Network for Greening the Financial System

# NGFS long-term scenarios, narratives and key findings: Net Zero 2050, Current Policies and Fragmented World

November 2025

NGFS
Central Banks and Supervisors
Network for Greening the Financial System

# Authors list

Léa Hayez[1], Fabrice Lécuyer[1], Mel George[2], Yiyi Ju[3], Meghal Arora[4], Miodrag Stevanovic[1], Jacob Anz[5], Christoph Bertram[2, 1], Jae Edmonds[2, *], Allen Fawcett[2, *], Jay Fuhrman[2, *], Gunnar Luderer[1, 6], Franziska Piontek[1], Carl-Friedrich Schleussner[3, 5], Bas van Ruijven[3], Anne Zimmer[5], Elmar Kriegler[1, 7].

1 Potsdam Institute for Climate Impact Research (PIK), member of the Leibniz Association, Potsdam, Germany.
2 Center for Global Sustainability, School of Public Policy, University of Maryland, College Park, Maryland, USA.
3 International Institute for Applied Systems Analysis (IIASA), Laxenburg, Austria.
4 Office of the Superintendent of Financial Institutions, Canada.
5 Climate Analytics, Berlin, Germany.
6 Global Energy Systems Analysis, Technische Universität Berlin, Berlin, Germany.
7 Faculty of Economics and Social Sciences, University of Potsdam, Potsdam, Germany
* J.E., A.F., and J.F., are also affiliated with Pacific Northwest National Laboratory, which did not provide specific support for this report.

**Suggested citation:** Hayez, L., Ju, Y., Arora, M., Stevanovic, M., Anz, J., Bertram, C., Edmonds, J., Fawcett, A., Fuhrmann, J., Luderer, G., Pionthek, F., Schleussner, C., van Ruijven, B., Zimmer, A., Kriegler, E., (2025). NGFS long-term scenarios, narratives and key findings: Net Zero 2050, Current Policies and Fragmented World. Network for Greening the Financial System. https://www.ngfs.net/en/publications-and-statistics/publications/explanatory-notes-ngfs-long-term-climate-scenarios.

**Acknowledgements:** The note is a collaborative effort of the members of the Workstream on Scenarios Design and Analysis and was prepared under the auspices of Livio Stracca (European Central Bank), Chair of the Workstream with support from the NGFS Secretariat. The NGFS Workstream on Scenarios Design and Analysis has been working in partnership with an academic consortium from the Potsdam Institute for Climate Impact Research (PIK), International Institute for Applied Systems Analysis (IIASA), University of Maryland (UMD), Climate Analytics (CA) and the National Institute of Economic and Social Research (NIESR). Special thanks are given to: Mario Morelli, Agnieszka Trzcinska, Lucy Hager, Tina Emambakhsh, Benedikt Scheid (European Central Bank, Chair's team), Paul Champey, Léopold Gosset, Tess Teuliere, Léa Grisey, Laurent Carlino, Charles Grison, Hadrien Marquant (Banque de France, NGFS Secretariat), Helena Herber (Deutsche Bundesbank, NGFS Secretariat), Lukasz Krebel (Bank of England), Sha Yu (International Monetary Fund).

## Notice to readers on physical risk estimates in Phase V of NGFS long-term scenarios

The NGFS long-term climate scenarios are a set of forward-looking pathways designed to explore how the global economy and financial system might evolve under different levels of climate policy ambition and physical climate impacts over the rest of the 21st century. They were developed by the Network for Greening the Financial System (NGFS) to provide a consistent analytical basis for assessing climate-related financial risks and opportunities. The academic paper underpinning the physical risk estimates in Phase V of NGFS long-term scenarios (released in November 2024), Kotz *et al.* (2024), has received academic critiques (see first and second Matters Arising) as part of the post-publication review process at Nature.

Therefore, users should be aware of this academic debate pertaining specifically to the Phase V physical risk methodology when interpreting and applying Phase V results, alongside the broader limitations of physical risk estimates already detailed in NGFS documentation.

It should be noted that the long-term scenarios outputs which do not incorporate physical loss estimates from Kotz *et al.* (2024) remain unaffected.[1] Also, the outputs of NGFS short-term scenarios are not impacted, as they do not rely on the Kotz *et al.* (2024) paper.

It cannot be excluded that the economic effects of climate change might turn out to be more severe than anticipated in the NGFS scenarios, for instance, if certain tipping points are reached. Thus, users should also take into account the tail risks of climate change, along with other risks such as nature-related ones, which are not necessarily captured by these scenarios.

The NGFS is constantly working to further improve the scenarios, including with regard to physical risks. Users are reminded that neither the NGFS, nor its member institutions, nor any person acting on their behalf, is responsible or liable for any reliance on, or for any use of the NGFS scenarios and/or supplementary documentation. This also applies to the use of the data produced under the scenarios – see section 5 in https://data.ene.iiasa.ac.at/ngfs/#/license. Thus, while the NGFS climate scenarios are certainly a helpful tool, they do not alleviate the responsibility of users, including banks and other (financial) organisations, to design and implement their own risk management frameworks.

1 The affected variables are those reflecting physical loss estimates from Kotz *et al.* (2024) in Phase V of NGFS long-term scenarios. This includes: all outputs of "Integrated Physical Damages" scenarios by REMIND-MAgPIE, all "physical" and "combined" (i.e. combined physical and transition damages) outputs by NiGEM, as well as post-processed or downscaled outputs for GDP damages from the damage function (i.e. GDP change and Net GDP variables referring to "Kotz-Wenz"). All other variables from Phase V, the physical risk estimates as presented in the "https://climate-impact-explorer.climateanalytics.org/" Climate Impact Explorer, as well as outputs from previous phases of NGFS long-term scenarios, remain unaffected.

# Table of Contents

# Executive summary

In November 2024, the Network for Greening the Financial System (NGFS) published its fifth vintage of long-term scenarios, providing financial institutions with key information to assess and manage climate-related transition and physical risks. The scenarios stem from the integration of an ensemble of models including three Integrated Assessment Models (REMIND-MAgPIE, GCAM and MESSAGEix-GLOBIOM), the macroeconomic model NIGEM and climate-impact projection tools. This report provides important context to NGFS scenario users for the assessment of financial and macroeconomic risks associated with three of the NGFS scenarios: Net Zero 2050, Current Policies and Fragmented World. For these scenarios, the report describes the underlying narratives and selected quantitative features, including model comparison.

## 1. NGFS Net Zero 2050 scenario

**Among the NGFS scenarios, the Net Zero 2050 scenario showcases the benefits of an immediate transition for long-term socio-economic stability and reduced damages.**

**The Net Zero 2050 scenario limits global warming to 1.5 °C by 2100 through stringent climate policies and innovation, reaching global net zero $CO_2$ emissions around 2050. This scenario assumes that ambitious climate policies are introduced immediately.** Carbon sequestration technologies are used to accelerate the decarbonisation but kept limited and broadly in line with sustainable levels of bioenergy production. The scenario gives at least a 50 % chance of limiting global warming to below 1.5 °C by the end of the century, with a temporary overshoot of up to 0.2 °C around mid-century. The overshoot has increased compared to previous vintages of the Net Zero 2050 scenario due to continued high global emissions in recent years. Physical risks are relatively low but transition risks are medium to high.

**The Net Zero 2050 scenario represents a transition *"as orderly as still possible"*: ambitious climate policies are introduced early and effectively, however these are not sufficient to avoid a 0.2 °C overshoot.** In fact, the annual vintages of the NGFS Net Zero 2050 scenario from Phase I (2020) to Phase V (2024) have grown less orderly, as the continued high emissions are followed by ever more disruptive emissions reductions to still achieve the mid-century target. In comparison, the Low Demand scenario features a more orderly transition in the energy sector, as a significant behavioural change in terms of energy consumption alleviates the decarbonisation efforts.

**Reaching net-zero global $CO_2$ emissions by 2050 will require an ambitious transition across all sectors of the economy.** In consequence, transition risks result from fast technological change required to accelerate the decarbonisation, steep penalties for emission intensive production and resulting price increases for emission intensive goods exerting inflationary pressure, and changes in business and consumer preferences leading to substantial shifts in investment and consumption patterns.

**The physical risks are substantially reduced compared to the Current Policies scenario thanks to the ambitious mitigation strategy.** However, given that global warming has already progressed and emission reductions take time, substantial residual risks are considered unavoidable, and will require adaptation efforts. These are the main drivers of climate risks in the future.

## 2. NGFS Current Policies scenario

**The Current Policies scenario demonstrates the lack of stringency on a global scale of implemented policies to mitigate climate change, and the associated macroeconomic risks and instability.** The Current Policies scenario belongs to the Hot House World category of the NGFS framework, assuming that only currently implemented policies are preserved, leading to high physical risks. $CO_2$ emissions remain high, leading to about 3 °C of warming at the of century and severe physical risks, as well as irreversible biophysical changes.

**The Current Policies scenario is the least ambitious scenario of the NGFS Scenario framework.** It is a valuable tool for central banks and supervisors to consider the long-term physical risks to the economy and financial system if the World remains on the current path towards a "hot house world".

**In the Current Policies scenario, the transition is limited and occurs gradually. The power sector remains fossil-fuel reliant and continues to drive emissions up. The integration of renewable technologies is slow, and energy consumption increases.** Consequently, socio-economic systems face relatively few short-term disruptions, while the long-term economic consequences, including the aggregate GDP loss driven by climate change impacts, are more unprecedented.

**High long-term costs are expected, due to increasing gradual climate shifts, climate-related disasters and economic instability.** This scenario projects increased likelihood of irreversible impacts, and an increasing exposure in many regions to hazards such as drought, heat and heavy precipitation.

## 3. NGFS Fragmented World scenario

**The Fragmented World scenario underscores the systemic inefficiencies and inequities of a delayed and regionally divergent climate policy action.** The Fragmented World scenario belongs to the 'Too little, too late' category of the NGFS Scenario Framework, which encompasses scenarios with a late and globally uncoordinated transition that fails to limit physical risks.

**The Fragmented World scenario assumes delayed and divergent climate policy ambition globally, leading to high physical and transition risks.** Countries with net zero targets achieve these only partially (80% of the target), while the other countries follow current policies.

**The Fragmented World scenario faces both short-term and long-term disruptions, due to uneven climate action. Fragmented climate action is more costly, more carbon-intensive, and less equitable across regions than in more coordinated transitions.** The delayed and uncoordinated action leads to emissions lock-ins, and divergent carbon and fossil fuel prices put global energy security at risk.

**The lack of stringent emission reduction despite costly, but ineffective climate policy action in some regions results in a strong increase in physical risks in the medium to long run, albeit still reduced compared to a Current Policy scenario.**

**Finally, while fragmentation and lower ambition may reduce policy costs, particularly in the short term, it also leads to higher residual damages and therefore lower benefits of climate policy.** These trends underscore the systemic inefficiencies and inequities of a piecemeal global response.

# 1. Introduction

## 1.1 Purpose of this report

**The Network for Greening the Financial System has developed long-term climate scenarios for financial institutions, aligned with latest climate impact and climate transition science. The scenarios – stemming from an ensemble of models including three Integrated Assessment Models, the macroeconomic model NiGEM, and tools for climate impact projections – provide a carefully designed set of climate transition pathways describing the interaction between the economy, energy, land and climate systems (Box 1).** With a time horizon up to 2100, they allow users to analyse the near-term implications of long-term climate change and climate policy goals. The NGFS long-term scenarios are specifically designed for central banks and supervisors to assess and quantify both transition and physical risks related to various climate policy ambitions[2]. The risk assessments can be tailored to stress-test the financial system, to inform macro-economic policy and to explore alignment of investment strategies with long-term climate goals and climate impacts. The long-term scenarios include a granular description of system transitions provided by Integrated Assessment Models (IAMs). These descriptions provide the backbone to bridge climate research with climate impact and nature-related risk analysis as well as macro-economic and finance models. They provide critical information on *"how energy, land-use, water and climate systems could transform"* and *"how much climate change could impact the economy"* under a variety of climate policy ambitions and climate change futures.

**This report aims to provide important context to NGFS members and scenario users for the assessment of financial and macroeconomic risks associated with three of the NGFS Phase V[3] scenarios: Net Zero 2050 (Section 2), Current Policies (Section 3) and Fragmented World (Section 4).** Each scenario section is divided into: 1) scenario narrative, 2) narrative quantification, 3) transition risks, 4) macroeconomic effects, 5) key findings and 6) conclusions. The narrative (Section 2.1, 3.1 and 4.1) provide a high-level description of the projected world future that aims to allow users to contextualise the scenario in terms of climate-related risks and alignment with climate policy goals. The narrative quantification describes important aspects on how IAMs translate qualitative scenario narratives into quantitative model inputs. This is followed by a description of key quantitative features of the scenario that critically determine the level of transition risks (Section 2.3, 3.3 and 4.3), as well as macroeconomic implications for the economy and the financial sector (Section 2.4, 3.4 and 4.4). The quantitative presentation of key variables on transition risks is augmented by a discussion around findings of particular relevance for each of the analysed scenarios (Section 2.5, 3.5 and 4.5).

2 See NGFS Guide to climate scenario analysis.

3 NGFS Scenarios results version 5.0 were released in November 2024.

## Box 1

### NGFS Scenario framework

The NGFS scenarios have been designed to provide a common reference framework for analysing the impacts of climate change on the economy and financial sector. The set of seven scenarios available in the NGFS phase 5 are categorised in four categories: orderly transition, disorderly transition, hot world and too little, too late. Figure 1.1 represents a range of levels of policy ambition, coordination and timeline for the policy implementation, and technology choices. Read more in the NGFS Phase V Technical documentation.

Figure 1.1 **Matrix of transition and physical risks in the NGFS scenario framework**

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

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

- Lower risk
- Moderate risk
- Higher risk

- The impact of CDR on transition risk is twofold: on the one hand, low levels of CDR imply an increase in transition costs, as reductions in gross emissions should be obtained in a different way; on the other hand, high reliance on CDR is also a risk if the technology does not become more widely available in the coming years.
+ Risks will be higher in the countries and regions that have stronger policy. For example, in Net Zero 2050, various countries and regions reach net zero GHG by 2050, while many others have emission of several Gt of $CO_2$eq.
^ This assessment is based on expert judgment based on how changing this assumption affects key drivers of physical and transition risk. For example, higher temperatures are correlated with higher impacts on physical assets and the economy. On the transition side economic and financial impacts increase with a) strong, sudden and/or divergent policy, b) fast technological change even if shadow carbon price changes are modest, c) limited availability of carbon dioxide removal meaning the transition must be more abrupt in other parts of the economy, and d) stronger policy in those countries and/or regions.

## 1.2 Note on physical risks and upcoming updates

The NGFS long-term scenarios framework provides estimates of physical risks from climate change and their relative macroeconomic impacts. The NGFS framework to assess physical risks includes: direct aggregate GDP impacts assessed with econometric damage estimates, the biophysical risk indicators provided in the Climate Impact Explorer (CIE) and the economic assessment of selected extreme events with NiGEM.

A key resource for analysing physical risks and climate change impacts is the Climate Impact Explorer (CIE), which has been updated in October 2025. The CIE explores projected climate impacts across climate scenarios, and in particular the NGFS scenarios. It features a large range of climate and biophysical indicators on country level, covering both slow-onset as well as extreme events. The "report on physical risks in the updated Climate Impact Explorer" is dedicated to describing the tool updates and results, and thus are not discussed in details in this report. The NiGEM assessment of extremes was not updated in Phase V, but selected new estimates will be made available in Phase VI.

The NGFS informs users that the academic paper underpinning the economic damage estimates from physical risks in Phase V, Kotz *et al.* (2024), has received critiques post-publication in Nature (for more detail, please refer to the notice at the start of this document).

The next vintage of the NGFS long-term scenarios will be released in 2026, as the 2-year NGFS scenario design cycle allows for implementation of modelling improvements for the next phases. NGFS Phase VI will include the update of physical risks estimates and related macroeconomic damages, as well as updated climate policy and recent geopolitical developments.

# 2. Net Zero 2050: narrative and key findings

## 2.1 Narrative of the Net Zero 2050 scenario

*Short summary: The Net Zero 2050 scenario limits global warming to 1.5 °C by 2100 through stringent climate policies and innovation, reaching global net zero $CO_2$ emissions around 2050. This scenario assumes that ambitious climate policies are introduced immediately. Carbon sequestration technologies are used to accelerate the decarbonisation but kept limited and broadly in line with sustainable levels of bioenergy production. The scenario gives at least a 50% chance of limiting global warming to below 1.5 °C by the end of the century, with a temporary overshoot of up to 0.2 °C around mid-century. The overshoot has increased compared to previous vintages of the Net Zero 2050 scenario due to continued high global emissions in recent years. Physical risks are relatively low but transition risks are medium to high.*

| Warming at end of century[4] | Peak warming | Policy reaction | Technology change | CDR | Regional policy variation | Physical risks |
|---|---|---|---|---|---|---|
| 1.35-1.45 °C in 2100 | 1.65-1.70 °C in peak year 2040-2050 | Immediate as of 2025, as smooth as possible | Fast change | Medium-high use | Medium variation | Substantially reduced |

### Climate policy ambition and action

**The Net Zero 2050 scenario assumes that ambitious climate policies are introduced immediately and worldwide to achieve the long-term goal of limiting warming to below 1.5 °C by 2100. The transition to net-zero emissions by 2050 relies on coordinated and collective effort, political stability and on prioritisation of the climate policies on the global and national policy agendas.** The Net Zero 2050 scenario describes a World in which international cooperation and geopolitics allows for implementation of Net Zero pledges in some countries, while the level of commitment remains uneven across regions. Countries that made a political commitment to a net zero target (defined before end of March 2024) meet this target before or after 2050[5]. As a result of this worldwide policy push, the scenario reaches global net zero $CO_2$ emissions around 2050 and moves to net negative $CO_2$ emissions thereafter. Existing national emission reduction targets for 2030 and mid-century are also reached in the scenario. The global policy push is reflected in an immediate sharp increase of the carbon price (reaching globally 100-260 US$2010/t $CO_2$ in 2030, and 500-1,250 US$2010/t $CO_2$ in 2050). The carbon price serves as a proxy for the strength of a set of well-balanced set technology and sector policies to achieve the desired emissions reductions. Given this rapid increase, the scenario provides information on the economic and financial stress that would be imposed by immediate global action on the long-term goal of limiting warming 1.5 °C.

