The NGFS Scenarios:

Main features and results

Cristina Angelico, Pietro Cova and
Valentina Michelangeli

NGFS
Central Banks and Supervisors
Network for Greening the Financial System

BANCA D'ITALIA
EUROSISTEMA

Photo by Alexander Grey on Unsplash

Agenda

1 **Introduction to the NGFS long-term scenarios**

2 **Scenario narratives and key results**

3 **Overview of thee NGFS short-term scenarios**

1

Introduction to the NGFS long-term scenarios

What is the NGFS?

- **The NGFS is a group sharing best practices on climate risk management and contributing to their development in the financial sector**

N — Network of Central Banks and Supervisors

Launched at the Paris One Planet Summit in 2017, the NGFS is a **group of Central Banks and Supervisors** who collaborate on a voluntary basis. Currently, the network has 171 members and observers.

G — for Greening

Members share best practices and contribute to the development of **environment and climate change risk management**. The Network's purpose is to help strengthening the global response required to meet the goals of the Paris agreement.[2]

FS — the Financial System

The network aims to **enhance the role of the financial system** to manage risks and to mobilize capital for green and low-carbon investments in the broader context of environmentally sustainable development.

1. As registered on 30 January 2024. Observers are not central banks, nor supervisors, but actively contribute to the network
2. At COP21 in Paris in 2015, global leaders decides we should keep global warming to well below 2°C compared to the pre-industrial average, and preferably limit it to 1.5°C

What are climate scenarios?

NGFS scenarios have been developed to provide a common starting point for analysing climate risks to the economy and financial system

They help answering the questions:

What can happen? If climate change is not mitigated

What should happen? To shed light on long-term benefits from green transition

The NGFS Scenarios…

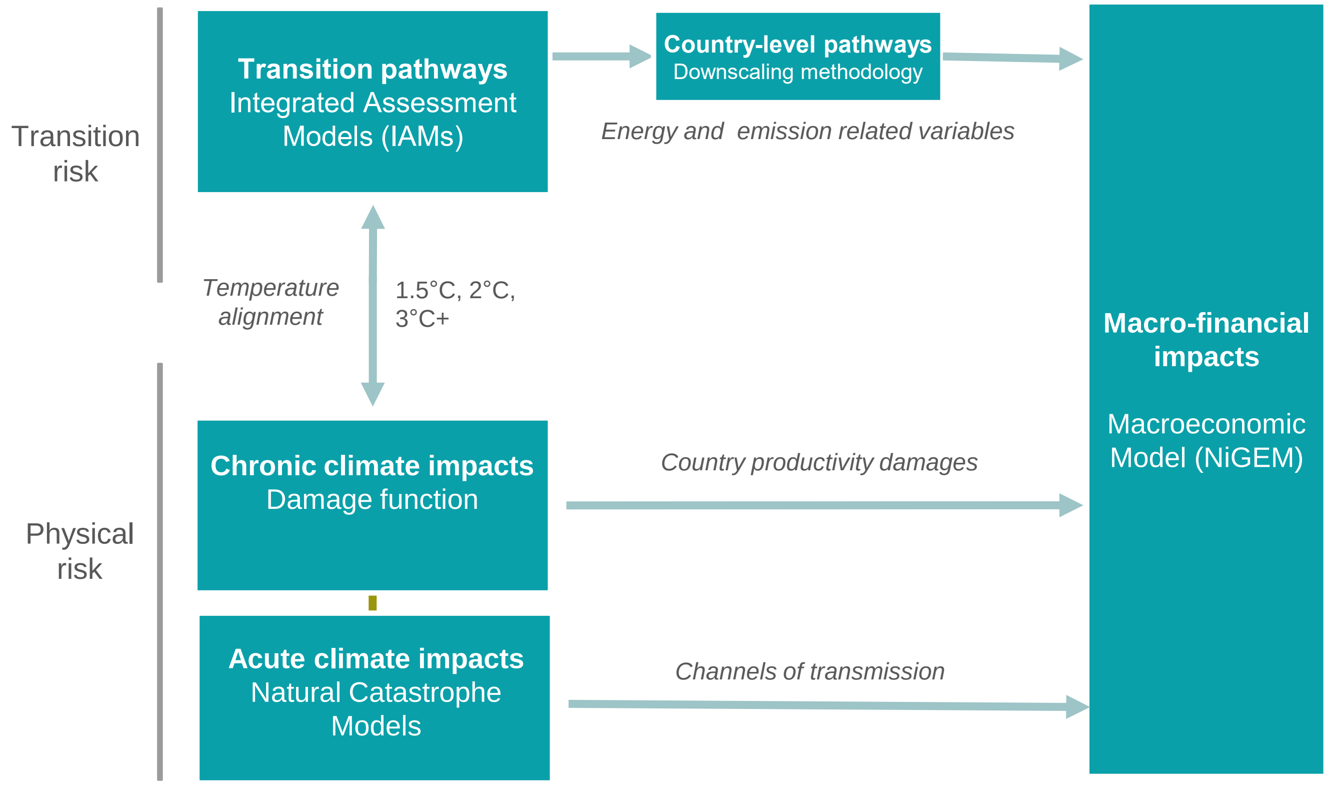
- …**have been created as a tool to shed light on potential future risks**, and to prepare the financial system for the shocks that may arise
- …**explore a range of plausible outcomes** by employing different models and examining a wide range of scenarios across regions and sectors
- …**present unique features that make them suitable for a wide range of applications**, with results freely accessible through an online platform
- …**are not forecasts** as they are intended to explore the bookends of plausible futures (neither the most probable nor the most desirable)

Modelling framework

A suite of models are aligned in a coherent way, each with its own scope: physical risks, transition risks, and macro-financial impacts

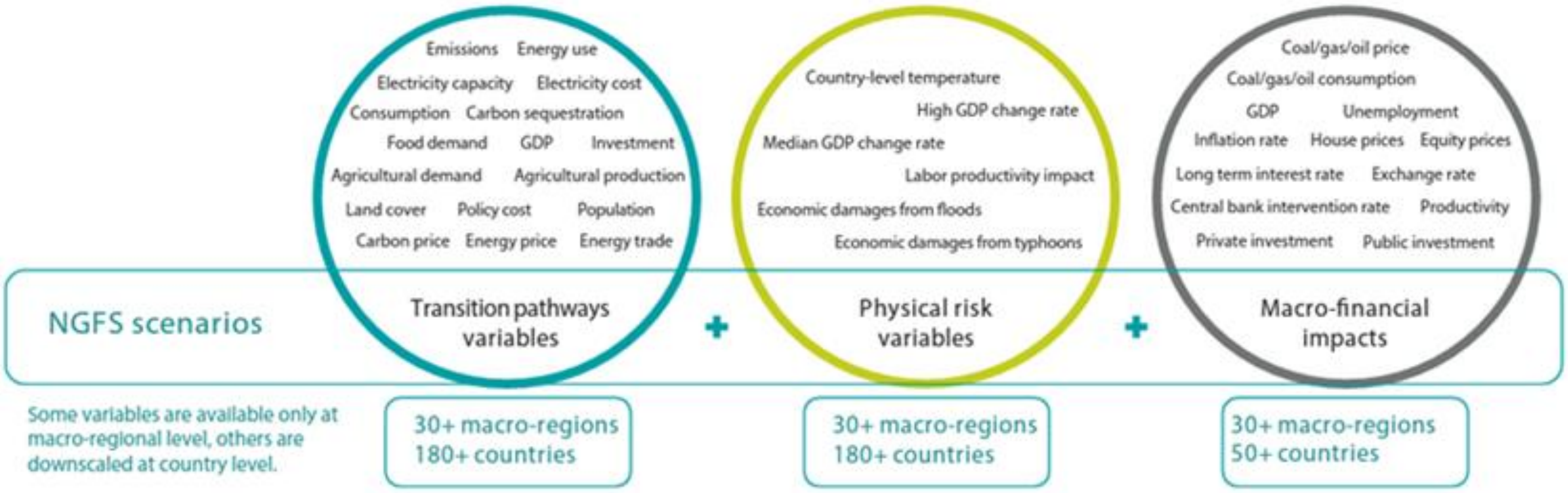
- **Transition risk models** include 3 Integrated Assessment Models (IAMs), that derive the impacts of policy ambitions on emissions, energy sector, and land use
- **Physical risk models** include acute and chronic physical risk models, projecting physical risk based on the Global Temperature Paths (GMTs)
- The **macroeconomic model** is NiGEM, employed to understand the consequences of transition and physical risks on key macro-financial fundamentals
- **Country-level downscaling** is applied to IAMs world regions to provide more granular information on the implications of NGFS Scenarios for 184 countries.

NGFS suite of models approach



Overview of output variables

Each NGFS scenario consists of a set of climate-related and macro-financial variables available for each model and geography.



