Network for Greening the Financial System

# NGFS Climate Scenarios
## for central banks and supervisors

June 2021

NGFS
Central Banks and Supervisors
Network for Greening the Financial System

# Joint foreword

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Chair of the NGFS

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Chair of the workstream on "Macrofinancial"

It is our very great pleasure to present the second iteration of the NGFS' climate scenarios. They represent a true milestone in the race to better understand the risks from climate change.

The world is at a critical juncture where climate pathways could move in materially different directions: from a successful transition to net-zero emissions by 2050; to a hot house world with global warming of 3˚C or more by 2100. In the face of such uncertainty, climate scenario analysis is a vital tool that helps us to prepare for a range of future pathways. And it does this by focussing minds on a variety of different outcomes, challenging users to consider what risks and opportunities might arise – and crucially, what action might be required today in light of these potential challenges tomorrow.

A major obstacle to undertaking this analysis has been the availability of detailed scenarios that analyse both the physical and transition risks from climate change and their economic impacts. The challenges and costs of creating such scenarios are beyond most individual firms or institutions, so it is against this background that the NGFS has developed a common set of scenarios. These scenarios are designed to act as a foundation for analysis across many institutions, creating much needed consistency and comparability of results. Indeed, a growing number of central banks, supervisors and private firms are already using NGFS scenarios as a basis to better understand risks to financial systems, economies and their own businesses and balance sheets.

We are proud of how far these scenarios have come in a very short time. It was just one year ago that the NGFS released its first iteration of NGFS scenarios, a milestone in itself. The first iteration provided a foundation for climate scenario exercises by offering a consistent set of pathways for global changes in policy, the energy system, and the climate. Whilst an ambitious first step, these scenarios represented a foundation for future work.

This second iteration of the scenarios takes a huge step forward. Not only does it include a mapping to impacts at a country level, but it includes nearly 1,000 economic, financial, transition and physical variables across six different scenarios. These have been created through a suite of models, supported by a consortium of world leading climate scientists and modelling groups. The variables are calibrated to the latest available data and will be kept up to date in future iterations to ensure their continued relevance. And all variables are made available for free on the NGFS website so that anyone can take advantage of the wealth of information they provide.

Huge strides have been made, but the opportunity to deepen scenarios further remains large. For this reason, the NGFS will continue to invest in developing these scenarios, and to welcome views from others on where development can be most valuably focussed. In doing this, we remain cognisant that the modelling of future pathways that encompass changes in policy and climate are subject to significant uncertainties and valuable debate. To help navigate this uncertainty the NGFS scenarios: provide six scenarios with variable assumptions on future changes in policy and technology; utilise multiple models to provide a range of results and hedge against model bias; and are transparent on the underlying models and methodologies used.

We are grateful to all of those that have contributed to these scenarios and look forward to seeing them applied in practice. After all, as we improve our understanding of how the future can play out, we will be better equipped to take the actions that are needed today to reduce the risks of tomorrow.

# Acknowledgements

The Network for Greening the Financial System (NGFS) is a group of 91 central banks and supervisors and 14 observers 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 NGFS Workstream on "Macrofinancial" has been working on updating the June 2020 NGFS Scenarios 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), the Swiss Federal Institute of Technology in Zurich (ETHZ) and the National Institute of Economic and Social Research (NIESR). This work was made possible by grants from Bloomberg Philanthropies and ClimateWorks Foundation.

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# Contents

# Overview of the scenarios

# Key messages

## Scenarios differ markedly in their physical and transition impacts, with significant uncertainty in the size of the estimates and variation across regions.

- The NGFS Scenarios have been developed to provide a **common starting point** for analysing climate risks to the economy and financial system. While developed primarily for use by central banks and supervisors they may also be useful to the broader private sector, government and academia.

- In this second iteration, the NGFS scenarios have been brought up to date, including by incorporating countries' commitments to reach net-zero emissions, and have been enriched with an expanded set of macroeconomic variables, country-level granularity, and an online portal through which users can explore the physical risks from climate change.

- Reaching net zero $CO_2$ emissions by 2050 on a global basis will require an ambitious transition across all sectors of the economy. The NGFS scenarios highlight a few important themes including rapid decarbonisation of electricity, increasing electrification, more efficient uses of resources, and a spectrum of new technologies to tackle remaining hard-to-abate emissions.

- The impacts on the economy will be modest, and even positive depending on how smoothly the transition occurs. While stronger policy incentives will be needed to spur on the transition, new economic modelling in this release suggests that higher private and public investment in new technologies and sectors would offset impacts on both demand and supply.

- However, it is prudent to assess a wide range of outcomes across different sectors and regions given the potential uncertainties. The NGFS scenarios also highlight the increased macro-financial risks that could crystallize in scenarios with divergent policies or delay followed by stronger action, and from physical risks.

# Objectives and framework

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

- The NGFS scenarios explore a set of six scenarios which are consistent with the NGFS framework (see figure) published in the First NGFS Comprehensive Report covering the following dimensions:

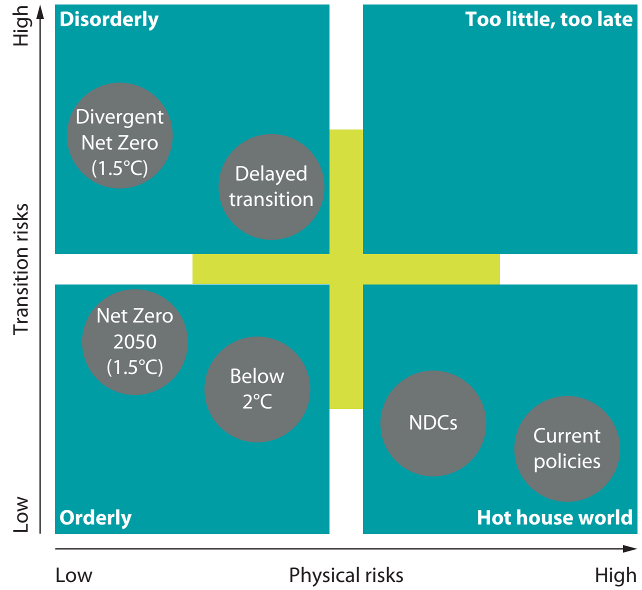
  – **Orderly** scenarios assume climate policies are introduced early and become gradually more stringent. Both physical and transition risks are relatively subdued.

  – **Disorderly** scenarios explore higher transition risk due to policies being delayed or divergent across countries and sectors. For example, carbon prices would have to increase abruptly after a period of delay.

  – **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 like sea-level rise.

- These six scenarios were chosen to show a range of lower and higher risk outcomes. The scenarios have been further refined since the first iteration that was published in June 2020 to leverage the latest versions of models, reflect the shifts in climate policy since 2018, and reflect the near-term IMF growth projection from COVID-19.

**NGFS scenarios Framework**




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 policy, emissions, and temperatures evolve.

**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. Some jurisdictions such as the US, EU and Japan reach net zero for all GHGs.

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

**Disorderly**

**Divergent Net Zero** reaches net zero around 2050 but with higher costs due to divergent policies introduced across sectors leading to a quicker phase out of oil use.

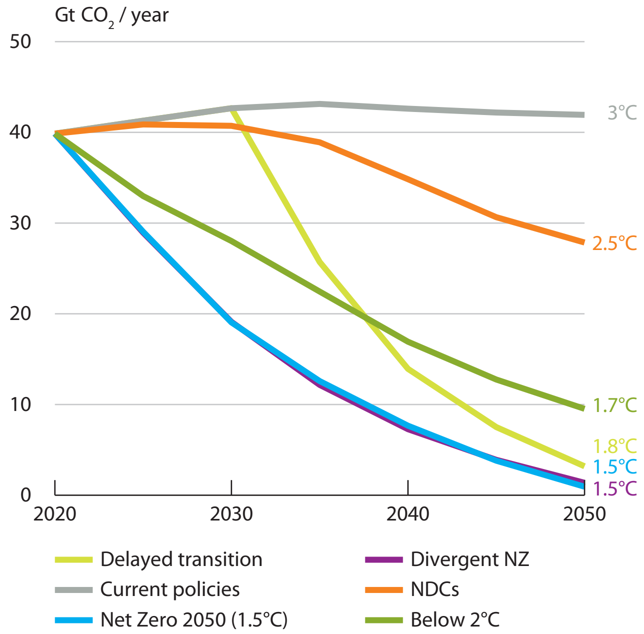
**Delayed transition** assumes annual emissions do not decrease until 2030. Strong policies are needed to limit warming to below 2°C. $CO_2$ removal is limited.

**Hot house world**

**Nationally Determined Contributions (NDCs)** includes all pledged policies even if not yet implemented.

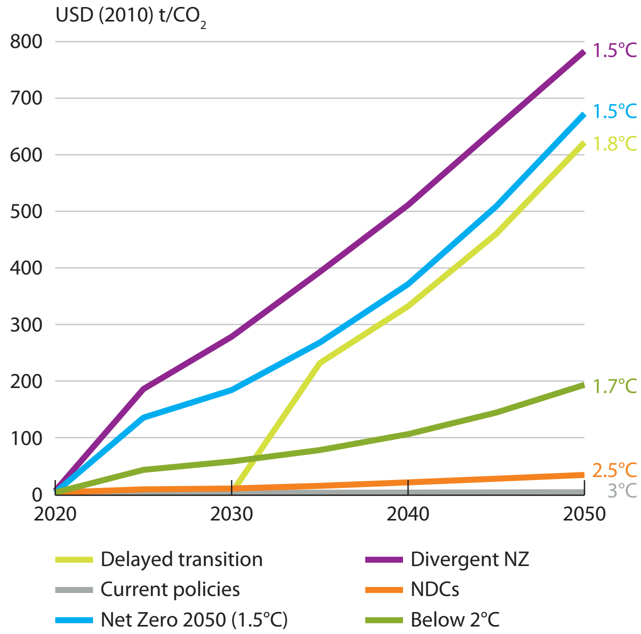
**Current Policies** assumes that only currently implemented policies are preserved, leading to high physical risks.

### $CO_2$ emissions by scenario




Source: IIASA NGFS Climate Scenarios Database, REMIND model. End of century warming outcomes shown.

### Carbon price development




Source: IIASA NGFS Climate Scenarios Database, REMIND model. Carbon prices are weighted global averages. End of century warming outcomes shown.

# Scenarios at a glance

## 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 | | | |
|---|---|---|---|---|---|---|
| **Category** | **Scenario** | **Policy ambition** | **Policy reaction** | **Technology change** | **Carbon dioxide removal** | **Regional policy variation+** |
| Orderly | Net Zero 2050 | 1.5°C | Immediate and smooth | Fast change | Medium use | Medium variation |
| | Below 2°C | 1.7°C | Immediate and smooth | Moderate change | Medium use | Low variation |
| Disorderly | Divergent Net Zero | 1.5°C | Immediate but divergent | Fast change | Low use | Medium variation |
| | Delayed transition | 1.8°C | Delayed | Slow/Fast change | Low use | High variation |
| Hot House World | Nationally Determined Contributions (NDCs) | ~2.5°C | NDCs | Slow change | Low use | Low variation |
| | Current Policies | 3°C+ | None – current policies | Slow change | Low use | Low 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

* See slide 18 for more details.

+ Risks will be higher in the countries and regions that have stronger policy. For example in Net Zero 2050 the EU, USA and Japan reach net zero GHGs by 2050, but globally only net zero $CO_2$ is reached by this point.

^ 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 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, d) stronger policy in those particular countries and/or regions.

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# Transmission channels

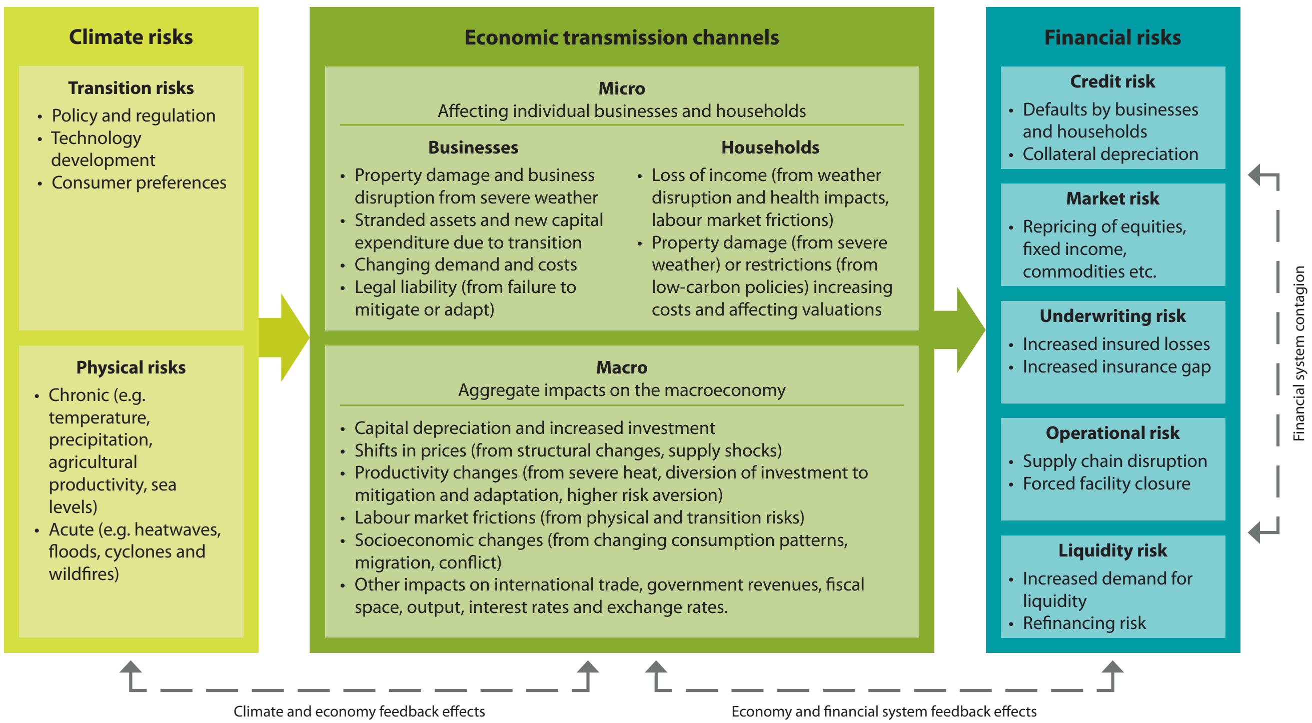
## Climate risks could affect the economy and financial system through a range of different transmission channels.

