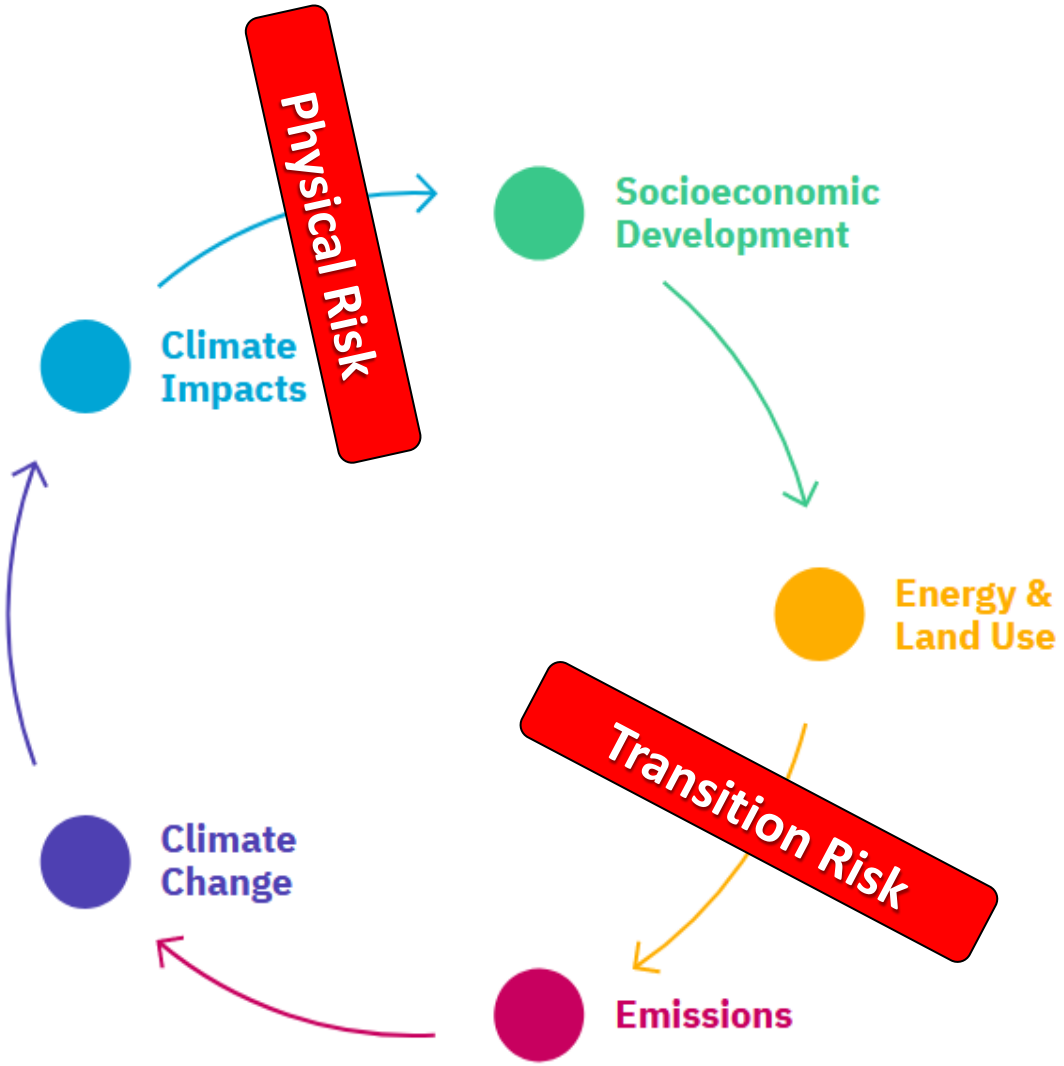
Climate change scenarios

SENSES

Primer on Climate Change Scenario Approaches:
https://climatescenario.org/primer/
Developed by SENSES project on scenario communication and visualization (senses-project.org)



NGFS Scenarios

The Network for Greening the Financial System (NGFS) is a group of [66] central banks and supervisors and [13] 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 result of NGFS 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) and Climate Analytics (CA). This work was made possible by grants from Bloomberg Philanthropies and ClimateWorks Foundation.