Scenario framework | Transition risk

Transition risks arise from adjustments made by the society towards developing a low-carbon economy to mitigate climate change

These transition risks* arise from…

- Sudden or drastic policy and regulatory changes that aim to boost the green transition
- Exceptional or rapid technological advancements that make existing technologies obsolete
- Large and sudden shifts in consumer preferences towards more sustainable products and services
- Rapidly evolving funding landscape that redirects resources to more sustainable firms

>

And could materialize by…

- Lowering the profitability of businesses
- Decreasing the wealth of households
- Igniting financial risks for lenders and investors
- Creating stranded assets
- Hurting the broader economy through investment, productivity and relative price channels

*Similar phenomena could also enable transition 'opportunities', if they are presented in an orderly, rather than disorderly, manner

Scenario framework | Physical risk

Physical risks arise due to the direct physical consequences of climate change, either through chronic impacts or acute impacts

Chronic physical risk

Chronic physical risks refer to long-term shifts in climate patterns that may cause chronic heat or sea level rise

- Chronic risks typically arise from increase in global mean temperatures, sea levels rise and precipitation changes
- The impact can be observed in reduced labour and land productivity, capital depreciation, scarcity of natural resources, forced migrations, increased adaptation costs…
- The NGFS scenarios incorporate (mainly) the impacts of rise in Global Mean Temperature (GMT) on (labour) productivity and, consequently, GDP growth

Acute physical risk

Acute physical risks refer to those risks that are event-driven, including severity of extreme weather events

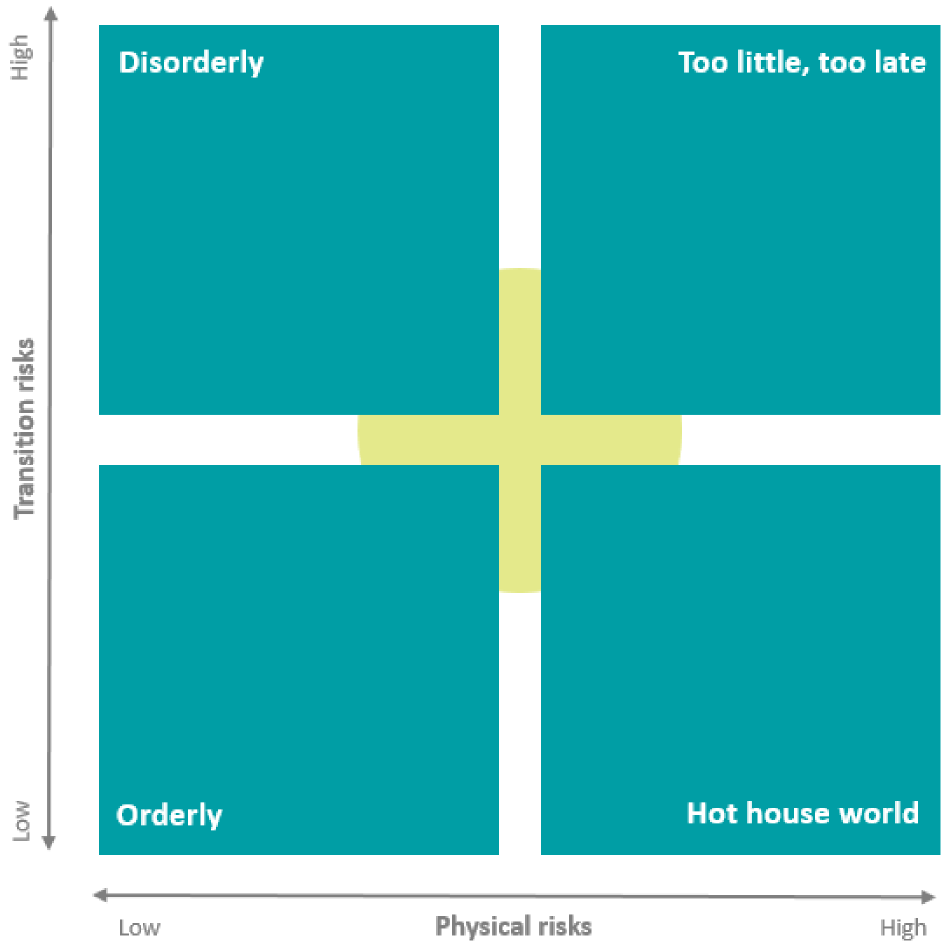
- Climate change not only has chronic impacts, but also increases the likelihood of extreme weather events to occur
- The impact can be observed in business disruptions, damages to property, reduction of agricultural yields, lower labour productivity…
- The NGFS currently focuses on four extreme weather events: droughts, heatwaves, riverine floods, and tropical cyclones

Scenario framework

The scenarios differ in the combination of transition risks (y-axis**) and physical risks (**x-axis**), which depend on the timing and stringency of the climate policies and on the availability of decarbonization technologies**

Which identify 4 quadrants of potential futures for economies and financial systems:

- **Orderly** scenarios assume climate policies are introduced early and become gradually more stringent
- **Disorderly** scenarios explore higher transition risks due to policies being delayed or divergent across countries and sectors
- **Hot house world** scenarios assume that globally efforts are insufficient to halt significant global warming
- **Too little, too late** scenarios assume that a late and uncoordinated transition fails to limit physical risks



Scenarios at a glance

7 scenarios are currently available, each of them exploring a different set of assumptions

Low Demand assumes that reduced energy demand mitigates the 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.

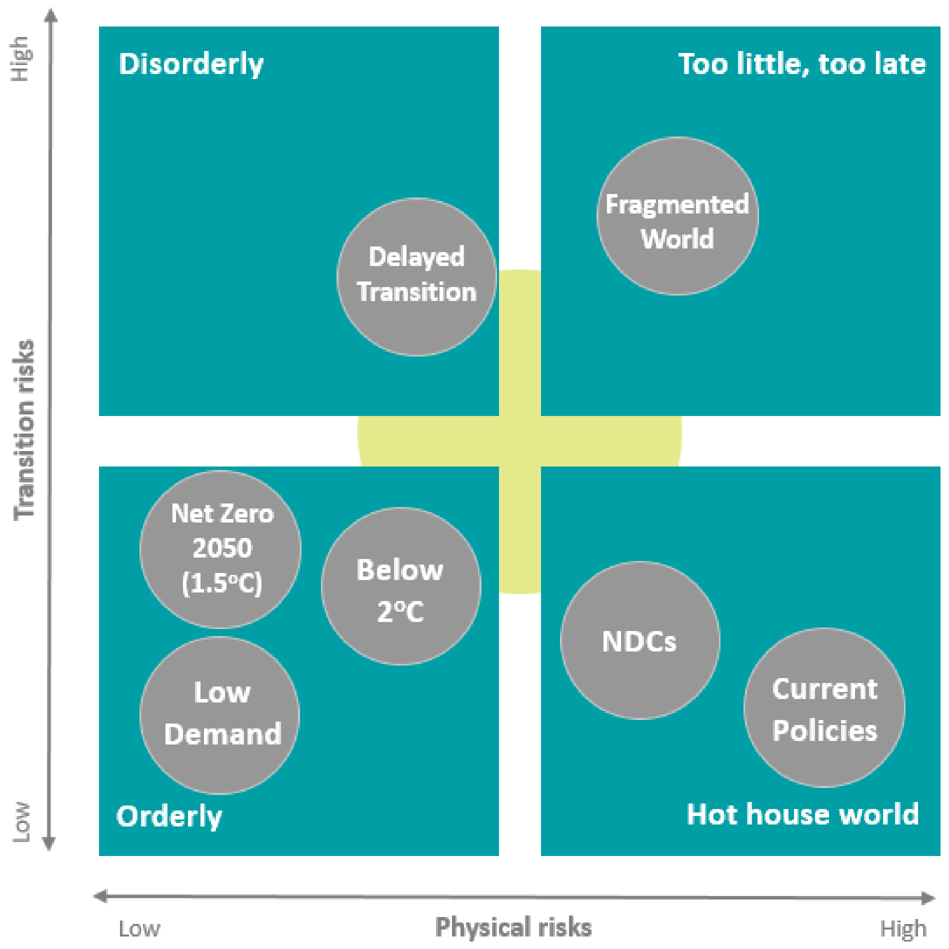
Below 2°C gradually increases the stringency of climate policies, giving a 67% chance of limiting global warming to below 2°C.

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.

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.

Fragmented World assumes a delayed and divergent climate policy response among countries globally, leading to high physical and transition risks.

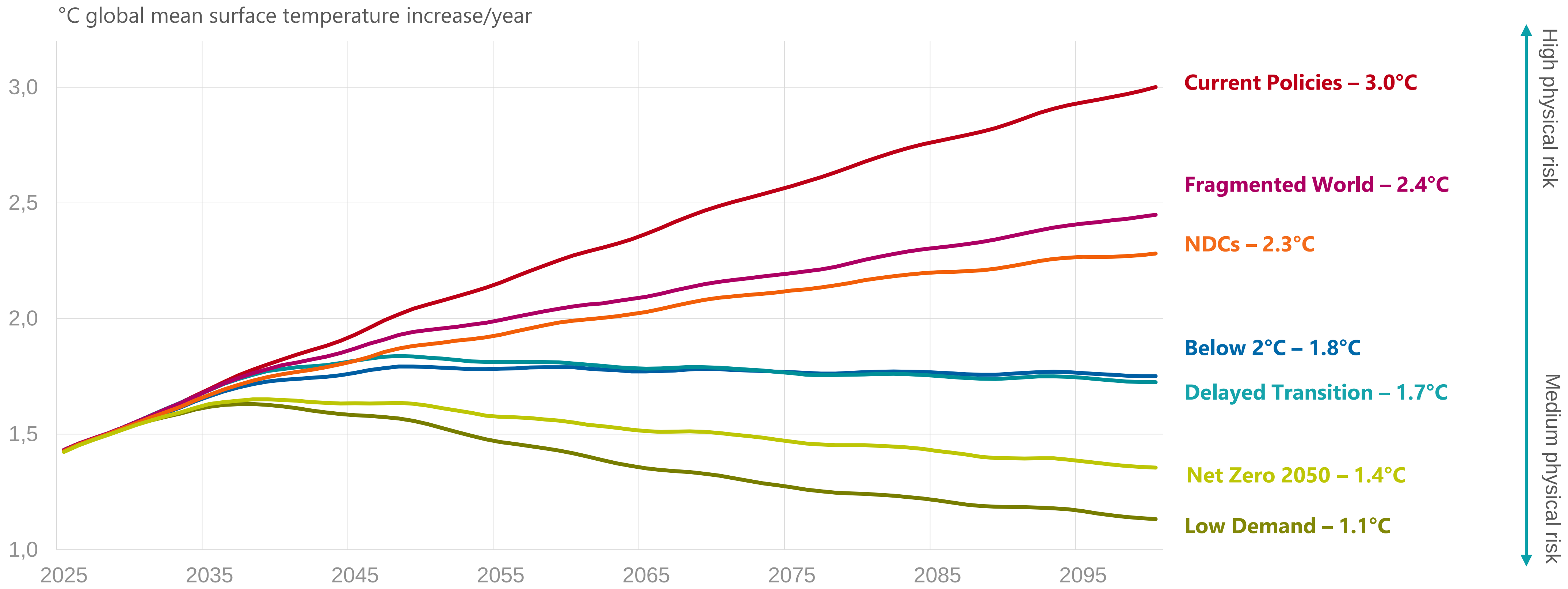


2

Scenario narratives and key results

Temperature pathways

Orderly and Delayed Transition scenarios reach peak temperatures around mid-century; in other scenarios, temperatures keep rising



Source: 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.

