase V (% of global GDP)

NiGEM with REMIND inputs



(*) See Annex 1 of the explanatory note on "Damage functions, NGFS scenarios, and the economic commitment of climate change" for a full breakdown.

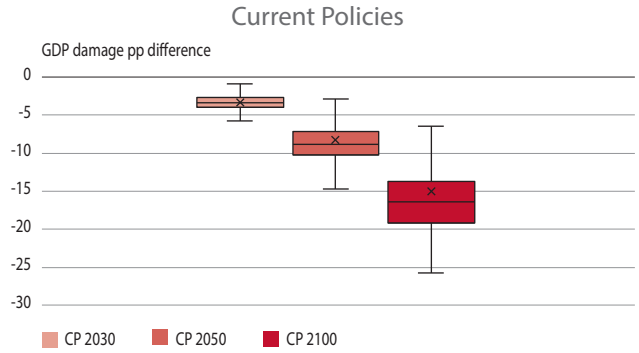
(Chronic) physical risk: new dynamics

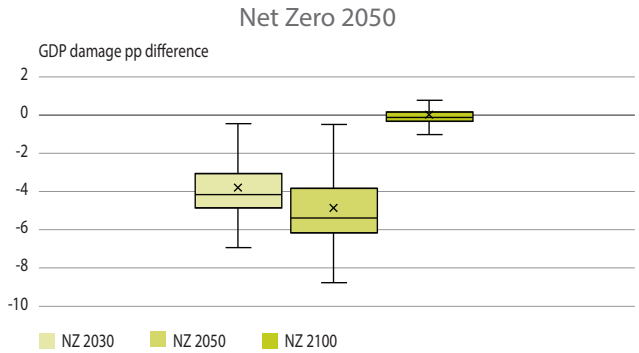
Implementation of the new damage function has altered global loss estimates and resulted in heterogenous changes across scenarios, regions, and timelines.

- **Changes are heterogenous across scenarios.**
  By 2050, loss projections increase significantly for both the Current Policies (5% to 15%) and Net Zero 2050 scenario (2% to 7%). Substantial increases are also observed in the remaining scenarios.

- **Changes are heterogenous across countries/regions.**
  In general, most countries are faced with higher loss estimates using the new damage function. Yet, there are large differences between countries. Some countries experience a loss increase above 20 pp. In contrast, in a few cases losses have decreased.

- **Changes are heterogenous across timelines.**
  Figures on the right show the spread of damage estimate differences between the new and old damage function in the Current Policies and Net Zero 2050 scenario*. In the Current Policies scenario, the spread increases at more distant time horizons (and thus higher warming levels). In the Net Zero 2050 scenario, the spread in 2030 is similar to the Current Policies scenario, but towards 2100, the distance between the first and third quartile decreases significantly.





(*) Shown as percentage point difference in damage estimates across 179 individual countries in 2030, 2050, and 2100.

Interpreting and using physical risk results

The introduction of the new damage function in NGFS scenarios calls for careful reconsideration of how loss projections are interpreted and used.

- **A simple aggregation of chronic and acute physical damages could lead to double-counting.** The methodologies used to estimate chronic and acute risks are not mutually exclusive. We no longer represent total physical climate risks as the simple sum of acute and chronic impacts. Both types of risk assessment can still be used as each other's complement, but users need to exercise caution when combining results.

- **While damage projections are much higher with the new damage function, a global economic recession caused by climate change is not foreseen.** A 30% loss under the Current Policies by 2100 scenario should be compared with a baseline that assumes no climate change. Under the baseline, the GDP is expected to grow substantially by the end of the century, so even with climate change damages standing at 30%, global GDP would still grow by more than 150% in the Current Policies scenario by 2100 compared to today (while it would grow by 215% without climate change).

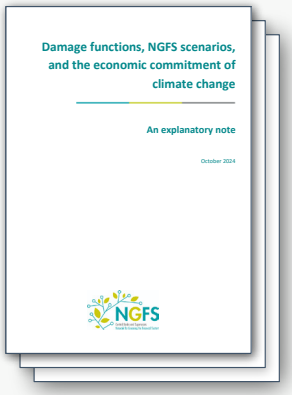
- **Adaptation is not explicitly covered by the damage function.** The study underlying the damage function may implicitly account for historic short-run adaptation. Persistence effects indicate that it may require at least ten years to fully recover from a climate shock. However, as long-term climate adaptation is not included in this damage function, it remains uncertain if long-term climate change losses will be higher or lower than those projected based on short-term shocks.

- **While the new damage function is a significant improvement, the NGFS scenarios still have some limitations in physical risk modelling.** The scenarios do not claim to capture the exhaustive impact of climate change (e.g. the impact of tipping points). Caution should always be exerted when using the NGFS scenarios and damage function results, especially in light of the high uncertainty surrounding these projections. Consequently, the scenarios should not be considered a suitable standalone instrument for a cost-benefit analysis on the opportunity of climate action.