- **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.
  - **Acute impacts** from extreme weather events can lead to business disruption and damages to property. There is some evidence that with increased warming they 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.
  - **Chronic impacts**, particularly from increased temperatures, sea levels rise and precipitation, 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.

**Transmission channels**

Climate risks to financial risks

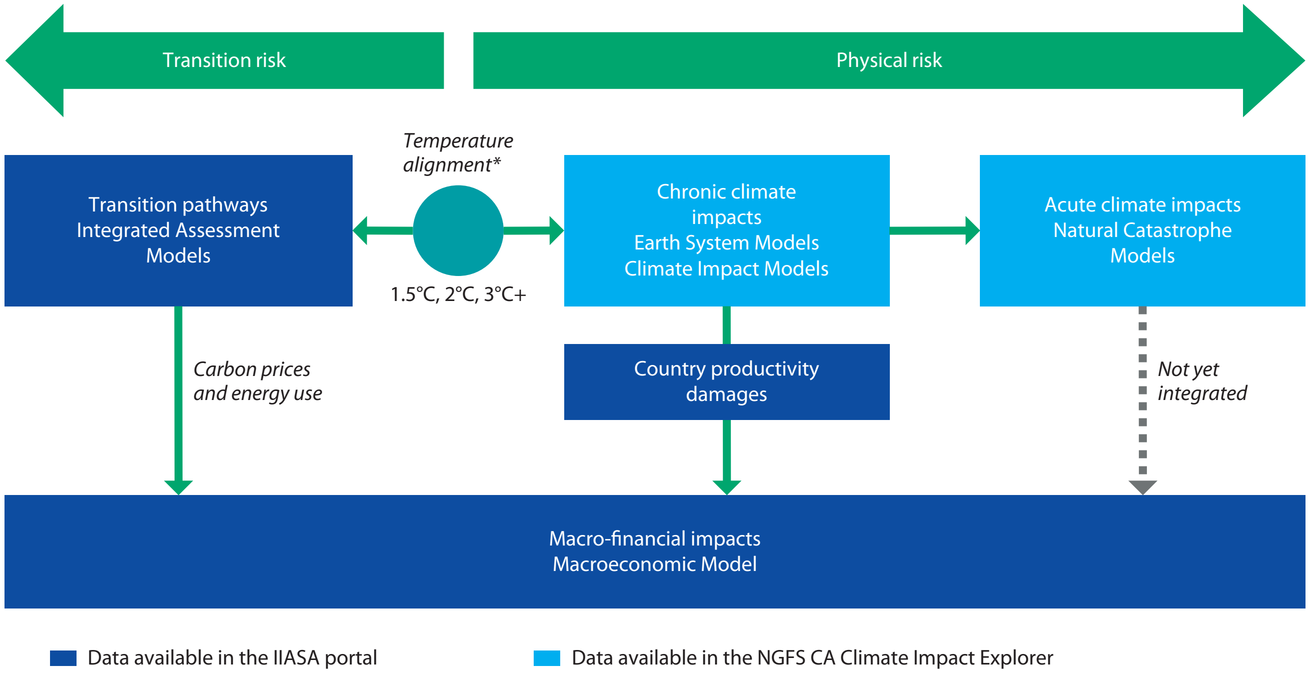


# Available data and resources

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

- Transition and economic variables are made available in the NGFS Scenarios Database hosted by IIASA. The transition pathways were produced by three teams: PIK (REMIND-MAgPIE model), IIASA (MESSAGEix-GLOBIOM model) and UMD (GCAM model). Economic variables were produced by the National Institute for Economic and Social Research (NIESR) (NiGEM model).
- Selected climate variables can be explored through the NGFS CA Climate Impact Explorer hosted by Climate Analytics. Additional data are available via the ISIMIP project. Physical risk analysis was supported by Climate Analytics, ETH Zurich and PIK.
- Key data and resources can be explored interactively on the NGFS Climate Scenarios website.

**NGFS suite of models approach**



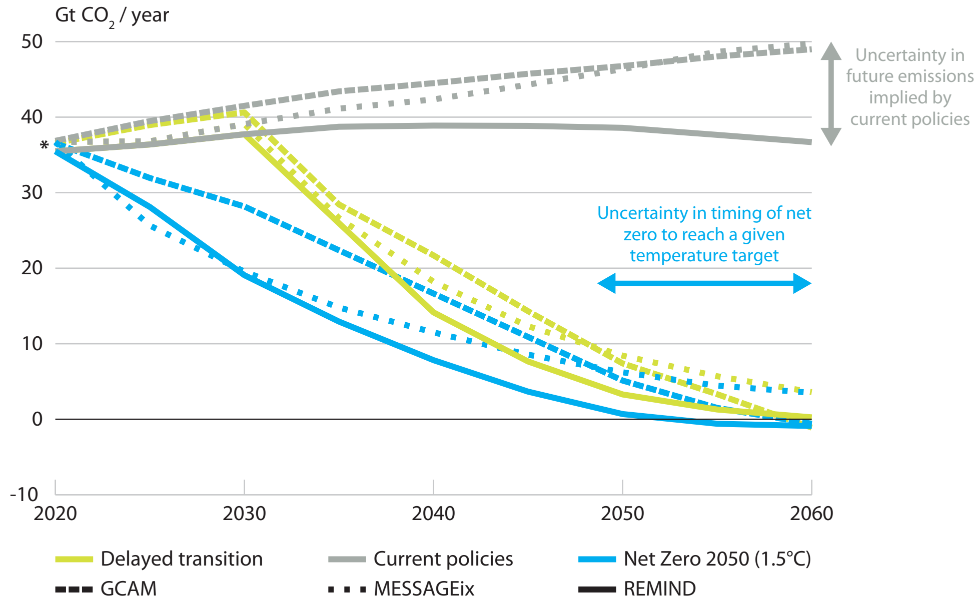
# Uncertainty in climate scenarios

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

A key guiding principle of the project has been embracing the uncertainty inherent in scenario modelling. This is captured in the following ways:

- **Transition risk:** the NGFS provides six different scenarios so that users can explore how a range of different climate policy pathways change the results. For each scenario, three different models were used to provide estimates of model uncertainty. The uncertainty range for energy and industrial $CO_2$ emissions in three of the six scenarios is shown in the right chart. Estimates of the amount of emissions implied by current policies differ considerably in the medium term (grey lines). There are also different estimates for when net zero $CO_2$ emissions must be reached in order to limit warming to 1.5°C: 2050 for REMIND and GCAM and 2060 for MESSAGEix (blue lines). There are other uncertainties that are not captured due to modelling simplifications such as behavioural change, policy heterogeneity and market allocation of capital.
- **Physical risk:** A visualisation tool, the NGFS CA Climate Impact Explorer, was developed for this release to allow users to explore the range of possible outcomes for different climate change indicators at the country level. It shows, for example, the different level of precipitation or heatwave risk for a given rise in mean average temperatures ('warming level').
- **Economic impacts:** The sensitivity of the economic modelling was tested to several assumptions, such as the choice of government policy (slide 39).

**Differences in energy and industrial $CO_2$ emissions**




Source: IIASA NGFS Climate Scenarios Database.

* Emissions estimates for 2020 were based on pre-pandemic trends as this data had not been finalised at the time of the models runs. The pandemic was estimated to reduce emissions by approximately 7%. There is in any case usually a +/- 5% level of uncertainty in estimation.

# Transition risks

## Scenarios in detail

# Understanding transition risk

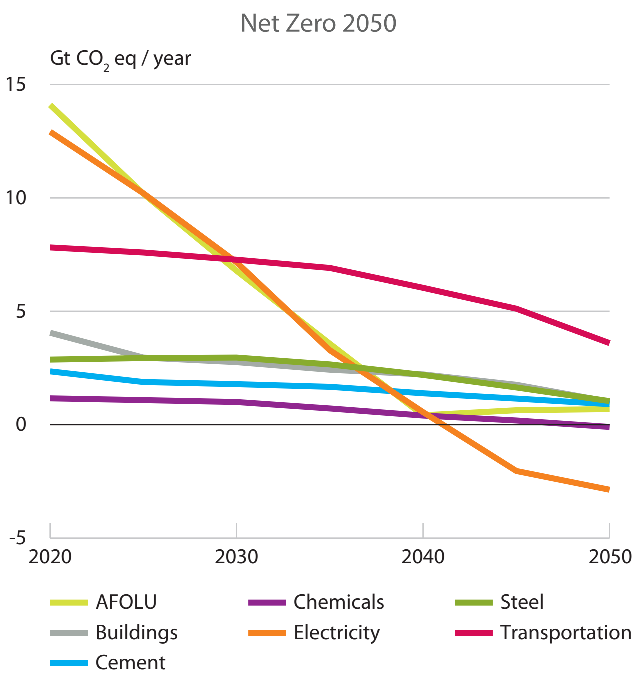
## Eliminating most greenhouse gas emissions will affect all sectors of the economy, and gives rise to transition risks for the economy and financial system.

- Transitioning away from fossil fuels and carbon-intensive production and consumption requires significant shift towards emissions-neutral alternatives in all sectors (left chart). Policy-makers 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.

- The NGFS transition pathways have been modelled using three detailed **integrated assessment models** (IAMs)*. They can be used to assess the changes in energy, land-use and policy needed to meet a particular temperature outcome or carbon budget (right figure). This is not necessarily the *socially optimal price* which depends on an assessment of avoided damages and valuing impacts on present vs. future generations.

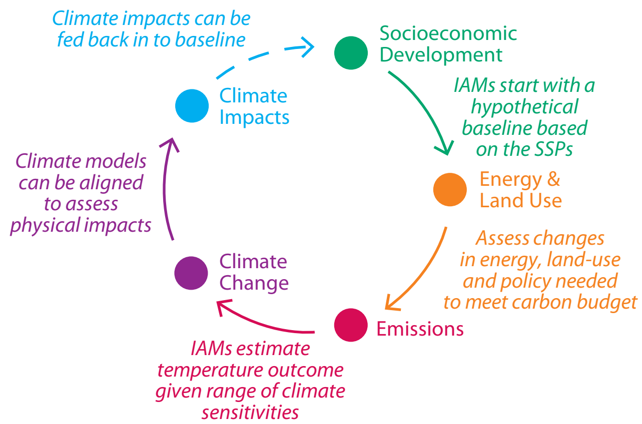
* These models have been used extensively to inform policy and decision makers and feature in several climate assessment reports, cf. IPCC, 2014. IPCC, 2018. UNEP, 2018.

**Sector GHG emissions**




Source: IIASA NGFS Climate Scenarios Database, GCAM model. AFOLU is agriculture, forestry and other land use.

**Modelling climate policy and climate change**




Source: SENSES scenario primer.

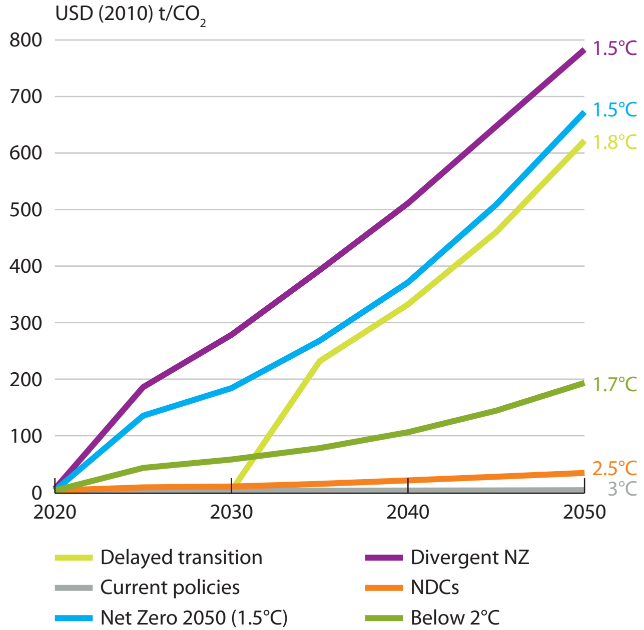
# Emissions prices

## A key indicator of the level of transition risk is the shadow emissions price, a proxy for government policy intensity and changes in technology and consumer preferences.

- In the IAMs used to produce the NGFS scenarios, a higher emissions price implies more stringent policy. Models suggest that a carbon price of around $160/ tonne would be needed by the end of the decade to incentivise a transition towards net zero by 2050 (right chart). This price is a measure of overall policy intensity. In reality, governments are pursuing a range of fiscal and regulatory policies, which have varying costs and benefits.

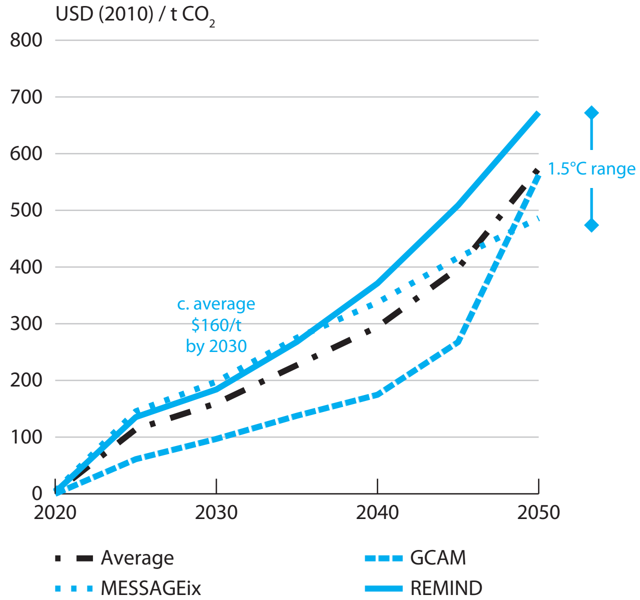
- Shadow emissions prices are sensitive to:
  - The level of ambition to mitigate climate change. Higher ambition translates into higher emissions prices.
  - The timing of policy implementation. Higher emissions prices are needed in the medium to long-term if action is delayed.
  - The distribution of policy measures across sectors and regions.
  - Technology assumptions such as the availability and viability of carbon dioxide removal.