### Socio-economic developments

**Like all other NGFS scenarios, the Net Zero 2050 scenario assumes social, economic, and technological developments that reflect trends observed during the first two decades of the 21st century**, following the assumptions of the Shared Socio-economic Pathway 2 (SSP2)[6]. Countries and international relations are relatively stable, markets are globally connected, although some barriers remain, development and economic growth proceed unevenly (with a global annual average growth rate of 4% for 2020-2030 and 3% for 2030-2050), and global population growth is moderate and levels off at 10 billion people in the second half of the 21st century. Multilateral institutions make only slow progress towards achieving

4 End-of-century and peak warming values represent the results range across IAMs, and the 50th percentile of the surface temperature variation (AR6 Surface Temperature (GSAT)|MAGICCv7.5.3|50.0th Percentile).

5 Net-zero targets as published by the UNFCCC as of March 2024 for the following countries: Argentina, Australia, Brazil, Canada, Colombia, EU + UK, Japan, New Zealand, South Africa, South Korea and USA in 2050; China, Indonesia and Russia in 2060; and India in 2070. Some jurisdictions such as the US, EU, UK, Canada, Australia, and Japan reach net zero for all GHGs.

6 Riahi *et al.*, 2017, O'Neill *et al.*, 2017.

the sustainable development goals and environmental systems continue to degrade gradually. Technological development is moderate. The collective and ambitious action on climate change and associated transformation of energy and land use constitutes a break from these moderate and uneven trends, but such trends persist in other sectors.

## Energy transition and technology trends

**Net Zero 2050 relies strongly on decarbonising the electricity supply, increasing electricity use, increasing energy efficiency, and developing new technologies to tackle hard-to-abate emissions.** Reducing dependencies to fossil fuels drives the future of energy systems and services in industrialised countries which have defined net zero commitment. The use of carbon dioxide removal (CDR) is significant, however CDR is constrained to remain broadly in line with sustainable levels of bioenergy production.

## Food systems and land use transition

**Economic development and population growth are transforming global food systems and land use, creating complex trade-offs between nutrition, energy production, and climate goals.** In developed countries, continuing diet patterns and trends of overconsumption and food waste strain resources, while in many emerging economies, rising incomes are driving higher calorie consumption – especially from meat and dairy products – which in turn increases demand for feed crops and puts greater pressure on agricultural land. Under the Net Zero 2050 scenario, arable land is also diverted to bioenergy crops and afforestation for carbon removal, intensifying competition between food security, energy production, and carbon dioxide removal strategies. To navigate these competing demands, agriculture becomes more productive through sustainable intensification and innovative technologies that boost yields without further expanding cropland.

## Physical risks and climate change impacts

**Most regions are projected to experience increased exposure to climate hazards such as heat stress, drought and heavy precipitation risks. However, the physical risks and related economic climate damages remain substantially reduced compared to any less ambitious pathway, given the immediate and steep reduction in emissions.** A certain level of residual damages is already locked in in the near-to-medium term and also remains in the long run. This requires adaptation measures and policies in parallel to mitigation efforts, which together can place a burden on development. Climate impacts might also affect mitigation measures, e.g. through water availability, disruptions of grids from extremes or increasing energy demand for cooling. Finally, the emission pathway leads to a mid-century temperature peak above 1.5 °C with a decline afterwards. This raises the question of reversibility of some impacts after the peak, for example locked-in sea-level rise, impacts in biodiversity or health.

## Economic transition

**Immediate and worldwide climate action – implemented via rapidly increasing (shadow) carbon pricing – raises energy costs in the short term which causes an initial strain on the economy through decreased demand and market losses.** This is accompanied by modest increases in inflation and unemployment before returning to previous trends. Carbon revenue recycling can offset some of the negative impacts on economic growth and reduce unemployment. Inflationary pressure and employment effects differ across countries. Policy interest rates spike initially, and long-term interest rates tend to increase, reflecting the inflationary pressure created by mitigation policies.

## A transition as orderly as still possible

**The Net Zero 2050 scenario belongs to the orderly transition category in the NGFS scenario framework, assuming that ambitious climate policies are introduced early and effectively on a global scale so that climate change and associated physical and transition risks are relatively limited.** The scenario is characterised by medium-to-high transition risks. Global greenhouse gas emissions, and in particular $CO_2$ emissions, have remained stubbornly high over the past five years after rebounding from a 6% drop in 2020 due to the COVID-19 pandemic. As a result, the annual vintages of the NGFS Net Zero 2050 scenario from Phase I (2020) to Phase V (2024) have grown less orderly, as the continued high emission trajectories have to be followed by ever more disruptive emissions reductions to still achieve the mid-century target. To achieve these emission reductions, (shadow) carbon prices have to reach higher levels than those projected in previous vintages – especially from 2030 onwards.

**In consequence, this scenario shows a peak warming around 1.65-1.7 °C (exceeding by 0.1 °C the peak warming in the Net Zero 2050 scenario of NGFS Phase IV), before returning to below 1.5 °C by the end of the century.**

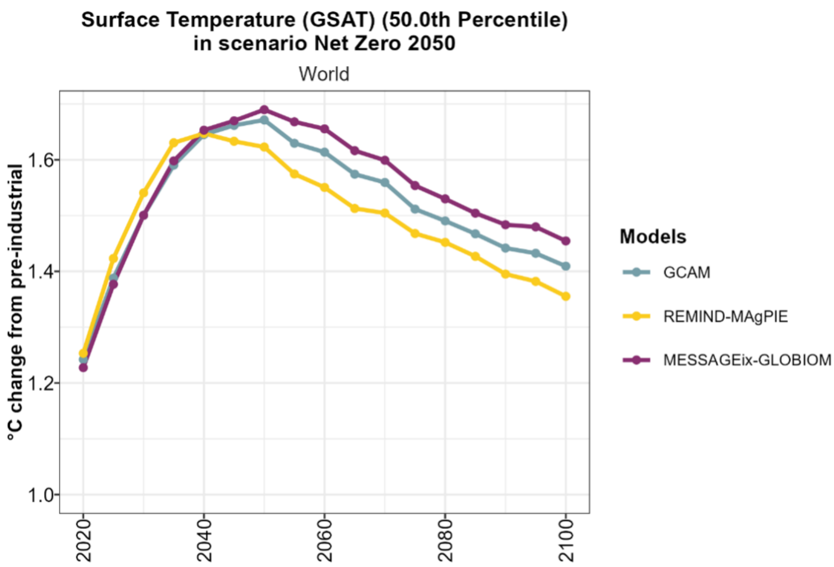
**A fully orderly transition is no longer available.** The Net Zero 2050 scenario is therefore not only relevant for the assessment of policy and investment alignment, but also for stress testing. In comparison, the Low Demand scenario features a more orderly transition, as a significant behavioural change in terms of energy consumption alleviates the decarbonisation efforts.

## 2.2 Narrative quantification

Robust SSP and scenario frameworks allow the translation of the qualitative narrative into quantitative assumptions to the Integrated Assessments Models[7]. The implementation of the following parameters are essential to the Net Zero 2050 scenario.

- **SSP2 assumptions on population and GDP baseline are reflected as exogenous parameters in IAMs.** The GDP then changes (semi-)endogenously when affected by energy transition costs, and by integrated damages when they are included. SSP2 assumptions enforce moderate rates of socio-economic development on average globally, and moderate convergence between low and high income countries (Annex A).
- **Policy commitments are translated into constraints on the emissions and technology targets, and are reflected in the shadow carbon price.** A carbon budget is set to reflect the policy ambition, and in the case of Net Zero 2050, is aligned with the goal of limiting global warming to 1.5 °C by 2100 (with 50% likelihood) (Figure 2.1).
- **Climate change directly affects physical risks and impacts on natural and human systems, and therefore socioeconomic developments.**
- **Collaboration between countries impacts how smoothly the transition can occur.** The Net Zero 2050 scenario has moderate regional differences in policy ambition, which alters the coordination, as some countries will implement a faster transition (at higher transition risks), and others will take less or slower mitigation action (causing higher physical risks globally).
- **Ambitious assumptions on innovation together with growth constraints define the technology deployment:** the Net Zero 2050 scenario exhibits set with fast technological change (for both land use and energy-related innovations). Additionally, CDR is an important technology lever to reach emission goals. The Net Zero 2050 allows for medium-to-high use and fast deployment of CDR.

Figure 2.1 **Surface Temperature Variation**
*(MAGICCv7.5.3, 50.0th Percentile)*




7 Fricko *et al.*, 2017.

However, modelling exercises show there are many ways to reflect complex systems, and many strategies to implement a transition. IAMs characteristics and assumptions influence their future projections and pathway towards reaching emission targets. Key assumptions are summarised in the "NGFS Note on Key assumptions, 2025", and more technical details on the models are available in the "NGFS Technical documentation, 2025". Where relevant, this report highlights how model results compare and what drives the differences.

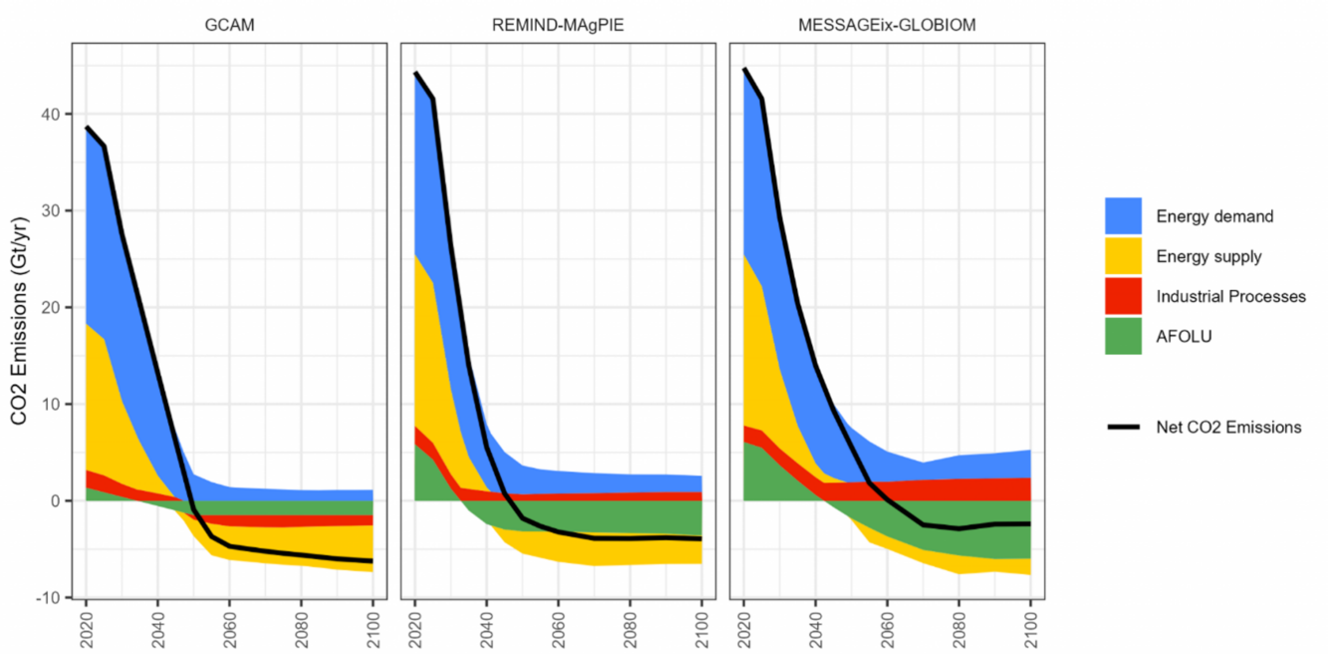
## 2.3 Transition risks

This section highlights key characteristics of the climate transition in the Net Zero 2050 scenario, that are of particular relevance for describing the scenario implications in various sectors, as well as for using this scenario for risk assessments. NGFS long-term scenarios offer a multi-model study that is needed to derive robust insights in long-term scenarios. In this section, results from the three IAMs are shown and compared. Key similarities and differences between IAMs are highlighted and crossed with the models own characteristics and assumptions.

### 2.3.1 Emissions trajectory

With stringent and immediate policy action for climate neutrality, all three models show that global $CO_2$ emissions are very quickly reduced in the first half of the century, from around 40Gt/year in 2020 to around 20Gt/year in 2035 (Figure 2.2). The emission reduction curve and timing of reaching neutral emissions varies across models: REMIND-MAgPIE follows a quick plunge and reaches net-zero around 2045, while MESSAGEix-GLOBIOM takes a more gradual approach and reaches neutrality in 2060. A driver to this timing difference is due to how models implement net-zero emission constraints, and specifically the flexibility window around the target year. Most $CO_2$ emissions from the energy sector are avoided or captured by 2050, and negative emissions in the AFOLU sector (agriculture, forestry and other land use) compensate for residual emissions after 2050. All three models assume that yearly emissions will remain constant in the second half of the century. Major decarbonisation efforts are implemented by 2050 across all energy demand and supply sectors. Sectoral and regional variations are discussed further in this report (Section 2.5.2), as well as the role of carbon sequestration to achieve emissions reductions (Section 2.5.3).

Figure 2.2 **Yearly Net Emissions|$CO_2$ (Mt $CO_2$ /yr)**[8]




8 Gross $CO_2$ emissions would allow for better specification of the sectoral transition, in particular to represent the share of carbon capture and storage in energy and industry sectors. These variables will be reported in the next NGFS phase, following the IAM community initiative of aligning their common variables definitions.

### 2.3.2 Primary energy mix

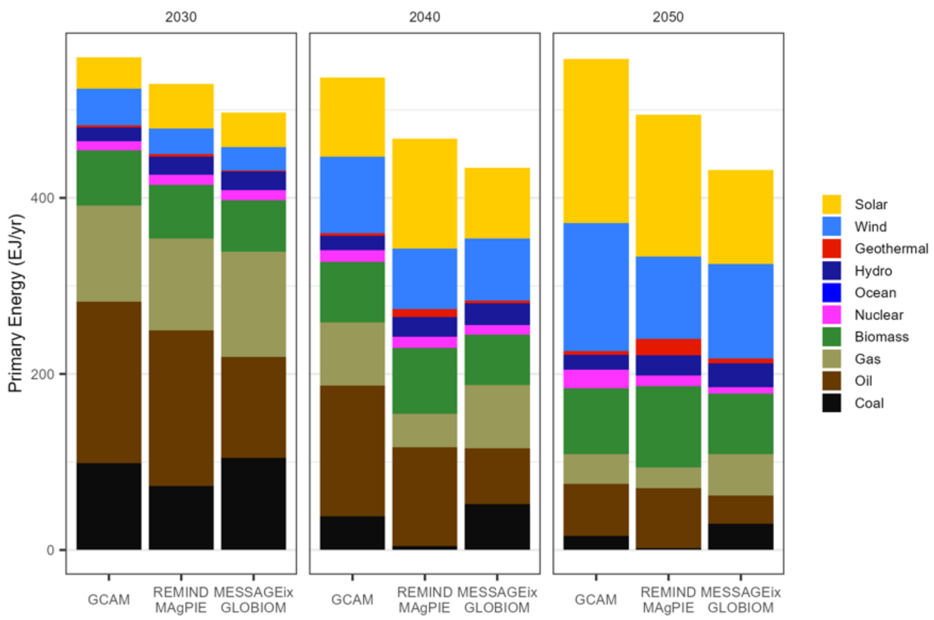
Globally, the Net Zero 2050 scenario shows an immediate and rapid decrease of fossil fuel consumption (oil, coal and gas), and subsequent increase in renewable energy use (mostly solar and wind resources) (Figure 2.3). The deployment of renewables and increasing electrification leads to higher energy efficiency, which causes a temporary decline in primary energy in the near-term despite increasing GDP and service provision, as reflected by all three IAMs.

All models align on renewables becoming a dominant share of the total primary energy by mid-century: the combined share of solar, wind and biomass reaches 60-70%. The use of biomass steadily increases to 100EJ/year for all models[9]. REMIND-MAgPIE and MESSAGEix-GLOBIOM project up to 50EJ/year from geothermal resources in 2100, while GCAM observes a similar production from nuclear energy. All models show a residual use of conventional and unconventional oil and gas, to the range of 30-100 EJ/year by 2050. GCAM generally uses a higher amount of primary energy, due to optimistic assumptions on renewable technology costs and a high income elasticity.

### 2.3.3 Electricity and final energy mix

Under the Net Zero 2050 scenario, the transformation of the global electricity production system is particularly fast and profound. Electrification becomes a major measure for decarbonisation, as (i) electricity supply decarbonises and grows considerably (multiplied by a factor 2.3 to 4 between 2025 and 2050, see Figure 2.4) and (ii) electricity assumes the largest share of final energy by 2050 (Figure 2.5). As the installation of renewable capacity accelerates globally, solar, wind and hydro power technologies supply more than half of the total production already by 2030. Nuclear electricity remains steady, while fossil-fuel electricity generation reduces dramatically by 2040. Such rapid technology shift comes with transition risks, due to decreasing revenues for fossil generators, a substantial reallocation of employment within the energy sector and high investment needs for the transition. The impact on energy prices is discussed in Section 2.3.5.