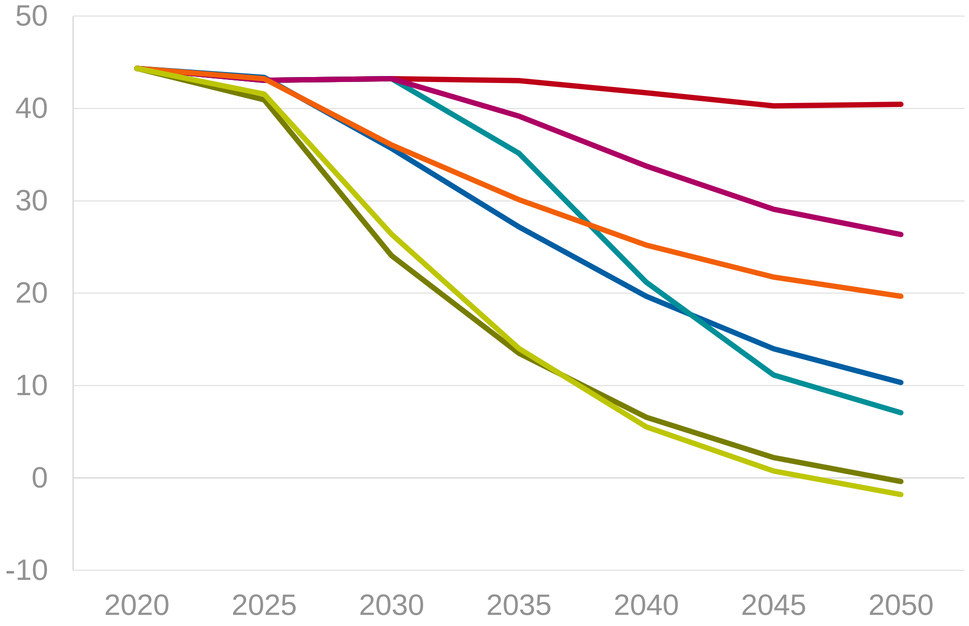
Global carbon emissions & shadow carbon prices

Orderly scenarios require more significant carbon reductions, which calls for higher shadow carbon prices

In the NGFS scenarios carbon prices are 'shadow' prices, reflecting the overall stringency of climate policies (i.e., not limited to carbon taxes). The scenarios do not distinguish between alternative fiscal instruments—which may have varying effects on economic growth and energy mix—and therefore cannot be directly used to calibrate policy measures.

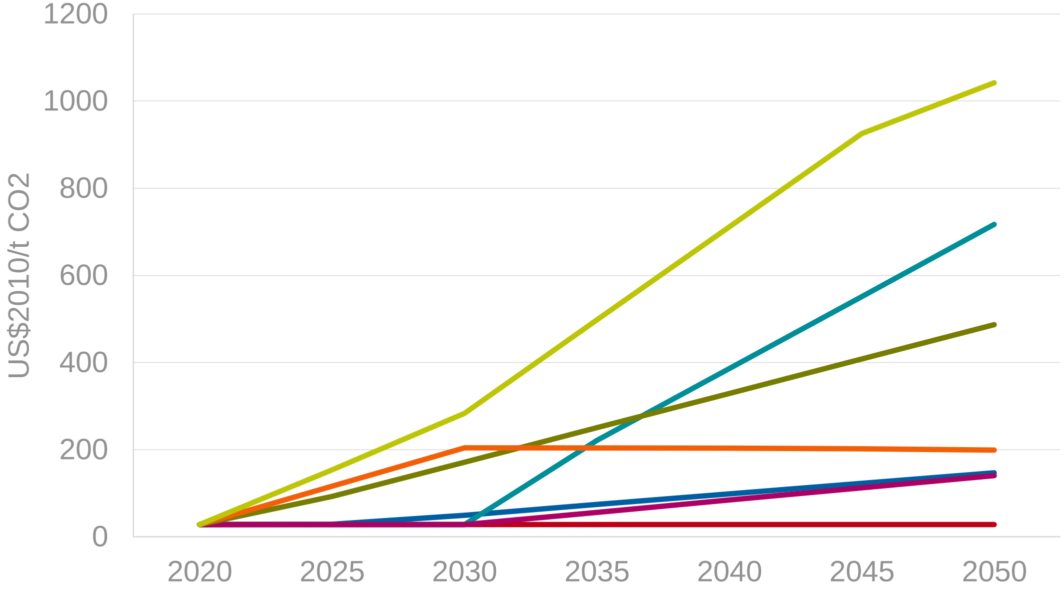
Emissions barely decrease in Current Policies, while they are reduced to (near) zero in NZ2050

CO_2 emissions - World (Gt /year)



Carbon prices remain at current levels in Current Policies, while reaching more than $1000/t in NZ2050

Shadow carbon price - World (US$$_{2010}$/t CO_2)



Net Zero 2050 | Delayed Transition | Below 2°C | NDCs | Fragmented World | Current Policies | Low Demand

Source: REMIND-MAgPIE 3.3-4.8

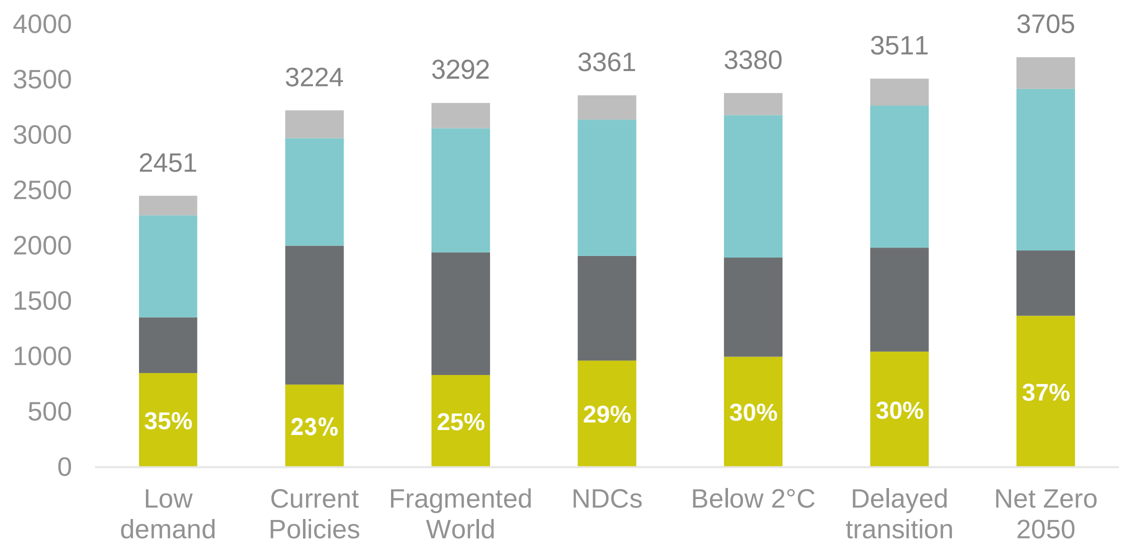
Global and EU energy investments

In most scenarios, global energy supply investments need to be above 3 trillion USD annually, with around 1/3 going to renewables

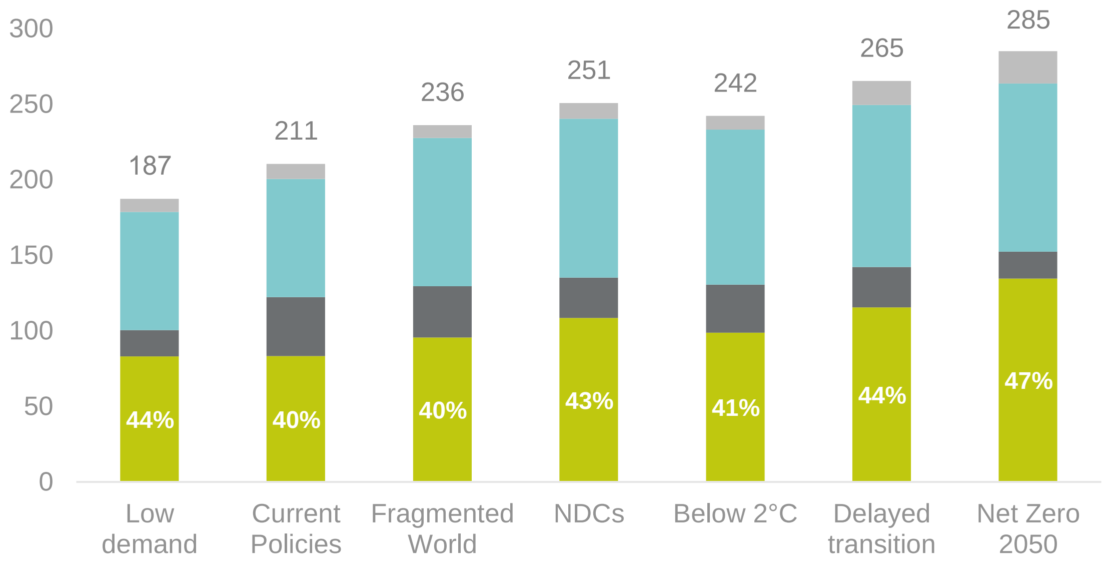
NZ2050 requires highest investment, while Low Demand reaches similar warming levels with lowest investments

EU28 energy investment needs are similar to global needs, but somewhat more skewed towards renewables

Average yearly global energy supply investment: 2025 - 2050 (in billion $US\$_{2010}$)



Average yearly energy supply investment for EU28: 2025 - 2050 (in billion $US\$_{2010}$)



Renewable electricity
Transmission and distribution
Other
Non-renewable electricity
Electricity storage