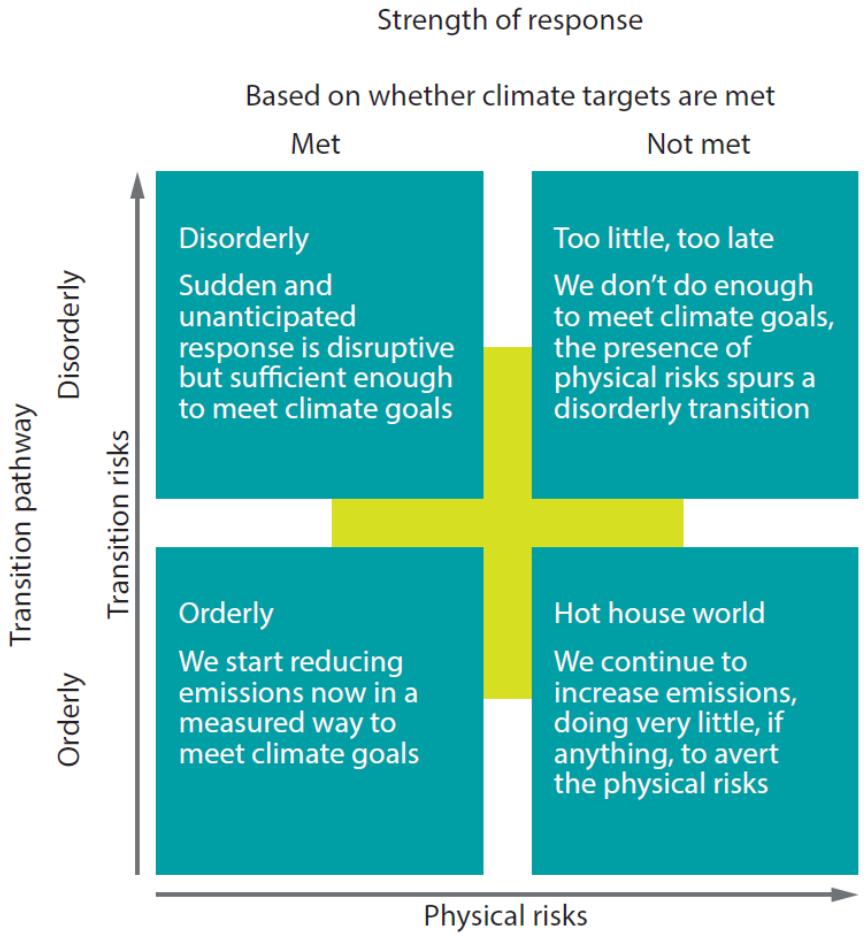
Special thanks is given to lead coordinating authors: Thomas Allen (Banque de France), Cornelia Auer (PIK), Ryan Barrett (Bank of England), Christoph Bertram (PIK), Antoine Boirard (Banque de France), Leon Clarke (JCGRI/UMD), Jae Edmonds (JGCRI/UMD), Jérôme Hilaire (PIK), Elmar Kriegler (PIK), Theresa Löber (Bank of England), Jihoon Min (IIASA), Franziska Piontek (PIK), Edo Schets (Bank of England), Carl-Friedrich Schleussner (Climate Analytics), Bas van Ruijven (IIASA) and Ryna Yijun Cui (JCGRI/UMD). Thanks also go out to all contributing authors: Cristina Angelico (Banca d'Italia), Rie Asakura (Japan FSA), Ivan Faella (Banca d'Italia), Philipp Haenle (Bundesbank), Craig Johnston (Bank of Canada), Federico Lubello (Bank of Luxembourg) and Simone Russo (Bank of Malta).

Objectives and framework

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

- Initial set of **8 scenarios** which are consistent with the NGFS framework with **three representative scenarios**, which each cover one of the following dimensions:
  - **Orderly:** Early, ambitious action to a net zero CO_2 emissions economy;
  - **Disorderly:** Action that is late, disruptive, sudden and / or unanticipated;
  - **Hot house world:** Limited action that leads to a hot house world with significant global warming and, as a result, an increased exposure to the physical risks from climate change.

- **Uncertainty**
  - Alternative scenarios
  - Multiple models



NGFS Scenarios Framework introduced in the NGFS First Comprehensive Report (2019)

Three Representative scenarios

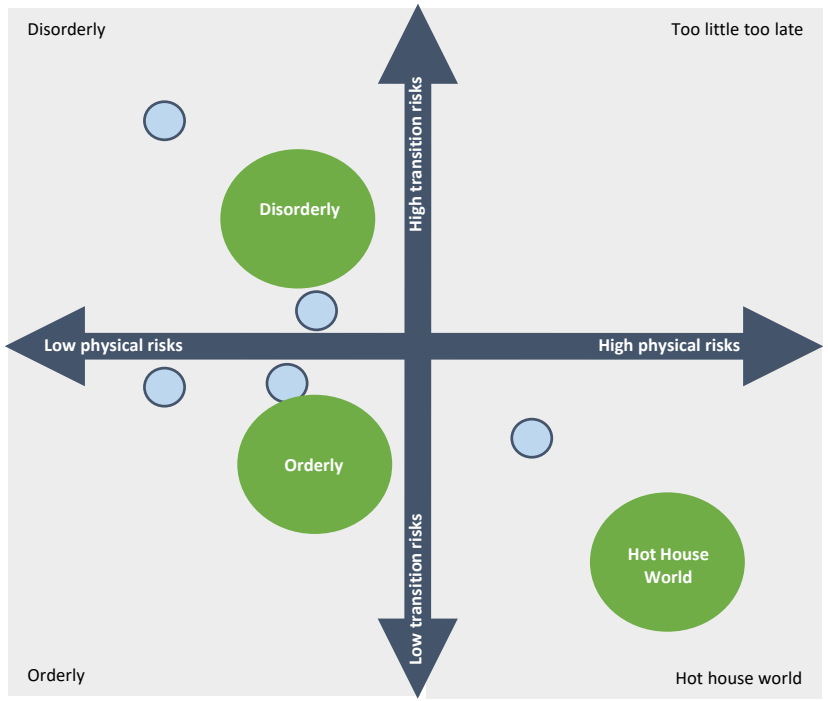
The Orderly and Disorderly scenarios explore a transition which is consistent with limiting global warming to 2°C. The Hot house world scenario leads to severe physical risks

- **Orderly** assumes climate policies are introduced early and become gradually more stringent. Net zero CO_2 emissions are achieved before 2070, giving a 67% chance of limiting global warming to below 2°C. Physical and transition risks are both relatively low.

- **Disorderly** assumes climate policies are not introduced until 2030. Since actions are taken relatively late and limited by available technologies, emissions reductions need to be sharper than in the Orderly scenario to limit warming to the same target. The result is higher transition risk.

- **Hot house world** assumes that only currently implemented policies are preserved. Nationally Determined Contributions are not realised. Emissions grow until 2080 leading to 3°C+ of warming, with severe physical risks including irreversible changes like sea-level rise.