Figure 2.3 **Primary energy, World**




9 When produced in a sustainable way, biomass is renewable on a short time scale. Bioenergy accounts for zero emission because the carbon that it releases has been previously absorbed during the growth of the biomass. CCS applied on bioenergy therefore leads to negative emissions.

Figure 2.4 **Sources of Electricity, World**

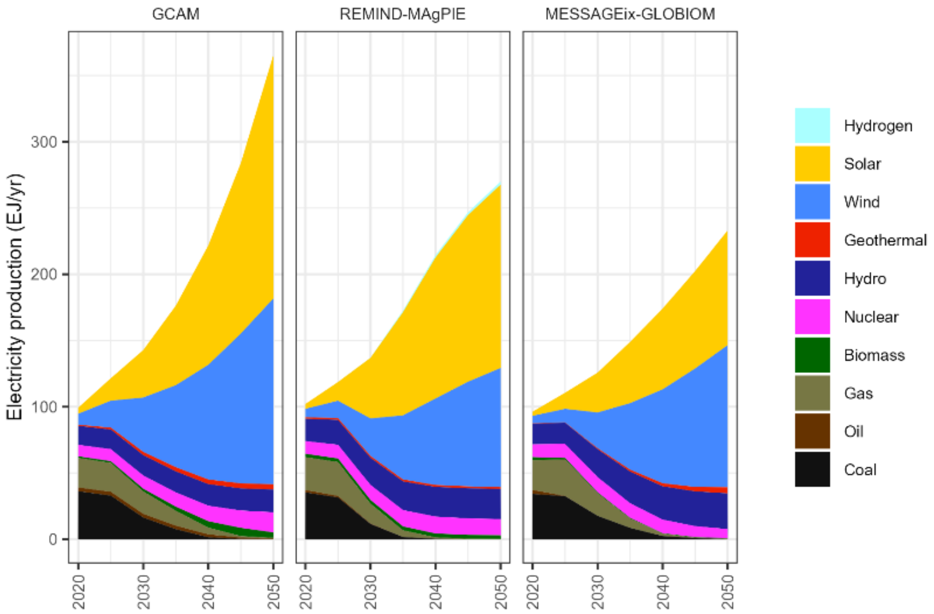
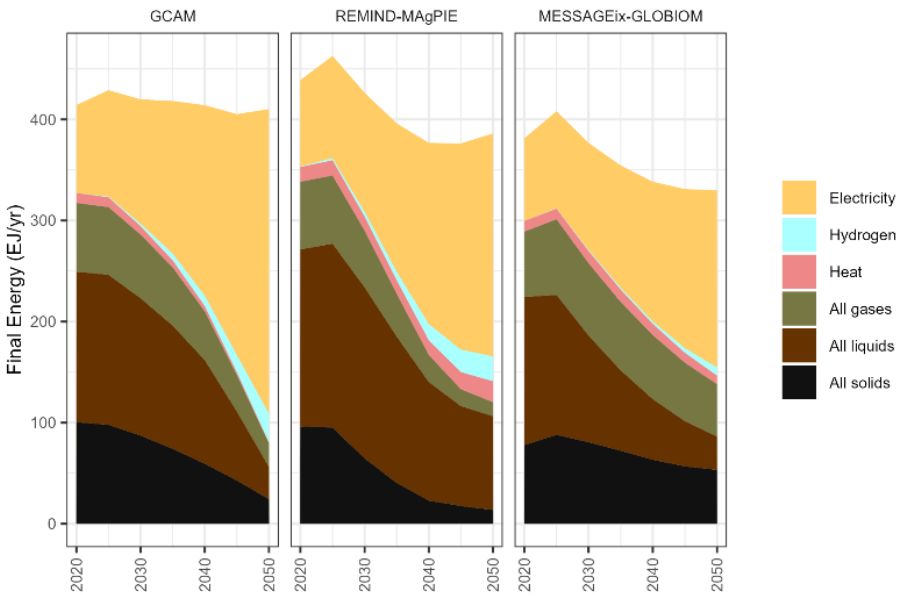


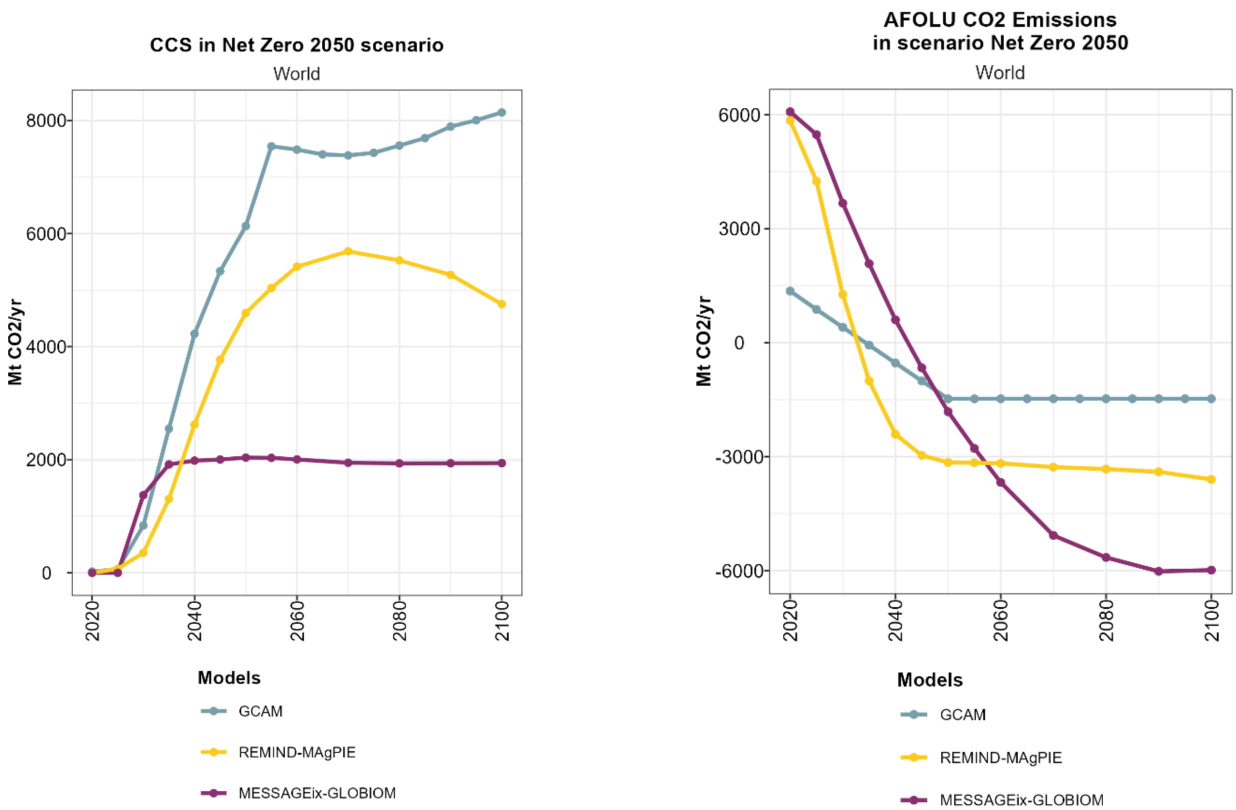

Figure 2.5 **Final Energy per Carrier, World**



## 2.3.4 Carbon sequestration

Carbon sequestration includes processes to *capture* $CO_2$, either at the outlet of a plant or through biomass growth, and to *store* the $CO_2$ into geological deposits (such as in depleted oil and gas fields) or through land-based sinks (such as afforestation). In the Net Zero 2050 scenario, carbon capture and storage (CCS) contributes to compensate for residual $CO_2$ emissions after 2050: all three models agree on a similar increase until 2040, and on a range of 2-6Gt $CO_2$ per year in 2050 (Figure 2.6). From land-based sinks, models project a continuous decrease in net $CO_2$ emissions, albeit at different paces. Models combine different shares of carbon storage solutions to compensate for residual $CO_2$ emissions (see 3.2.1). GCAM takes more optimistic assumptions on CCS deployment, while MESSAGEix-GLOBIOM tends to rather compensate residual emissions with land-use carbon sinks. In total, land-based and technological carbon sequestration sums to around 9Gt of $CO_2$ per year in the second half of the century. This represents a medium-high use compared to less ambitious NGFS scenarios (e.g. the Current Policies scenario sees CCS capacities to only 0-1.2Gt $CO_2$ /year in 2050). Section 2.5.3 of this report discusses in more detail the role of carbon dioxide removal and CCS in a global net zero context.

Figure 2.6 **Carbon Sequestration|CCS (left), Emissions|$CO_2$|AFOLU (right)**

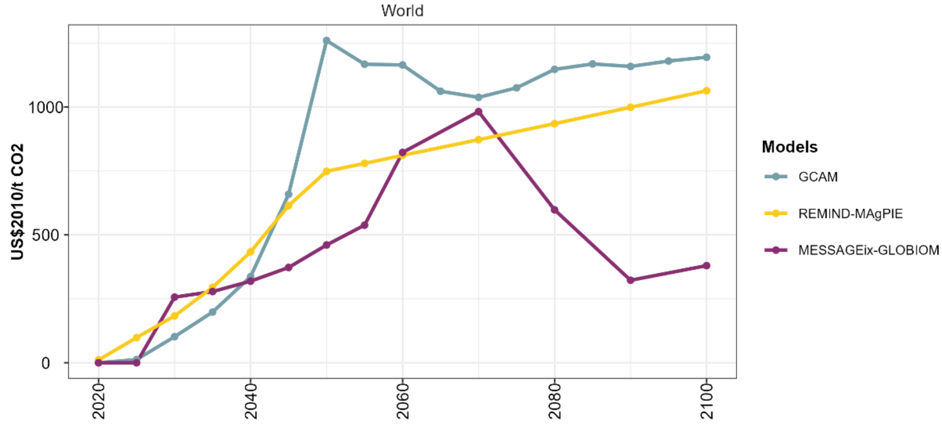



## 2.3.5 Carbon, energy and agricultural prices

### Carbon prices

The main policy lever driving the transition is a (shadow) carbon price that (i) represents the marginal cost of abatement of carbon emissions and (ii) is a proxy for overall climate policy ambition and effectiveness, accounting for a variety of real-world climate policies (carbon tax, subsidies, environmental standards, etc.). Under the Net Zero scenario, the carbon prices lead to achievement of climate policy goals defined in the scenario: net-zero emissions for countries that have made such commitments, as well as a global net-zero target around 2050. All three IAMs show a sharp increase of the shadow carbon price from 2025 (immediate action), reaching 100 to 250US$/t $CO_2$ in 2030, and 320 to 430US$/t $CO_2$ in 2040 (Figure 2.7). Section 2.4 and 2.5.1 of this report will explore the regional differences.

Figure 2.7 **(Shadow) Price|Carbon in scenario Net Zero 2050**



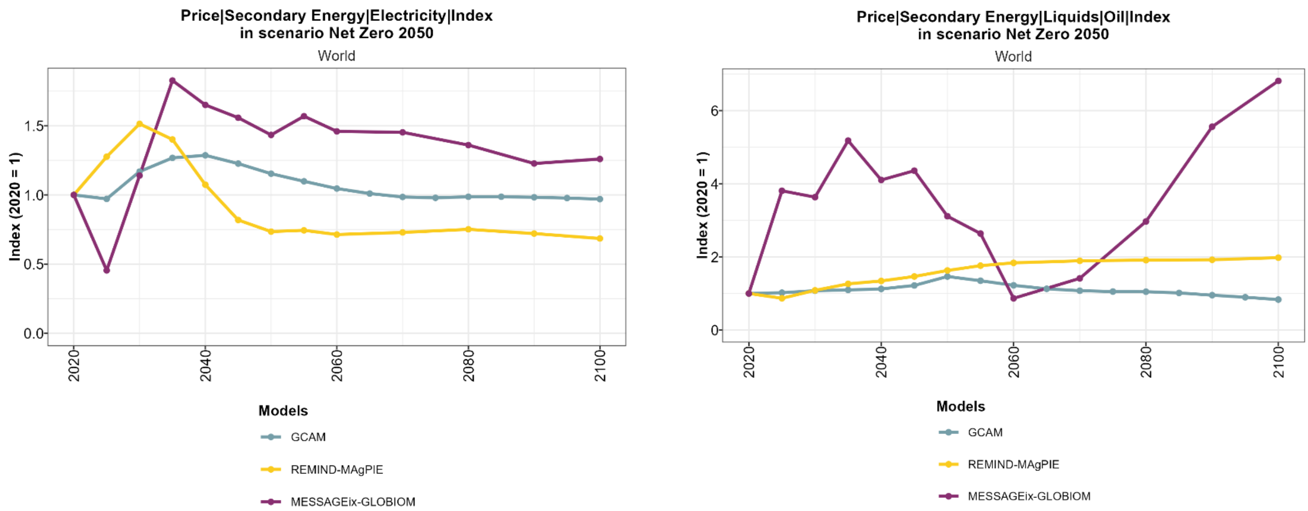

The IAMs expect a global carbon price of around 1,000 USD in 2070, but the steepness of the price curve varies across models. IAMs take different approaches to interpolate the curve, and to consider the effects of marginal abatement costs and technology changes. To reach emissions targets, REMIND-MAgPIE assumes the carbon price to follow an exponential growth from 2020 to the target year, and increases linearly after. With MESSAGEix-GLOBIOM, once net-zero targets are met, regional carbon prices tend to decline (after India's net zero target in 2070).

## Energy prices

Secondary energy prices represent energy costs as the gross price paid by large scale consumers, such as industrial actors or energy suppliers. All IAMs provide price information with a 5-year timestep, indicating the trend for energy prices until the end of the century. The price at the second energy level (i.e. Price|Secondary Energy|Oil) includes the costs of extraction, transport and transformation as well as the carbon tax (applied when converting from primary to secondary energy).[10]

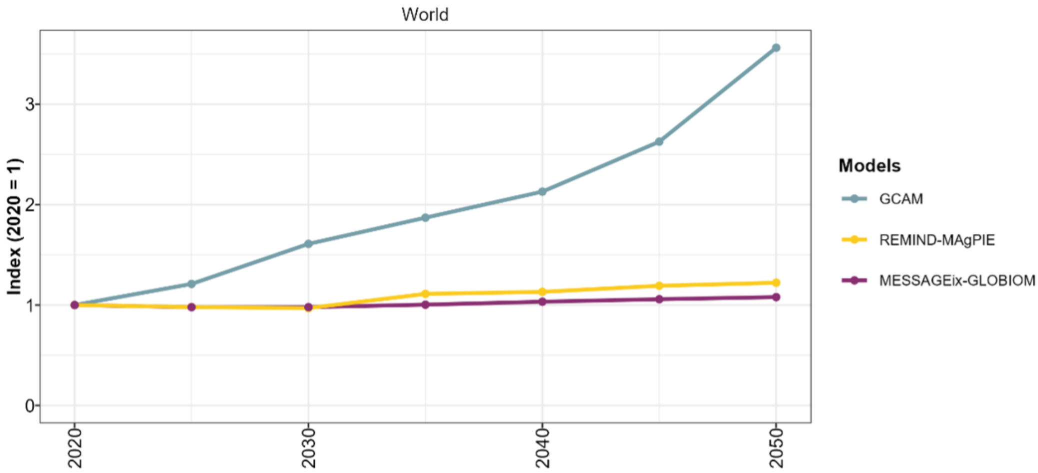
Under the Net Zero 2050 scenario, significant investments must be channelled to renewable energy infrastructure to decarbonise the energy system, while fossil assets phase out. REMIND-MAgPIE and GCAM see the effect of such investments on secondary electricity prices (Figure 2.8, left), as a temporary increase until 2030. The models follow a decreasing trend for electricity prices, as renewable energy

Figure 2.8 **Secondary Electricity (left) and Oil (right) index prices**




10 Secondary energy prices provided by IAMs are based on economics fundamentals and driven by extraction costs. They may differ from prices provided by the NiGEM macro-economic model (in particular in the short-term), which takes different assumptions to represent demand and supply dynamics. The use of either results depends on the case study and its assumptions. More information on the market assumptions of IAMs and the NiGEM model can be found in the Note on Key assumptions and in the Technical documentation.

Figure 2.9 **Price|Agriculture|Non-Energy Crops|Index in scenario Net 2050**




is low-carbon and has low operational costs compared to fossils. MESSAGEix-GLOBIOM prices behaviour in the near-term is due to its region-specific assumptions of coal availability after COVID (slight revival) in 2025.

Fossil energy price trends vary across models, as they depend on fossil extraction assumptions and carbon price defined by each model (Figure 2.8, right). REMIND-MAgPIE expects carbon-intensive energy prices (oil, coal and natural gas) to increase. For instance, oil prices increase by 60% between 2020 and 2050 due to carbon pricing and depletion of oil fields that have lower extraction cost. MESSAGEix-GLOBIOM oil prices show an increasing trend in the second half of the century, due to the model's sensitivity to increasing carbon prices in the dominant oil-exporting regions.

### Agricultural prices

As the Net Zero 2050 scenario projects non-negligeable land use changes, it is important to consider the potential impacts on agriculture prices. The models project notably different trends in crops commodity prices (excluding energy crops): REMIND-MAgPIE and MESSAGEix-GLOBIOM both anticipate relatively stable prices – implying muted inflationary pressure from food – whereas GCAM projects the agricultural price index to roughly double in 2035 and more than triple in 2050.