Focus region: EU28
Source: REMIND-MAgPIE 3.3-4.8

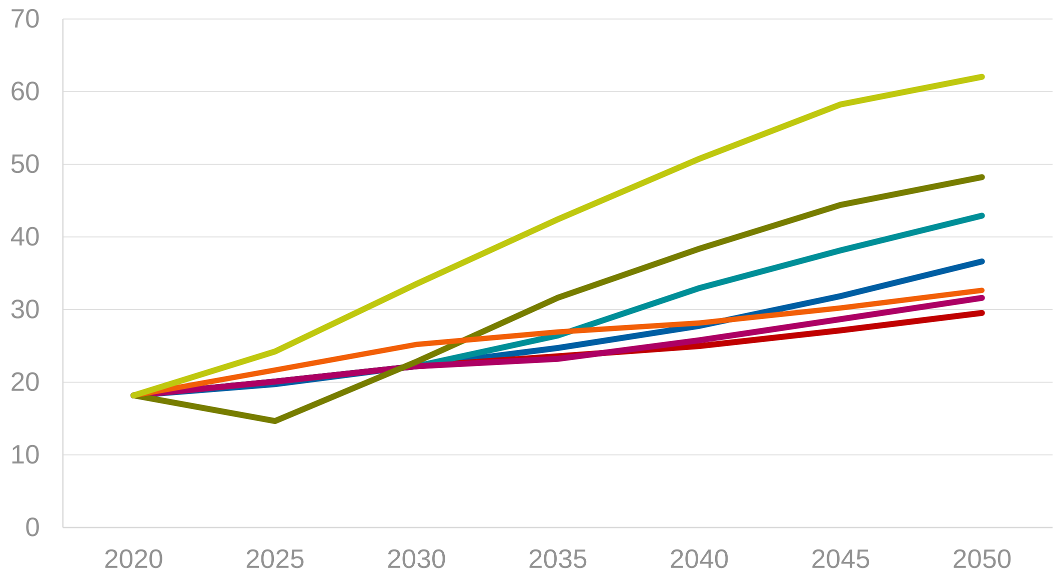
Global energy prices

Transition pushes energy prices upwards initially, which keep rising for oil in following decades, but prices stabilize at lower levels for electricity

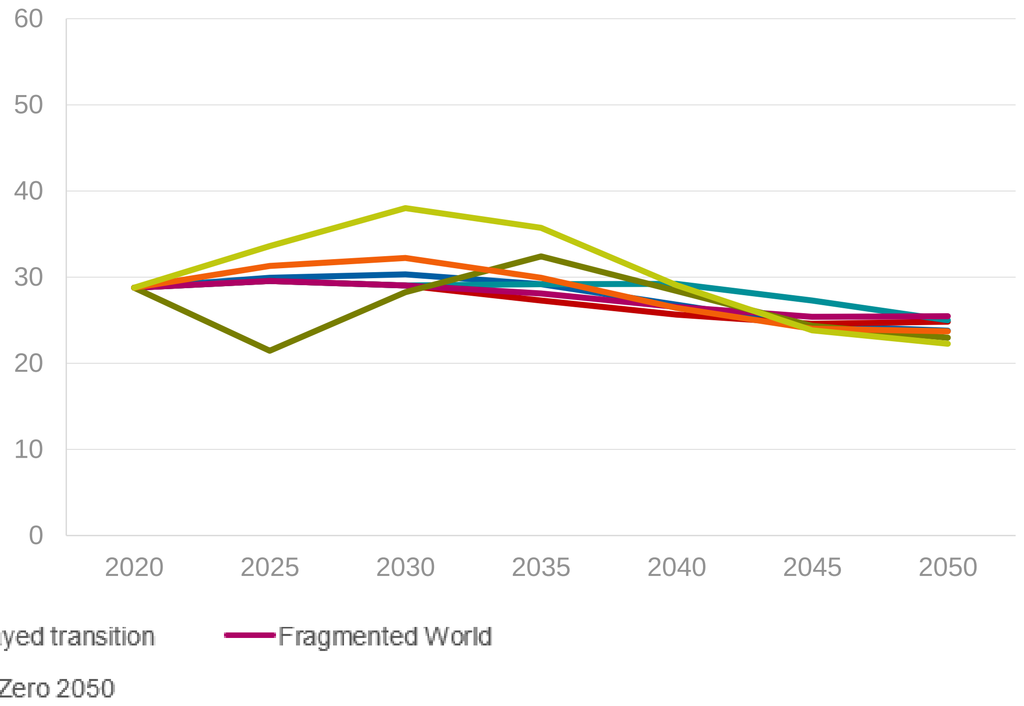
Residential oil price* increases most significantly in Net Zero 2050 scenario due to high carbon prices

Residential electricity prices rise initially in Net Zero 2050, but stabilize later at levels slightly below average

Oil price in US$$_{2010}$/GJ (Final energy - Residential - World)



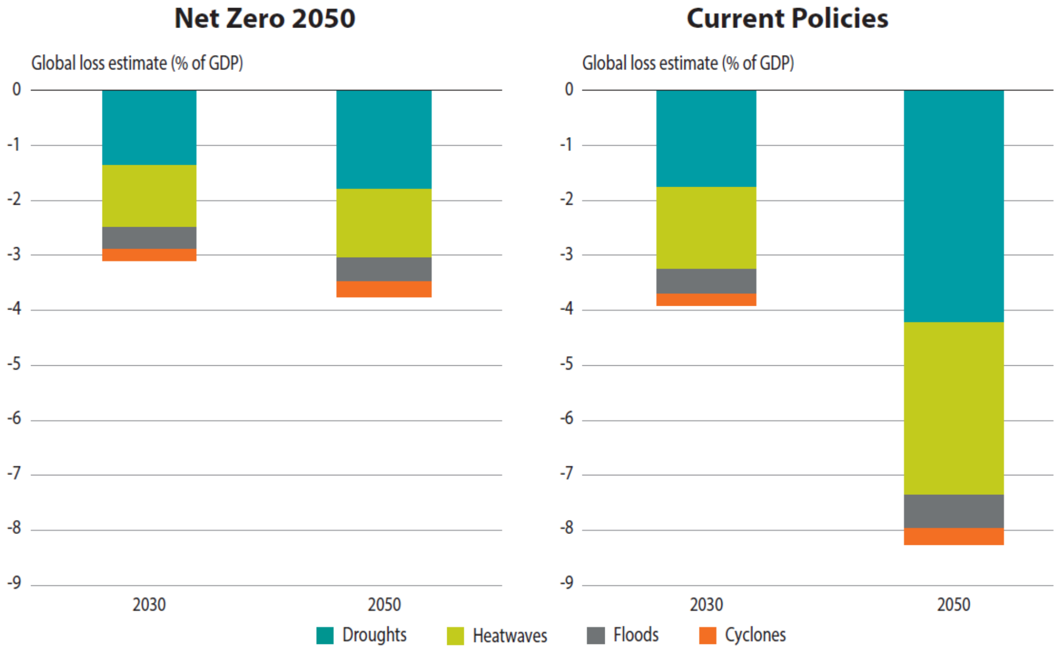
Electricity price in US$$_{2010}$/GJ (Final energy - Residential - World)



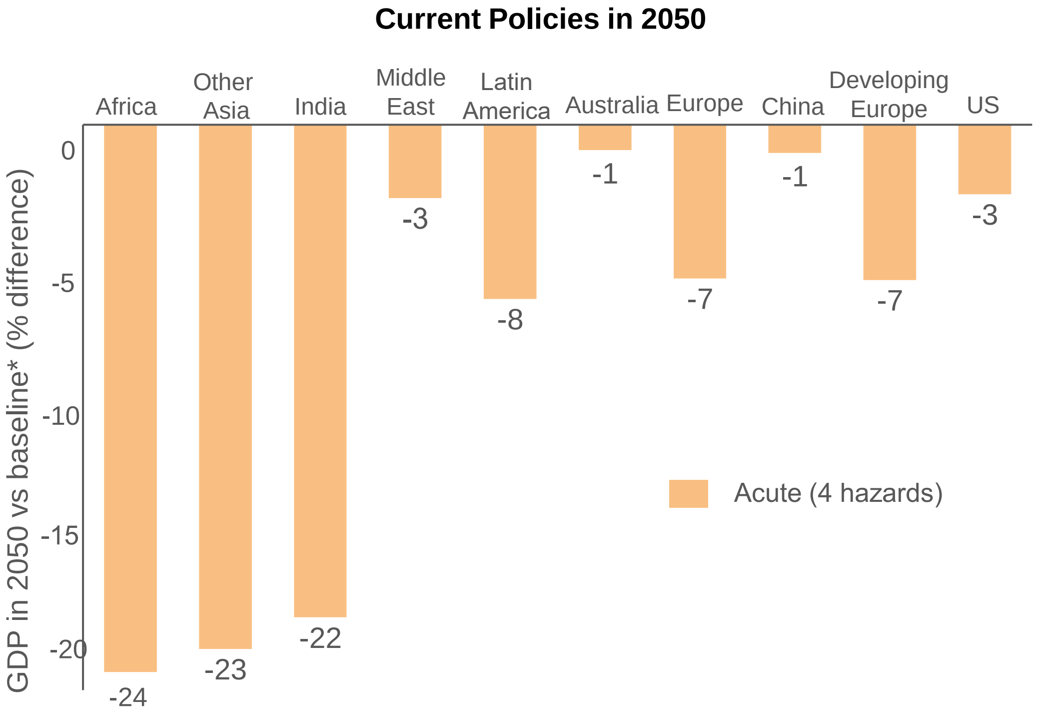
*Residential oil prices are prices for final energy for residential consumption, this includes extractions costs, carbon pricing, transportation costs, etc.
Source: REMIND-MAgPIE 3.3-4.8

GDP impacts: acute physical risks

Acute physical risk impacts increase in the Current policy scenario and are not evenly distributed across the world, with losses in the Global South being disproportionately larger



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).