More on (chronic) physical risk modelling

As part of the Phase V release, we drafted an explanatory note on the implementation of the new damage function. The key arguments of the note are also reflected in two VoxEU columns.

Explanatory note



Chapter 1: **Physical climate risks and damage functions**

Chapter 2: **New damage function explained**

Chapter 3: **Results of the new damage function under review**

Chapter 4: **Implications of new damage function for the NGFS scenarios**

VoxEU columns

Part 1: Measuring economic losses caused by climate change

The column explores the concept of damage functions, highlighting the persisting uncertainties and the importance of continued dialogue to refine our understanding of climate-induced economic losses.

Part 2: Economic losses from climate change are probably larger than you think: new NGFS scenarios

The column highlights advances in understanding and measuring the economic impact of climate change and discusses their implications for NGFS climate scenarios.

Main results of the NGFS Scenarios

Key macrofinancial results

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Gross Domestic Product

The NGFS scenarios show that inaction or delayed transition will generate higher costs in the longer term. Economic impacts differ significantly across scenarios, time and countries.

- **Transition risk** leads to a negative short-term impact on GDP in the *Net Zero 2050* scenario. However, the cost-saving later more than offsets these initial losses compared to the *Delayed Transition* or *Current Policies* scenario.

- **(Chronic) physical risk*** is the main source of risk in the NGFS scenarios. The implementation of the new damage function has resulted in a significant increase in projected losses. Already in the short-term (by 2030), these impacts are non-negligible in all scenarios, greatly outweighing the cost of an early and orderly transitions. In the long-run (by 2050), losses continue to deepen substantially in the *Delayed Transition* and *Current Policies* scenarios as higher temperatures caused by a lack of mitigation efforts result in higher chronic physical risk. Physical risk losses peak before mid-century in the *Net Zero 2050* scenario.

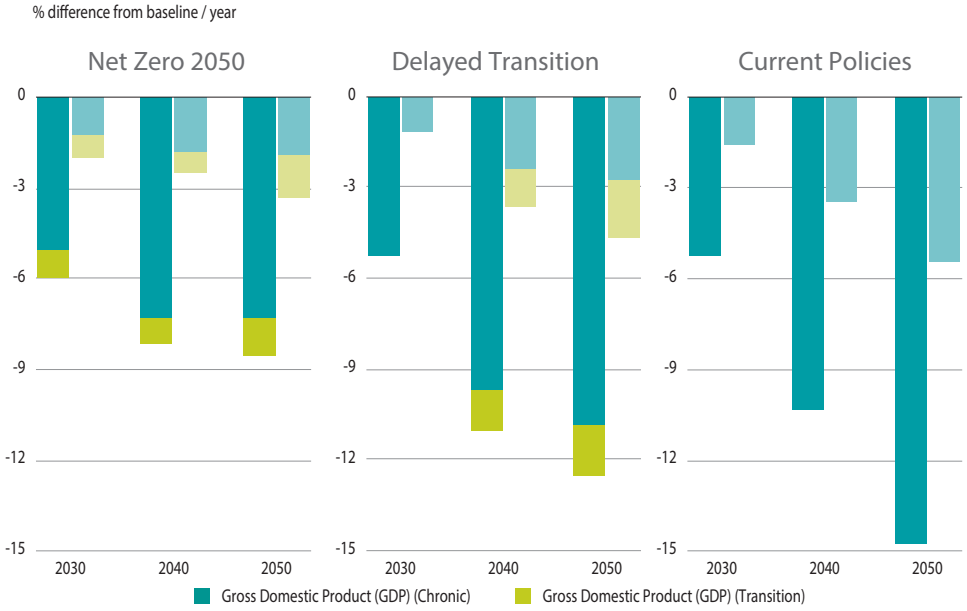
- **Acute physical** risk is not displayed in the graphs on the right. No updates have taken place in Phase V. With the implementation of the new damage function, we no longer recommend displaying physical risk losses as the simple sum of acute and chronic risks**.

(*) The estimates of physical risks do not include the effects of reaching climate tipping points or compound risks.

(**) More detailed reasoning behind this choice can be found in the explanatory note on "Damage functions, NGFS scenarios, and the economic commitment of climate change".

Global GDP Impact by Climate Risk Source in Phase V and Phase IV

NiGEM based on REMIND input, Phase IV in transparent



Note: The above figure shows how GDP is impacted across scenarios compared with a hypothetical (and impossible) baseline scenario in which no transition or physical risks occur. This baseline scenario represents a world in which climate change does not occur. Thus, climate change has a negative impact on GDP in every plausible scenario, but the magnitude of the losses differs across them.

Inflation and unemployment

Higher carbon prices in the Net Zero 2050 scenario generate inflationary pressures in the short-term. Structural relationships between key aggregates such as unemployment and inflation differ across regions.