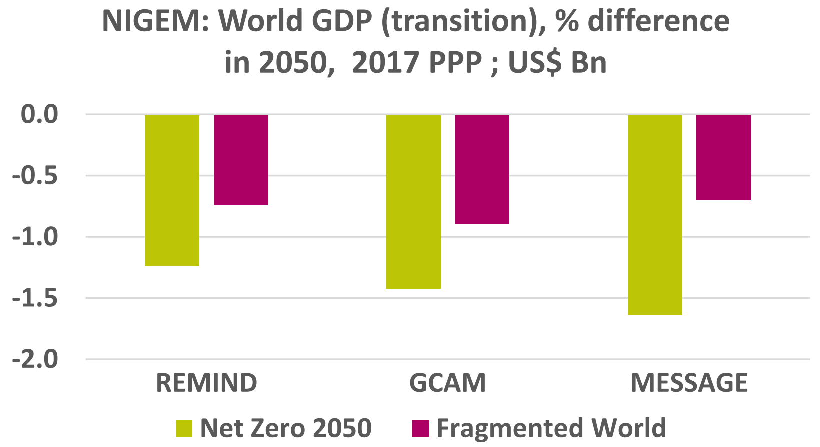
In the context of the Net Zero 2050 scenario, GHG pricing plays a key role in shaping the agricultural commodity prices. Deforestation and related $CO_2$ emissions are effectively prevented even through moderate GHG tax levels, which restricts the further expansion of arable land. This intensifies competition of existing agricultural land, which must now meet growing food and feed demand while also purposing carbon sequestration through afforestation and bioenergy crops production. Emissions from crop production (e.g. from nitrogen fertiliser use) can be reduced at relatively moderate cost though improved practice of plant nitrogen uptake efficiency. In contrast, non-$CO_2$ emissions from livestock production systems (e.g. methane from enteric fermentation in cattle) remain difficult and costly to mitigate amid growing global (region-specific) demand for meat and dairy products.

To balance land constraints and rising demands, sustainable investments in agricultural productivity are needed – such as improving crop yield levels, expanding irrigation, and enhancing agricultural management more efficiently. The modeling assumptions about how these investment costs are repaid (i.e. though annuity rates over time) help buffer their impact on food prices, contributing to price stability (c.f. Figure 2.9, REMIND-MAgPIE and MESSAGEix-GLOBIOM projections). GCAM, however, assumes a direct effect of emission prices onto costs for agricultural production, leading to much higher projected increases in the agricultural price index for crop commodities under the same scenario.

## 2.4 Macroeconomic effects from transition risks

The following section presents results and trends for key macroeconomic variables from the model NIGEM. Regional GDP damages from transition risks are discussed and compared with other scenarios from the NGFS framework.

Figure 2.10 **World GDP losses due to transition risks wrt baseline levels in 2050 (NiGEM output)**




In the Net Zero 2050 scenario, another important component of macroeconomic impacts is due to the physical damages associated with the emissions trajectory and global temperature rise (see Sections 1.2 and 2.2).

For the calibration of climate scenarios, NiGEM takes inputs from different modules of the NGFS modelling framework. The trends for all macroeconomic variables (from NiGEM) in this section are presented relative to a climate neutral forecast baseline (see Annex B). The IAMs provide data for a new baseline forecast and climate transition risk scenarios.

### 2.4.1 GDP damages from transition risks

**The Net Zero 2050 scenario presents relatively low physical risks but medium to high transition risks as compared to a disorderly transition scenario such as Fragmented World[11].** As shown in Figure 2.10, GDP losses due to transition risk are projected to be relatively higher in Net Zero reaching up to -1.6% by 2050, but only remain below -1% in the Fragmented World scenario.

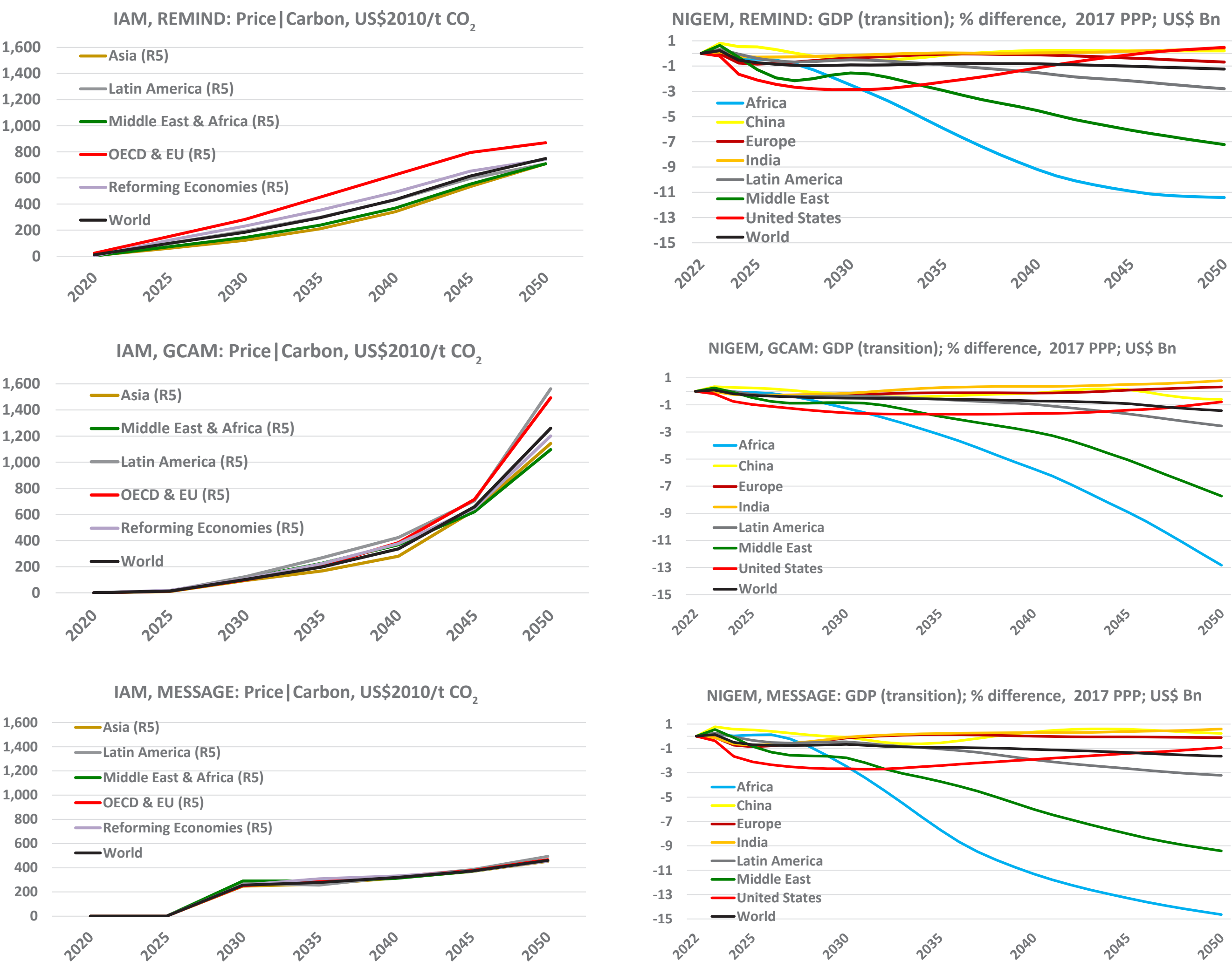
#### GDP impact across jurisdictions

**GDP impact of transition risk varies across jurisdictions depending on how ambitious the climate transition policy is or how stringent the carbon prices are, compared to the current policy environment.** Figure 2.11 shows carbon prices and GDP impacts from transition across key regions. Across the three models, R5 OECD+EU region experiences one of the steepest increases in carbon prices, ranging from \$450 to \$1,500 per ton of $CO_2$ by 2050, while Asia, the Middle East and Africa show relatively lower increases in carbon price (\$450 to \$1,200 per ton of $CO_2$[12]). As a result, Asian economies such as China and India face one of the lowest declines in GDP, ranging from -0.5% to 1% across the models by 2050. While the US and Europe experience a relatively higher decline with GDP impacts ranging from -1% to 0.3% across the three IAMs. The Middle East and Africa being net exporters of fossil fuels are impacted by the decline in demand for fossil fuels, thus experiencing one of the highest declines in GDP despite having one of least stringent carbon prices.

11 The Fragmented World scenario assumes delayed and divergent climate policy ambition globally, leading to high physical and transition risks. Countries with net-zero targets achieve these only partially (80% of the target), while the other countries follow current policies (see Section 4).

12 Carbon prices figures quoted in this section are IAMs outputs, and represent the range across regions and models.

Figure 2.11 **Regional carbon prices (IAM outputs) and GDP losses from transition risks (NiGEM output)**




## 2.4.2 Inflationary strain and unemployment

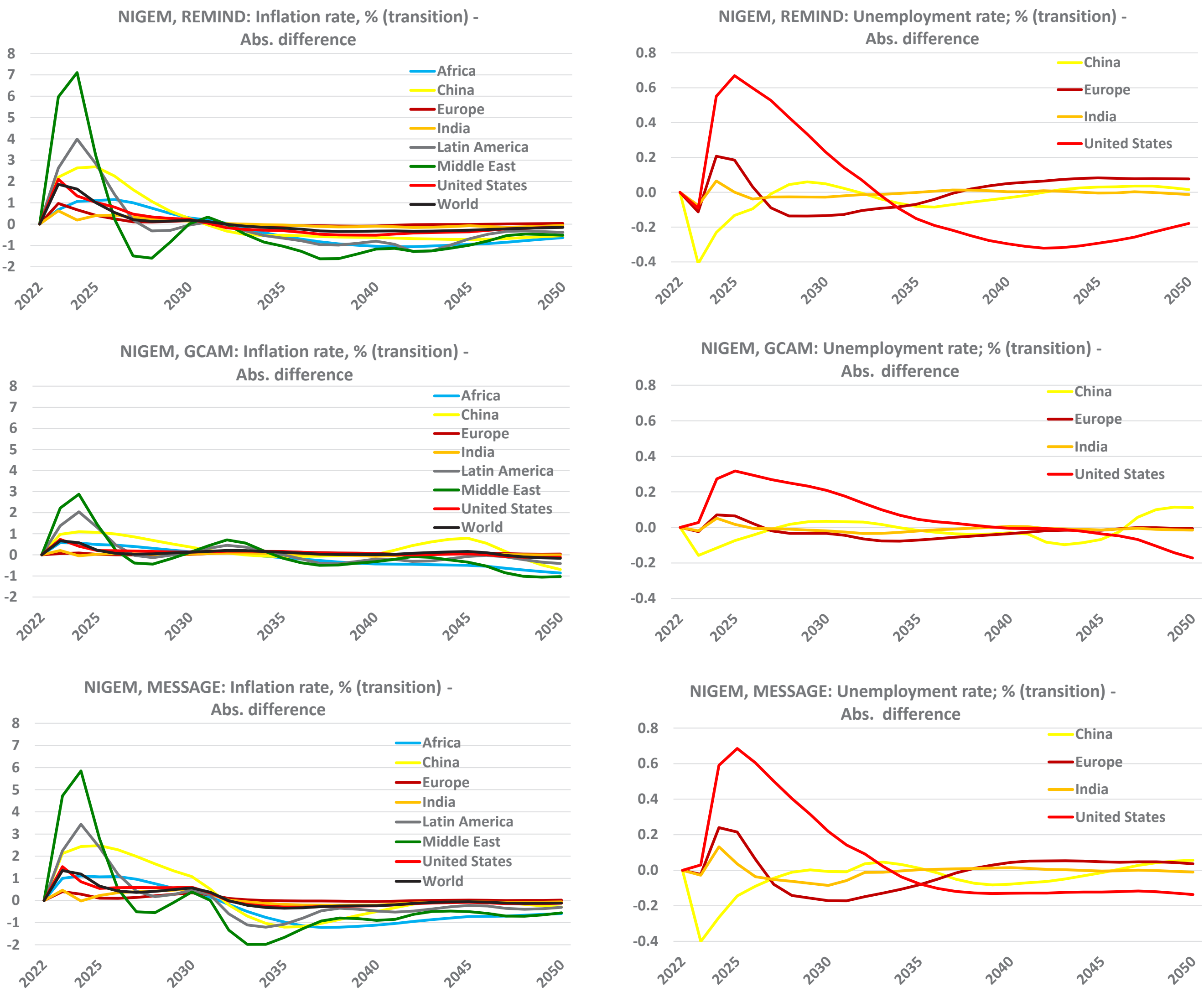
Regions face an initial cost-push inflationary strain due to immediate transition policy action as carbon pricing raises energy costs in the short term. **These inflationary effects, combined with the aforementioned GDP losses, are also accompanied by a rise in unemployment.** Inflation and unemployment trends vary across regions. Inflationary pressures across regions depend on the amount of carbon tax revenue collected and recycled[13] into the economy through government investment and debt. On the other hand, as final energy demand declines in Net Zero (relative to current policies), this could potentially offset inflationary pressures. Finally, the decline in the demand for fossil fuels and energy mix shifts over time cause fossil fuel primary energy prices to decline in the Net Zero 2050 scenario relative to current policies. For regions such as China and India that are net importers of fossil fuel primary energy, this could further offset inflation. Figure 2.12 shows the inflation and unemployment trends across regions. The Middle East faces the maximum initial spike in inflation (3 to 7pp above baseline across the three IAMs in 2024, while in comparison the initial spike is lower in Europe and the US (0.05 to 2pp). This is primarily because the Middle East is projected to experience the highest increase in carbon tax revenue in 2020-2025 over current policies, while the US and Europe have one of the lowest increases.

13 In the Net Zero scenario and other orderly scenarios, taxes are recycled and split evenly between government investment and government debt.

While India and China also have a similar increase in carbon tax revenues as the Middle East, the initial inflationary impact is lower for them[14]. The decline in fossil fuel primary energy prices offsets the inflationary impact for India and China as they are net fossil fuel importers. After the initial spike in 2025, even though carbon tax revenues in the net zero scenario continue to increase, the pace of growth slows down relative to current policies. As final energy demand also continues to decline, this eases inflationary pressures over time.

Unemployment spikes in 2025 across the US, Europe and key Asian economies such as India. The US faces the highest spike ranging from 0.3pp to 0.7pp above the baseline levels, while China sees a decline in unemployment, but it increases in the medium term.

Figure 2.12 **Inflation and unemployment rates impacts due to transition risks (NiGEM output)**



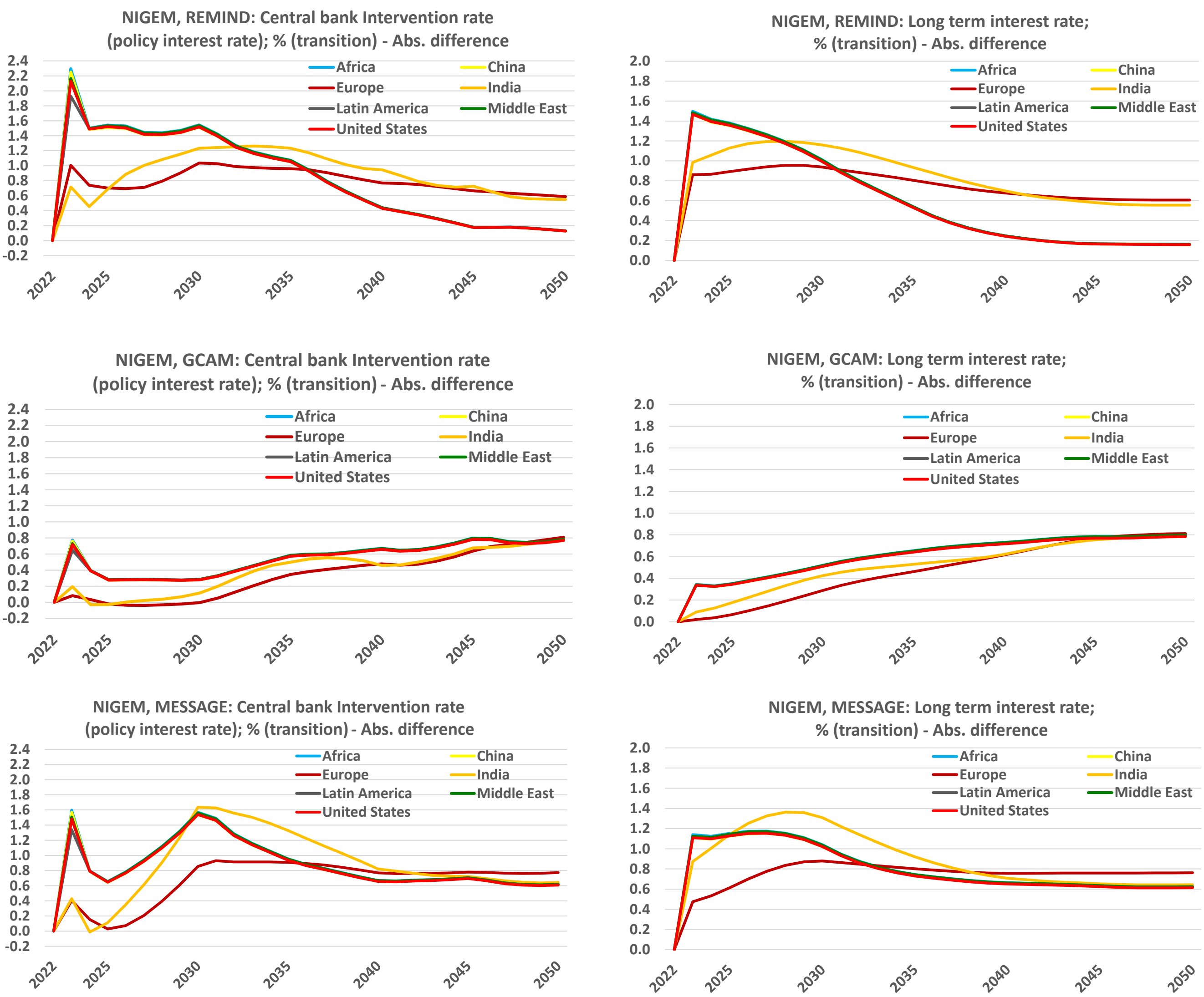

14 Under the Net Zero 2050 scenario, government tax revenue from carbon pricing increases drastically between 2020 and 2025 – by nearly 3,000% in the Middle East, 2,400% in India, and 1,200% in China, compared to current policies.