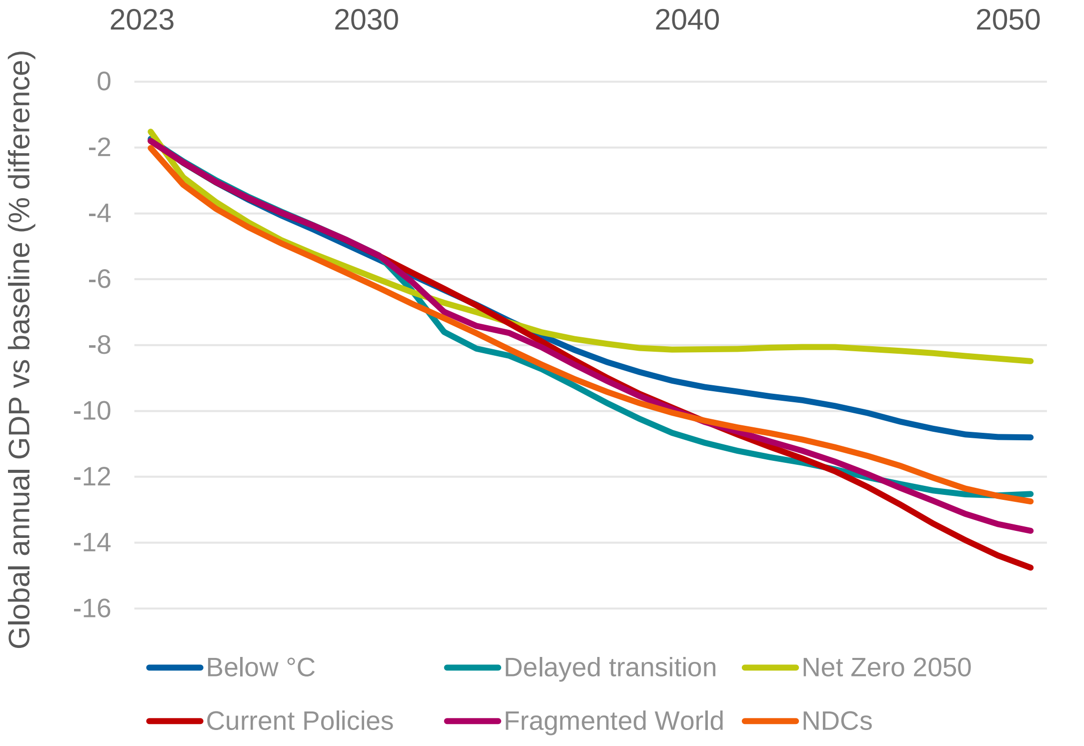
*Baseline constitutes a fictional scenario in which climate change does not occur, i.e., there are no physical or transition risks. Chronic risk impacts are represented by Kotz et al. (2024) damage function projections; Acute risk impacts are represented as the sum of 4 individually modelled hazards: droughts, heatwaves, cyclones, and floods.
Source: NiGEM v1.24.2 with inputs from REMIND-MAgPIE 3.3-4.8

GDP impacts: chronic physical risks

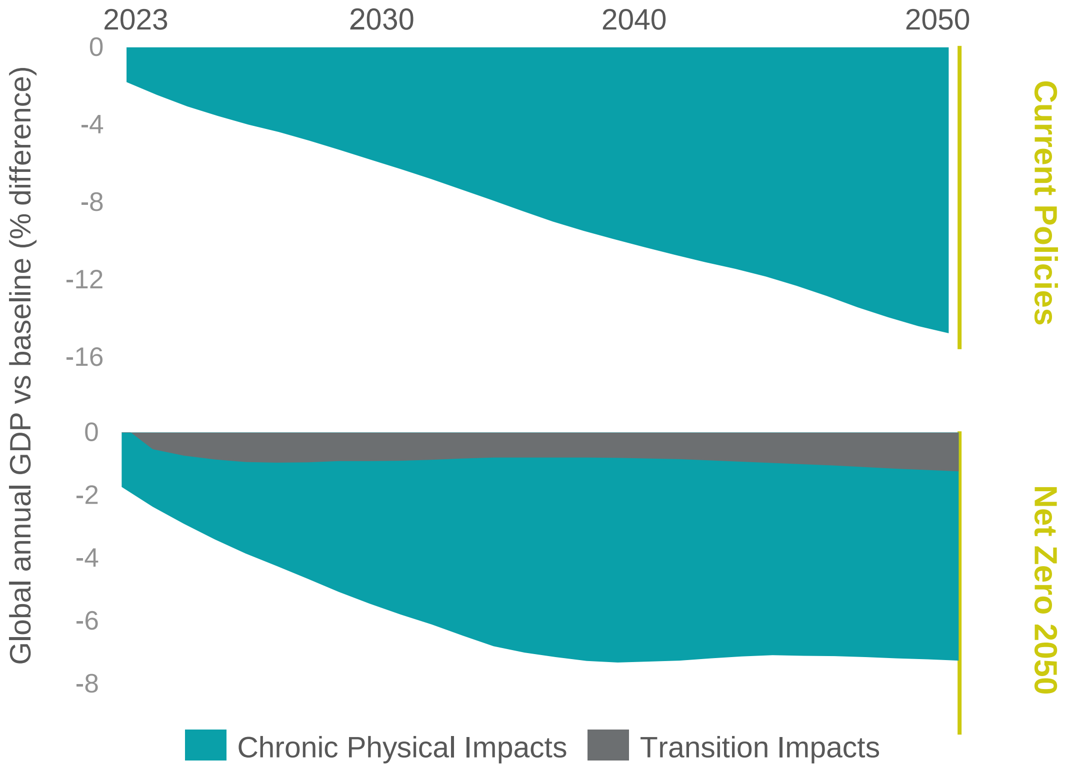
The academic paper underpinning the chronic physical risk estimates in Phase V (Kotz et al., 2024) has received critiques in a post-publication review by Nature. The paper has since been substantially revised and is now subject to a new peer-review process. Users are advised to take this revision into account, especially considering that estimated losses in Phase IV were significantly lower than those in Phase V. Results related to transition risks (i.e., from IAM or NIGEM transition risk only) or acute physical risks are not affected by this revision.

Climate change reduces global GDP across all scenarios(*), but physical damages deepen losses in Hot House & Fragmented World scenarios

By 2050, annual global GDP losses would be higher in Current Policies than in Net Zero 2050



Transition losses are limited compared to by physical losses, especially over longer horizons



(*) Compared to a baseline scenario without climate change. Baseline constitutes a fictional scenario in which climate change does not occur, i.e., there are no physical or transition risks
Source: NiGEM v1.24.2 with inputs from REMIND-MAgPIE 3.3-4.8

Caveats on GDP impacts

The academic paper underpinning the chronic physical risk estimates in Phase V (Kotz et al., 2024) has received critiques in a post-publication review by Nature. The paper has since been substantially revised and is now subject to a new peer-review process. Users are advised to take this revision into account, especially considering that estimated losses in Phase IV were significantly lower than those in Phase V. Results related to transition risks (i.e., from IAM or NIGEM transition risk only) or acute physical risks are not affected by this revision.

1. Alternative damage functions to estimate the impacts of chronic physical risks are available in the literature

- Growing literature and active academic debate
- **Estimates vary substantially depending on the methodology (i.e., data, econometric models) requiring awareness and caution by users**
- Extreme (tail) estimates can be suitable for stress testing
- **Phase V applied a new damage function based on Kotz et al. (2024) which projected substantial damages relative to Phase IV**
- **Kotz et al. (2024) is currently subject to a post-publication review**

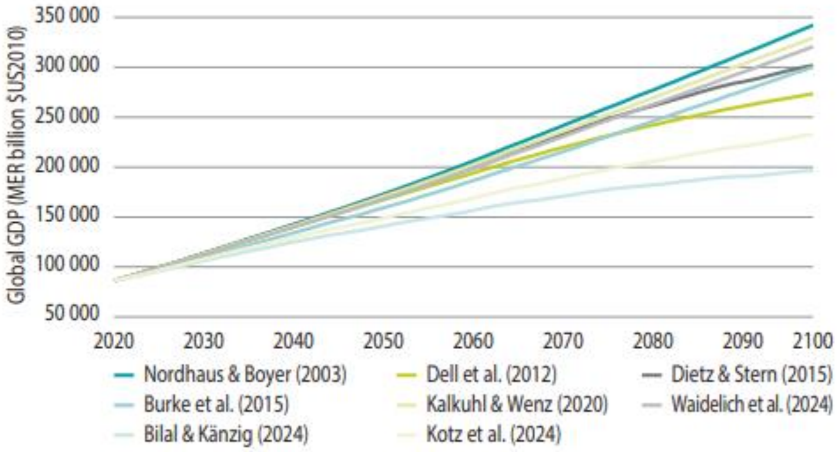
2. Chronic and Acute physical risk damages should not be added up

- Top-down damage function used to estimate the effect of chronic risks captures to some extent also acute risks
- Bottom-up approach to estimate acute risks is more precise but not comprehensive

3. Other limits:

- No adaptation is envisaged in the scenario
- Optimizing agents are myopic with respect to physical costs
- Non-exhaustive estimates of the potential damages from climate change
- See Aiello, Angelico, Cova and Michelangeli (2024) for more details

Figure 2 **GDP projections across damage functions under the NGFS Current Policies scenario**



Source: [NGFS explanatory note on the damage function]

NGFS short-term scenarios overview (first vintage)

Date of publication: May 2025

What benefits do NGFS short-term scenarios provide?

The NGFS short-term scenarios represent a first-of-its-kind, publicly available tool offering a detailed and granular analysis of the near-term impacts of climate-related risks across the globe.

Focused on **a five-year horizon**, these scenarios complement the NGFS long-term scenarios, addressing the growing need for tools that support policy responses, financial risk assessments, and evidence-based decision-making in the short term. They are specifically designed to assess the dynamic interplay between:

- **Climate policies** (transition risks),
- **Extreme weather events** (physical risks),
- **Macro-financial developments.**

Key innovations of these scenarios include:

- **Modelling of compound climate events**, specifically: simultaneous occurrences of multiple hazards such as floods, storms, heatwaves, droughts, and wildfires.
- **Cross-regional transmission of shocks:** incorporating short-term spillover effects of both transition and physical shocks through trade linkages, financial markets, and disrupted global supply chains.
- **Integration of real economy–financial sector feedback loop:** capturing how changes in the cost of capital, financial conditions, and monetary policy responses influence macroeconomic dynamics and financial stability.

Short-term scenario narratives

The short-term scenarios explore a different set of assumptions on the evolution of climate policies and physical risk. The narratives are outlined in the NGFS conceptual note

TRANSITION RISK

Highway to Paris: A technology-driven (and orderly) transition unfolds gradually. Carbon tax revenues are reinvested into green subsidies and investments. While short-term energy prices rise, economic growth from higher investments offsets these impacts. Consumers and investors increasingly favour green sectors, while high-polluting sectors face rising credit risks and capital costs.