**Carbon price development**




Source: IIASA NGFS Climate Scenarios Database, REMIND model. Carbon prices are weighted global averages.

**Carbon prices across models**




Source: IIASA NGFS Climate Scenarios Database.

* Emissions prices are defined as the marginal abatement cost of an incremental tonne of greenhouse gas emissions. Prices are influenced by the stringency of policy as well as how technology costs will evolve. Prices tend to be lower in emerging economies which reduces efficiency but reflects equity considerations.

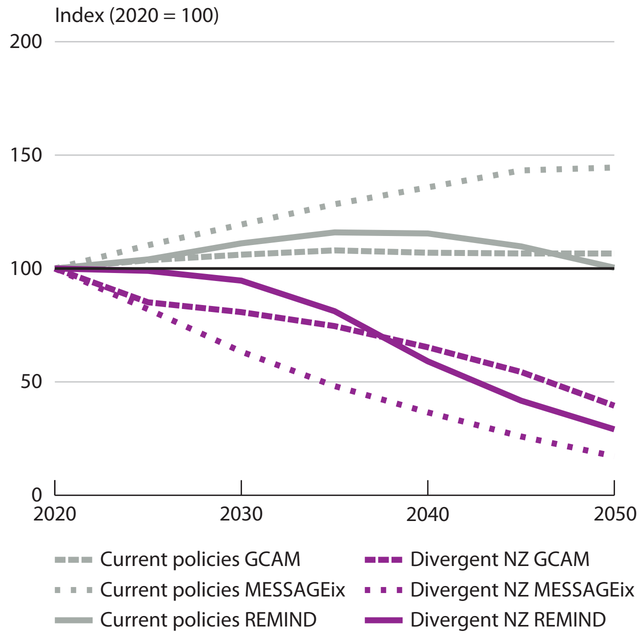
# Commodity markets

## A key driver of transition risk is the future pathway of fossil fuel prices and volumes, with potential spill-over effects to the broader economy.

- The future pathways of **commodity prices** are highly uncertain. IAMs include a baseline assumption that prices increase in line with increasing marginal extraction costs (right chart). In mitigation scenarios some downward pressure comes from declining fossil fuel use (left chart). However, this does not capture the full range of outcomes. Pathways do not account for the possibility of 'sell-off' behaviour from producers, or other volatility between 5-year time steps.

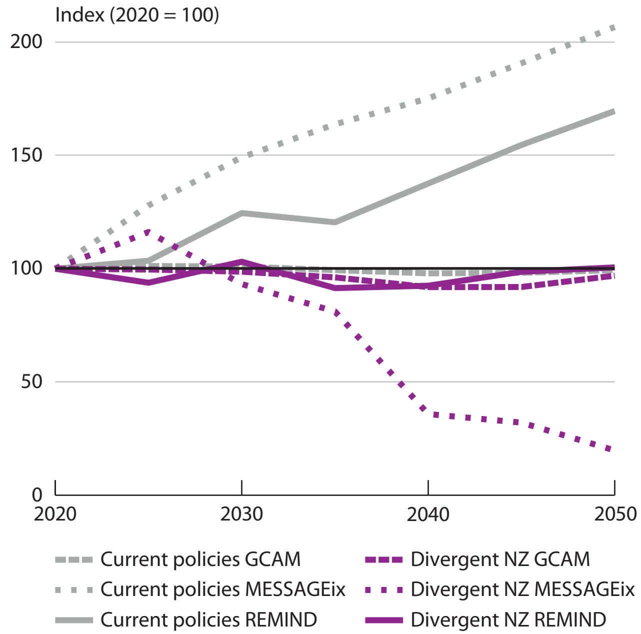
- Users may wish to make further assumptions when using commodity prices for macro-financial analysis. A change in oil prices is likely to affect producers and consumers differently, and a carbon price can drive a wedge between producer and consumer prices. The extent to which prices change also depends on how quickly alternative energy sources are deployed.

**Oil volumes by scenario**




Source: IIASA NGFS Climate Scenarios Database.

**Oil prices by scenario**




Source: IIASA NGFS Climate Scenarios Database.

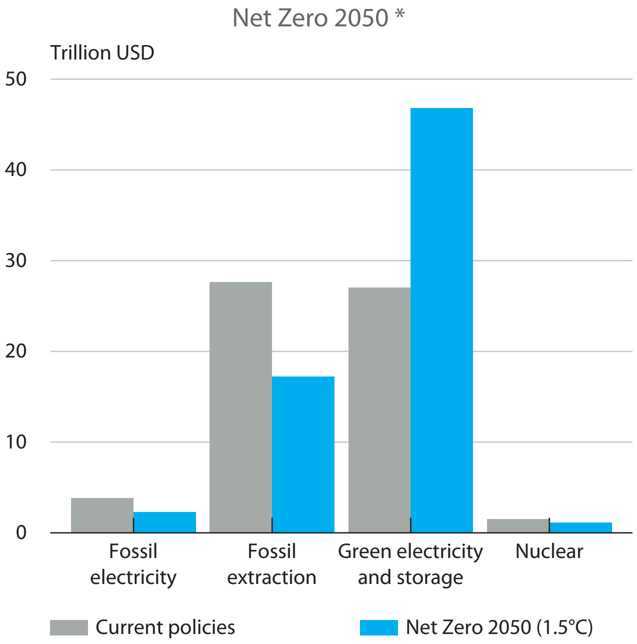
# Energy investment

## Significant investment flows would need to be directed towards green energy in the coming decades to achieve net zero.

- Transitioning to a net zero economy would require **investment flows** to be geared towards mass deployment of green electricity and electricity storage (left chart). There is some legacy capital investment in fossil fuel extraction, which is a holistic measure of all investments in mining, shipping and ports for fossil fuels, transmission and distribution for gas as well as the transport and refining for oil.

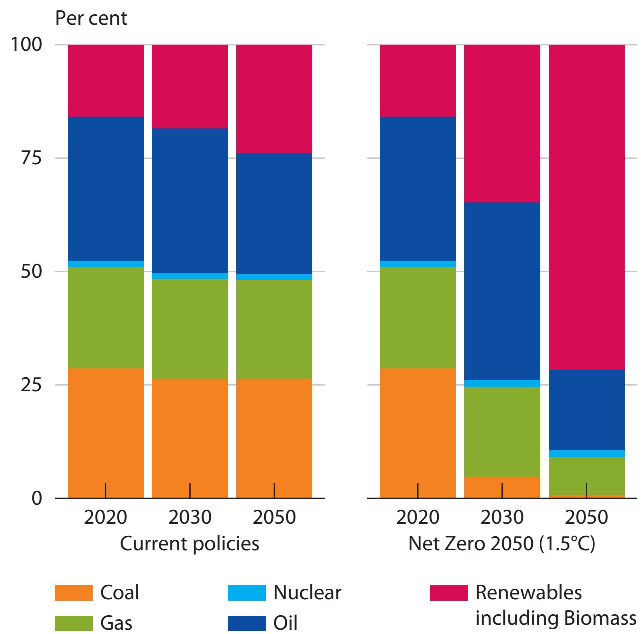
- By 2050, renewables and biomass would deliver 68% of global primary energy needs (right chart). This is a marked contrast to the current policies scenario where fossil fuels continue to be the dominant source of primary energy, even after accounting for current technology trends.

**Cumulative energy investment to 2050**




Source: IIASA NGFS Climate Scenarios Database, REMIND model.

**Primary energy mix by scenario**




Source: IIASA NGFS Climate Scenarios Database, REMIND model. Direct equivalent accounting method used, which is predominant in publications on long-term transition pathways.

* Fossil power generation investments include investments into generation with CCS, which dominate in the Net Zero 2050 scenario. Investments into fossil fuel extraction are estimated based on constant investment intensity assumption of fuel use, and so likely overestimate the required investments where declining demand can be met with existing projects requiring less investments than new ones.

# Carbon dioxide removal

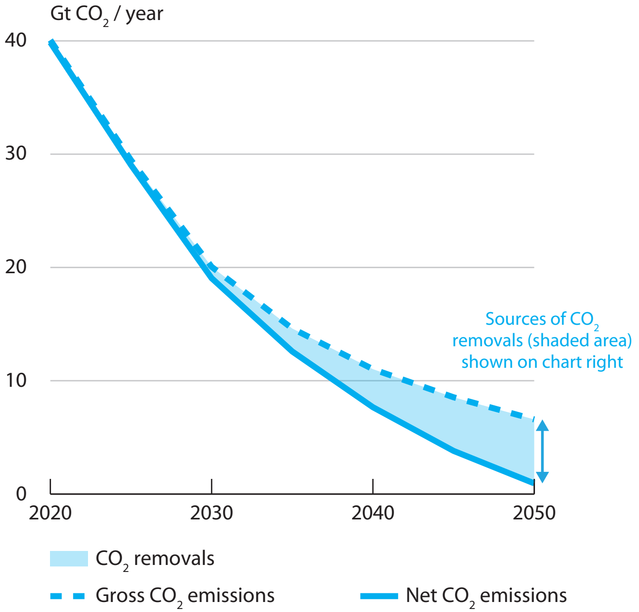
## The speed and timing of the transition depends on the availability and deployment of various forms of carbon dioxide removal, i.e. the long-term storage of carbon in soils, plants and rocks.

- **Carbon Dioxide Removal** (CDR) involves removing carbon from the atmosphere through increasing forest cover and soil sequestration (land use) or growing crops for bioenergy (bioenergy with carbon capture and storage, BECCS).

- CDR assumptions play an important role in IAMs. If deployed effectively lower warming outcomes could be achieved, or targets could be reached sooner given the practical difficulty of eliminating all emissions in the near term. However, they only currently take place on a limited scale and face their own challenges.

- The NGFS scenarios assume **low to medium availability of these technologies**. However patterns vary strongly across models (right chart) depending on cost assumptions. They also vary substantially across countries depending on the costs and availability of CDR options.

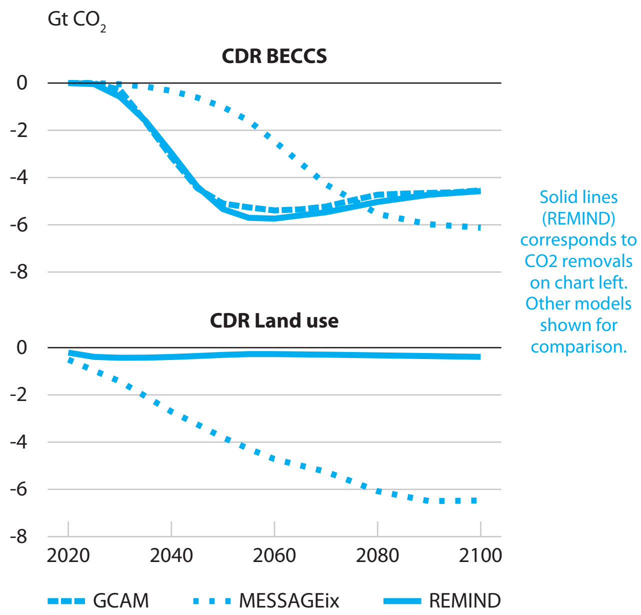
**$CO_2$ removals in Net Zero 2050**




Source: IIASA NGFS Climate Scenarios Database, REMIND model.

**$CO_2$ removals across model**

Net Zero 2050




Source: IIASA NGFS Climate Scenarios Database.

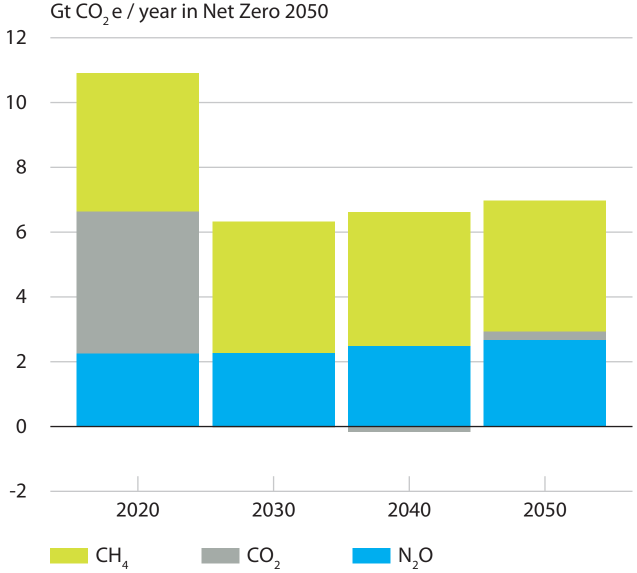
# Agriculture, forestry and land use

## Changes in agriculture, forestry and land use are important as they account for about 20% of total greenhouse gas emissions and forest cover can help remove $CO_2$ from the atmosphere.

- Land uses such as agriculture account for significant emissions (left chart). As shown on the previous slide, preventing deforestation would play a significant role in lowering $CO_2$ emissions and even provide a net sink in some models and time periods.
- The increase in forest cover and bioenergy cropland in a Net Zero by 2050 scenario would have to be facilitated by a reduction in other land uses, e.g. cropland for food production and pasture land (right chart). The types of land cover that are reduced vary across models.
- Emissions from other important GHGs, Methane ($CH_4$) and Nitrous Oxide ($N_2O$), reduce more gradually in the scenarios compared to $CO_2$ (left chart). Still, this would imply significant reductions in emissions intensity given the increase in population during the first half of the century.