### 2.4.3 Policy interest rates and long-term interest rates

**Policy interest rates spike initially to curtail the sharp initial inflationary pressures.** The US, Middle East, Africa and Latin America face the steepest spike in policy rates, ranging from 0.8pp to 2.5pp above baseline levels in 2023, while the spike is relatively lower across regions such as Europe and India. This trend is consistent with the initial inflationary spike across regions where Europe and India face a relatively lower spike in inflation.

**As a result of the increase in policy interest rates, long-term interest rates also rise, reflecting the inflationary pressure created by shadow carbon price as well as the increased investment demand that the transition spurs on.** As shown in the plots below, the regional variation in the trends of long-term interest rates is consistent with that of policy rates, with Europe and India reflecting the lowest increase in policy rates.

Figure 2.13 **Long-term and policy interest rates impacts due to transition risks (NiGEM output)**

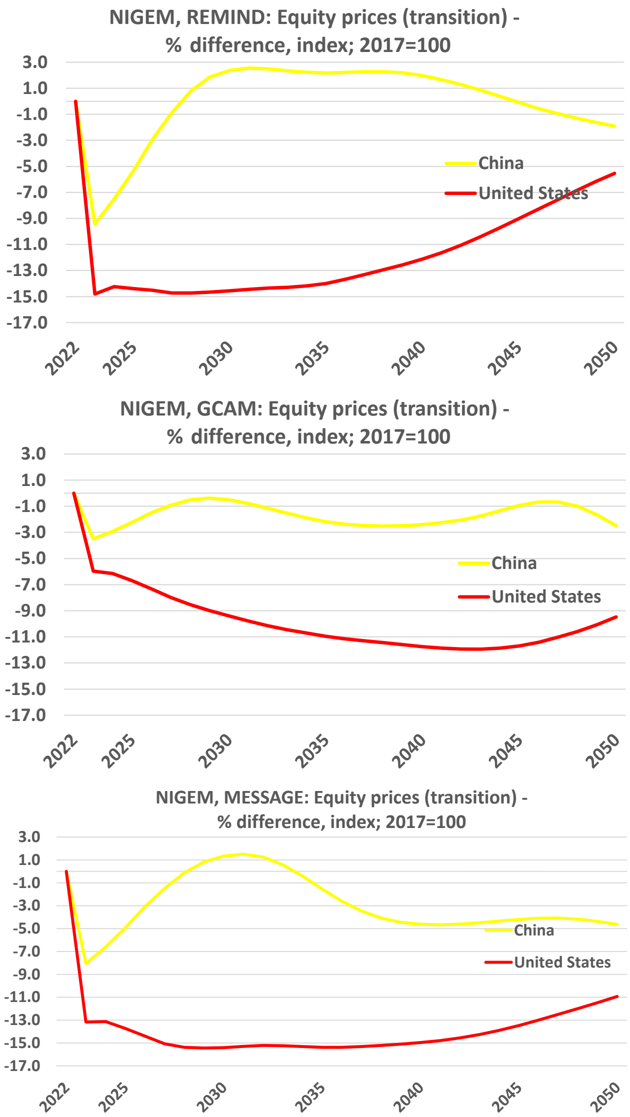


### 2.4.4 Equity market disruptions

**Carbon pricing also introduces policy uncertainty, leading to sudden disruptions in equity markets.** This is reflected in a sharp initial decline in equity prices in 2023 when carbon pricing is introduced, followed by a gradual but continuous decline as investors continue to form their expectations. As shown in Figure 2.14, the equity market drop is more severe in the US (ranging from -6% to -15% across the three models) compared to China (-4% to -10%), consistent with the trend of carbon prices applied in these regions. For the US, the drop in equity prices is primarily driven by its heavy reliance on energy. Despite becoming a net exporter of oil, the non-oil producing sectors dominate, causing the US economy to be heavily impacted by the reduction in overall energy use.

Figure 2.14 **Equity prices impacts due to transition risks**

*(NiGEM output)*




15 https://www.un.org/en/climatechange/net-zero-coalition.

## 2.5 Key findings: transition to Net Zero 2050

This section provides a detailed analysis of the Net Zero 2050 scenario key findings using projections from three leading Integrated Assessment Models (IAMs) – GCAM, MESSAGEix-GLOBIOM, and REMIND-MAgPIE. This scenario demonstrates how reaching net-zero emissions by 2050 is possible through immediate and coordinated climate action. The resulting emissions trajectory limits climate change impacts on natural and human systems, a necessary effort to secure liveable conditions this century and for future generations.

The Net Zero 2050 scenario projects a global response to climate change with ambitious and internationally coordinated action towards a low-carbon economy. The transition risks associated with mitigation action include: the timing and speed of policy and regulation, technological development, market changes and changes in consumer preferences. Transition risks affect the profitability of businesses and wealth of households, creating financial risks for lenders and investors. They also affect the broader economy through investment, productivity, and relative price channels, particularly if the transition leads to stranded assets.

As global climate action comes with important transition risks for socio-economic developments, Section 2.5.1 analyses these risks by discussing impact on fossil-dependent sectors and financial institutions. To reach net zero emissions, the energy sector transition is characterised by an early uptake of mitigation technologies. The energy and power sectors undergo a deep and rapid transformation in the next 20 to 30 years, shifting from fossil-based to low-carbon and carbon removal technologies (Section 2.5.2 and 2.5.3).

### 2.5.1 International climate policy implications and related transition risks

#### Global response and high transition risks associated with ambitious and fast policy action

According to the UNFCCC, as of June 2024, around 100 countries had committed to reduce their emissions to net zero by mid-century[15]. These long-term strategies are crucial to achieve the Paris Agreement goals, and represent the most ambitious international effort put in place to address climate change mitigation[16]. However, these long-term strategies combined with NDC 2030 targets are not sufficient to remain below 1.5 °C by 2100, and more stringent climate policies are needed. The Net Zero 2050 scenario limits global temperature rise to 1.5 °C in 2100, by setting a global net-zero $CO_2$ emissions constraint around 2050. While the scenario ensures the countries that committed to NDC 2030 targets and net-zero pledges reach them timely, the scenario projects a higher global ambition for climate action and innovation, in order to respect the end-of-century 1.5 °C goal. Moreover, while these additional policies to achieve net zero by 2050 are necessary to limit temperature rise to 1.5 °C on the longer-term, they are still not ambitious enough to remain strictly below the temperature threshold. In fact, the Net Zero 2050 scenario expects that global temperature will increase 1.7 °C (low overshoot, with 50% chance) by mid-century and stabilise to 1.5 °C by 2100. **Therefore, successful climate mitigation depends on all governments, and specifically in industrialised countries, and all public and private sectors reinforcing their climate policy ambitious and respecting their commitment in time.**

Time-pressured transitions to low-carbon economies are typically associated with high transition risks. To transition to net zero in the next 25 years, all governing institutions and actors need to take legal, market and technological risks due to the deep policy changes that are required. As this immediate action is possible with cost-effective policies such as carbon taxes, the carbon price[17] is a key IAM indicator to analyse policy transition risks. A high and fast-increasing carbon price means stringent and robust climate mitigation policies and socio-economic changes must be in place. The Net Zero 2050 scenario pictures a steep increase of carbon prices in all regions (see Figure 2.11 in Section 2.4.1), which acts as an immediate strong signal to the entire economy, in particular through energy prices. Due to slow implementation of climate policies in recent years, global emissions remain high, which has increased pressure on countries to reach their climate commitments for mid-century. This pressure translates into higher carbon prices compared to previous NGFS phases, as progress in emission reduction has not been sufficient. To avoid further challenges in achieving net-zero pledges and fulfilling the Paris Agreement goals, global collaboration and immediate coordinated action must be taken with a long-term vision.

## Moderate regional differences in policy action

In all R5 regions, the pattern of shadow carbon prices projected by all three IAMs (GCAM, MESSAGEix-GLOBIOM, and REMIND-MAgPIE) reflects a consistent and significant mitigation effort, as it reaches at least 150$US/t $CO_2$ by 2030 and 450$US/t $CO_2$ by 2050, with a continued increase afterwards (see Figure 2.11 in Section 2.4.1). GCAM's regional difference in carbon prices in 2050 reflects how some regions are further from their emission goals than others. For instance, the R5 OECD+EU region (reaching 1,500$US/t $CO_2$ in 2050) encompasses GHG-intensive industrialised countries, some of which had committed to net-zero emissions as of March 2024 (e.g, Australia, Canada, EU28, USA, Japan, New Zealand). While carbon price differences between R5 regions are small, national differences are expected due to the ambition gap between countries that are only following their NDC targets, and those with additional net-zero pledges. These variations may cause inequality in mitigation costs and market distortions.

## Transition risks for the fossil fuel and power sector

**A major consequence of international mitigation actions towards a low-carbon global economy is the reduction of fossil fuel use, which puts the fossil fuel investments and fossil-dependent end-sectors at risk.** Technological shifts towards renewable energy production and increasing carbon prices will inevitably affect the role of fossil resources and assets for the global economy. In the Net Zero 2050 scenario, all three IAMs foresee a strong reduction of coal, oil and gas use by 2050 (Figure 2.15), enabled by carbon pricing, regulation measures and consumer behaviour change. Coal sees the strongest declining trend, and only minor use after 2050. Oil and gas are likely to still play a two-fold role: in hard-to-abate sub-sectors of industry and transportation (see section 2.5.2), and in developing economies for which total final energy demand (Figure2.16) is expected to keep increasing (mostly gas, in Asia, Latin America, Middle East and Africa). As fuel demand decreases, the fossil fuel sector will see its investments put at risk and revenues become uncertain. Industries must therefore decarbonise their operations, invest in clean technologies, and adopt circular economy practices.

16 As the NGFS Nationally Determined Contributions (NDC) 2030 scenario has shown, NDC targets are not sufficient to mitigate climate change, and lead to 2.3 °C temperature rise at the end of the 21st century. https://www.ngfs.net/ngfs-scenarios-portal/explore.

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

Figure 2.15 **Primary Energy|Coal (left), Oil (center) and Gas (right)**

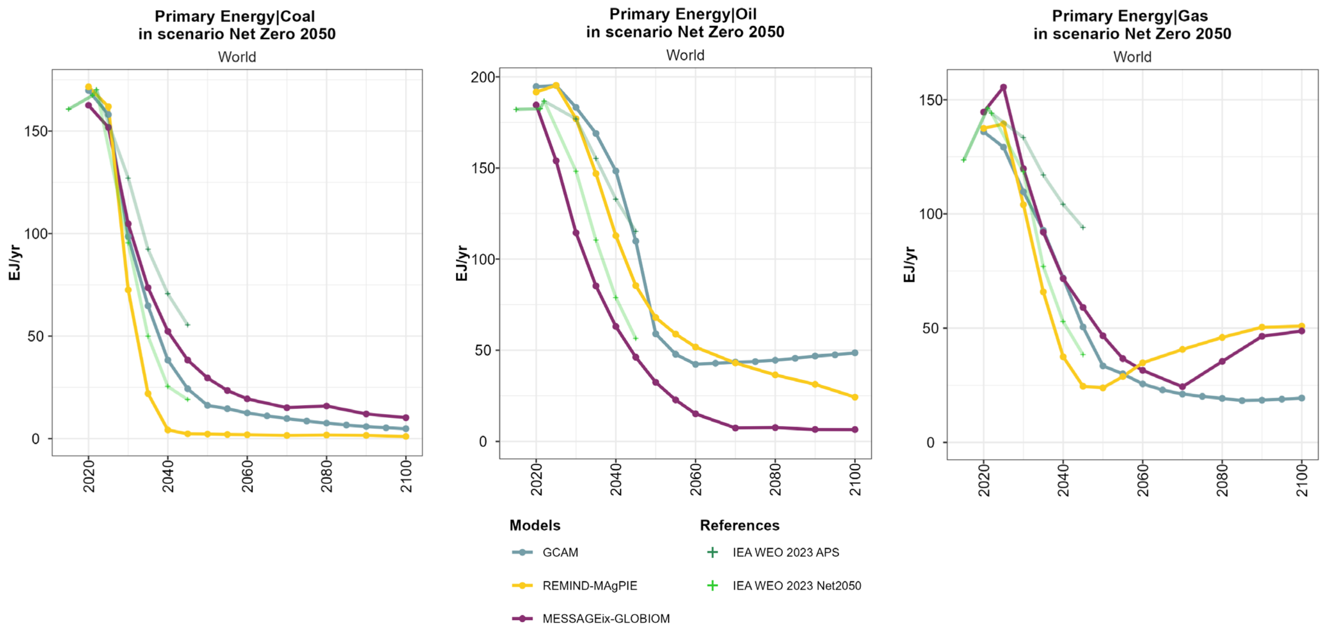
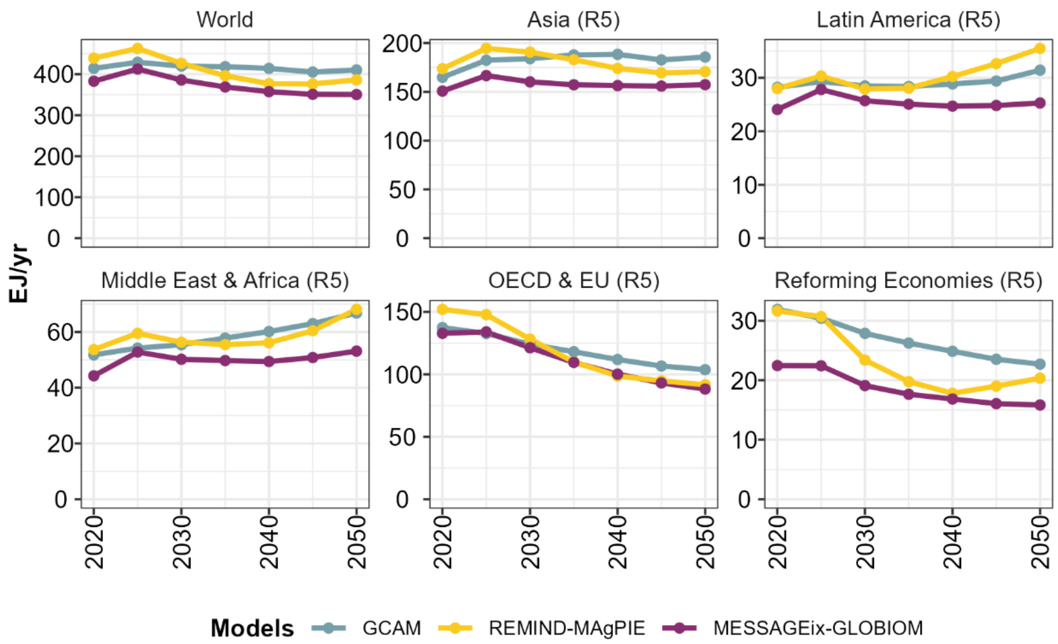



Figure 2.16 **Final Energy per region in the Net zero 2050 scenario**




Mitigation ambition consistent with Net Zero 2050 results in an accelerated decarbonisation of electricity production, characterised by a rapid ramping-up of renewable power (mostly from solar and wind, see section 2.3.3), combined with a rapid phase-out of fossil fuels. As fossil power generation becomes increasingly less competitive in electricity markets with a high carbon price and high renewable energy penetration, this transition poses significant transition risks to the producers of coal and gas, as well as the fossil power generation assets. At the same time, the power sector faces a rapid transformation and significant technology change. Therefore, to enable a smooth transition, the renewable electricity transition needs sufficient capital investments, and the challenge of resource scarcity for the production of renewable assets must be sustainably addressed.

In the section on the energy transition dynamics (2.5.1), the use of the non-abated fossil fuel in different end-use sectors will be discussed. An in-depth analysis into the required energy investments of the Net Zero 2050 scenario is provided in the NGFS Report on Energy investments.

### Economic transition: near-term economic adjustments, for long-term stability

**As climate action advances and carbon prices increase, all actors of the economy must collectively adapt: governments implement robust policies and clean investments, industries decarbonise and contribute to a sustainable and circular economy, consumers prefer more sustainable consumption, and financial institutions redirect investment to sustainable projects.** In their strategic planning and risks management, financial organisations should consider both near-term and long-term transition risks and opportunities. Transition risks can be analysed through the effect of the steep increase of carbon price of the Net Zero 2050 scenario, which may cause rising energy and food prices, inflationary pressure, and increases in long-term interest rates. Long-term shifts in demand and cost structure of assets in all economic sectors will require a redirection of investments and change in capital management. Adopting a forward-looking approach would enable financial organisations to avoid losses and to take a key role in facilitating the transition by scaling up low-carbon technologies and innovations.

## 2.5.2 Energy transition dynamics

The Net Zero 2050 scenario depicts an ambitious mitigation pathway of rapid and deep decarbonisation. Achieving carbon neutrality requires transformations towards low-carbon and efficient technologies in all sectors, ranging from production and conversion of energy to end-uses in industry, transportation and buildings. Transitioning towards net zero also requires a fundamental re-alignment of investments[18]. The Net Zero 2050 pathways harness the potential of increasingly cheap renewable energy and electrification, in particular in land transport. Mitigation challenges are dominated by the decarbonisation of non-electric energy demands for aviation, shipping and base material industries, as well as the scale-up of carbon dioxide removal.