TRANSITION RISK + PHYSICAL RISK

Diverging Realities: Advanced economies (North America, Europe, Oceania and part of Asia) pursue a net-zero transition in line with the Highway to Paris scenario. The rest of the world is hit by a sequence of extreme weather events, with effects that propagate globally via trade and financial linkages. Supply chain disruptions in critical raw materials create spillover effects for advanced economies and increase the cost of their transition to a low-carbon economy.

TRANSITION RISK

Sudden Wake-Up Call: A world of widespread climate unawareness is challenged by a sudden change in policy preferences. Consumer and investor preferences shift abruptly toward green sectors. A sharp surge in carbon prices triggers a supply shock. The transition occurs too suddenly for markets to adapt, leading to a "Climate Minsky Moment" - a wave of financial instability as asset values adjust abruptly.

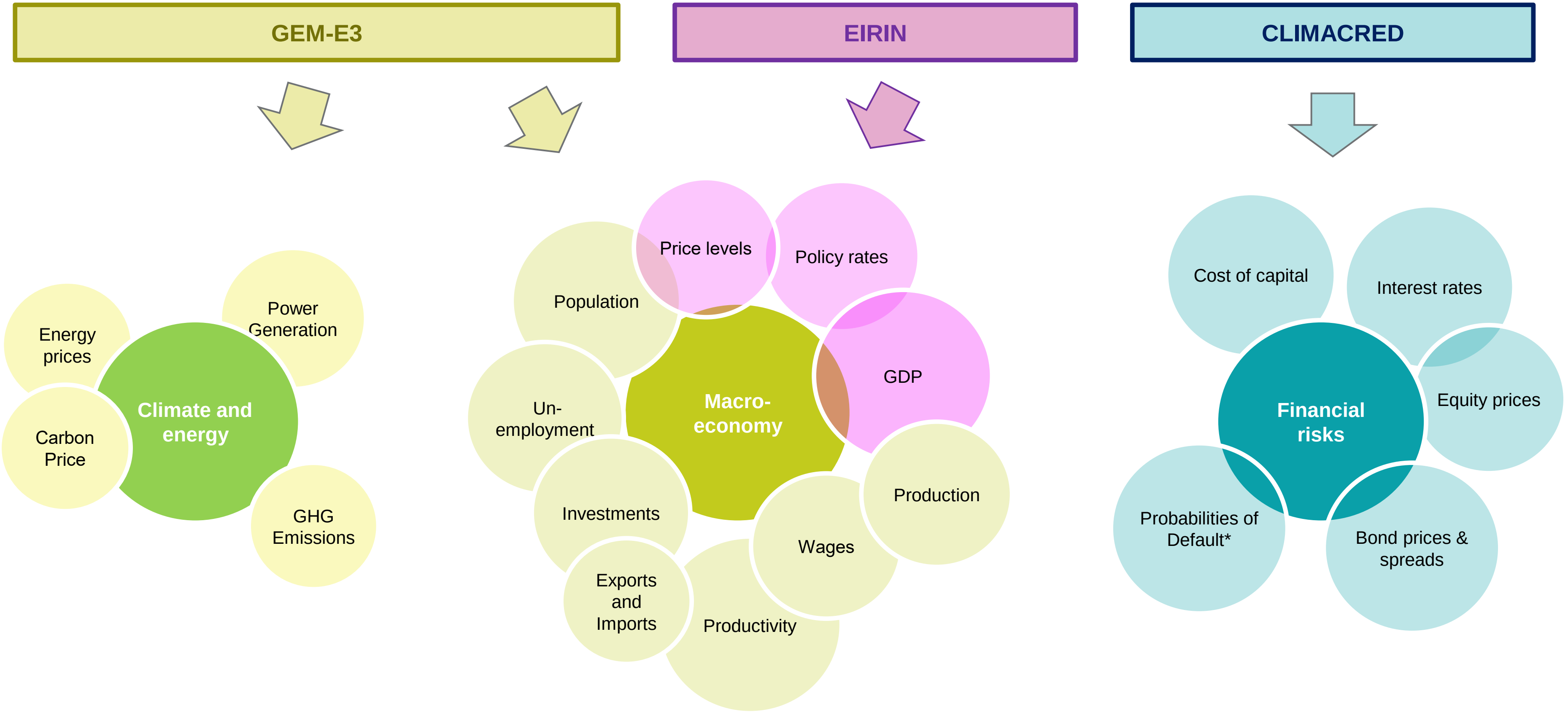
PHYSICAL RISK

Disasters and Policy Stagnation*: A sequence of region-specific extreme weather events occurring in 2026 and 2027 result in capital destruction, reduced productivity and production, and creates cascading economic impacts. Trade and financial linkages spread the negative impacts across the world, amplifying financial and economic instability.

* The "Disasters and Policy Stagnation" scenario is called "Low Policy and Ambition" in the conceptual note. This scenario has 6 versions, one simulation of extreme weather events per region, with the rest of the world is only affected via trade and financial linkages.

Modelling framework

The model outputs can be grouped in three data categories: climate, macroeconomic, and financial variables.

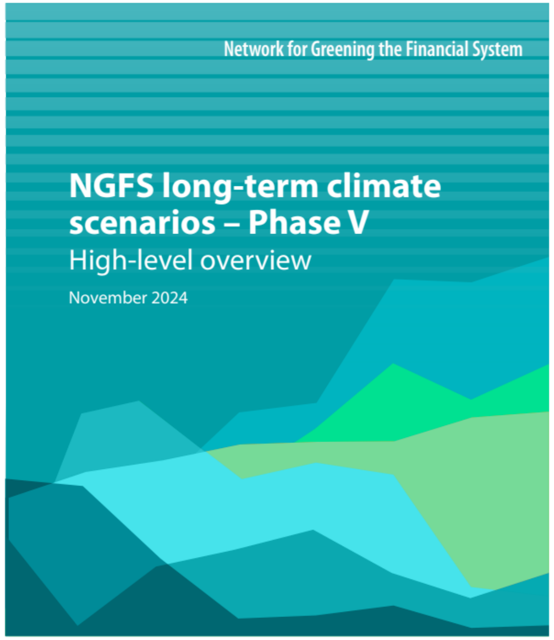


- ✓ **Sectoral granularity and country coverage:** 50 sectors and 46 countries covered by GEM-E3 and Climacred, 5 macro-regions by EIRIN
- ✓ **Financial and macroeconomic variables** enabling a wide range of analyses and applications
- ✓ **Transition and physical risk:** covering both types of climate risks and the combination of the two (in the Diverging Realities scenario)

Resources and references

- Aiello, Maria Alessia and Angelico, Cristina and Cova, Pietro and Michelangeli, Valentina, *Climate-Related Risks for Italy: an analysis based on the latest NGFS scenarios* (April 26, 2024). Bank of Italy Occasional Paper No. 847

- NGFS Website
- NGFS Scenarios Portal
- NGFS Scenarios Phase V Publication
- NGFS Short-term Scenarios Publication



Appendix

IAMs

A

- **There are 3 IAMs (REMIND, MESSAGE, and GCAM), which have similar outputs, albeit with small differences between them**

The below table displays some of the differences between the IAMs, which have an impact on the available variables

Model	REMIND-MAgPIE 3.2-4.8	MESSAGEix-GLOBIOM 1.1-M-R12	GCAM 6.0
Hosting institution	Potsdam Institute for Climate Impact Research (PIK)	International Institute for Applied Systems Analysis (IIASA)	Pacific Northwest National Laboratory (PNNL) & University of Maryland (UMD)
Economic Equilibrium	Computable general equilibrium (CGE)	Computable general equilibrium (CGE)	Partial Equilibrium (PE)
Cross sectors	Primary energy supply, transformation, manufacturing, and end uses, including residential, commercial, transport, construction, agriculture, and forestry		
Model specific sector - Transport	Road, rail, aviation, sea – freight vs passenger – vehicle type	Aggregated only	Road, rail, aviation, sea – freight vs passenger – vehicle type
Model specific sector - Buildings	Residential vs commercial	Aggregated only	Residential vs commercial
Model specific sector – Industry	Cement, chemicals, steel	Cement, (high value) chemicals, non-ferrous metal, steel	Cement, chemicals (ammonia), non-ferrous metal, steel – breakdown by technology investment, fuel type
#regions*	12	12	32
CDR** options	Electricity technologies and bioenergy with CCS***, afforestation, DACS****, enhanced weathering	Electricity technologies and bioenergy with CCS, afforestation, reforestation	Included in electricity, refining, hydrogen production, and manufacturing technologies, bioenergy with CCS, afforestation, reforestation

More details on model differences and available variables can be found in the Technical Documentation

*IAMS are modelled as aggregated regions, but results are broken down into individual country level through downscaling for a few key variables, see slide 10