Mapping of representative (bubble) and alternate (dot) scenarios to the NGFS matrix



Source: IIASA NGFS Scenarios Portal, using marker models

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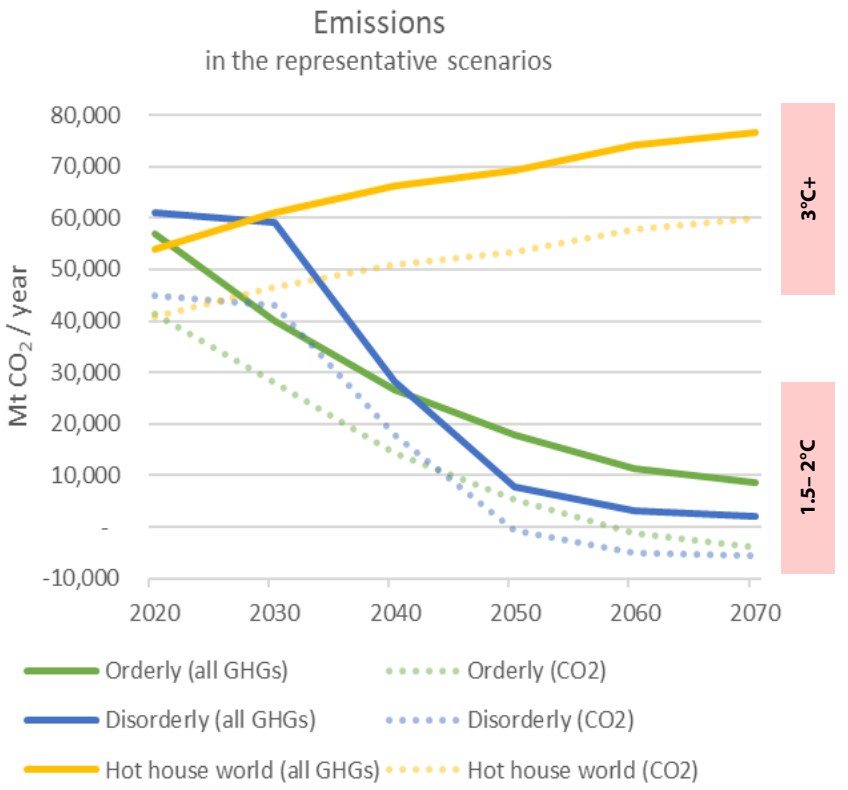
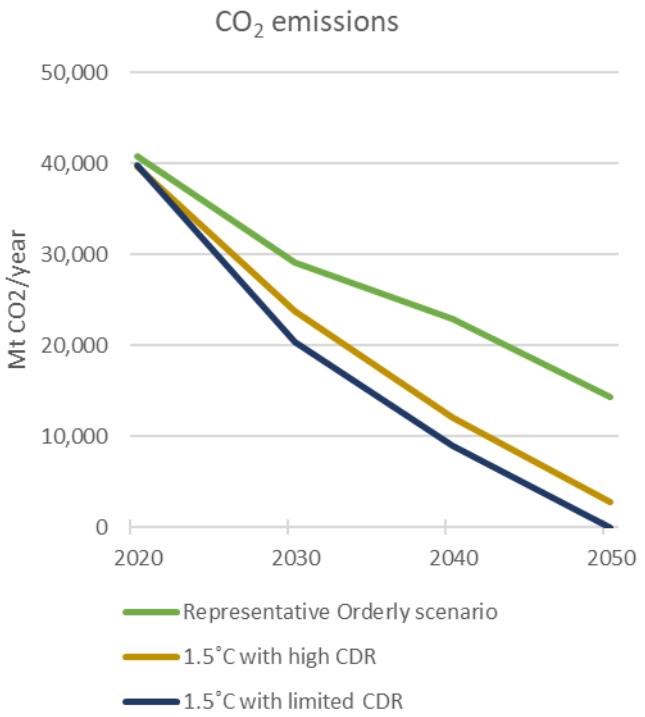


Source: IIASA NGFS Scenarios Portal, using marker models

Five Alternate scenarios

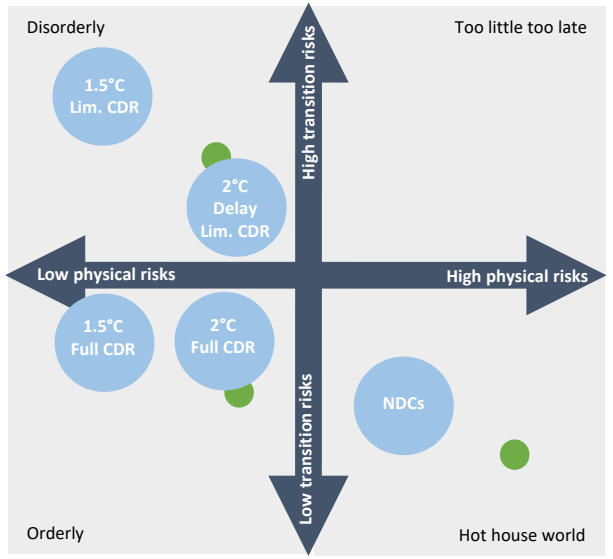
Five alternate scenarios have been produced which explore the impact of variations in key assumptions, including the temperature target, policy delay and/or technology availability

- The NGFS scenarios include two alternate 1.5˚C pathways (left chart). In both, CO_2 emissions need to reach net zero before 2050 to limit global warming to 1.5˚C with a 67% chance. This reduction in emissions is much more rapid than in the Orderly scenario, leading to higher transition risks.
- Scenarios also differ in their assumptions about the level of CO_2 removal (CDR) in the second half of the century. These negative emission technologies could be limited by innovation or investment bottlenecks.
- An alternative scenario that explores high physical risks has also been included. It assumes that governments implement further policies consistent with Nationally Determined Contributions (NDCs), making it less adverse than the Hot house world scenario.