### Decarbonisation in all sectors

**Emission reduction is steep in energy supply largely due to a switch from coal and gas power plants to variable renewable energy** (VRE, see Section 2.3.3). In the Net Zero 2050 scenario, all models reach zero net $CO_2$ emissions globally between 2040 and 2060 (Section 2.3.1). As the main contributor to current emissions, the energy sector experiences a fast decline in emissions. The fastest transformation happens on the supply side (which includes power generation and other energy supply), with yearly emissions dropping from 14-17 Gt to 2-4 Gt over a fifteen year period (2025-2040). These numbers and the chart below represent gross fossil emissions; they do not include the negative emissions achieved from BECCS, the combination of bioenergy with carbon capture and storage (CCS). Such negative emissions of the energy supply together with CDR and AFOLU (Section 2.5.3) compensate for remaining emissions in the demand sectors.

**Decarbonisation patterns differ between end-use sectors, with a full decarbonisation in buildings, residual emissions in transportation, and more uncertainty in industry.** Residential and Commercial buildings are only responsible for 3 Gt in 2020, an amount that steadily diminishes until 2050 to reach 544 Mt in MESSAGEix-GLOBIOM and as low as 80-90 Mt in the other models. The trajectory of industry emissions from 9-12 Gt in 2020 to 1-4 Gt in 2050 differs more across models: direct emissions (like fossil combustion for heat) and process emissions (like cement calcination) depend on material demand and the carbon intensity of production, the evolution of which remains highly uncertain. The transportation sector follows a more consensual trajectory from 7-8 Gt in 2020 to 1-2 Gt in 2050 with residual fossil use in international aviation and shipping.

### Uncertainty for future demand in materials and energy services

Two factors determine final energy demand: the consumption of materials and energy services, and the energy intensity of these activities. The demand per capita shows different patterns in different sub-sectors, and the global population increases slightly throughout the century. As many regions reach a saturation of infrastructure, per-capita demand decreases for materials (like steel and cement) but keeps

18 Investments in the energy transition for the Net Zero 2050 scenario are extensively discussed in the dedicated Report on Investments, 2025.

increasing for other energy services (such as floor space and passenger transport). Cement is an important source of $CO_2$ emissions; mitigation efforts and increasing material efficiency reduce the per-capita demand in 2050 by 9% relative to 2020 values for MESSAGEix-GLOBIOM and by 50-60% for the other models. Improving living standards lead to an increase in per-capita floor space by 14-30% and travelled distance by 11-27%. The final energy required to provide the service or produce the material generally reduces over time (due to electrification and other efficiency gains), with the exception of cement where it decreases by 37% in REMIND-MAgPIE but increases by 6-21% in the other models.

Figure 2.17 **$CO_2$ Emissions in energy sectors**

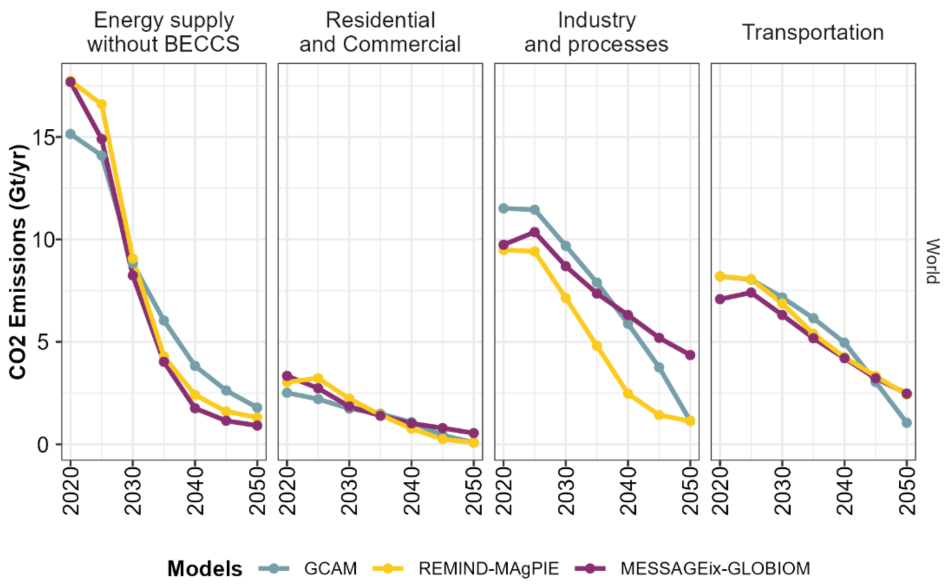
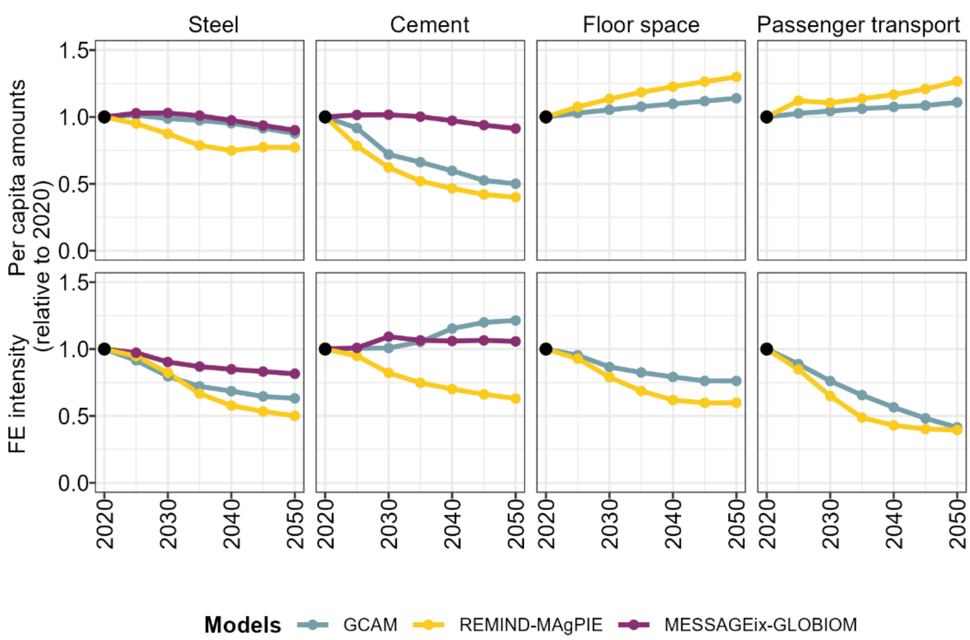



Figure 2.18 **Per capita demand and energy intensity of materials and energy service provision, World**

*(index with reference 2020 =1, note that the impact of the pandemic is limited since the model year 2020 represents a five-year time span)*



## Low-carbon electrification and fuel substitution

**Three complementary steps are necessary to reach net-zero $CO_2$ emissions: decarbonising electricity, electrifying end uses, and replacing fossil fuels in other carriers.** Following a trend that started in the 2010s, solar and wind power play an increasingly dominant role in electricity production, reaching 45-54% in 2030 on their way to 83-89% in 2050. Other decarbonised sources like hydro-, nuclear and geothermal power cover the rest of the mix (Section 2.3.3), but their contribution remains close to current levels because of limited potential or high cost. This fast first step decarbonises the energy supply and facilitates a second step: the electrification of end uses. The remaining non-electric final energy relies on other carriers: solid, liquid or gaseous hydrocarbons, heat or hydrogen (Section 2.3.3). While most of these currently stem from fossil hydrocarbons, they can in principle be substituted with biomass, hydrogen, hydrogen-based electrofuels (produced from captured carbon and hydrogen from electrolysis), or renewable heat (e.g. from geothermal sources). The third step entails a partial replacement of fossil fuels with these alternative fuels, as they account for minimal $CO_2$ emissions if the biomass is produced in a sustainable way (not aggravating deforestation) and if carbon-free electricity is available for the electrolysis.

**The trade-off between electrification and fuel substitution is still subject to a large uncertainty.** Models diverge in their preference for step two or three: from the 20-21% of electrification in 2020, they offer a range of pathways leading to 50-73%. In consequence, the non-fossil share in other carriers, representing 7-12% in 2020, is as diverse as 27-50%. GCAM shows high electrification and low fuel replacement; the opposite happens in REMIND-MAgPIE and MESSAGEix-GLOBIOM. The lower electrification in MESSAGEix-GLOBIOM explains its higher remaining emissions in 2050. These differences partly originate from variation in model assumptions, such as the availability of biomass or the costs, efficiency and upscaling of emerging technologies like carbon capture and large-scale electrolysis. They also reflect real-world uncertainties around the scale-up and commercial viability of these technologies.

**Electrification plays a key role in all end-use sectors but substantial uncertainty remains around the share of electricity in final energy since some sub-sectors are hard to electrify.** All sectors undergo a deep electrification, but the shares in 2050 reflect model differences and real-world uncertainty. The residential and commercial sector is relatively easy to electrify: electric heat pumps can provide inexpensive heating and cooling, and most home appliances use electricity. The rate is already 36-38% in 2020 and reaches 72-88% in 2050. In the industry, electricity can provide mechanical work and low- to medium-temperature

Figure 2.19 **Share of VRE, electricity and non-fossil fuels, World**

*(non-electric carriers are solid, liquid and gaseous hydrocarbon fuels, heat and hydrogen)*

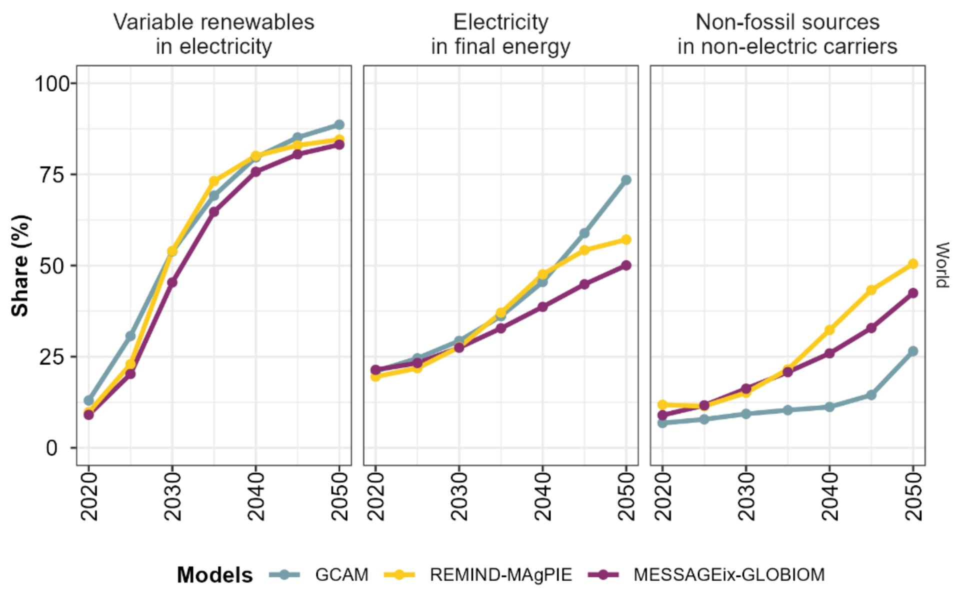
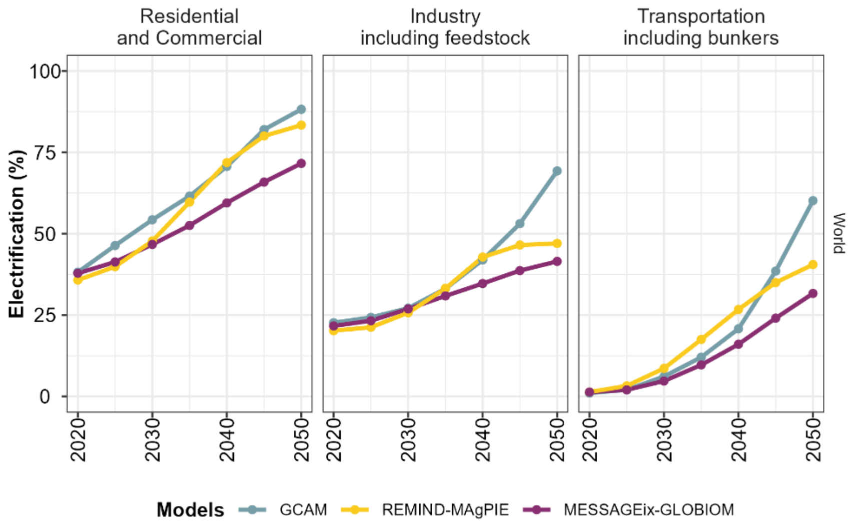


Figure 2.20 **Electrification of final energy in demand sectors, World**




heat, but its use for high-temperature heat is more uncertain. Besides, electricity cannot replace hydrocarbons used as feedstock in materials like plastic, steel or fertilisers. Models describe an industry electrification of 20-23% in 2020 and a wide range of 41-69% in 2050. The same diversity arises in transportation: electrification is only 1% in 2020 as electric vehicles are just phasing in, but the models project 32-60% in 2050 for the Net Zero scenario, subject to assumptions and uncertainty around future battery costs and autonomy, feasibility of electric trucks, fleet lifetime etc.

### 2.5.3 Role of carbon dioxide removal and carbon capture and storage

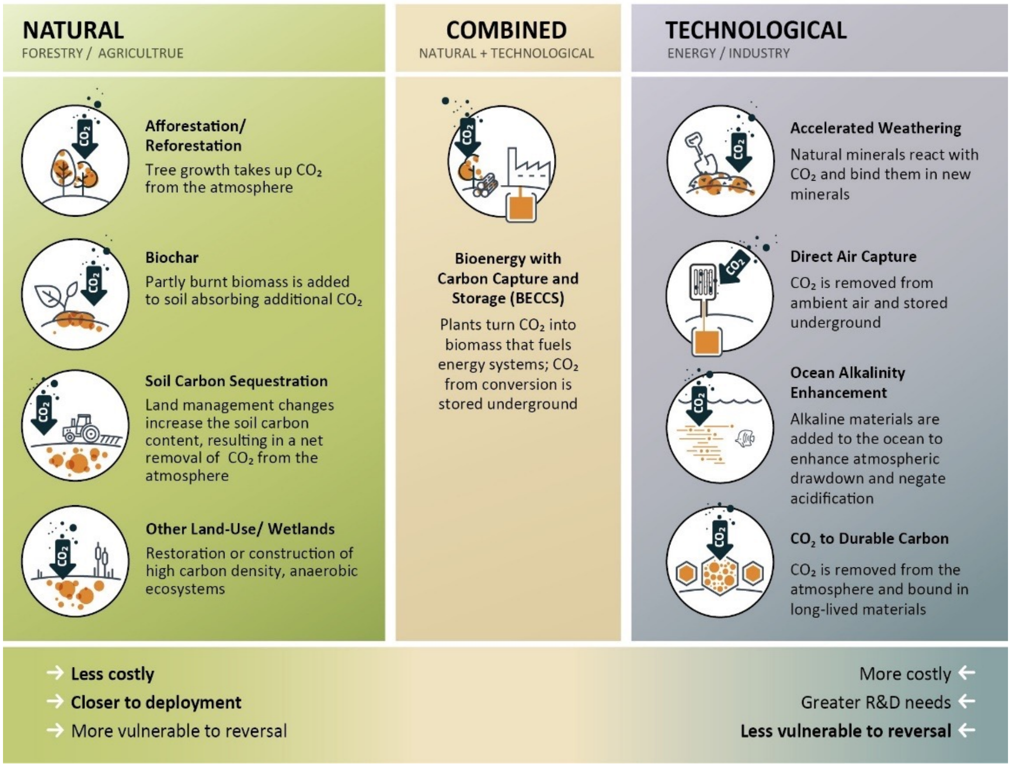
Carbon dioxide removal has an important role to reach emission reduction goals in ambitious climate mitigation scenarios. The energy demand and agricultural sectors are responsible for the majority of GHG emissions, despite the technological shifts and drastic reduction of fossil fuels. As described in Section 2.3.5, the Net Zero 2050 scenario projects around 10 Gt $CO_2$ per year to be sequestrated in the second half of the century to avoid further emissions and to compensate for residual $CO_2$ emissions that are not abated. Diverse natural and technology-based solutions exist, though at various stages of maturity, and they are central to the achievement of a global net-zero emissions target (see Figure 2.21, UNEP Emission Gap Report 2017).

It is important to distinguish emissions that are effectively removed from the atmosphere – therefore contributing to negative emissions -, and those that are emitted but not released in the atmosphere. Carbon dioxide removal (CDR)[19] refers to a wide set of solutions that aim at removing $CO_2$ from the atmosphere, and storing it durably in geological, terrestrial or ocean reservoirs. Carbon capture and storage (CCS) and usage (CCU) refer to technologies capturing emissions at their source (e.g., at the outlet of a power plant) and are either i) stored permanently, or ii) used in a different process and released at a later stage. Carbon capture and storage (CCS) and usage (CCU) are not considered CDR methods, unless a net-positive amount of $CO_2$ has been removed from the atmosphere, for instance through direct air capture (DACCS) or biomass growth (BECCS, bioenergy CCS).