**CDR = Carbon Dioxide Removal

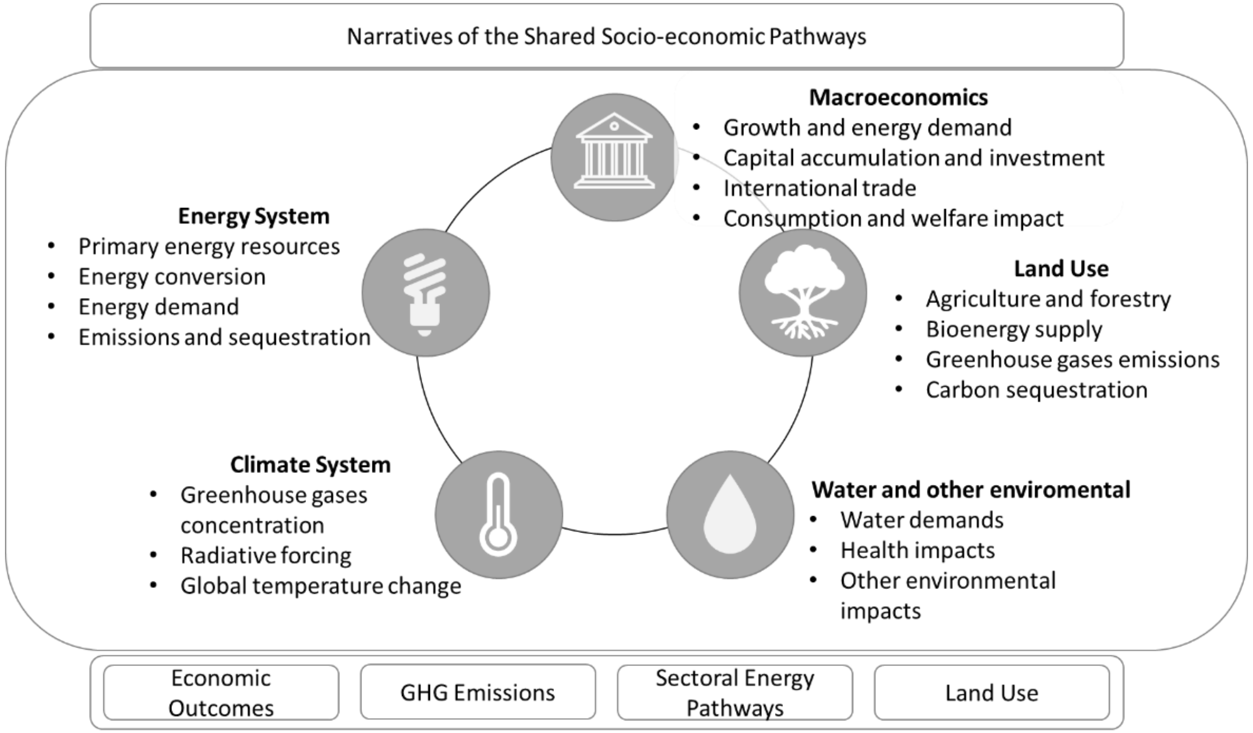
***CCS = Carbon Capture and Storage

****DACS = Direct Air Capture and Storage

Modelling framework | IAMs

- **Integrated Assessment Models (IAMs) are simplified representations of complex physical and social systems**

NGFS IAMs are process-based IAMs, covering a multitude of systems with fine granularity and process detail



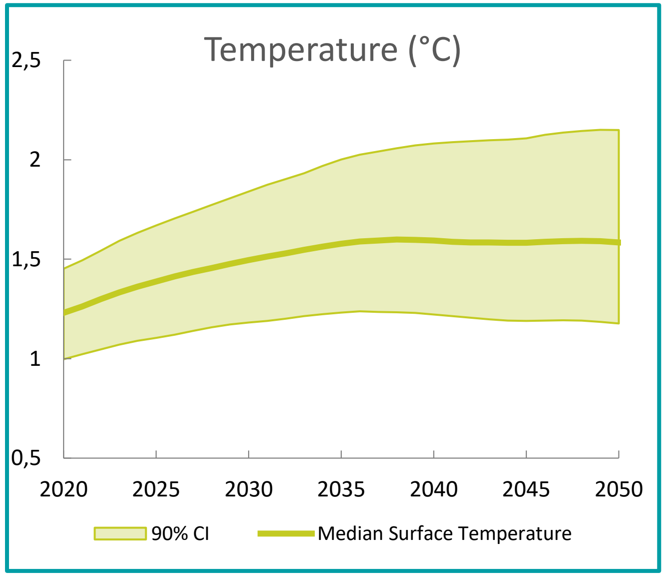
We use 3 different models to develop a more diverse and robust set of results

	REMIND-MAgPIE	MESSAGEix-GLOBIOM	GCAM
Modelling institution	Potsdam Institute for Climate Impact Research (PIK)	International Institute for Applied Systems Analysis (IIASA)	University of Maryland (UMd) & Pacific Northwest National Laboratory (PNNL)
Economic equilibrium	General Equilibrium (GE)	General Equilibrium (GE)	Partial Equilibrium (PE)

Modelling framework | (Chronic) physical risk

- **Chronic physical risk impacts are estimated using a damage function that projects the effect of a change in climate on GDP**

For each scenario, a **temperature pathway** is calculated by the IAMs based on emission developments

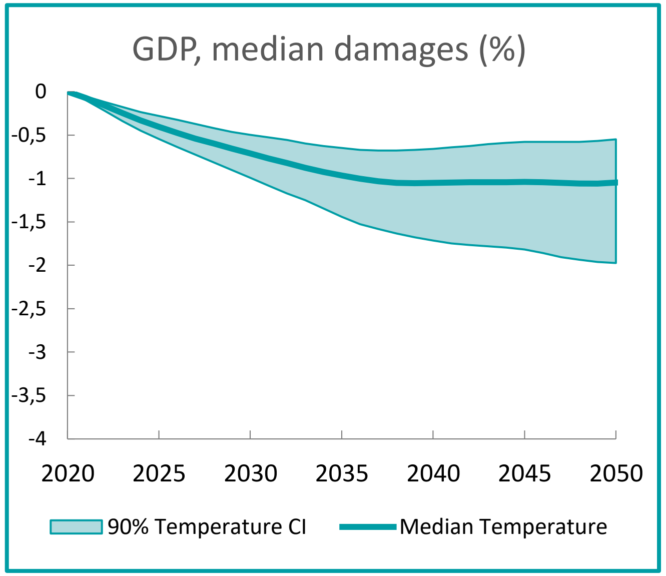


A **damage function** developed by Kotz et al. (2024)[1] is used to estimate the impact of this temperature change on GDP growth

$$
\begin{aligned}
\Delta \mathrm{lgrp}_{r,y} = {} & \mu_r + \eta_y + k_r y + \sum_{L=0}^{N} \left(\alpha_{1,L} \Delta \bar{T}_{r,y-L} + \alpha_{2,L} \Delta \bar{T}_{r,y-L} \times \bar{T}_r\right) \\
& + \sum_{L=0}^{N} \left(\alpha_{3,L} \Delta \tilde{T}_{r,y-L} + \alpha_{4,L} \Delta \tilde{T}_{r,y-L} \times \hat{T}_r\right) \\
& + \sum_{L=0}^{M} \left(\alpha_{5,L} \Delta P_{r,y-L} + \alpha_{6,L} \Delta P_{r,y-L} \times P_r\right) \\
& + \sum_{L=0}^{M} \left(\alpha_{7,L} \Delta \mathrm{Pwd}_{r,y-L} + \alpha_{8,L} \Delta \mathrm{Pwd}_{r,y-L} \times \mathrm{Pwd}_r\right) \\
& + \sum_{L=0}^{M} \left(\alpha_{9,L} \Delta \mathrm{Pext}_{r,y-L} + \alpha_{10,L} \Delta \mathrm{Pext}_{r,y-L} \times \bar{T}_r\right) + \epsilon_{r,y}
\end{aligned}
$$

ΔLgrp = year-on-year change in log-transformed gross regional product; ΔT = change in mean temperature; ΔT̃ = change in temperature variability; P = annual precipitation; Pwd = number of wet days; Pext = extreme daily rainfall

We obtain a best estimate of **GDP losses** from (chronic) physical risk, which is fed back into the models



Detailed information about the damage function methodology can be found in the “explanatory note on the new damage function”

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

Modelling framework | Acute physical risk

- **Natural catastrophe models are used to assess the impact from extreme weather events**
- NGFS scenarios currently include the impacts of floods, cyclones, droughts, and heatwaves

For each peril, we identify a suitable **hazard indicator** and data source	We make a projection on how the hazard will evolve based on **temperature pathways**	We simulate the impact on a pre-defined factor in the **real economy**	We assess the **macro-economic impact** of this factor's evolution in NiGEM
Flood data is obtained from global hydrological models and ISIMIP	We extrapolate flood severity for different Global Mean Temperature (GMT) warming levels	We estimate economic losses using a damage function while correcting for flood protection	Ultimately, flood impacts enter NiGEM as **capital stock damages**
Historic track sets of **cyclones** are obtained from the IBTrACS dataset	Frequencies and intensities of such historic track sets are rescaled based on GMT warming levels	Losses are estimated based on cyclone exposure (via LitPop) and vulnerability (via damage functions)	Ultimately, cyclone impacts enter NiGEM as **capital stock damages**
Information on **droughts** is obtained from the SPEI (standardized precipitation evaporation index)	The relationship between GMT warming levels and drought impacts is estimated	The impact on crop yields is estimated by looking at harvested areas under drought conditions	Ultimately, drought impacts enter NiGEM as **shocks in the agricultural supply**
For **heatwaves**, we use the wet-bulb temperature – a measure of humid heat	The relationship between GMT warming levels and heatwave occurrence is identified	We analyse the total exposed population to heatwave events	Ultimately, drought impacts enter NiGEM as **shocks in labour productivity and demand**

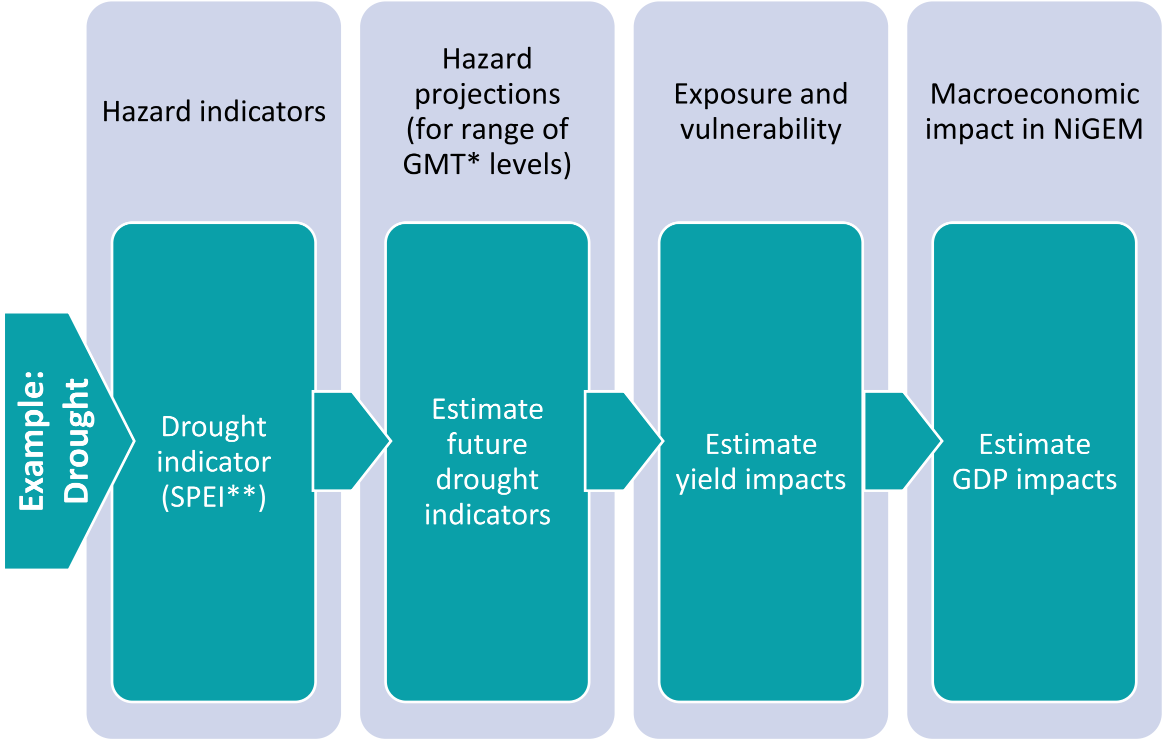
A

Improved modelling of acute physical risks

- **Acute physical risk modelling has been improved to include more hazards and greater geographical granularity, among others**

The modelling has been **enhanced** to include:

- **Four acute physical risk hazards**: heatwaves, droughts, tropical cyclones and riverine floods.
- **Additional channels of transmission** to the real economy.
- **Country level projections** of GDP losses for all hazards.