**Land use emissions**

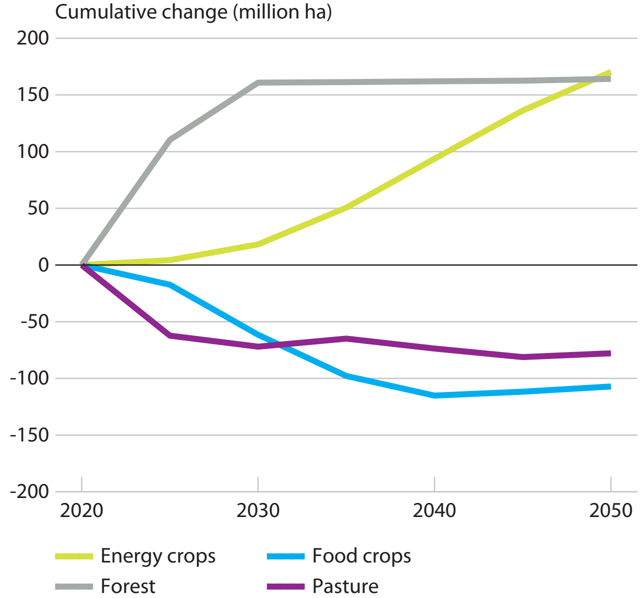
Net Zero 2050




Source: IIASA NGFS Climate Scenarios Database, REMIND-MAgPIE model.

**Changes in land use**

Net Zero 2050



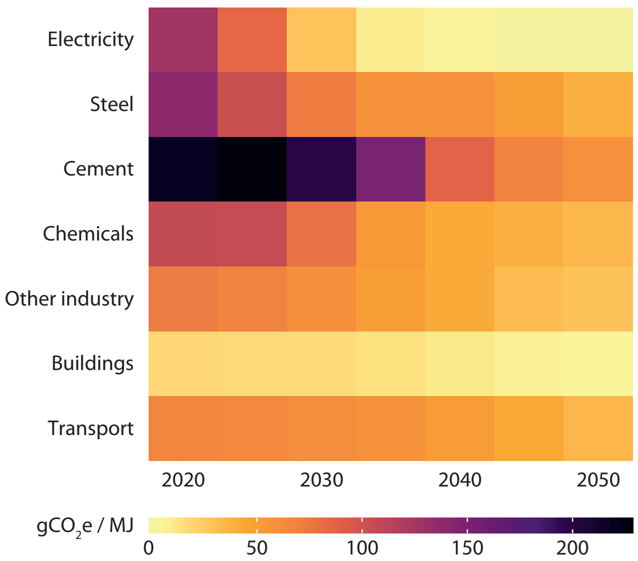

Source: IIASA NGFS Climate Scenarios Database, REMIND-MAgPIE model.

# Sector pathways

## Sectors that are more difficult to decarbonise face greater transition risks.

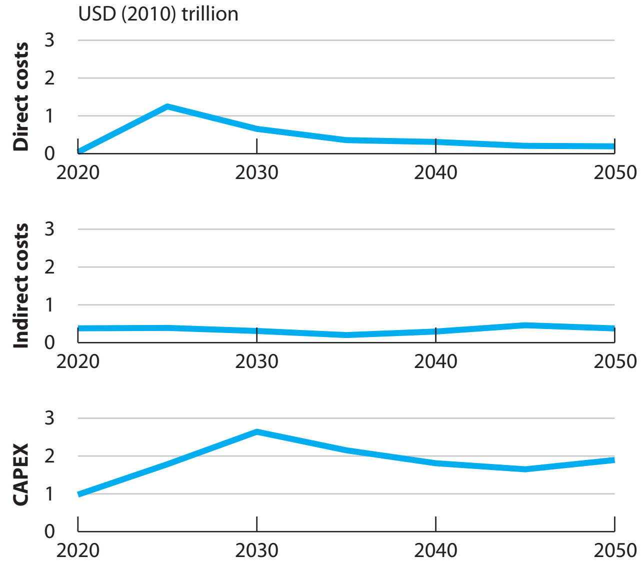
- Climate policies affect all actors in the economy, and can be particularly impactful for sectors that can less easily reduce their carbon footprint. The left chart illustrates, for example, that electricity could decarbonise more rapidly than the transport sector.
- To understand how transition risks materialise across different sectors of the economy, UNEP-FI has developed Risk Factor Pathways (RFPs), which represent key corporate credit risk drivers: direct and indirect emissions costs, changes in revenue, and required low-carbon investment.* The NGFS scenarios can be used to calculate these RFPs.
- The right chart illustrates RFPs for the utilities sector in Net Zero 2050. This shows that the direct cost of carbon emissions reaches zero well before 2050. Investment in emissions reductions ('capex') increases rapidly and peaks in 2030.

**Emissions per unit of energy input**




Source: IIASA NGFS Climate Scenarios Database, REMIND model.

**Risk factor pathways: Utilities**




Source: IIASA NGFS Climate Scenarios Database, REMIND model. Direct costs represent cost of emissions permits. Indirect costs represent changing cost of energy inputs. CAPEX represents capital investment.

* UNEP FI – Extending our horizons (2018).

# Key input assumptions

## Integrated Assessment Models assume as a baseline that population and productivity growth continue in line with trends. Technological advancement depends on learning dynamics.

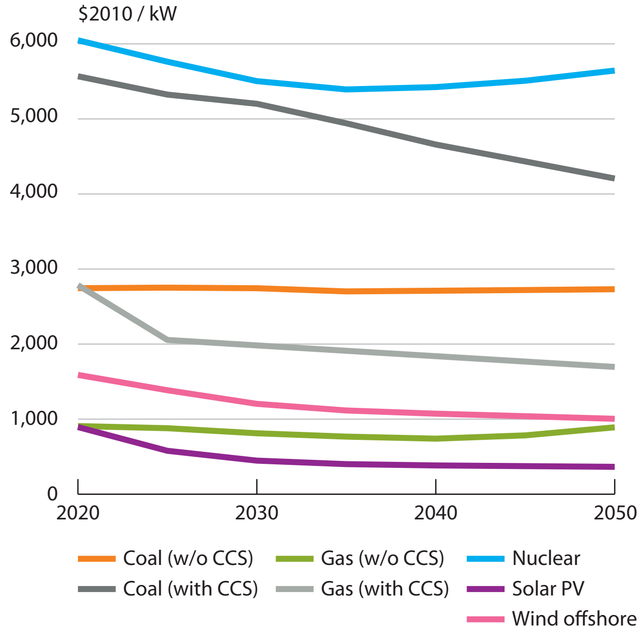
- The projections from IAMs rely on assumptions about the future state of the world, including on:
  - **Policy:** policy targets, global policy coordination, and policy delays;
  - **Technology:** costs of different types of energy, carbon sequestration technologies, and challenges to their deployment;
  - **Society:** population growth, migration, diets and preferences.

- Technology costs in the IAMs are initially based on estimates from academic literature. They evolve in each scenario on the basis of either exogenous assumption or endogenous learning dynamics depending on the model (see slide 24). The right chart shows how average global capital costs for installing new electricity capacity are assumed to evolve across different types of energy source in the REMIND model. These costs vary by region.

- Societal assumptions have been standardised by the academic community as the **Shared Socioeconomic Pathways (SSPs)**.* All scenarios are currently based on SSP2, which assumes that society evolves broadly in line with past trends and global population peaks around 2070. This is a scenario assumption. If consumer preferences were to shift, for example in line with the SSP1 narrative, this would reduce the potential impacts from the transition. The pathway for GDP as prescribed by SSP2 has been adjusted to account for the short-term COVID-19 impact on growth rates.

**Electricity capital costs**

Net Zero 2050




Source: IIASA NGFS Climate Scenarios Database, REMIND model.

* For an overview of the SSPs, see Riahi et al. (2017).

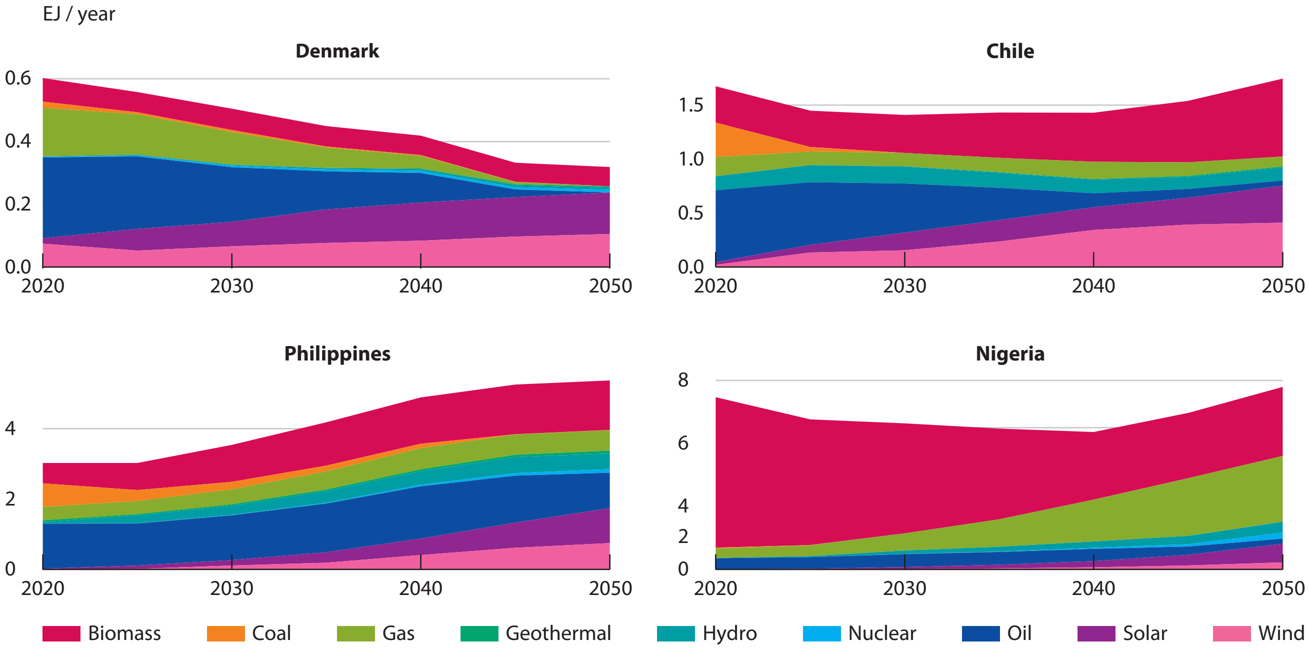
# Country-level downscaling

## The NGFS consortium has developed a downscaling methodology that can be used to assess the potential implications of the scenarios for 132 countries.

- To allow for country-level analysis, a subset of key variables like emissions, primary energy and final energy have been downscaled to country-level.
- Each country is assumed to start off in its current state and gradually converges to the regional pathway projected by the IAMs. The convergence speed is conditional on country-specific institutional factors. See NGFS Technical Documentation for further details.
- As the individual country results are derived from a standardised methodology, they do not at this stage reflect policies on a country by country basis. Users may need to cross-check these with other country specific factors and data where available. For example, national account of energy use and domestic scenario modelling.

**Primary energy (downscaled)**

Net Zero 2050




Source: IIASA NGFS Climate Scenarios Database, MESSAGE model.

Transition

# Integrating physical risk damages

## Integrating physical risk damages into the transition scenarios increases near-term carbon prices.

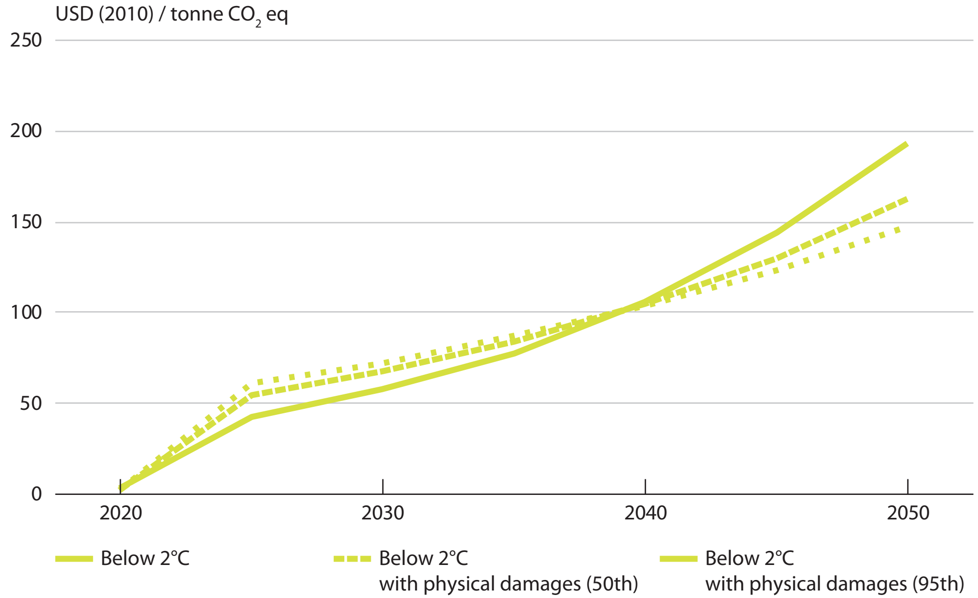
- Detailed energy and land-use IAMs typically ignore the potential increasing impacts from physical risks when assessing transition pathways. These damages were innovatively integrated into the optimisation of the transition pathways for a separate run of the REMIND-MAgPIE model for this phase of the NGFS scenarios.

- Including physical risk damages changes the optimal mitigation trajectory, with a higher carbon price in the first few decades and a slower rate of increase in the later decades (right chart). This flattening effect of the carbon price curve increases with higher physical risks. The chart shows the change in carbon price once median and 95th percentile damages for the temperature rise are integrated in each time period.

- Only one channel of chronic physical risks, temperature productivity effects, have been included here. It is clear that physical risks could also effect energy use and costs, investments and other economic indicators. The findings from this exercise would imply that even higher near-term carbon prices would be needed once any additional channels of physical risk damages are priced in.