- In many countries the implementation of **higher (shadow) carbon pricing** in transition scenarios tends to raise energy costs in the short term, which initially weighs on prices (as lower demand and financial market losses affect output). This causes an initial strain on the economy through decreased demand and market losses. Subsequently, higher (shadow) carbon prices result in modest increases in inflation and unemployment before returning to previous trends. In some countries and time periods, the offsetting growth effects from carbon revenue recycling lead to a reduction in unemployment.

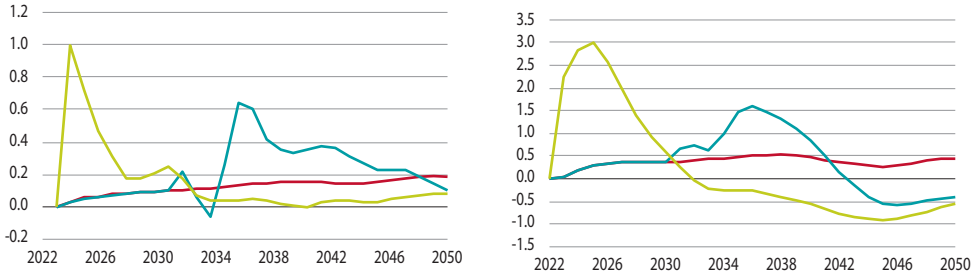
- The introduction of shadow carbon pricing could lead to a potential **monetary policy trade-off**. The NGFS modelling framework assumes a "two-pillar" strategy, targeting a combination of inflation and nominal GDP as a default.

- **Inflation.** In the Net Zero 2050 scenario, there is an initial steep rise in inflation in Europe. It captures price spikes due to immediate transition policy action. Conversely, in the *Delayed Transition* scenario where transition actions are postponed, inflation deviates sharply from the baseline around 2030, when the deferred transition begins.

- **Unemployment.** The Net Zero 2050 scenario shows a swift reversal of the initial increase in unemployment in Europe. On the other hand, China experiences an initial decline and somewhat delayed increase only in the medium-term. Furthermore, Europe sees highly volatile deviations from baseline unemployment at the onset of the Delayed Transition scenario in the 2030s.

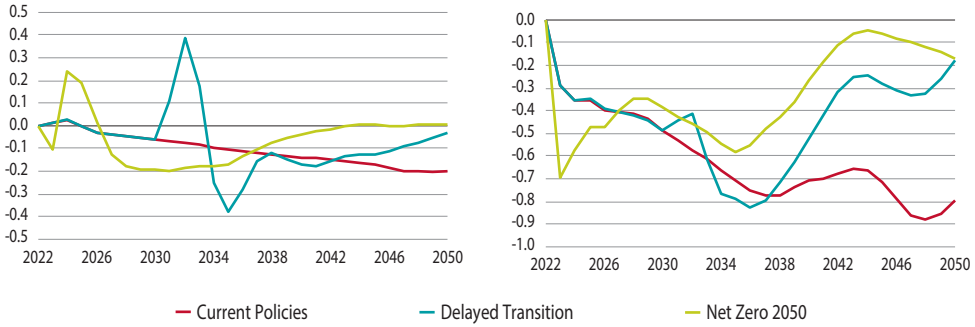
Inflation Rate Deviations from Baseline

(Combined Risk, NiGEM and based on REMIND input)



Unemployment Rate Deviations from Baseline

(Combined Risk, NiGEM and based on REMIND input)



Interest rates

Climate change and transition policies create significant financial fluctuations, producing changes to interest rates that differ across scenarios and over time.

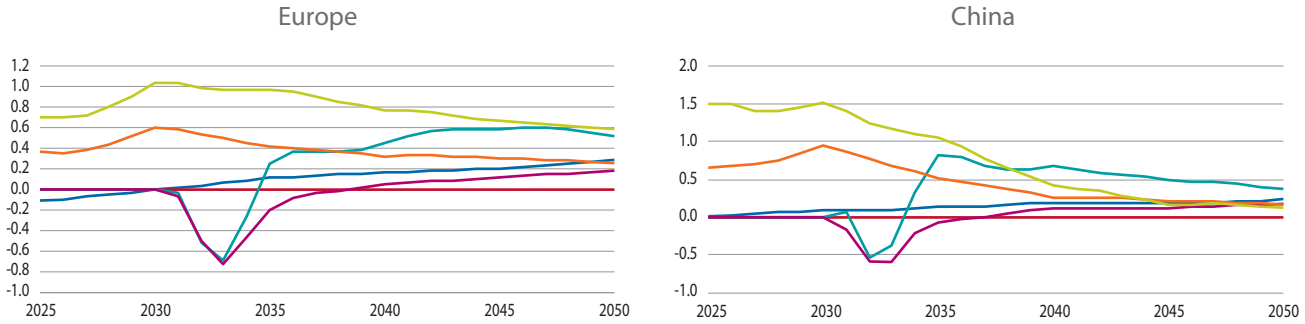
- **Policy interest rates** spike initially in the Net Zero 2050 scenario. They decrease slightly after 2030 in the Fragmented World and Delayed Transition scenario. By 2050, policy rates stabilize at slightly different levels across scenarios, a phenomenon which can also be observed for long-term interest rates.