Source: IIASA NGFS Scenarios Portal, MESSAGE model

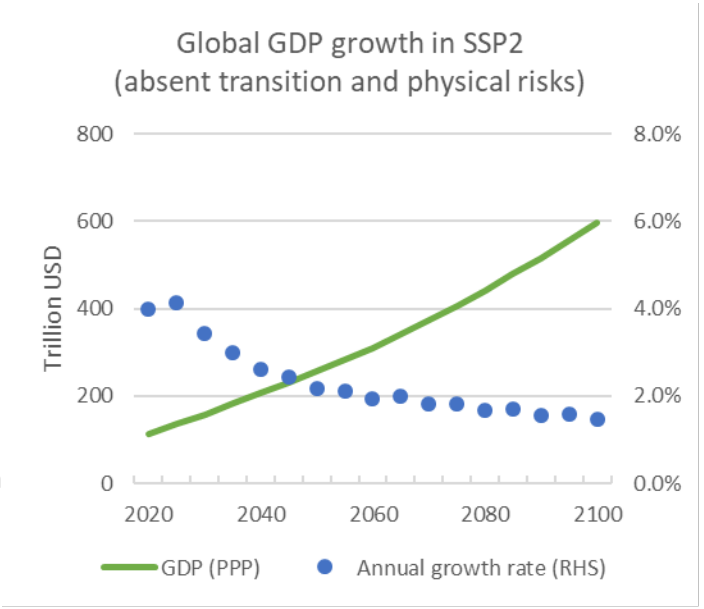
Mapping of alternate (bubble) and representative (dot) scenarios to the NGFS matrix



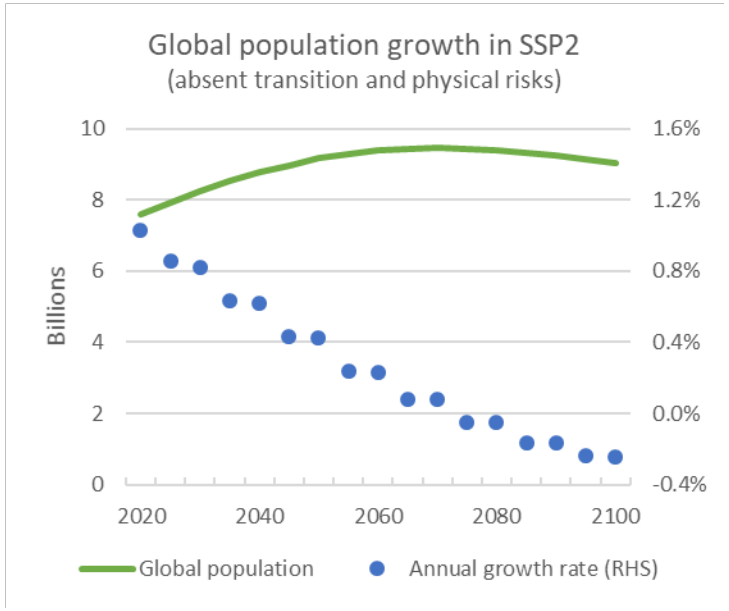
Socioeconomic assumptions

All scenarios make a background assumption that social and economic trends continue in line with historical trends

- Socioeconomic pathways are key background assumptions in climate scenarios. These assumptions, such as GDP, population and urbanisation, have been standardised by the academic community. These **Shared Socioeconomic Pathways** (SSPs) also include detailed narratives regarding technological advancement, international cooperation and resource use.*
- All NGFS scenarios are currently based on the 'middle of the road' assumptions provided by SSP2 to ensure they are comparable. In this SSP global population growth is moderate and levels off in the second half of the century and GDP continues to grow in line with historical trends. Sensitivity to these assumptions will be explored in the future.
- The SSPs do not consider impacts from physical risks on these background assumptions. This includes socioeconomic changes related to migration and conflict.



Source: IIASA NGFS Scenarios Portal



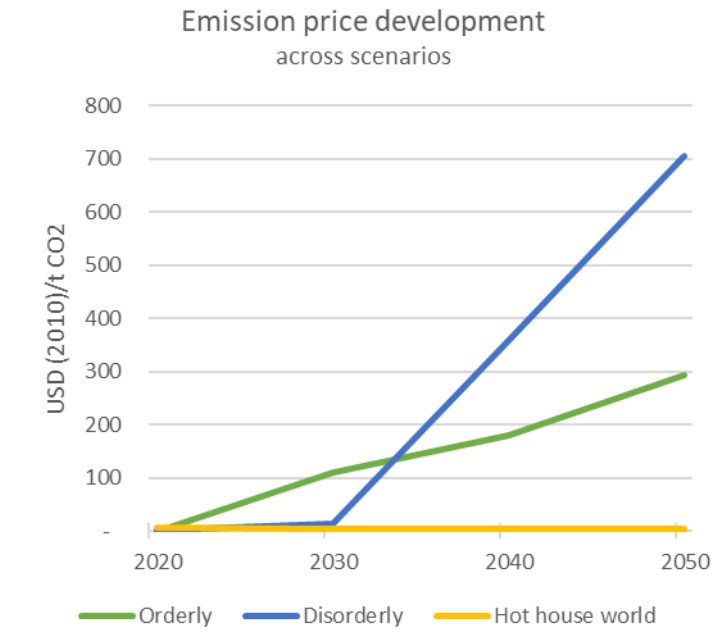
Source: IIASA NGFS Scenarios Portal

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

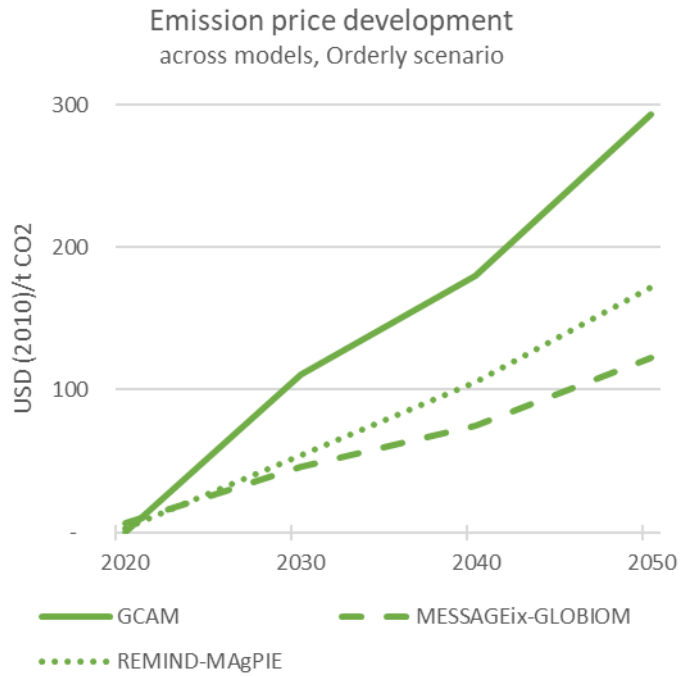
Policy and technology assumptions

Assumptions related to policy action and technological development are a key driver of scenarios and the results between models