**Carbon prices in integrated IAM run**

Below 2°C



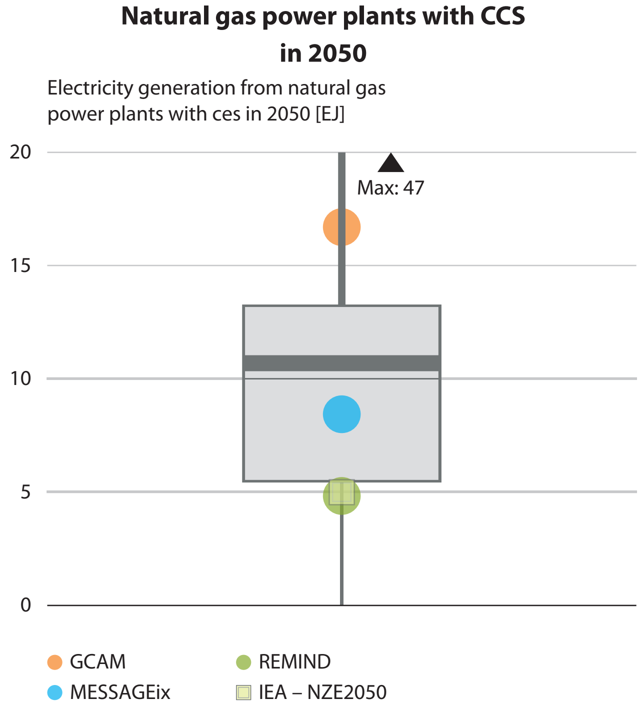

Source: IIASA NGFS Climate Scenarios Database, REMIND Model with integrated physical risk GDP damages.

# Navigating models and data

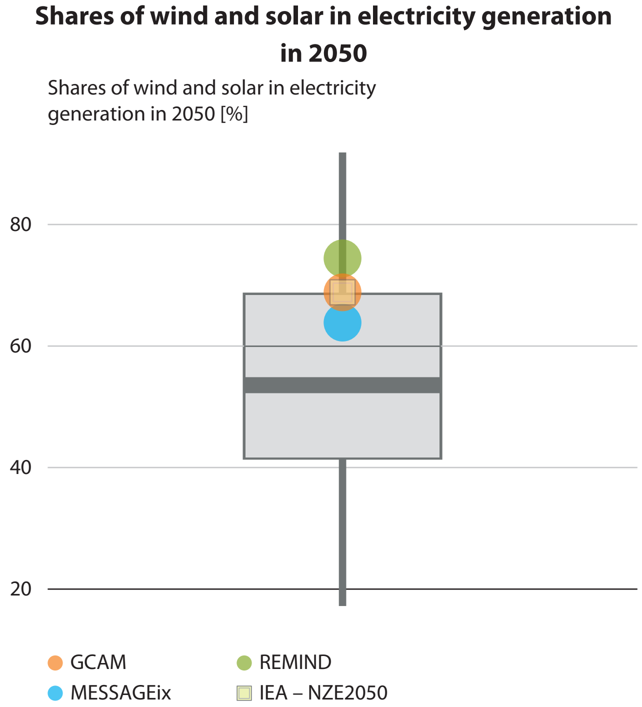
## The three integrated assessment models differ in key respects, allowing users to compare scenarios under different modelling approaches.

- IAMs differ in a few important ways, including their policy and technology assumptions, regional and sectoral granularity, and how they are solved (e.g. representative agent objectives and anticipation of the future).
- Policy assumptions have been aligned across the three IAM models used by the NGFS so the user can see how other assumptions drive differences in the results.
- The charts on this slide show how the level of electricity generation (left – natural gas with CCS, right – wind and solar) compare to selected low-overshoot scenarios from the IPCC Special Report on 1.5°C and IEA Net Zero scenario.

**Comparing participating NGFS IAMs to IPCC Special Report on 1.5°C and IEA**




Source: Boxplot shows distribution of results from the IPCC Special Report on 1.5°C (2018).




Source: Boxplot shows distribution of results from the IPCC Special Report on 1.5°C (2018).

# Physical risks

## Scenarios in detail

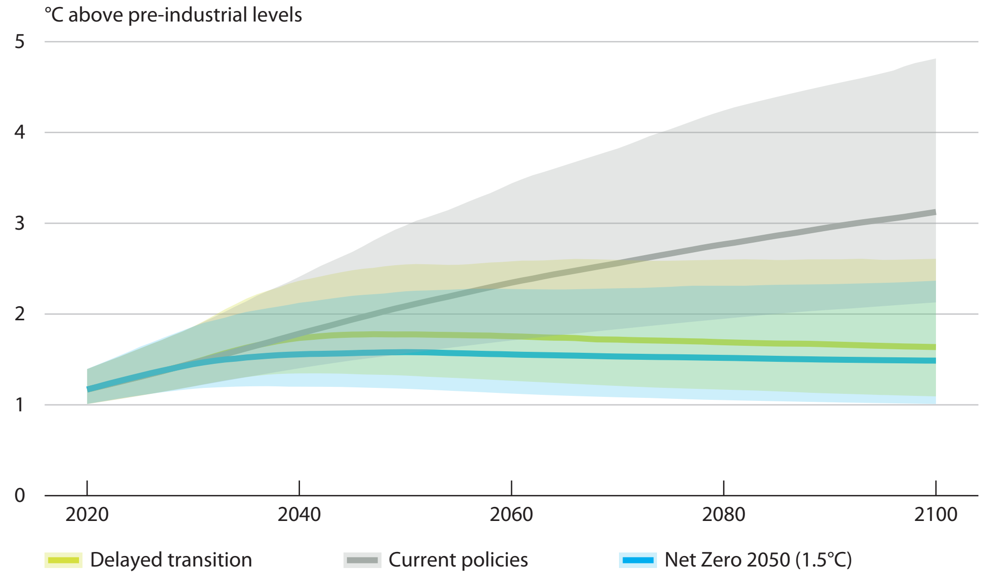
NGFS
Central Banks and Supervisors
Network for Greening the Financial System

# Temperature rise

## Mean temperatures rise in all scenarios, exceeding 3°C in Current Policies. Changing climate conditions affect physical labour productivity and lead to severe and irreversible impacts.

- Global mean temperatures have increased by around 1.2°C from pre-industrial levels. Temperatures to date are very likely higher than at any time in the last 12,000 years, the period in which human civilisation has developed.*
- In scenarios where climate goals are met deep reductions in emissions are needed to limit the rise in global mean temperatures to below 1.5°C or 2°C by the end of the century. This does not occur in the Current Policies scenario, leading to a temperature rise exceeding 3°C and severe and irreversible impacts. The shading indicates uncertainty in the temperature response. Temperatures are increasing unevenly across the world with land warming faster than oceans and high latitudes experiencing higher warming.
- Temperature changes lead to chronic changes in living conditions affecting health, labour productivity, agriculture, ecosystems and sea-level rise. It is also changing the frequency and severity of severe weather events such as heatwaves, droughts, wildfires, tropical cyclones and flooding.

**Global mean temperature rise**




Source: IIASA NGFS Climate Scenarios Database, REMIND model.

* See Kaufman, D. et al. (2020).

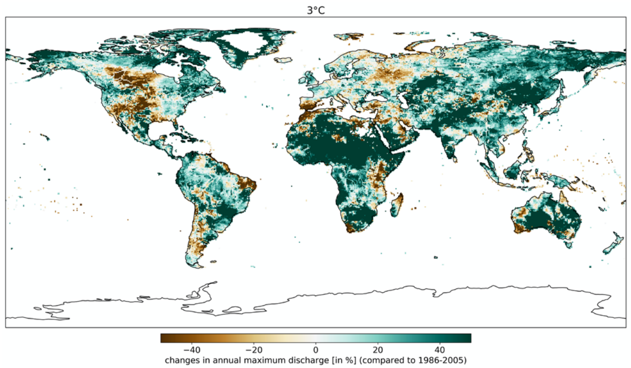
# Precipitation

## The rise in temperature leads to increased heavy precipitation across many regions of the world, which in turn increases risks from flooding.

- Global warming will lead to an increase in heavy precipitation and flood risks in most parts of the world.
- Annual maximum discharge (water flow) in a river or watershed is a measure for fluvial flood risk from heavy precipitation. Green shading on the LHS chart shows regions where annual maximum discharge increases by the most where end of century warming exceeds 3°C. The magnitude of this change increases in warmer climates.
- The RHS chart shows how annual maximum discharge scales with temperature for particular regions. It increases sharply in some (+27% in North India) and decreases in others that have drier climates (-30% in Southern Europe).

**Changes in annual maximum discharge**

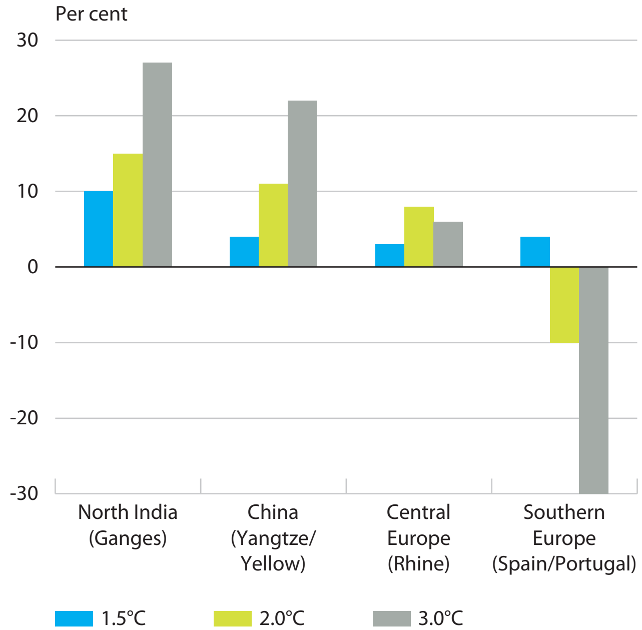
3°C of warming in 2100




Source: ISIMIP Archive.

**Changes in annual maximum discharge**

Relative to 1986-2005




Source: ISIMIP Archive.

Physical

# Heat and labour productivity

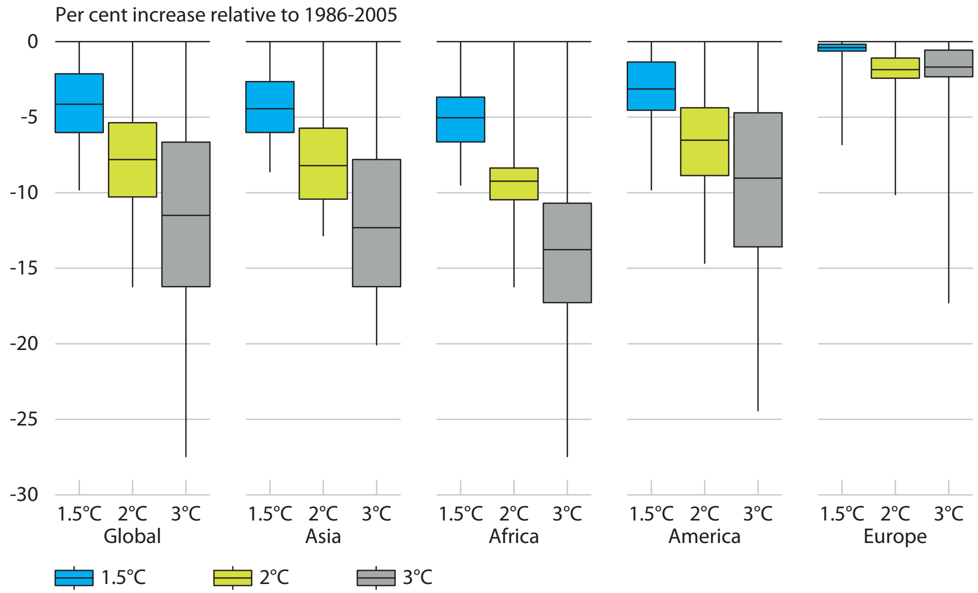
## Physical labour productivity is significantly reduced by hot and humid climate conditions.

- The capacity of the human body to perform physical labour is significantly diminished under hot and humid climate conditions. These conditions are expected to deteriorate with rising mean temperatures, leading to material impacts on the economy and society.

- Global physical labour productivity is projected to decrease up to 12% in a 3°C warmer world, about three times higher than if warming was limited to 1.5°C (right chart). However, there is a wide range of uncertainty with some models projecting no impacts and others projecting impacts of greater than 25%. This range across models is represented by the box and whiskers. These changes are relative to a baseline of approximately 0.6°C of warming since pre-industrial levels representative of the period 1986-2005.

- The impact is most pronounced in tropical regions, with particularly high impacts in Africa and Asia. While Europe is expected to experience lower mean impacts there is a significant range of results across countries in the region depending on their latitude and local climate.

**Change in physical labour productivity**




Source: Dasgupta et al. (in review), including future population growth based on the SSP2.

Physical

# Crop yields and food security

## Crop yields are complex to model, but evidence suggests that they are likely to be negatively impacted by climate change, particularly in tropical regions.

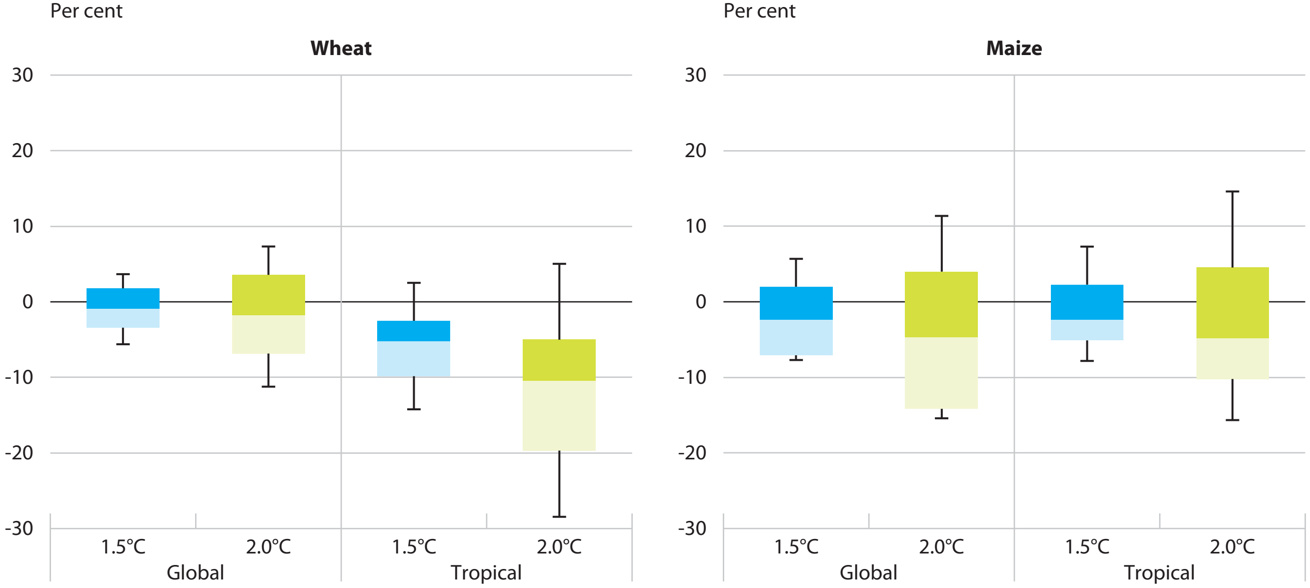
- Gradual climate change is already impacting crop productivity,* and this will worsen with higher levels of warming. The adjacent charts show the differences in low production extremes (10y minima) at 1.5°C and 2°C.