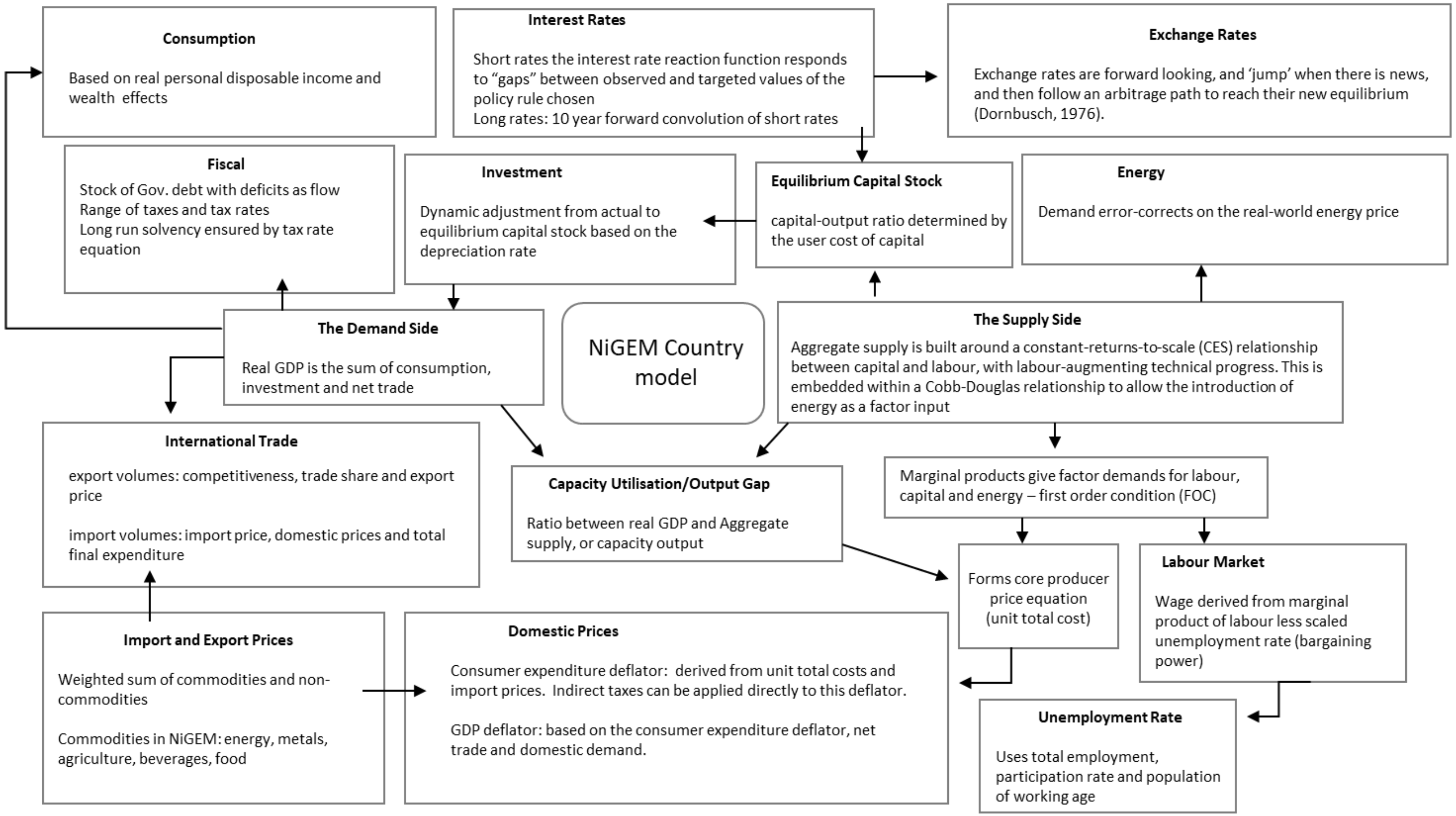


*GMT (Global Mean Temperature): increase in average earth surface temperature
**SPEI (Standardised Precipitation Evapotranspiration Index): drought indicator that account for multiple drought elements such as onset, duration and magnitude versus normal levels

Modelling framework | NiGEM

- **Macro-financial impacts are calculated using NiGEM*, a peer-reviewed, global general equilibrium econometric model**

- NiGEM consists of individual country models
- It contains a well-specified supply-side and the 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

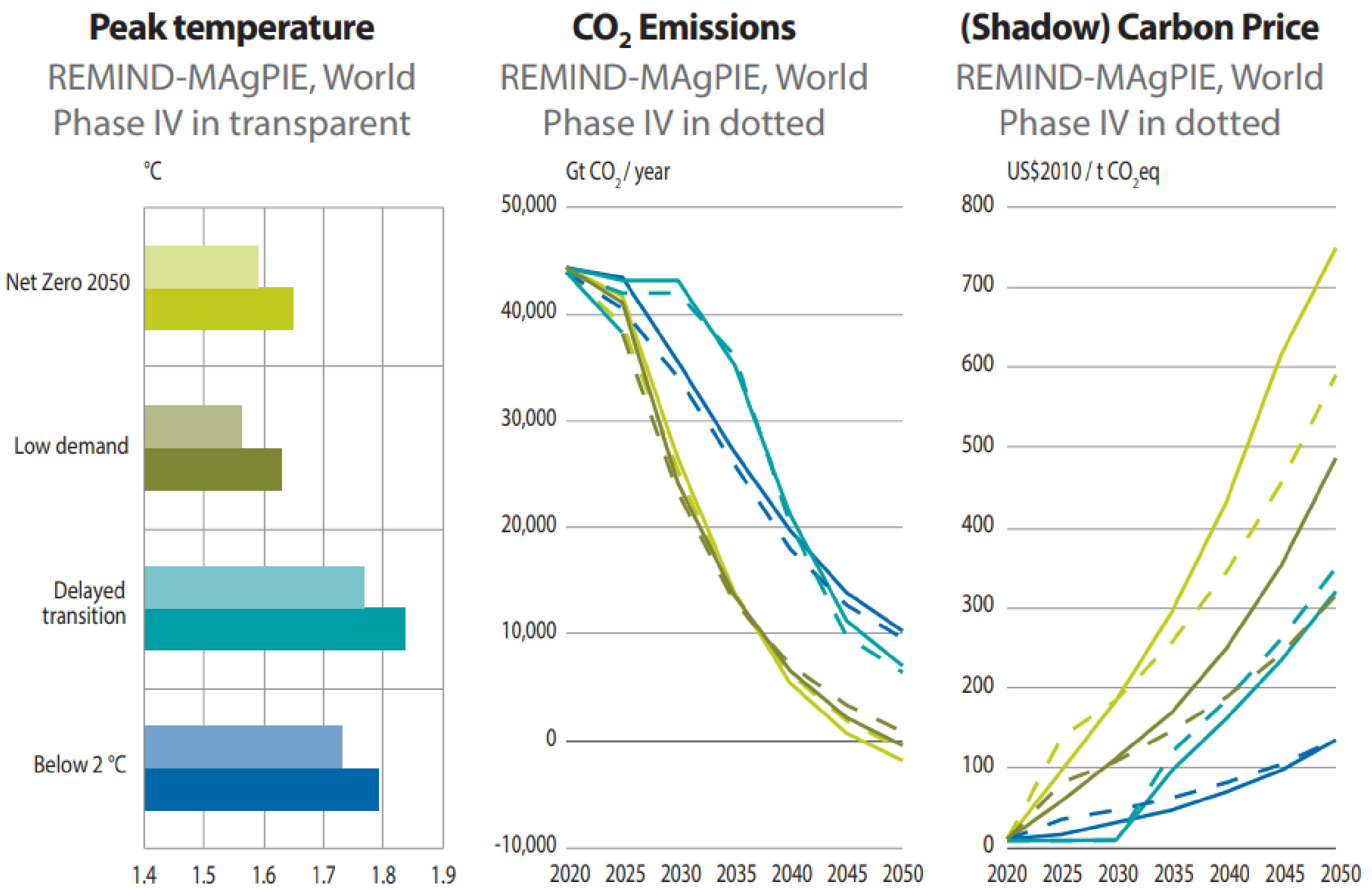


*NiGEM = National Institute Global Econometric Model

Updated data and commitments

• NGFS scenarios have been brought up to date with the latest economic and climate data, and policy commitments

- **All scenarios are more disorderly in Phase V** reflecting delays in policy action.
- Higher emissions in the near term cause **higher peak warming** for most scenarios in Phase V vs Phase IV
- The scenarios account for targets and pledged policies published by the UNFCC until **end of March 2024**.
- The **use of carbon dioxide removal (CDR) technologies** has been further refined reflecting current trends.
- In Phase V, the NGFS scenarios rely on the assumptions from the **latest release of the Shared Socioeconomic Pathways** (SSP2, version 3.0)



Source: REMIND-MAgPIE