- In the Integrated Assessment Models used to produce the NGFS scenarios, **shadow emissions prices** are a proxy for government policy intensity. The prices are calculated to be consistent with a pre-defined temperature target (e.g. 66% chance of limiting global warming to 2°C). In reality, governments are likely to pursue a range of different policies meaning actual carbon prices will diverge from model optimal levels.
- The **timing of policy action** has a significant impact on the emissions price level that is required to achieve a given temperature target, as illustrated in the left chart.
- These emissions price trajectories also vary across models (right chart) due to other underlying assumptions such as the level and nature of technological development.



Source: IIASA NGFS Scenarios Portal , using marker models



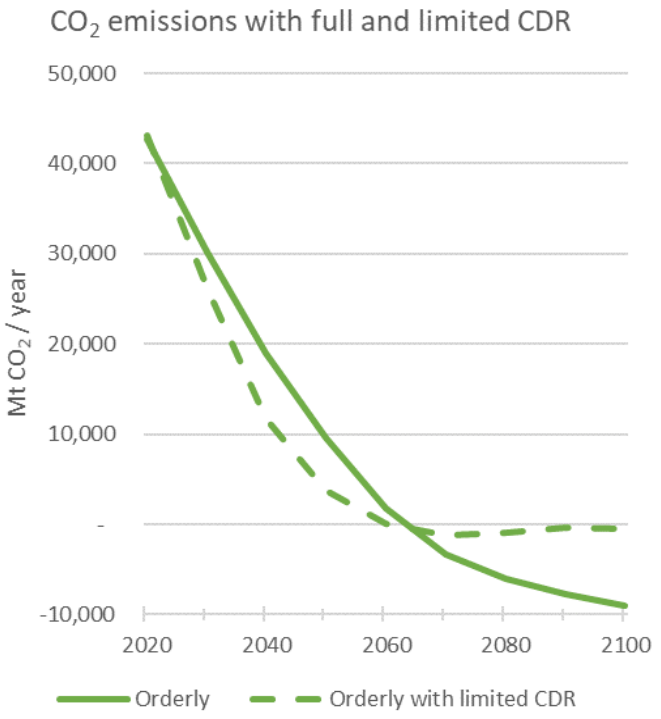
Source: IIASA NGFS Scenarios Portal

*Emissions prices are defined as the marginal abatement cost of an incremental ton of greenhouse gas emissions.

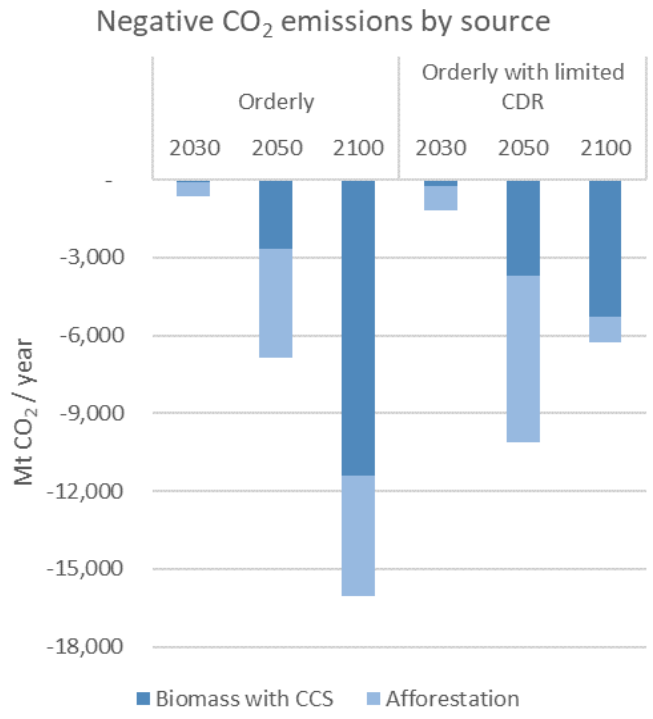
Carbon dioxide removal assumptions

Scenarios also make assumptions about the level of negative CO_2 emissions achieved through Carbon Dioxide Removal, affecting the speed and timing of the transition

- **Carbon dioxide removal (CDR)** refers to direct removal of carbon dioxide from the atmosphere, for example by combining biomass with carbon capture and storage (CCS) or through land-related sequestration (e.g. afforestation). Currently, CDR takes place on a limited scale.
- CDR assumptions play an important in IAMs because they help determine whether, and how, climate targets can be met. For example, if CDR was deployed on a large scale, it is possible that fossil fuel emissions could stay higher for longer, or a lower climate target could be reached sooner.
- Some of the NGFS scenarios, including the representative Orderly scenario, assume **full availability of CDR technologies**. Other NGFS scenarios, including the representative Disorderly scenario, assume **limited CDR availability**, reflecting that there are challenges to achieving the necessary investment and deployment.