Fitting energy generation and industrial facilities (e.g., cement manufacturing) with Carbon Capture and Storage (CCS) can help avoid a substantial portion of their $CO_2$ emissions. In contrast, Carbon Dioxide Removal (CDR) technologies (several of which are underpinned by CCS) can compensate for emissions from hard-to-abate sectors such as aviation and shipping by removing carbon from the atmosphere and locking it into storages (e.g. forests, rocks, geological reservoirs). Current technologies have varying degrees of maturity and face several hurdles

19 Carbon dioxide removal (CDR) is defined by the IPCC AR6 WGIII as: "*anthropogenic activities removing carbon dioxide from the atmosphere and durably storing it in geological, terrestrial, or ocean reservoirs, or in products. It includes existing and potential anthropogenic enhancement of biological or geochemical $CO_2$ sinks and direct air carbon dioxide capture and storage (DACCS), but excludes natural $CO_2$ uptake not directly caused by human activities*".

Figure 2.21 **Major strategies for negative emission technologies**
*(UNEP Emissions Gap report, 2017[20])*




(e.g. public acceptance and policy support), so their deployment at scale remains subject to uncertainties. Therefore, DACCS (direct air carbon capture and storage) and enhanced weathering of rocks were switched off in the NGFS scenarios.

## Land-based CDR

The AFOLU sector (agriculture, forestry and other land use) accounts for more than 20% of total anthropogenic greenhouse gas emissions presently. The largest component of carbon emissions comes from land clearing and deforestation. In a Net Zero world, IAMs estimate the role of the AFOLU sector to absorb 1500-6000 Mt of $CO_2$ per year by the end of the century (see Section 2.3.5), and the sector to become net zero before 2045. Therefore, reversing the global deforestation trend and increasing forest cover is essential to meet net-zero targets. Moreover, to effectively compensate for residual emissions from other sectors, land-based sinks (e.g., forests, wetlands) need to be protected and restored to be able to play their key natural roles of atmospheric carbon sequestration.

Adopting sustainable land management practices that ensure both food security and emissions reduction is of paramount importance. To avoid further releasing fossil carbon dioxide into the atmosphere, using biomass as fuel enables remaining within a faster, biogenic carbon cycle. The carbon emitted in the atmosphere should either be reabsorbed by land-based sinks (through afforestation) or technologically captured and stored (with bioenergy carbon capture and storage, BECCS). The use of bioenergy is expected to increase significantly (tripling globally, Figure 2.23), which puts additional pressure on availability of land for ecosystems and food production. Although this is not considered in this scenario, shifting towards ecological agricultural practices and reduction of meat and dairy consumption is also key to lower human pressure on ecosystems and limit trade-offs in the land use sector.

20 The Emissions Gap Report 2017. United Nations Environment Programme (UNEP), Nairobi http://uneplive.unep.org/theme/index/13#egr.

Figure 2.22 **Land cover|Forest change in Net Zero 2050 scenario**

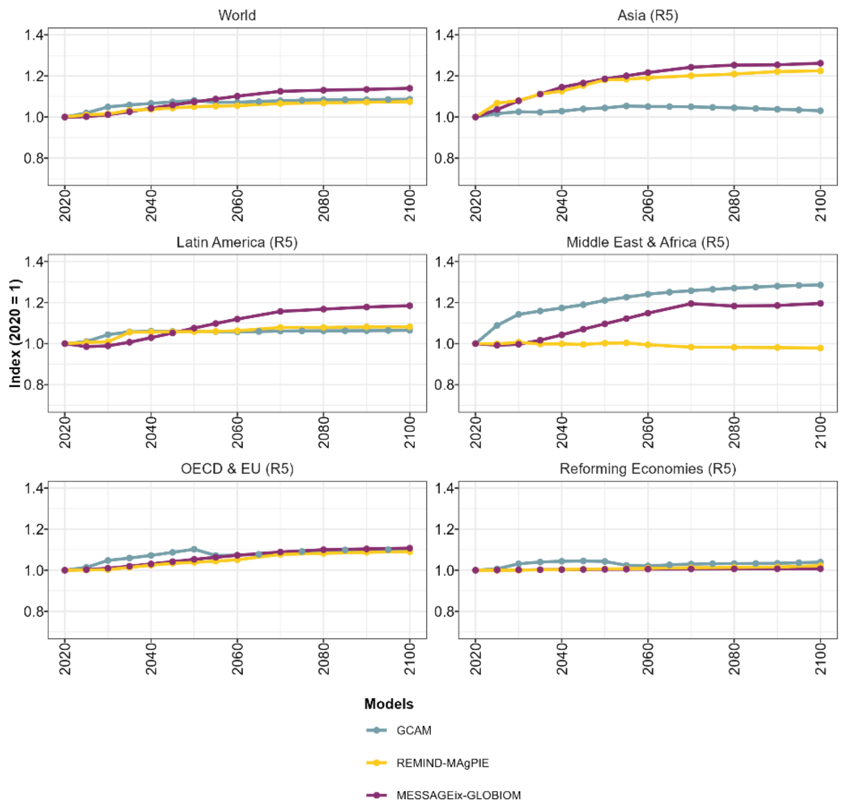
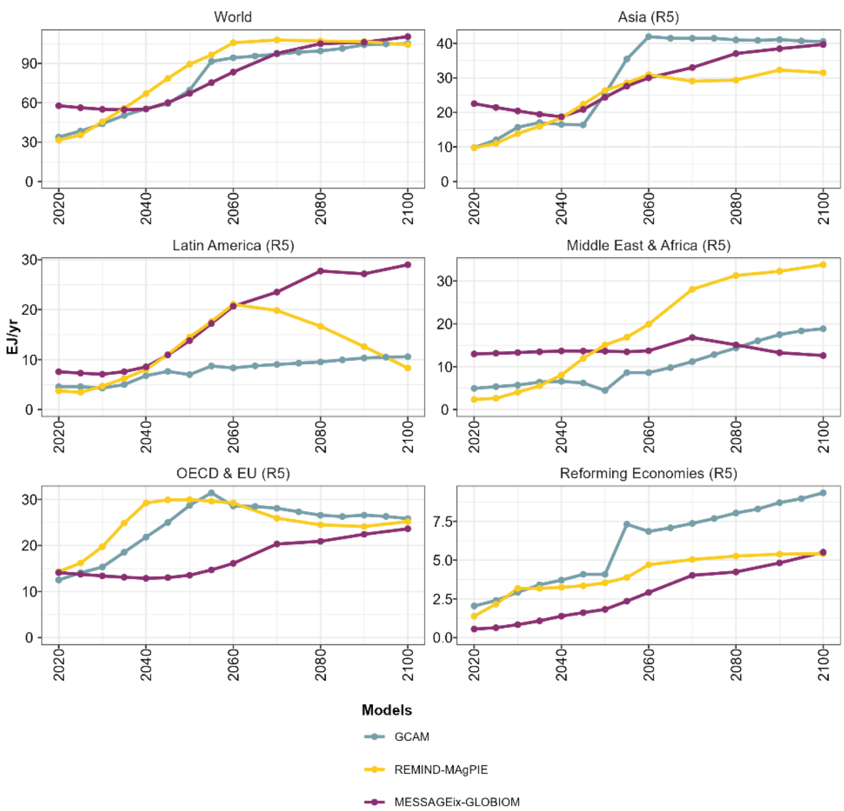



Figure 2.23 **Primary Energy|Biomass|Modernin Net Zero 2050 scenario**



## CDR and CCS technologies

In the Net Zero 2050 scenario, CCS technologies scale-up in sectors that cannot be decarbonised otherwise. In addition to BECCS, IAMs expect an important role of CCS in the fossil and bioenergy-powered sectors, and industrial processes (Figure 2.24). In ambitious scenarios, CCS technologies allow for carbon-intensive industrial processes to remain powered by fossil fuels while limiting their $CO_2$ emissions. Retrofitting of cement and steel factories are the most common in mitigation scenarios, due to their energy intensive nature.

IAMs show different pathways for which primary energy type CCS will play the largest role (Figure 2.25). Because of the coal phase out, GCAM expects an increasing role for gas-CCS. CCS retrofits in REMIND-MAgPIE rather help capturing emissions from biomass fuels, while MESSAGEix-GLOBIOM rather serve the coal-powered plants. Proportionally to total primary energy, CCS retrofits are limited to specific applications, as these technologies remain expensive and energy intensive.

Figure 2.24 **Carbon Sequestration|CCS per carrier, World**

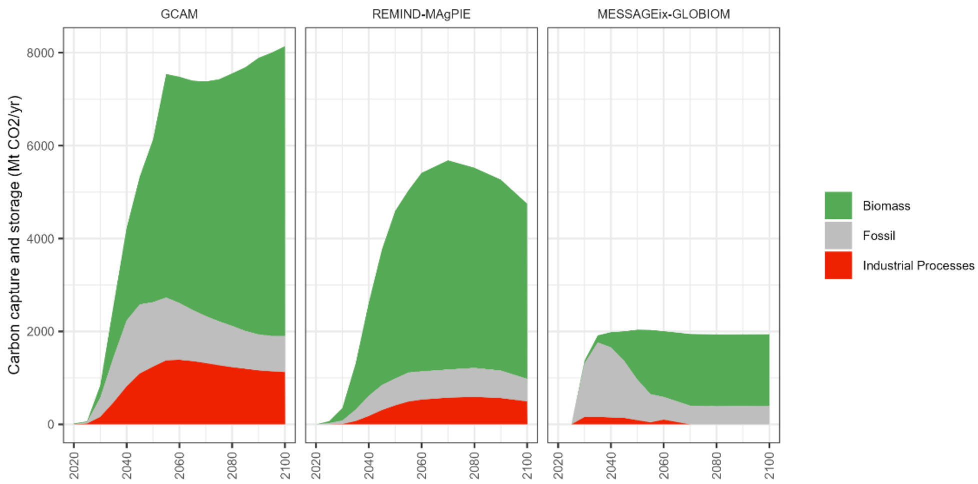
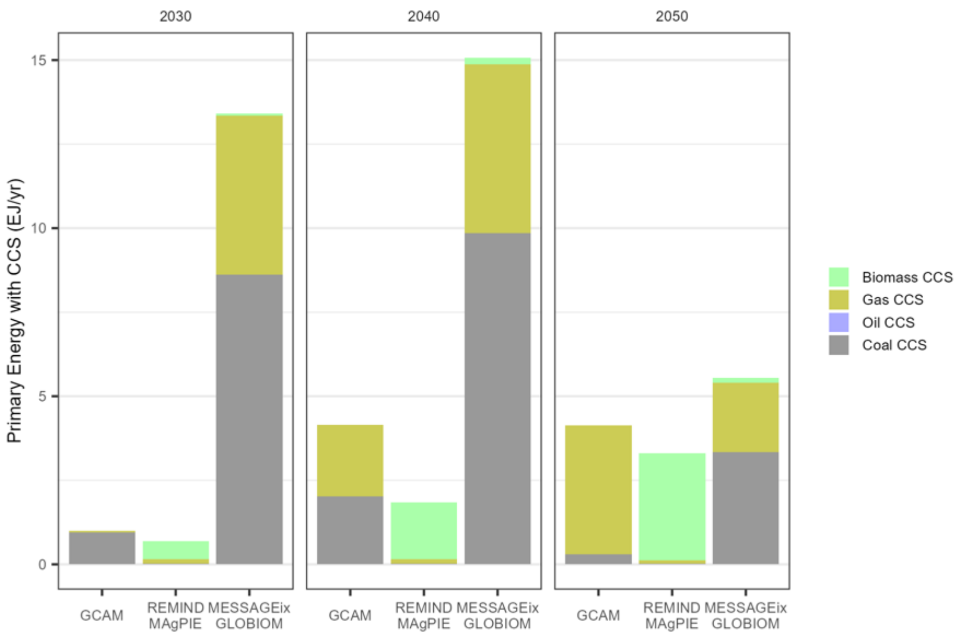



Figure 2.25 **Primary Energy with CCS, World**



## 2.6 Conclusions on the Net Zero 2050 scenario

**In the Net Zero 2050 scenario, climate action is immediate as of 2025, ambitious and globally-coordinated, and breaks from the current mixed trends in socio-economic development.** Due to continued high emissions until 2025, even the immediate and cost-effective implementation of measures to limit warming to below 1.5 °C by 2100 is **no longer a fully orderly transition.** Climate ambition increases sharply until 2030, and keeps its momentum thereafter. This stringency is reflected in steeply increasing shadow carbon prices, causing rising energy prices, inflationary pressure, and resulting increases in long-term interest rates.

**The global transition towards a net-zero economy is only possible with coordinated effort and immediate action to accelerate technology change and adjust investment flows for the transition.** There is a rapid transformation of energy and land use systems and a substantial role for new technologies and markets that remove carbon dioxide from the atmosphere. However, the future use of bioenergy and land-based CDR solutions is uncertain, puts pressure on ecosystems and areas available for food production. Reducing these risks could be achieved with additional behavioural changes, both on food and energy consumption. Fossil fuel sectors are at risk as demand falls dramatically, in reaction to robust climate policy implementation, leading to higher economic risks for fossil-dependent industries and for countries with a high share of fossil-fuel dependent income.

**Physical risks are strongly reduced under the Net Zero 2050 scenario, but remain a major component of the unavoidable GDP losses.** Major adaptation efforts would still be needed to address these risks. An updated quantification of these impact and damage estimates will be available in NGFS Phase VI, 2026.

Finally, physical and transition risks might be underestimated as some compounding socio-economic factors are not considered. This includes geopolitical and political economy factors and socio-economic disruptions in the medium-to long term (shocks to GDP, the labor force, and consumption). An exception to these caveats is energy demand, which is reduced substantially in response to climate policy in the Net Zero 2050 scenario.

# 3. Current Policies: narrative and key findings

## 3.1 Narrative of the Current Policies scenario

*Short summary: The Current Policies scenario assumes that only currently implemented policies are preserved, leading to high physical risks. $CO_2$ emissions remain high, leading to about 3 °C of warming and severe physical risks, as well as irreversible changes. This scenario can help central banks and supervisors consider the long-term physical risks to the economy and financial system if we continue on our current path to a "hot house world".*

| Warming at end of century[21] | Policy reaction | Technology change | CDR | Regional policy variation | Physical risks |
|---|---|---|---|---|---|
| 2.75-3 °C in 2100 | None – current policies | Slow change | Low use | Low variation | High |

### Climate policy ambition and action

**The Current Policies scenario assumes that only currently implemented policies are preserved, which leads to high physical risks and to a non-linear increase in severe and irreversible climate impact. The Current Policies scenario draws a world in which climate policy action is not prioritised, despite the experience and predictions of climate impacts on society.** While many countries have started to introduce climate policies, they are not yet sufficient to achieve official commitments and targets. Under the NGFS Current Policies Scenario, global warming of 1.5 °C could be reached around 2030, 2 °C around 2050 and 3 °C around 2100. Such global warming is projected to lead to a non-linear increase in severe and irreversible climate impacts. This would likely result in deteriorating living conditions in many parts of the world and lead to some irreversible impacts[22]. This policy strategy leads to high physical risks, while transition risks are low. The shadow carbon price – which serves as a proxy for the various policy instruments for emissions reduction – only sees a slight increase globally until 2100 (up to 10 US$2010/t $CO_2$ by 2030, and 28 US$2010/t $CO_2$ by 2100), which explains the low transition risks of this scenario.

### Socio-economic developments

**Like all other NGFS scenarios, the Current Policies scenario assumes social, economic, and technological developments that reflect trends observed during the first two decades of the 21st century**, following the assumptions of the Shared Socio-economic Pathway 2 (SSP2)[23]. Countries and international relations are relatively stable, markets are globally connected, although some barriers remain, development and economic growth proceed unevenly (with a global annual average growth rate of 4% for 2020-2030 and 3% for 2030-2050), and global population growth is moderate and levels off at 10 billion people in the second half of the 21st century. Multilateral institutions make only slow progress towards achieving the sustainable development goals and environmental systems continue to degrade gradually. Technological development is moderate.

### Energy transition and technology trends

**Current policies and investments lead to a continued fossil fuel reliance. Renewables continue to be scaled up, but only fast enough to cover the growth in global demand and not cutting decisively into fossil fuel use at the global level. The use of CDR technologies remains low, as the current policy strategies do not promote such mitigation measures.**

21 End-of-century and peak warming values represent the results range across IAMs, and the 50th percentile of the surface temperature variation (AR6 Surface Temperature (GSAT)|MAGICCv7.5.3|50.0th Percentile).

22 Irreversible changes may include higher sea level rise, which are not yet included in the NGFS scenarios (see Tipping Points note, report on physical risks in the updated Climate Impact Explorer).

23 Riahi *et al.*, 2017, O'Neill *et al.*, 2017.

## Food systems and land-use transition

**In the Current Policies scenario, global food systems and land use continue to shift in response to growing populations and GDP – but without additional policy measures to guide these transitions toward sustainability.** In developed countries, persistent trends of overconsumption and food waste remain, while in the emerging economics higher incomes drive increased consumption of animal-based products – intensifying demand for feed crops and expanding pressure on agricultural land expansion. With no incentives for bioenergy crop production, no afforestation targets for carbon removal and no land-use mitigation goals in NDCs, land-use change remains driven solely by food demand, missing critical opportunities for climate mitigation and ecosystem restoration.

## Physical risks and climate change impacts

**Most regions are projected to experience increased exposure to climate hazards such as heat stress, drought and heavy precipitation risks. Physical risks to the economy increase steadily with advancing climate change.** A 3 °C World will significantly impact key driving forces of economic growth, including impacts on land and agricultural productivity, labor productivity and destruction of capital and infrastructure. While not quantified in this analysis, it will see increasing impacts of sea-level rise, on biodiversity and ecosystems or health systems. The changing frequency and strength in extreme events might push societies beyond their limits of adaptive capacity, unprecedented event cascades might lead to larger socioeconomic disruptions which cannot be captured with current modeling approaches. Unabated climate change will furthermore set in motion shifts which may not be reversible at all or not for long time scales, including the risk of tipping points.