- **Long-term interest rates** tend to increase in the short-term transition scenarios, reflecting the inflationary pressure created by shadow carbon prices, as well as the increased investment demand that the transition spurs on.

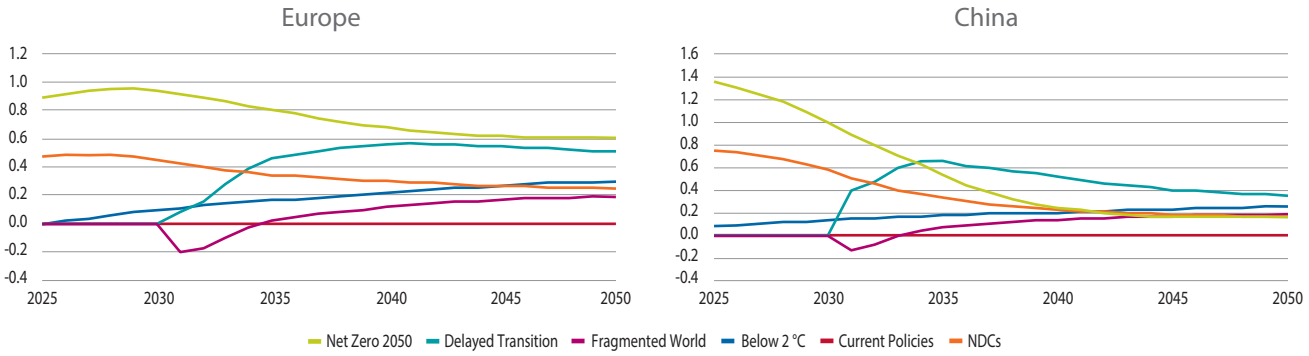
- Disorderly transitions can affect **real financial asset valuations** significantly, with considerable regional differences.

Central Bank Intervention (Policy Interest Rate)

(Combined Risk, NiGEM and based on REMIND input)



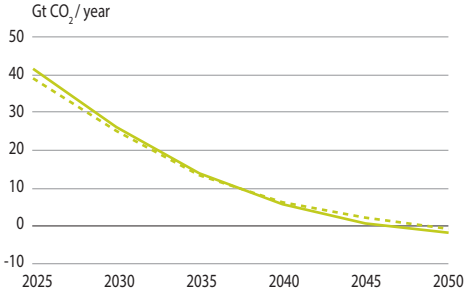
Long-term Interest Rate (Combined Risk, NiGEM and based on REMIND input)



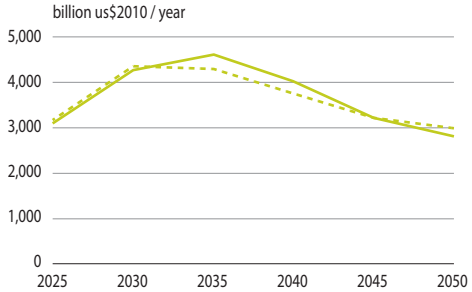
Phase V vs Phase IV: Net Zero 2050 scenario

Net Zero 2050 is an ambitious scenario that limits global warming to 1.5 °C through stringent climate policies and innovation, reaching net zero CO_2 emissions around 2050. This scenario assumes that ambitious climate policies and technological shift are introduced immediately and forcefully impact the economy.

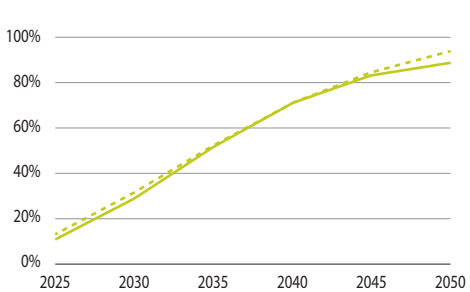
Global CO_2 Emissions
REMIND, Phase IV in dotted



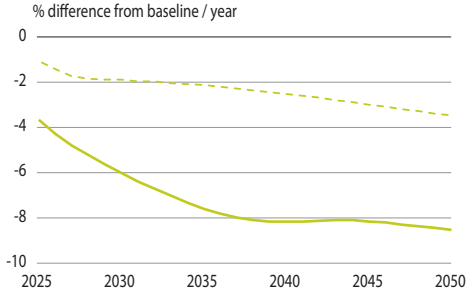
Global Energy Investments
REMIND, Phase IV in dotted