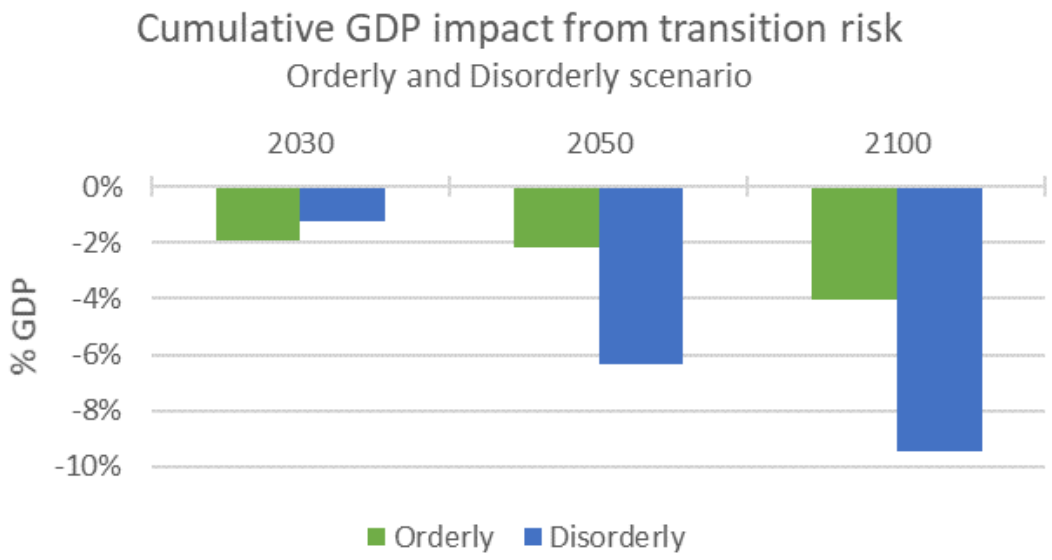
Source: IIASA NGFS Scenarios Portal, REMIND model

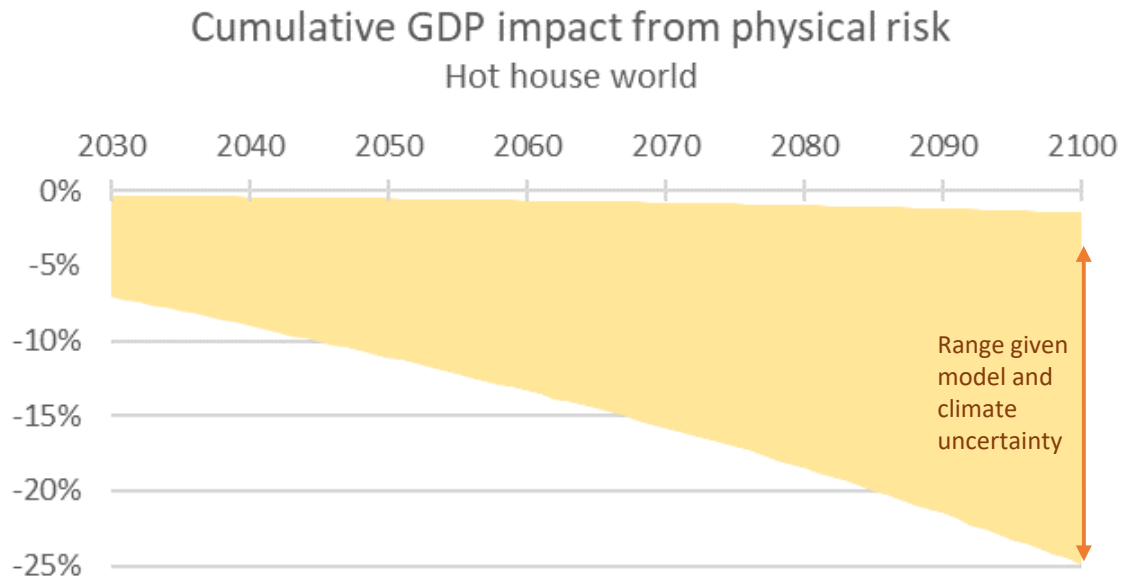


Source: IIASA NGFS Scenarios Portal, REMIND model

Economic impacts at a glance

Scenarios differ markedly in their economic impact, with significant uncertainty in the size of the estimates for both transition and physical risks





Source: IIASA NGFS Scenarios Portal, using marker models.

Source: PIK calculations based on literature damage estimates

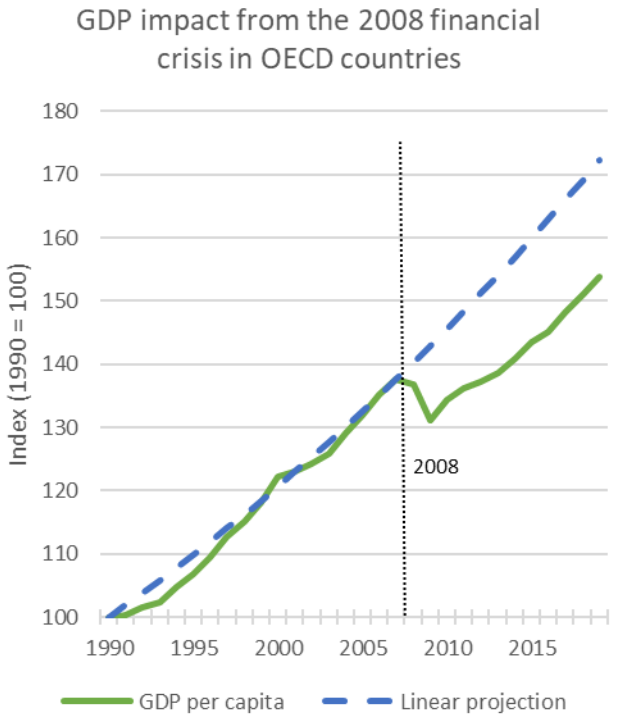
*See slide 13 for details.