- The intensification of low production years is significant across wheat, maize, rice and soy, particularly in tropical regions. These effects are crop-dependent and more pronounced at higher levels of climate sensitivity (warming response to emissions) due to potential positive fertilisation effects of increased $CO_2$.

- At temperatures higher than 2°C the risks are more substantial. Higher mean temperatures increase the chance that biophysical limits for crop production might be reached. This could have implications for food security and employment, particularly in regions with a relatively large agricultural sector. Impacts would be offset by adaptation actions like more climate resilient crops or moving growing areas.

**Change in crop low production extremes**

10 year minima in global/tropical production




Source: Schleussner et al. (2018) using data from ISIMIP archive.

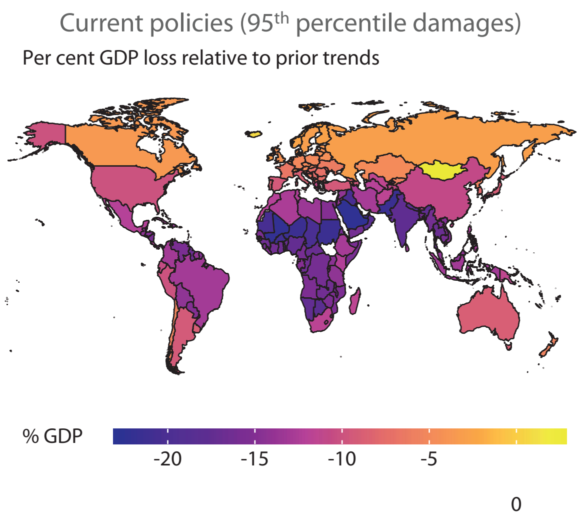
* Moore and Lobell, 2015.

# GDP loss estimates from chronic risks

## Global warming, and the associated changes in climate, will have significant impacts on the economy by the end of the century in a Hot house world scenario.

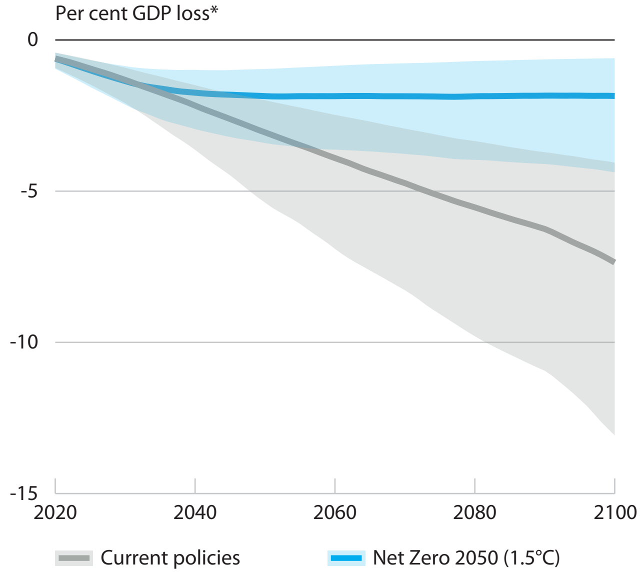
- Estimates of GDP losses from chronic risks vary considerably depending on assumptions about climate sensitivity and the method used to estimate the damages.
- GDP losses were calculated based on the methodology set out in Kalkuhl and Wenz (2020) at the country level for the change in average temperature in each scenario compared to the previous year (right chart). Estimates suggest a global GDP impact of up to 13% relative to a prior trends baseline in the current policies scenario. Losses are much higher in tropical regions (left chart).
- The methodology does not include impacts related to extreme weather, sea-level rise or wider societal impacts from migration or conflict. For given countries these would likely strongly increase the physical risk. These estimates also do not fully capture adaptation, which would reduce impacts but require significant investment.

**Physical risk GDP losses by country**




Source: Calculations by PIK based on scenario temperature outcomes and damage estimates from Kalkuhl and Wenz (2020). Base year for warming is 2005.

**Physical risk GDP losses**




Source: IIASA NGFS Climate Scenarios Database, REMIND model.
* 2005 used as the base year.

# Exposure to severe weather

## High warming scenarios lead to rapid increases in exposure to severe weather across the globe.

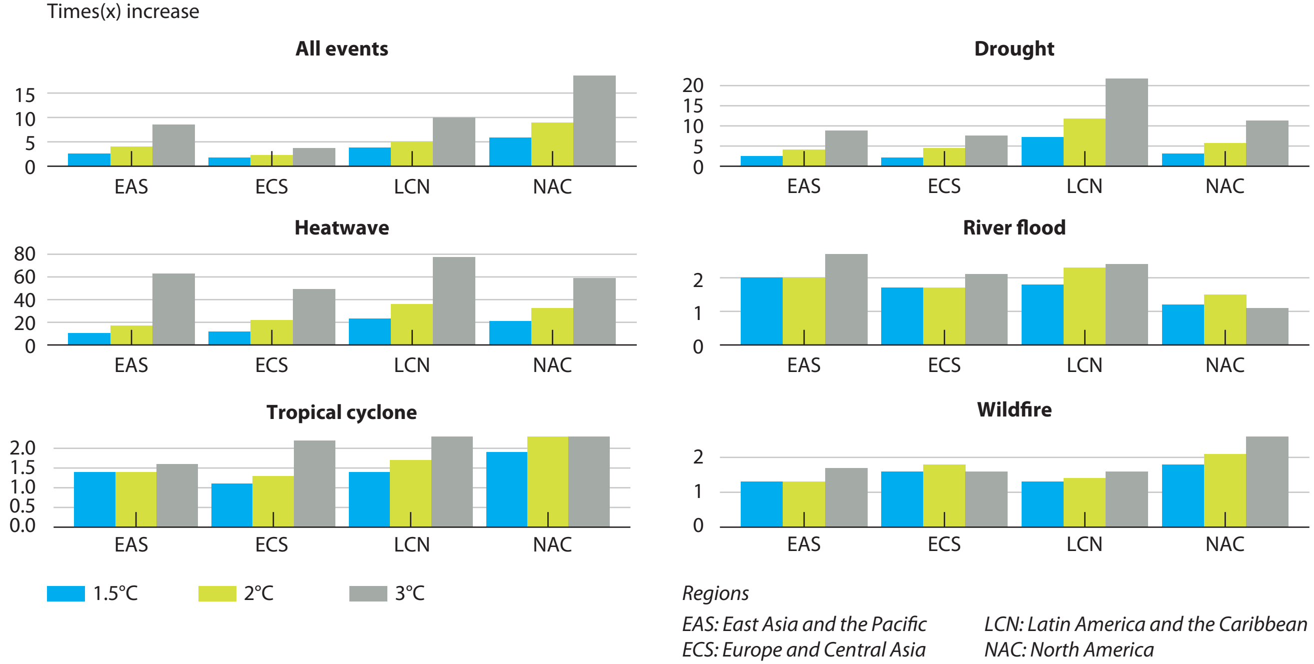
- Observed climate change of 1.2°C has already more than doubled both the global land area and the global population annually exposed to river flood, crop failure, tropical cyclones, wildfire, drought and heatwaves.*

- Global warming of 2°C relative to preindustrial conditions is projected to lead to a fivefold increase in exposure to all types of natural hazards globally. The most pronounced increases are projected for droughts and heatwaves.

- Changes in exposure are unevenly distributed. The right chart shows how four key regions will be affected by five different perils.

- Future socio-economic changes including population growth may exacerbate climate risks, while exposure to extreme weather at the same time could be a key driver of displacement and migration.

**Change in population exposed to extreme weather**




Source: Lange et al. (2020).

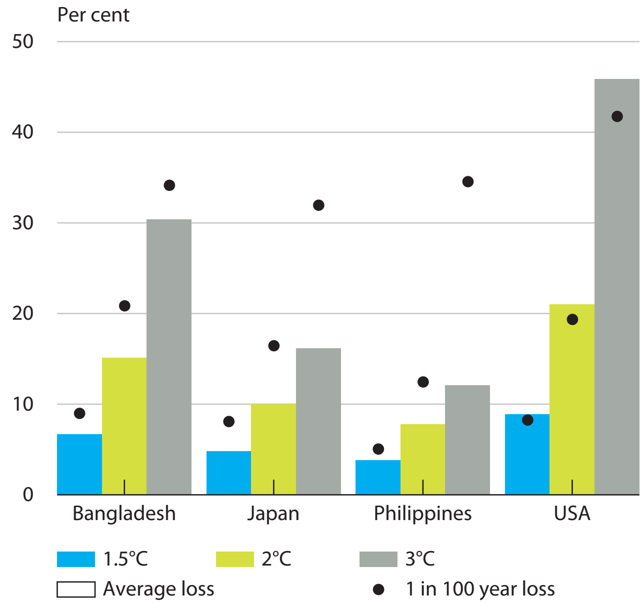
* Lange et al. (2020).

# Direct losses from tropical cyclones

## Climate change is contributing to the increasing costs of severe weather from tropical cyclones.

- The open-source natural catastrophe modelling tool CLIMADA was used to estimate the climate change impact on tropical cyclone and river flood damages.* Here, publicly available data on exposures and climate impacts indicators (e.g. from ISIMIP) were used as an input. The resulting global dataset of high granular data (assuming constant socio-economic conditions) is available in the NGFS CA Climate Impact Explorer. The results from the flood analysis is forthcoming.
- Global warming is projected to further increase the frequency and intensity of tropical cyclones in certain regions. This leads to an increase in associated damages up to 20% for a below 2° scenario and up to 45% for a 3° scenario relative to today's damages. A large fraction of the total damages is caused by singular but very severe events, e.g., those defined as occurring with a likelihood of 1-in-100 years. While in some regions, low-intensity events are decreasing in frequency the increase in annual expected damages is caused by the increase in damages associated with very severe events.
- These estimates focus on the direct damages on physical assets and do not include the wider social and economic impacts in affected regions. In addition, they only consider the impacts from cyclones and exclude changes in losses due to surge and precipitation induced flooding.

**Change in cyclone losses**




Source: NGFS Climate Impact Data Explorer, CLIMADA model.

Physical

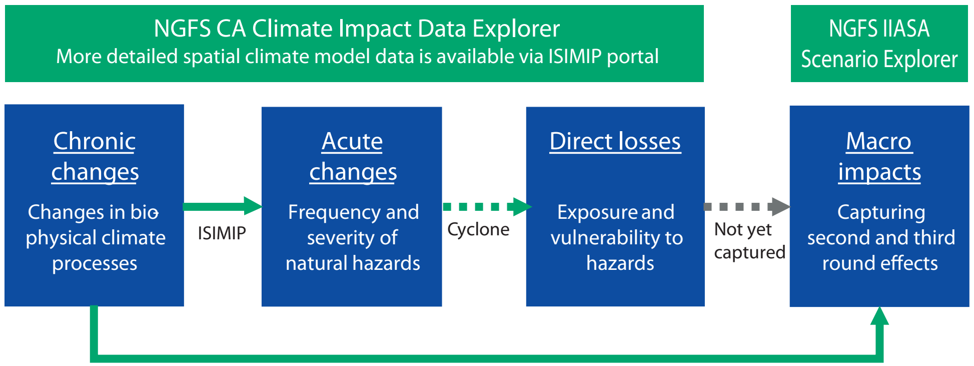
# Navigating the models and data

## The NGFS scenarios provide a range of physical risk data from climate impact models, alongside estimates of the economic impacts for each scenario.

- Physical risk data can be explored through a new NGFS CA Climate Impact Explorer. It provides projections of physical climate change indicators (e.g. temperature, precipitation) and selected impacts (e.g. labour productivity and tropical cyclone losses) at the national and subnational level. Data are provided for each scenario and incorporate model uncertainty.

- The NGFS IIASA Scenario Portal also includes a select number of physical risk indicators that are directly linked to each scenario in the diagnostics category.* Temperature pathways have been estimated using the MAGICC model and econometric damages are provided on a country basis (relative to a baseline forecast representing prior trends).

**Modelling macro-financial impacts from physical risks**




* These estimates are available for all transition pathways in the IIASA database. Physical damages were introduced exogenously into NiGEM at a country level (then allowing for equilibrium effects). Damages were also introduced endogenously in REMIND-MAgPIE for an integrated run meaning they not only affect economic outcomes but also the transition (e.g. emissions prices). See slide 23.