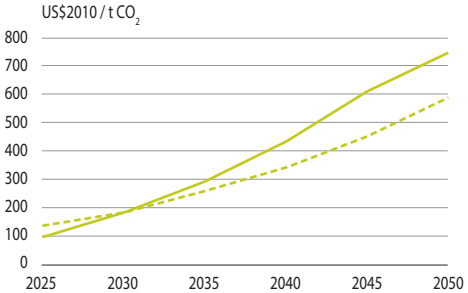
Share of Renewables in Global Primary Energy Mix
REMIND, Phase IV in dotted



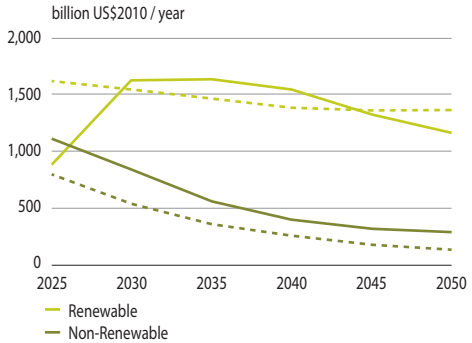
Global GDP Impacts*
NiGEM based on REMIND, Phase IV in dotted



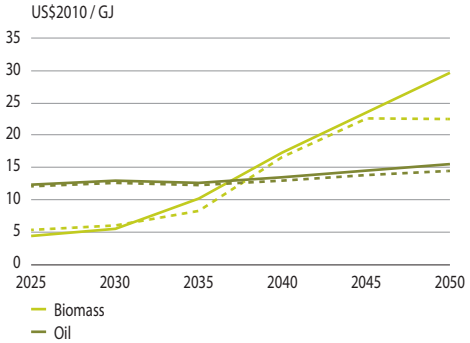
Global (Shadow) Carbon Price
REMIND, Phase IV in dotted



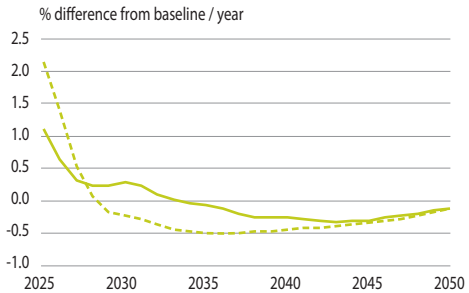
Renewable & Non-Renewable Global Energy Investments
REMIND, Phase IV in dotted



Global Oil & Biomass (Pre-tax) Prices
REMIND, Phase IV in dotted



Global Inflation (%)
NiGEM based on REMIND, Phase IV in dotted



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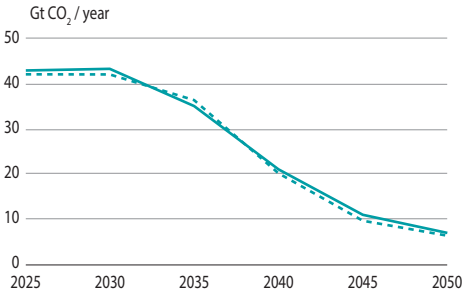
*GDP losses stemming from chronic physical and transition risk.

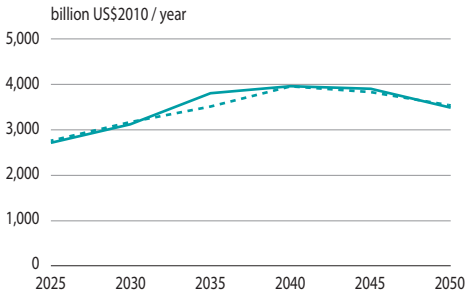
Phase V vs Phase IV: Delayed Transition scenario

Delayed Transition assumes global annual emissions do not decrease until 2030. Strong policies and investments are subsequently needed to limit warming to below 2 °C. The level of commitments of countries depend on currently implemented policies, leading to heterogeneity at the global level.

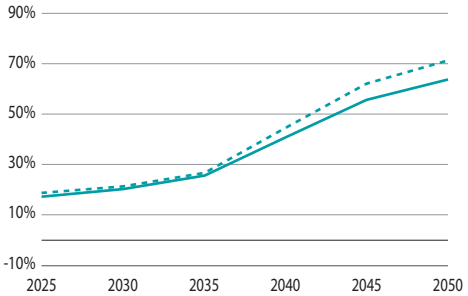
Global CO_2 Emissions
REMIND, Phase IV in dotted



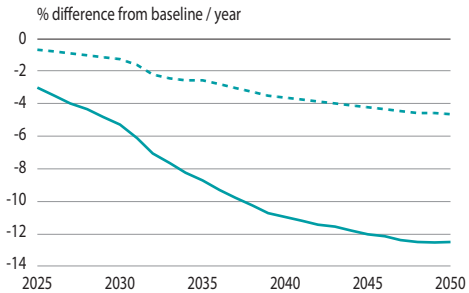
Global Energy Investments
REMIND, Phase IV in dotted