Uncertainty

Quantifying transition risk is subject to fundamental uncertainty due to model limitations and 'unknown unknowns'

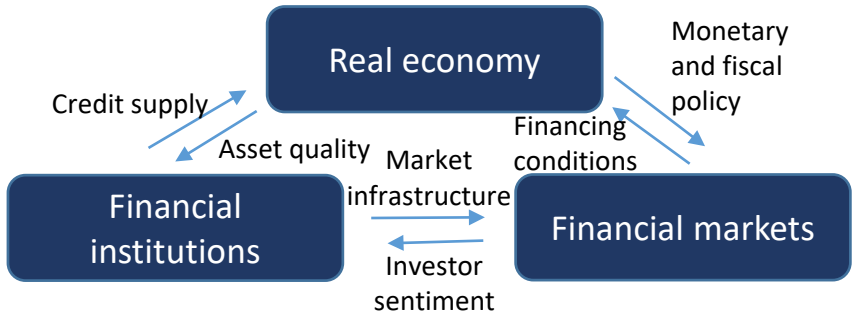
- Due to the complex nature and interconnectedness of climate policy, technological progress and consumer preferences, transition risk may materialize in ways that are difficult to foresee. Such **'unknown unknowns'** could lead to an unexpected technological breakthrough, reducing economy-wide transition costs, while at the same time creating pressures in certain sectors, with large financial losses as a result.

- **Changes in economic sentiment and interactions between the real economy and the financial sector** could significantly amplify economic impacts. The 2008 financial crisis demonstrated how these effects can affect growth in the long run (left chart). The Integrated Assessment Models used for the NGFS Scenarios do not include these channels in their economic modelling.



Source: OECD Economic Outlook, Vol. 2018-1

Interactions between finance and the real economy



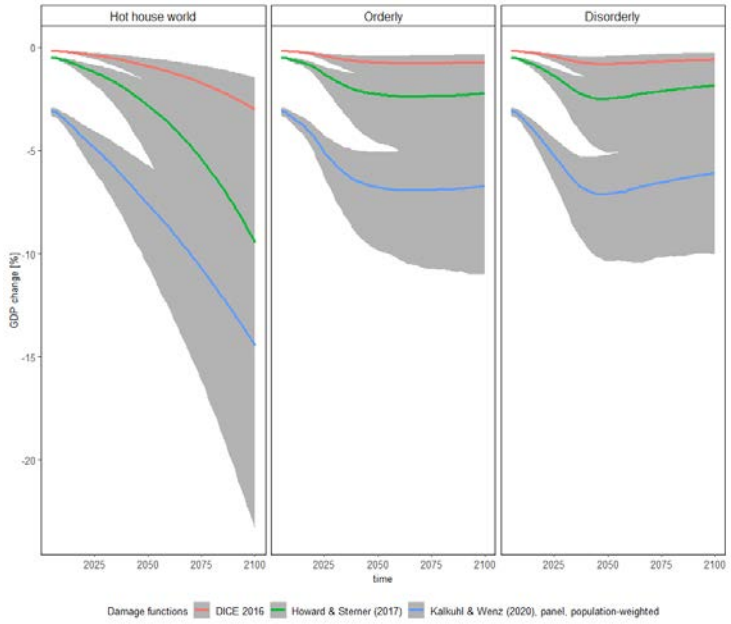
Source: Adapted from Hilbers and Van Hengel (2019)

Impacts from physical 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

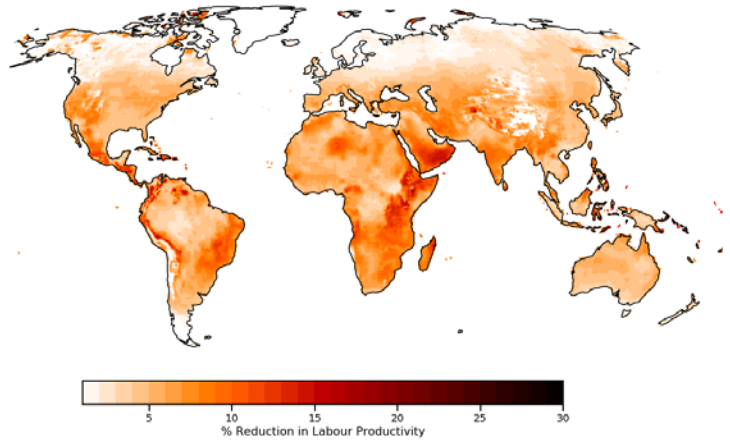
- Estimates of the size of GDP losses from physical risk vary considerably (e.g. Hot house world -10% to -25%) depending on the scenario, uncertainties in climate science and the type of economic modelling approach employed.
- The chart adjacent shows a range of GDP losses for the NGFS scenarios using three damage functions from the literature. They underestimate the impact as **they do not include all channels and effects on the growth rate** (see next slide). The grey shading represents the uncertainty about climate sensitivity (the response in temperatures to CO_2 emissions).
- Assessing average losses in this way disguises the significant distribution of impacts across regions. The right chart shows that tropical regions will be disproportionately impacted by heat stress and lower labour productivity. The impacts will vary further depending on regions' level of resilience and capacity for adaptation.

GDP losses in different scenarios using different damage functions



Source: Calculations by PIK based on scenario temperature outcomes and damage estimates from the literature

Climate Change Impacts on Labour Productivity at 3˚C Global Warming (2100 compared to 1986-2005)



Source: Calculations by Climate Analytics based on 3°C of warming, roughly aligned with the NDC scenario

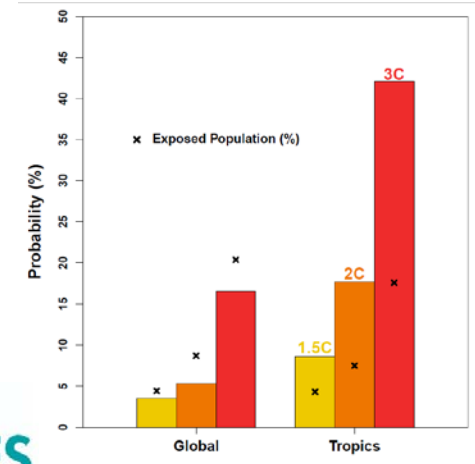
Other risks

There are other physical risks that are not yet captured in the ISIMIP dataset but will be included in Phase II. Many estimates are already available in the wider literature

Heatwaves

- At 3°C+ of warming an **extreme heatwave** (e.g. Europe 2003) would be expected in tropical regions every 2.5 years. Globally, over 20% of the world population would be exposed to such an event annually.