# Economic impacts

Scenarios in detail

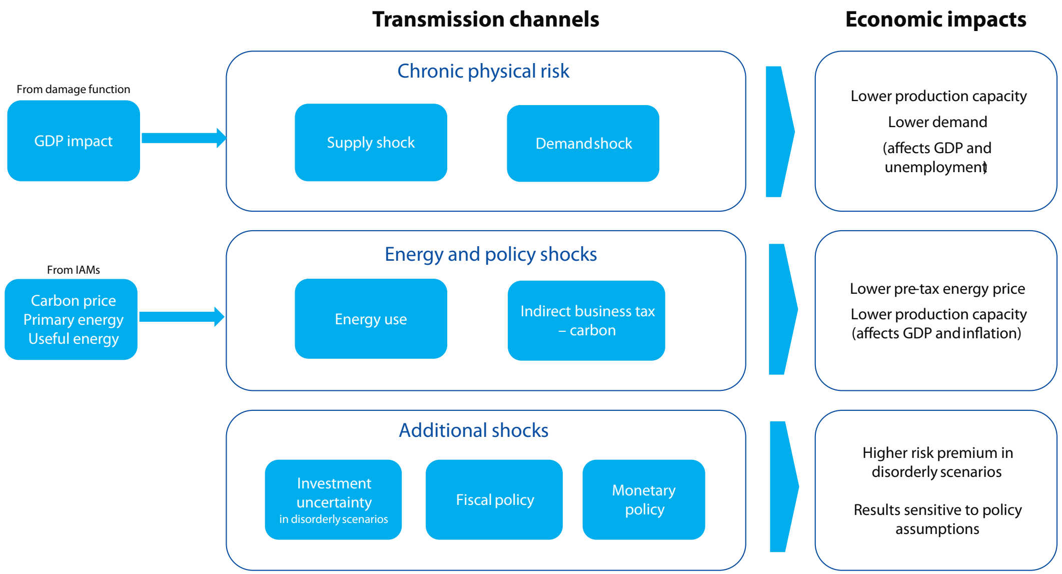
# Capturing economic impacts

## The NGFS scenarios capture the economic impacts from transition risk and physical risk.

- In phase II of the NGFS scenarios, the National Institute for Economic and Social Research joined the academic consortium to undertake detailed macroeconomic modelling. Their model, NiGEM is a quarterly econometric model with a time horizon to 2050 that is used widely for forecasting and scenario analysis. The model was shocked using transition inputs from the IAMs and estimates of chronic physical risk.

- **Transition risks** are captured through four main channels.
  - **Energy:** On the supply side, higher energy costs result in a reduction in energy use. This is mostly offset by improvement in energy efficiency. The net effect (a small reduction in energy services) results in a modest reduction in potential growth. Energy service levels were estimated with useful energy data from IAMs. Countries with a larger share of energy exports in the economy face higher impacts.
  - **Policy:** The introduction of carbon prices from the IAMs, represented as an indirect business tax, increases costs and leads to a demand shock. This reduces over the course of the scenario as the energy intensity and carbon intensity of economies falls. In orderly scenarios, negative impacts on demand are offset by increased government spending of the carbon tax revenues.
  - **Uncertainty:** In the disorderly scenarios policy and investment uncertainty is assumed to lead to a higher investment premium.

- There is a high degree of uncertainty around the impacts from **physical climate risk** on the economy. Damages representing the impacts from chronic climate change from one estimate in the literature were exogenously introduced into NiGEM as a shock to capacity. They were calibrated on a country-by-country basis for each scenario given the temperature rise (see slide 30). The estimated impacts do not include all sources of risk, such as low-probability high-impact events, sea-level rise, extreme events and societal changes like migration and conflict. As a result, actual damages under these scenarios are expected to be larger than shown, particularly in regions with lower resilience and capacity for adaptation.



# Gross domestic product

## Scenarios differ markedly in their economic impact, with significant uncertainty in the size of the estimates and variation across regions.

- Impacts on GDP (right chart) are specified relative to a forecast representing prior trends but also incorporating some of the potential near-term impacts from COVID-19. There are no assumed additional impacts from physical or transition risks.

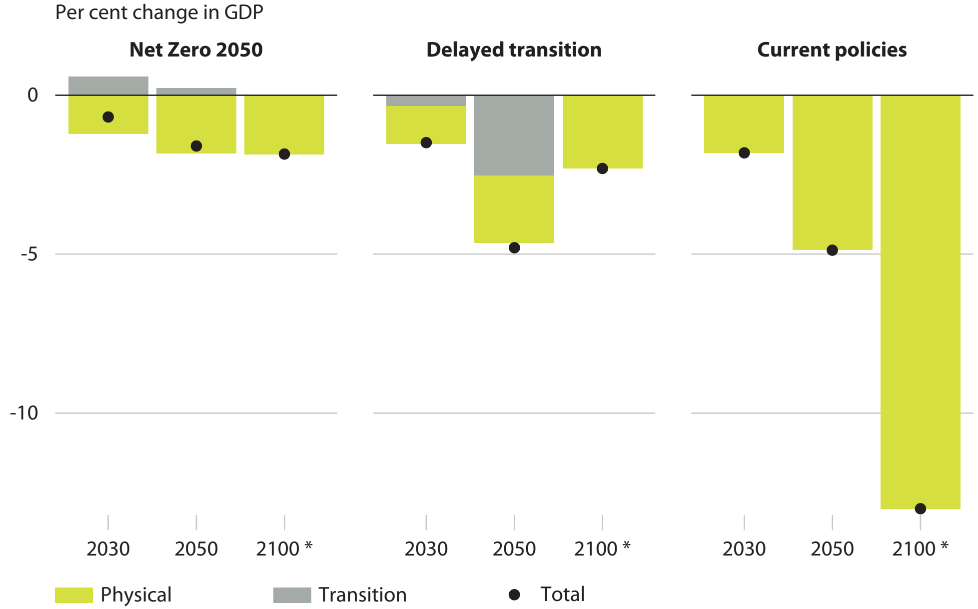
- World GDP impacts from **transition risk** are slightly positive in Net Zero 2050 as negative impacts on demand from higher carbon prices and energy costs are more than offset by the recycling of carbon revenues into government investment and lower employment taxes. GDP impacts are negative in the disorderly scenarios as the speed of the transition combined with investment uncertainty affects consumption and investment.

- GDP losses from **physical risks** scale with the change in temperatures in the scenario. In the first half of the century impacts are similar until they start to diverge. By 2100 impacts are far highest in the current policies scenario as temperature targets are missed. In the orderly scenarios physical risks dominate underlining the need to invest in adaptation.

- NiGEM also provides country and regional pathways for GDP. Impacts are higher for countries and regions that face higher emissions reductions, higher carbon prices, lower fossil fuel exports, or higher physical risk damages.

* Economic impacts are modelled out to 2050. To obtain an estimate of impacts in 2100, we took the estimate of physical risk impacts based on the damage function (see slide 30) and assumed no transition risk impacts at this point (ie. the GDP loss is solely due to physical risk).

**GDP impacts relative to prior trend**

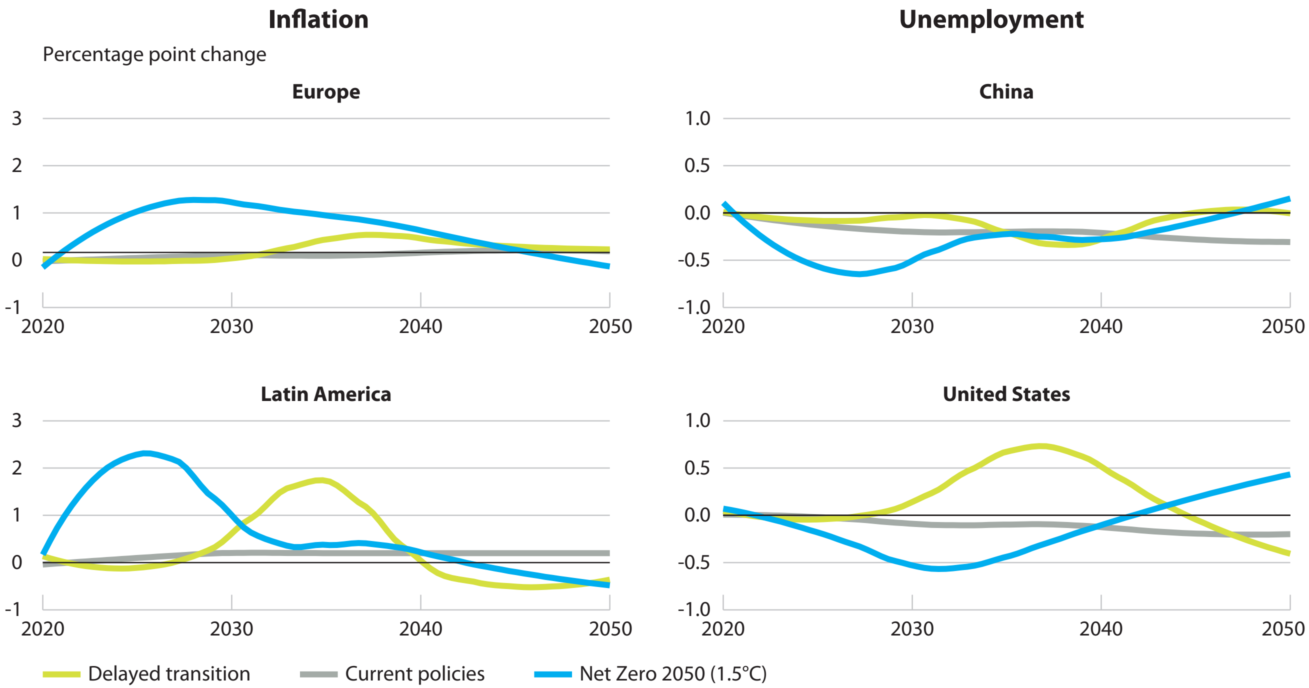



Source: IIASA NGFS Climate Scenarios Database, NiGEM based on REMIND. IAM data and damage estimates from Kalkuhl & Wenz (2020).

# Inflation and unemployment

## The scenarios include a wide range of macroeconomic variables, capturing structural relationships between key aggregates such as unemployment and inflation.

- In many countries, the implementation of carbon prices in the transition scenarios tends to raise energy costs in the short term leading to modest increases in **inflation** and **unemployment** before returning to prior trends. In some countries and time periods the offsetting positive growth effects from carbon revenue recycling lead to a reduction in unemployment.
- In some scenarios this leads to a potential **monetary policy tradeoff**. The NGFS modelling framework assumed a 'two-pillar' strategy, targeting a combination of inflation and nominal GDP as a default. This can be adjusted in the NiGEM model alongside fiscal policy assumptions (see slide 39).
- The negligible impacts in the Current policy scenario reflect not only limited transition risk, but also the fact that only one potential physical risk transmission channel (productivity) has been modelled. More research is needed on the potential for climate impacts to raise inflation (e.g through supply-side shortages) and/or unemployment (e.g. due to displacement).



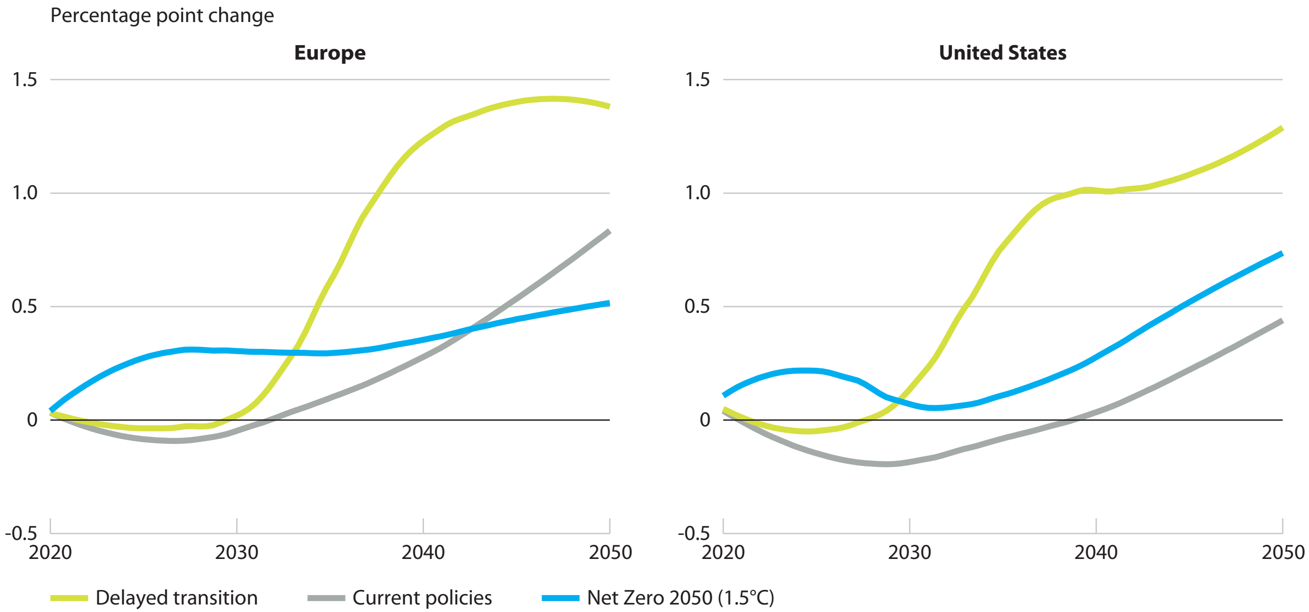

Results have been smoothed as a 5 year centred average.
Source: IIASA NGFS Climate Scenarios Database, NiGEM based on REMIND. IAM data and damage estimates from Kalkuhl & Wenz (2020).

# Financial markets

## Climate change and transition policies create significant financial fluctuations. The macrofinancial results reflect both risks and opportunities.

- **Long-term interest rates** tend to increase in the transition scenarios, reflecting the inflationary pressure created by 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. Although the NiGEM results cannot be disaggregated into individual sectors. It is likely that sectors that can decarbonise less easily will be affected more than sectors that can decarbonise more easily (cf. slide 20). The NGFS will work to further develop sectoral impacts going forward.
- In the disorderly scenarios we assumed that policy uncertainty leads to a higher investment premium. This lasts for two years, with the premium gradually returning to baseline thereafter. This occurs in the period 2021-2022 in the Divergent Net Zero policies scenario and 2030-2031 in the Delayed 2 degrees scenario.