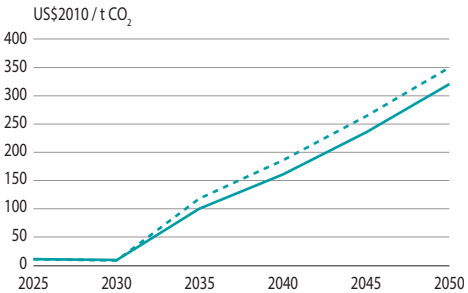
Share of Renewables in Global Primary Energy Mix
REMIND, Phase IV in dotted



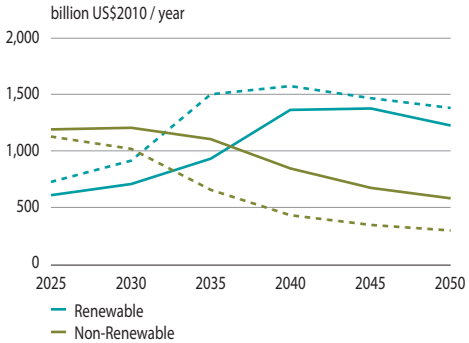
Global GDP Impacts*
NiGEM based on REMIND, Phase IV in dotted



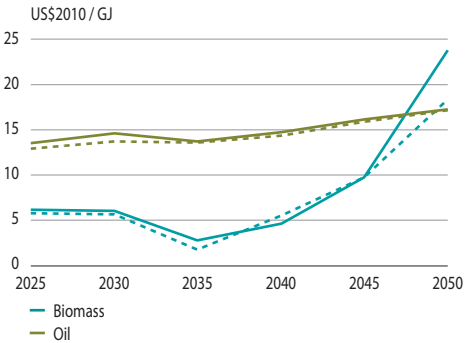
Global (Shadow) Carbon Price
REMIND, Phase IV in dotted



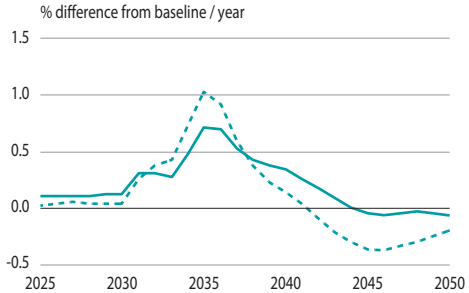
Renewable & Non-Renewable Global Energy Investments
REMIND, Phase IV in dotted



Global Oil & Biomass (Pre-tax) Prices
REMIND, Phase IV in dotted



Global Inflation (%)
NiGEM based on REMIND, Phase IV in dotted



NGFS Central Banks and Supervisors Network for Greening the Financial System

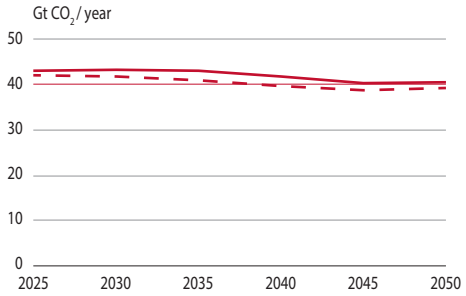
* GDP losses stemming from chronic physical and transition risk

Phase V vs Phase IV: Current Policies scenario

Current Policies assumes that only currently implemented policies are preserved, leading to high physical risks. Emissions grow leading to about 3 °C. Investments allocation and energy mix do not change.

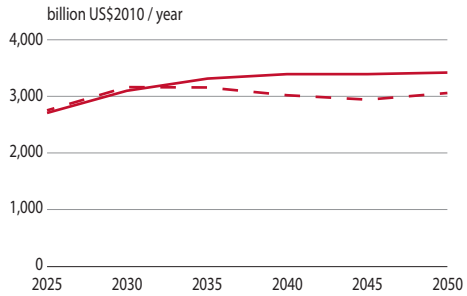
Global CO_2 Emissions

REMIND, Phase IV in dotted



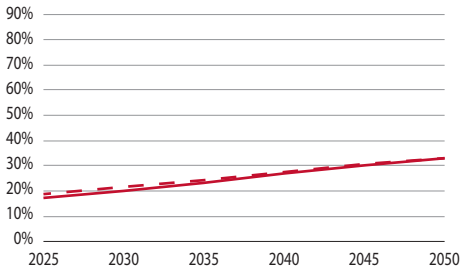
Global Energy Investments

REMIND, Phase IV in dotted



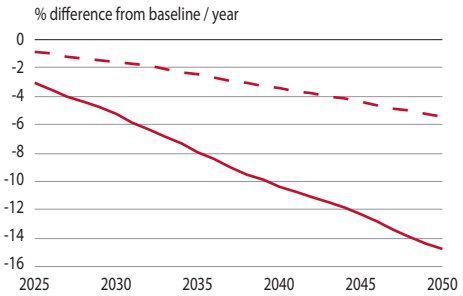
Share of Renewables in Global Primary Energy Mix