Probability and exposure to Extreme Heatwaves

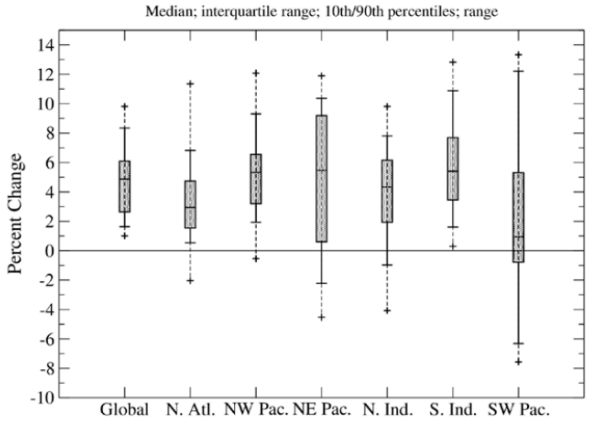


Source: Russo (2020)

Cyclones

- **Tropical cyclones** are complex to model but emerging evidence suggests that global warming will increase the intensity (1-10% higher wind speeds) and rain rate (14%) across basins. There is less agreement on the change in frequency.

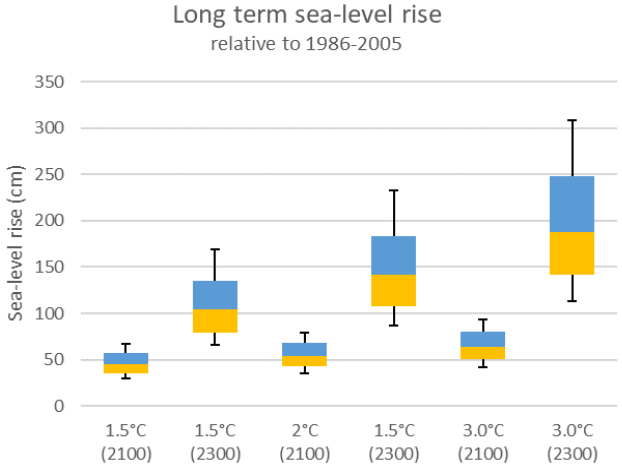
Change in intensity of tropical cyclones



Source: Knutson et al. (2019)

Sea-levels

- **Sea levels** will continue to rise for centuries to millennia after CO_2 emissions have reached net-zero. 3°C+ of warming might imply sea level rise of almost 2m or more by 2300. This range is even greater when the risks from low probability, high impact (H++) scenarios are factored in.



Source: Adapted from Geiges et al. (2019)

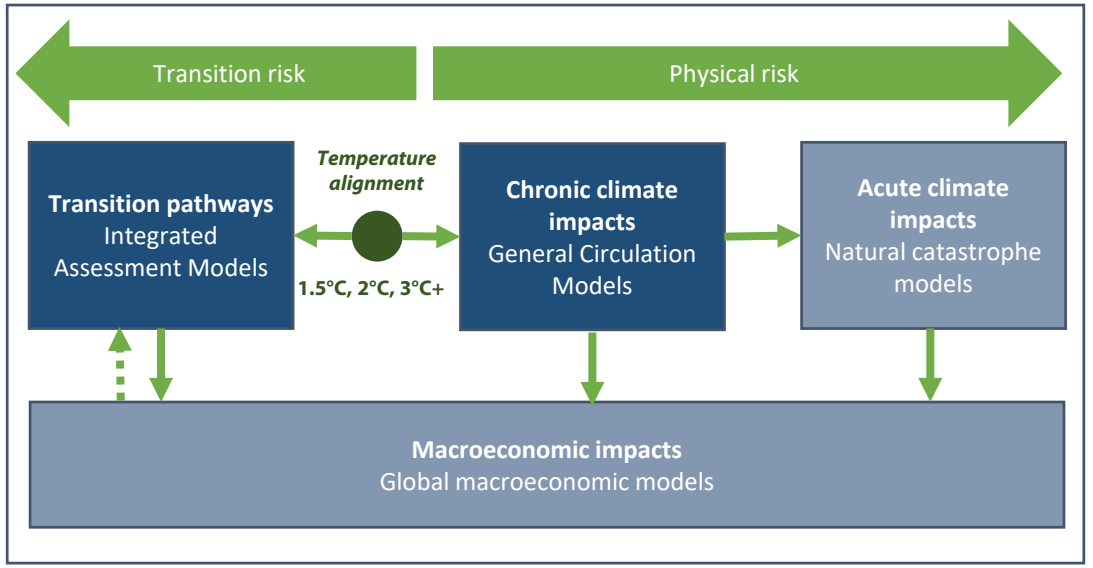
Future development

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

- Currently there is no single model that can cover the full range of required outputs. In the interim the approach is to use a suite of specialist models linked together in a coherent way.

- **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.
- In **Phase II** the NGFS will continue to work with a consortium of academic partners to refine and expand the scope of the scenarios. Areas of focus will include:
  - Expanding the scenario modelling to explore further dimensions of the risks
  - Improving regional coverage and sectoral granularity
  - Calculating probabilistic losses from acute climate impacts
  - Expanding the set of macroeconomic outputs
  - Improving the NGFS scenario database and portal

NGFS suite of models approach



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