**Long-term interest rate**



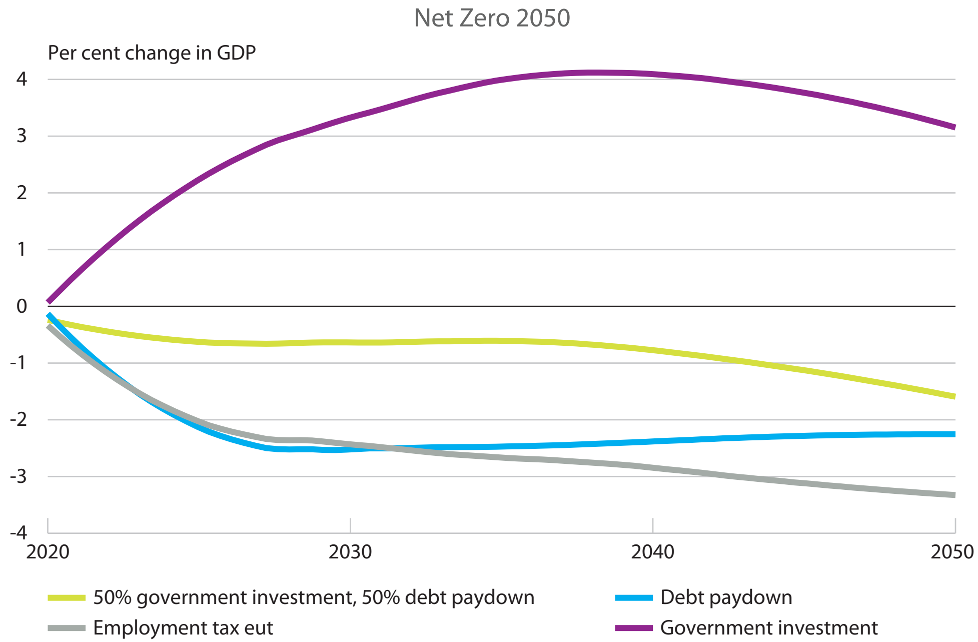

Results have been smoothed as a 5 year centred average.
Source: IIASA NGFS Climate Scenarios Database, NiGEM based on REMIND. IAM data and damage estimates from Kalkuhl & Wenz (2020).

# Sensitivity to fiscal policy options

## A key factor in the results are assumptions around fiscal policy, in particular on whether climate policy measures raise revenue (e.g. through carbon trading) that can be redistributed.

- The NGFS scenarios make a simplifying assumption that climate policy in each scenario is introduced as a carbon tax. In orderly scenarios, the generated government revenue is recycled through a combination of 50% higher government investment and 50% pay down of debt (see right chart green line).
- This is a relatively optimistic set of assumptions. In reality governments introduce a wide set of carbon policies, many of which may not generate revenue. Other ways of redistributing revenues, such as entirely through paying down debt, or reducing income tax, have lower offsetting positive impacts on GDP than government investment. In disorderly and hot house world scenarios, generated government revenue is offset via lower income tax rates.
- Using the most optimistic and most pessimistic assumptions leads to total GDP impacts (from both physical and transition risks) ranging from circa -3% to +3% by 2050 in the Net Zero scenario relative to prior trends.

**Total GDP impacts with different fiscal assumptions**




Source: IIASA NGFS Climate Scenarios Database, NiGEM based on REMIND. IAM data and damage estimates from Kalkuhl & Wenz (2020).



Economic

# Uncertainty in impacts from transition risk

## Quantifying transition risk is subject to key uncertainties given the dependency on policy choices and the influence of market failures.

- The costs and distributional effects of climate policies depend strongly on the **climate policy mix**. Estimates from the wider literature suggest that emissions pricing has a larger economic impact than policies such as emissions performance standards, renewable portfolio standards, and subsidies.* In the macroeconomic modelling for the NGFS scenarios carbon prices proxy for a wider range of policies.

- On the other hand, most IAMs and macroeconomic models, including the ones used for the NGFS scenarios, do not include the financial sector and therefore make an implied assumption that there is a smooth market allocation of capital. In practice, the presence of **market failures** could mean that stronger policy is needed than implied by the models, which would exacerbate transition risk impacts.^ The right table shows market failures that are likely to be relevant to transition risk.

| Market failures affecting transition risk | |
|---|---|
| Capital market imperfections | – Credit rationing leads to underinvestment in key areas, especially when social benefits are not priced in or uncertainty is large<br>– Myopic behaviour leads markets to undervalue future benefits and costs |
| Network effects | – Market participants typically do not fully take into account how their behaviour affects the overall economic and financial system, as was evident from the 2008 financial crisis |
| Imperfect information | – Uncertainties about the costs of climate change and the benefits of technological innovations constrain decision-making |

* See, e.g., Fischer, Preonas and Newell (2017).

^ See, e.g., Stern and Stiglitz (2021).



Economic

# Uncertainty in impacts from physical risks

## Economic impacts at high degrees of warming would be unprecedented and much more severe than currently estimated given known gaps in modelling.

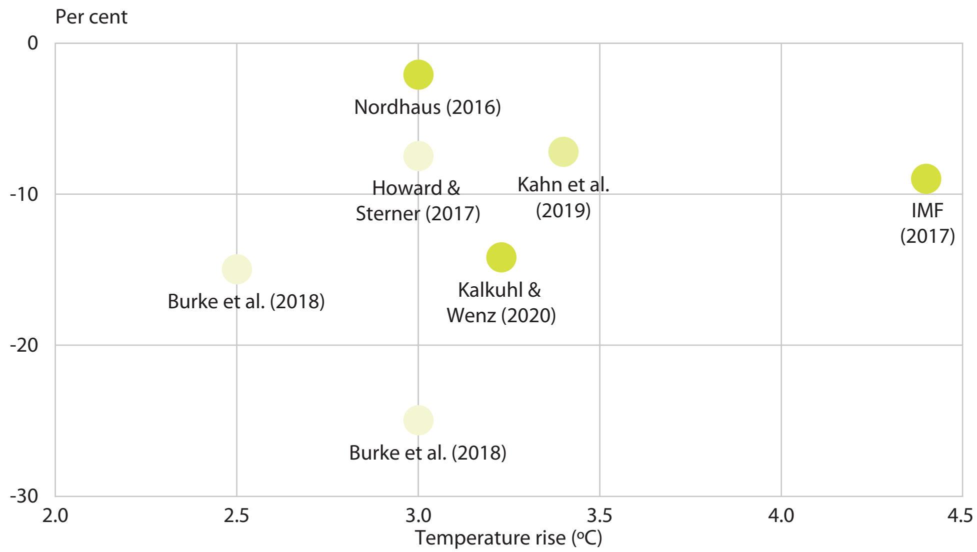
- Damage estimates from physical risks only cover a limited number of risk transmission channels. For example, they do not capture the risks from sea-level rise or severe weather. They also assume socioeconomic factors such as population, migration and conflict remain constant even at high levels of warming.* Potential correlation between risk channels, i.e. if the occurrence of one physical risk makes another more likely (e.g. food scarcity may increase the chance of conflict), can further amplify damages.

- In studies that focus on the relationship between temperature and the economy there is also a wide range of projected impacts. The adjacent chart shows a range of damage estimates for different levels of warming. The differences arise from the type of modelling approach, whether impacts are considered to directly affect the growth rate, and the future level of adaptation. The damage function used in the NGFS modelling framework was sourced from Kalkuhl & Wenz (2020) but based on the specific temperature outcomes of the NGFS transition pathways.

- There are a number of reasons to suggest that these are underestimates of the potential risks. Although some studies capture non-linearities in biophysical processes as temperatures increase, few fully capture the potential risks of tipping points accelerating global warming. Studies that have assessed the potential impacts from tipping points on policy responses find that emissions prices should be up to eight times higher.

* The World Bank (2018) has suggested that climate change could displace almost 140 million people by 2050 in countries in Sub-Saharan Africa, Latin America, and Asia.

**Estimates of GDP losses from rising temperatures in the academic literature**




Source: As shown. Shade of marker reflects temperature baseline used in the underlying study. Burke, Howard & Sterner (lightest shade) measure temperature rise relative to pre-industrial levels. Kahn (medium shade) uses a baseline of 1960-2014. Nordhaus, IMF and Kalkuhl & Wenz (darkest shade) use a near-term baseline (ranging from 2005-present day).

# Development pipeline

# Progress since Phase I (June 2020)

## The NGFS has made a substantial number of improvements to the NGFS Scenarios over the past 9 months in collaboration with its academic partners.

- In June 2020, the NGFS launched its first set of scenarios, which were based on input data and analysis from the 2018 IPCC Special 1.5 degree climate report. For the current release, the NGFS was able to design more bespoke scenarios based on the current climate policy environment. This included runs for the REMIND model that integrated physical risk damages into the transition pathways.

- NIESR joined the academic consortium to bring their expertise in macroeconomic modelling to the scenarios. A much richer set of economic variables from their NiGEM model are now available in the IIASA NGFS Scenario database.

- ETHZ, PIK and Climate Analytics assessed the global direct losses from extreme weather events from tropical cyclones and flooding. Assessments of labour productivity impacts and extreme event exposure have also been added. This analysis plus other country-level metrics of physical risk have been made available in a new NGFS CA Climate Impact Explorer.

- Integrated assessment modelling teams developed a standardized downscaling methodology to provide country level data for approximately 132 countries.

- Leveraging on the outcomes of the SENSES project, the NGFS collaborated with PIK to design a new website for the NGFS scenarios.

**Comparison of scenarios**

| Phase I name | Phase II name | Changes |
|---|---|---|
| • Orderly (1.5°C with CDR) | • Net Zero 2050 | This scenario still reaches 1.5°C and net zero by 2050. Individual regional pathways are updated. |
| • Orderly (rep) (2°C with CDR)<br>• Orderly (2°C with limited CDR) | • Below 2°C | This scenario still leads to warming between 1.5-2°C. CDR has been limited in the new scenario. |
| • Disorderly (1.5°C limited CDR) | • Divergent Net Zero Policies | This scenario now reflects the impact of divergent policies across sectors and regions represented as carbon price variation. |
| • Disorderly (rep) (2°C delay with limited CDR)<br>• Disorderly (2°C delay with CDR) | • Delayed 2°C | Delay to policies still occurs until 2030. CDR has been limited in the new scenario. In addition, the scenario includes regional carbon price variation, i.e. regions with net-zero targets are more ambitious than regions without them after 2030. |
| • NDCs | • NDCs | Emission and temperatures are lower due to increased climate policy commitments. |
| • Current Policies (rep) | • Current Policies | Overall emissions and temperature increase is lower due to lower baseline growth assumptions and more policies already implemented. |

# Gaps in scenario modelling

## Despite progress made, there are still areas that could be developed further to enhance macro-financial risk analysis, disclosures and decision-making. These gaps fall into three categories.

| Scope | Coherence | Uncertainty |
|---|---|---|
| • Providing sectoral economic variables, e.g. value added<br>• Quantifying the impact from a greater number of physical risks, and from adaptation<br>• Adding additional macroeconomic transmission channels<br>• Accounting for the impact of market failures | • Including physical risks in transition pathways to capture interactions<br>• Explicit role for financial sector in transition pathways<br>• Further explore assumptions related to fiscal and monetary policy, model structure, and energy use/costs on economic modelling | • Lack of a systematic approach to quantifying uncertainty<br>• Research gaps on the nature and size of impacts from physical risks, including on exposure, vulnerability and adaptation<br>• Uncertainty around commodity volumes and prices<br>• Analysis of impact of different background SSP assumptions |

Development

# Next steps

**The NGFS will continue to develop the scenarios to make them more comprehensive, with the aim to be as relevant as possible for economic and financial analysis.**

| Phase I | Phase II | Private and public sector implementation | Spring extension | Beyond |
|---|---|---|---|---|
| Phase I of the NGFS scenarios delivered a set of harmonised transition pathways, chronic climate impacts and indicative economic impacts for each of the NGFS scenarios. | Phase II brought the scenarios up to date, including by incorporating countries' commitments to reach net-zero emissions, and provided an expanded set of macroeconomic variables, country-level granularity, and an online portal through which users can explore the physical risks from climate change. | NGFS members will undertake a number of case studies with the scenarios and share key learnings. The NGFS will also collaborate with industry to ensure the scenarios are suitable for wider use. | The NGFS will continue to refine the Phase II scenarios, including by adding further sectoral granularity and improving the integration of the suite of models. | The NGFS is currently defining a longer-term project to refine and improve the scenarios further, as well as fostering their use among central banks and supervisors, and reaching out to the private sector. |
| Ended June 2020 | Ended June 2021 | Ahead of COP26 | Spring 2022 | Longer term |

# Annex

# Summary of models

## The NGFS scenarios have been developed with the participation of the following research institutions and models.

| Comparison | Climate impacts | Transition pathways | Economic impacts |
|---|---|---|---|
| **External research partners** | Climate Analytics<br>ETH Zurich<br>PIK | PIK<br>UMD<br>IIASA | NIESR |
| **Models** | Climate models participating in the ISIMIP project<br>CLIMADA | REMIND-MAgPIE 2.1-4.2<br>GCAM 5.3<br>MESSAGEix-GLOBIOM 1.1 | NiGEM v1.21<br>IAMs (only GDP provided as an output in the database) |
| **Inputs** | Atmospheric concentrations of emissions and associated radiative forcing.<br>Economic exposure data for assessment of economic impacts. | Constraints from an emissions budget and other climate policies at the global and regional level. | Carbon prices, use of energy services, primary energy mix, physical risk damage functions. |
| **Key assumptions and uncertainties** | Physical relationships between various aspects of the climate system.<br>Changes in climate at the local scale. | Technology costs. Inter-temporal optimisation (for REMIND-MAgPIE and MESSAGEix-GLOBIOM). Optimal government policy design and capital reallocation. | Econometric relationships between variables hold. Rational expectations and perfect foresight. |
| **Outputs** | **Climate indicators**<br>(e.g. temperature, precipitation, river flow, agricultural yields, soil moisture).<br>**Economic indicators**<br>(e.g. direct losses from flooding and cyclones, area and population exposed to extreme weather). | Energy demand, energy capacity, investment in energy, energy prices, carbon prices, emissions trajectories, temperature trajectories, agricultural variables, GDP. | GDP (and components), unemployment, inflation, productivity, personal disposable income, house prices, interest rates, exchange rates, equity prices, etc. |
| **Time horizon** | Time steps of 5 years, up to 2100 in Explorer<br>Up to daily time steps for underlying ISIMIP data | Time steps of 5 years<br>(10 years from 2060 onwards), up to 2100 | Annual steps, up to 2050 (NiGEM) |

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