REMIND, Phase IV in dotted



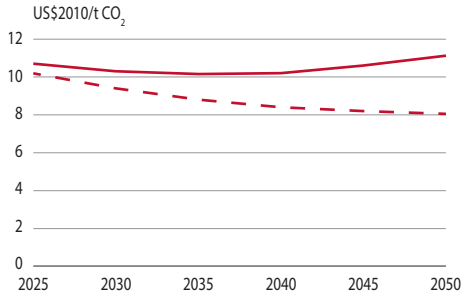
Global GDP Impacts*

NiGEM based on REMIND, Phase IV in dotted



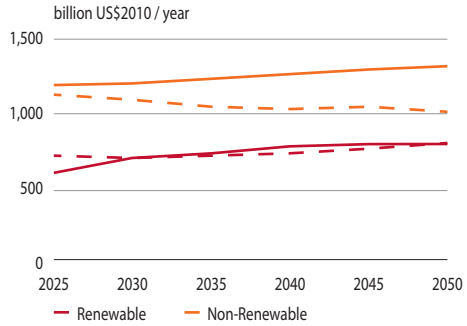
Global (Shadow) Carbon Price

REMIND, Phase IV in dotted



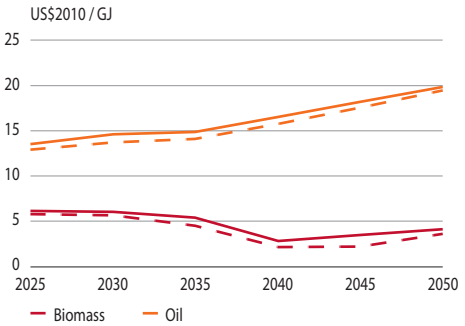
Renewable & Non-Renewable, Global Energy Investments

REMIND, Phase IV in dotted



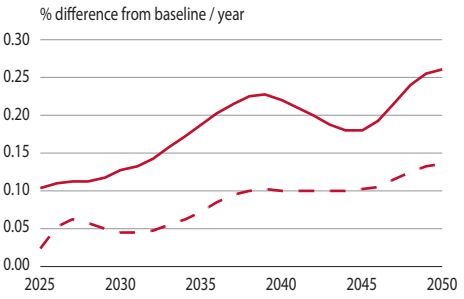
Global Oil & Biomass (Pre-tax) Prices

REMIND, Phase IV in dotted



Global Inflation (%)

NiGEM based on REMIND, Phase IV in dotted



*GDP losses stemming from chronic physical risk.

Data access, tools and resources

Accessing NGFS scenario data

NGFS climate scenario data are available on two platforms. There are several ways to access the data, which serve different users' needs and analytical requirements.

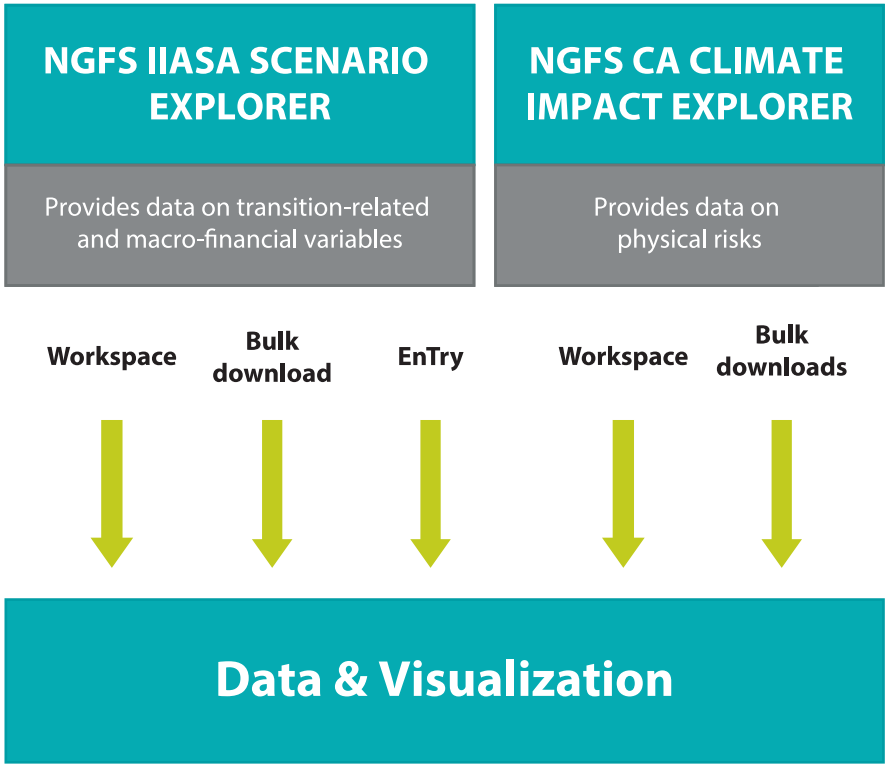
The NGFS scenarios provide a range of data on transition, physical and economic impacts produced by a suite of models aligned in a coherent way.

Data from the IAMs and NiGEM, covering **transition and macro-financial pathways**, can be found in the **NGFS IIASA Scenario Explorer**. Data on acute and chronic **physical risk impact** is stored on the **NGFS CA Climate Impact Explorer**.

There are three main ways to access NGFS climate scenario data:

- **Workspaces:** Both data explorers provide online interfaces to visualize and explore the data. Here users can explore and compare scenarios, regions, variables, and models.
- **Downloads:** Data can be downloaded in bulk as .csv or .xlsx data frames from the NGFS IIASA Scenario Explorer.
- **Code-based access:** Both data explorers provide direct APIs to access the data in coding scripts directly. To facilitate users' access to this method, the **NGFS EnTry Tool** is also available.

More details on how to work with the data are available in the **NGFS User Guide**.



Updated technical documentation

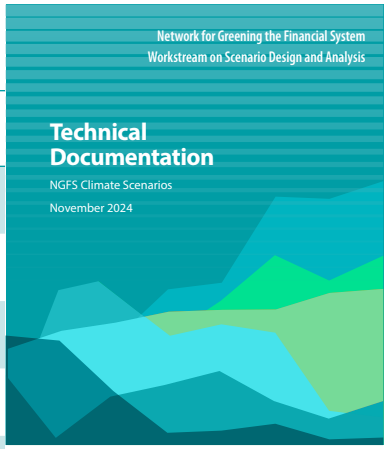
The technical documentation accompanying the NGFS follows a modular approach. This format allows readers with different levels of expertise and interest to better focus on the information relevant to them.

The revamped technical documentation includes:

- **High-level overview** for non-expert users
- **Technical modules** for each modelling component
- **Non-technical summaries** for each modelling component
- **Boxes** with explainers and deep-dives

The NGFS technical documentation can be downloaded directly at this link.

	Modules
1	High-level overview
2	REMIND-MAgPIE
3	Message
4	GCAM
5	NiGEM
6	Chronic Physical Risks
7	Acute physical risks
8	Country-level downscaling
	Technical Appendix



Data access

Overview of resources on NGFS scenarios

Data

- IIASA portal
- Climate Impact Explorer
- NGFS EnTry Toolkit

Web resources

- NGFS scenarios portal

Explanatory material

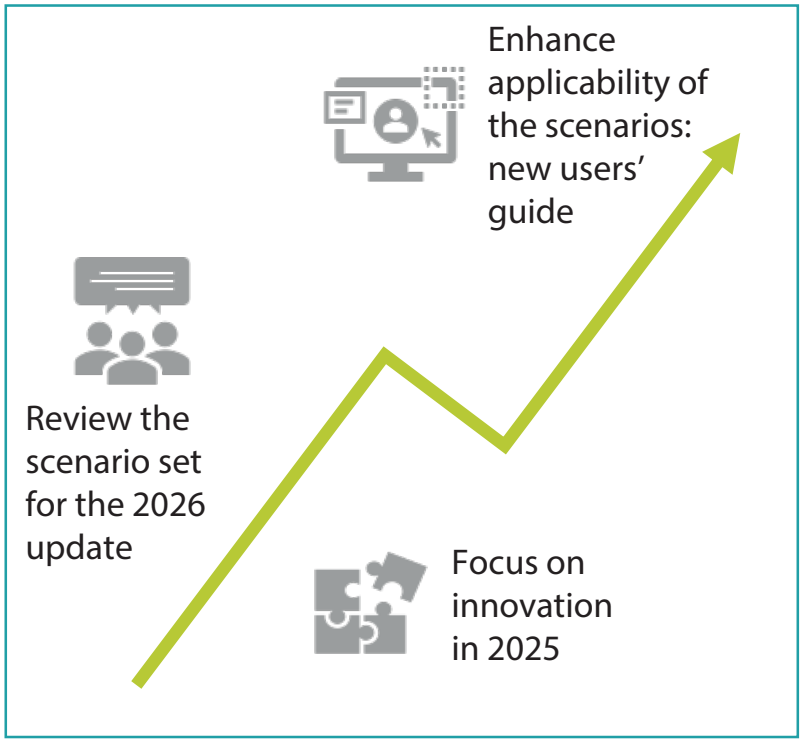
- High-level overview of the Phase V package — New
- Presentation on Phase V scenarios — Updated
- NGFS Scenarios Technical Documentation — Updated
- Explanatory note on "Damage functions, NGFS scenarios, and the economic commitment of climate change" — New
- Q&A and/or FAQ

Data access

What is next?

NGFS scenarios: improvement & innovation

NGFS long-term scenarios to be further enhanced



First vintage of the NGFS short-term scenarios