## Economic transition

***As there is no new climate policy change, no economic impact is accounted for due to the transition. Policy and long-term interest rates are assumed to not experience any changes compared to baseline trends.*** All GDP and unemployment losses are stemming from physical risks.

## A low-ambition, Hot House World scenario

**The Current Policies scenario belongs to the Hot House World category of the NGFS framework (see Box 1). Hot House World scenarios assume that some climate policies are implemented in some jurisdictions, but global efforts are insufficient to halt significant global warming.** By definition, the transition risks associated with this scenario are low, and in consequence to climate inaction, the physical risks are high. **The Current Policies scenario is the least ambitious scenario of the NGFS Scenario framework, reaching 3 °C of warming at the end of century.** It could be taken as a reference point to analyse the effect of different climate action strategies with respect to both physical risk and transition risk. However, it does not necessarily mean it is the most likely scenario, as continued development of climate policies can be expected, both due to evolving technology opportunities, but also due to pressure from experiencing increasing impacts. The Current Policy scenario is a policy baseline scenario that slightly deviates from a "no policy" baseline by taking into account currently legislated policies.

# 3.2 Narrative quantification

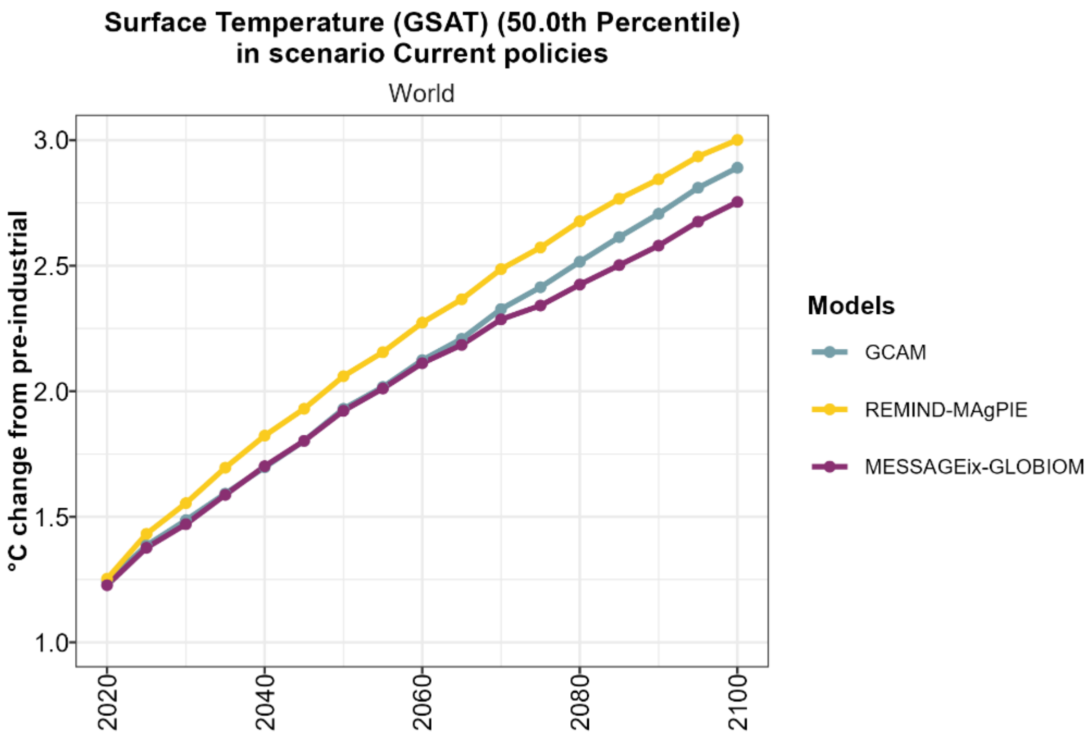
Robust SSP and scenario frameworks allow the translation of the qualitative narrative into quantitative assumptions to the Integrated Assessments Models[24]. The implementation of the following parameters are essential to the Current Policies scenario.

- **SSP2 assumptions on population and GDP baseline are reflected as exogenous parameters in IAMs.** The GDP then changes semi-endogenously when affected by energy transition costs, and by integrated damages when they are included. SSP2 assumptions enforce moderate rates of socio-economic development on average globally, and moderate convergence between low and high income countries (see Annex A).
- **Policy commitments are translated into constraints on the emissions or technology targets and are reflected in the shadow carbon price.** In the Current Policies scenario no additional policies or carbon budgets are implemented, leading to 3 °C of warming at the end of century (Figure 3.1).

24 Fricko *et al.*, 2017.

Figure 3.1 **Surface Temperature Variation**

*(MAGICCv7.5.3, 50.0th Percentile)*




- **Climate change directly affects physical risks and impacts on natural and human systems, and therefore socioeconomic developments.**
- **Collaboration between countries impacts how smoothly the transition can occur.** The Current Policies scenario has low regional differences, as policy ambitions are low across the board.
- **Current Policies scenario takes moderate assumptions on innovation and growth constraints, which only allow for slow technology change and deployment.** Specifically, only low use of CDR is applied in this scenario.

However, modelling exercises show there are many ways to reflect complex systems, and many strategies to implement a transition. IAMs characteristics and assumptions influence their future projections and pathway towards reaching emission targets. Key assumptions are summarised in the "NGFS Note on Key assumptions, 2025", and more technical details on the models are available in the "NGFS Technical documentation, 2025". When relevant, this report will highlight how model results compare and the drivers behind potential differences.

## 3.3 Transition risks

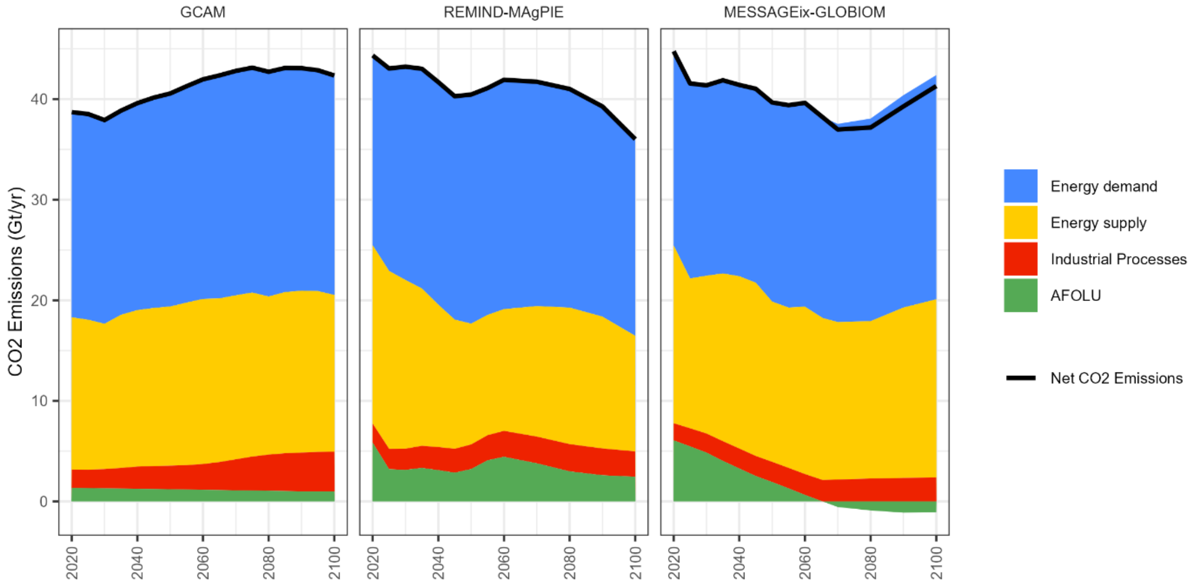
This section highlights key characteristics of the climate transition in the Current Policies scenario, that are of particular relevance for describing the scenario implications in various sectors, as well as for using this scenario for risk assessments. NGFS long-term scenarios offer a multi-model study that is needed to derive robust insights in long-term scenarios. In this section, results from the three IAMs are shown and compared. Key similarities and differences between models are highlighted and crossed with characteristics and assumptions of IAMs.

### 3.3.1 Emissions trajectory

Under current policies, the yearly global $CO_2$ emissions show a constant trend around 40Gt/year for all three models. However, how emissions would evolve without new legislation is uncertain, as the dynamics of technologies deployments are uncertain (Figure 3.2). For example, REMIND-MAgPIE sees decreasing emissions in the power energy sector, while they continue to increase in the other models. Further discussion in Section 3.5 of this report.

Figure 3.2 **Yearly Net Emissions|$CO_2$**[25]

*(Mt $CO_2$/yr)*




## 3.3.2 Primary energy

If all regions were to follow their current climate policies without introducing new ones, the IAMs expect the global primary energy use to keep increasing by around 20% by 2050 compared to 2025. All models expect a steady reliance on fossil fuels, with even some increase of gas resources according to GCAM and MESSAGE. The share of renewable resources (solar, wind, hydro and biomass) gradually increases to around 25-30% in 2050 for all models.

## 3.3.3 Final energy and electricity mix

Electrification follows the growth in energy demand that characterises the Current Policies scenario. Renewable electricity outcompetes carbon-intensive technologies by mid-century. In consequence to the absence of technology shift in the end-use-sectors, the transition risks are low.

25 Differences in emissions accounting, especially in the AFOLU sector, can cause discrepancies across models. Gross $CO_2$ emissions data would also allow for better specification of the sectoral transition, in particular to represent the share of carbon capture and storage in energy and industry sectors. Additional emissions variables will be reported in the next NGFS phase, following the IAM community initiative of aligning their common variables definitions.

Figure 3.3 **Primary energy, World**

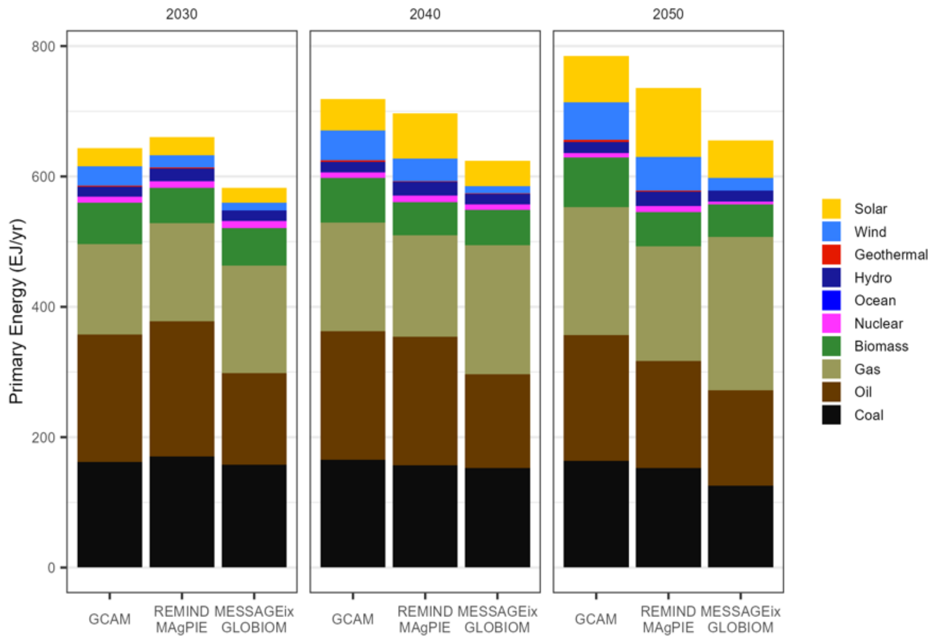



Figure 3.4 **Sources of Electricity, World**

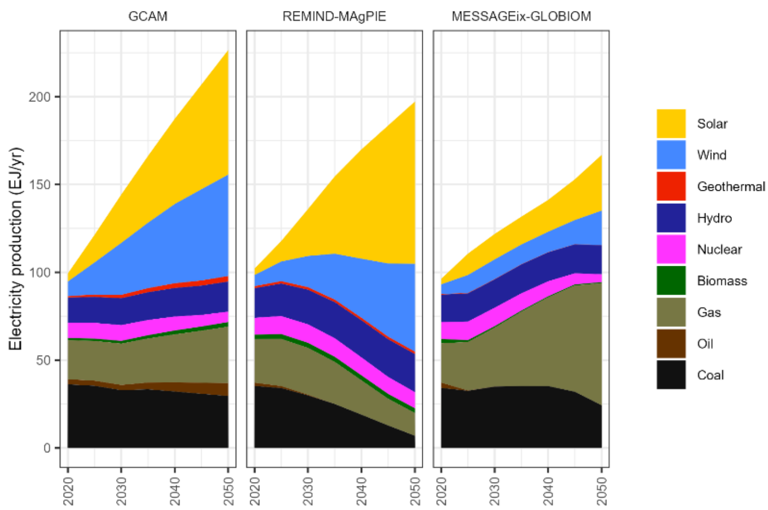
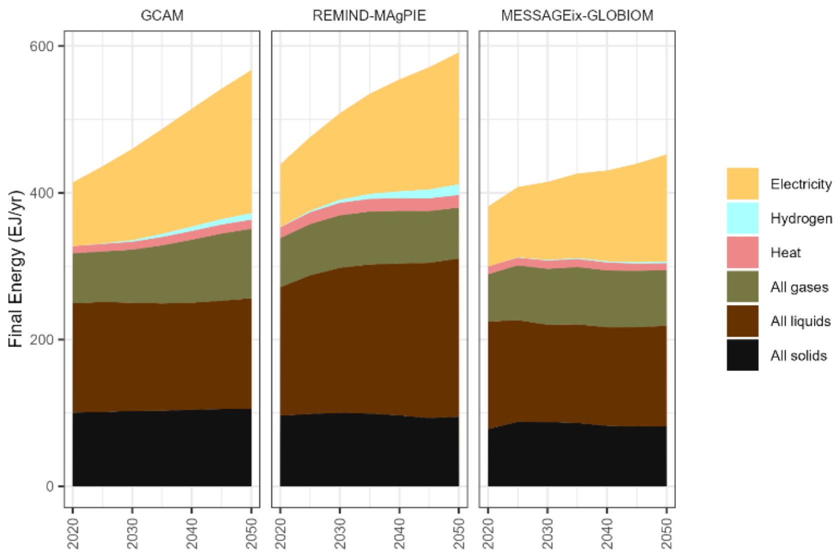


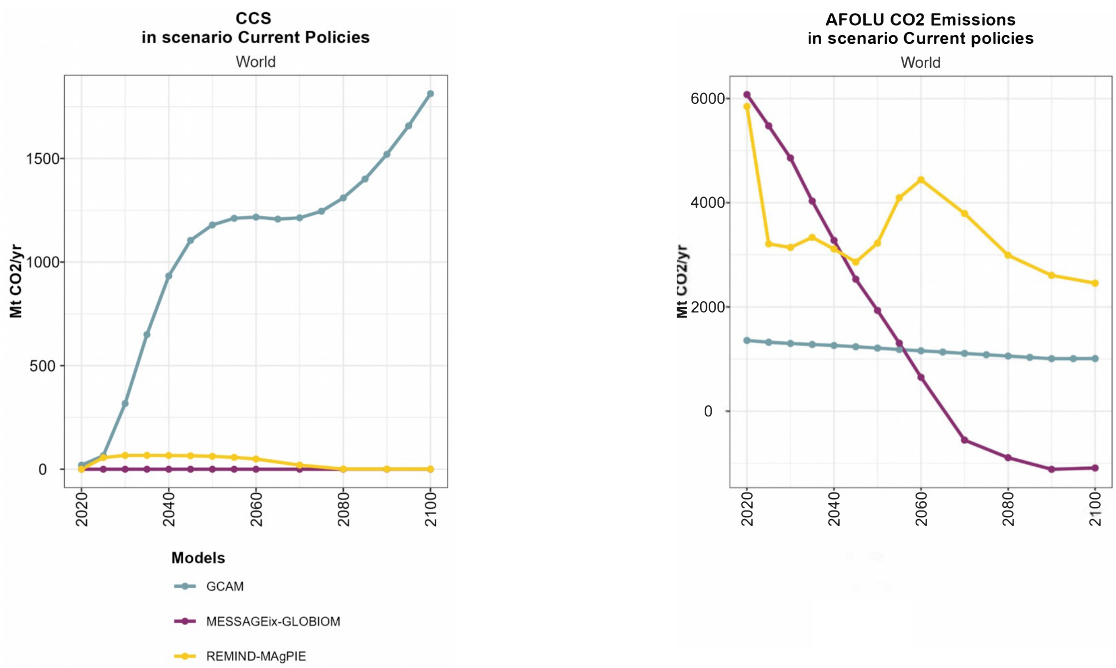
Figure 3.5 **Final Energy, World**




## 3.3.4 Carbon storage and land use

Carbon sequestration includes processes to *capture* $CO_2$, either at the outlet of a plant or through biomass growth, and to *store* the $CO_2$ into geological deposits (such as in depleted oil and gas fields) or through land-based sinks (such as afforestation). In the Current Policies scenario, CDR availability is constrained to low use, given the challenges associated with deployment of these technologies. The projection of carbon sequestration potentials remain different across models, as they take different assumptions on carbon capture and storage (CCS) costs and adoption assumptions. While REMIND-MAgPIE and MESSAGEix-GLOBIOM don't consider CCS to ramp-up in the Current Policies scenario, GCAM takes more optimistic assumptions and CCS allows for some minimal emission reduction. In the AFOLU sector (agriculture, forestry and other land use) REMIND-MAgPIE and GCAM expect little changes while MESSAGEix-GLOBIOM expects its net emissions to become negative in the second half of the century.

Figure 3.6 **Carbon Sequestration|CCS (left), Emissions|$CO_2$|AFOLU (right), World**

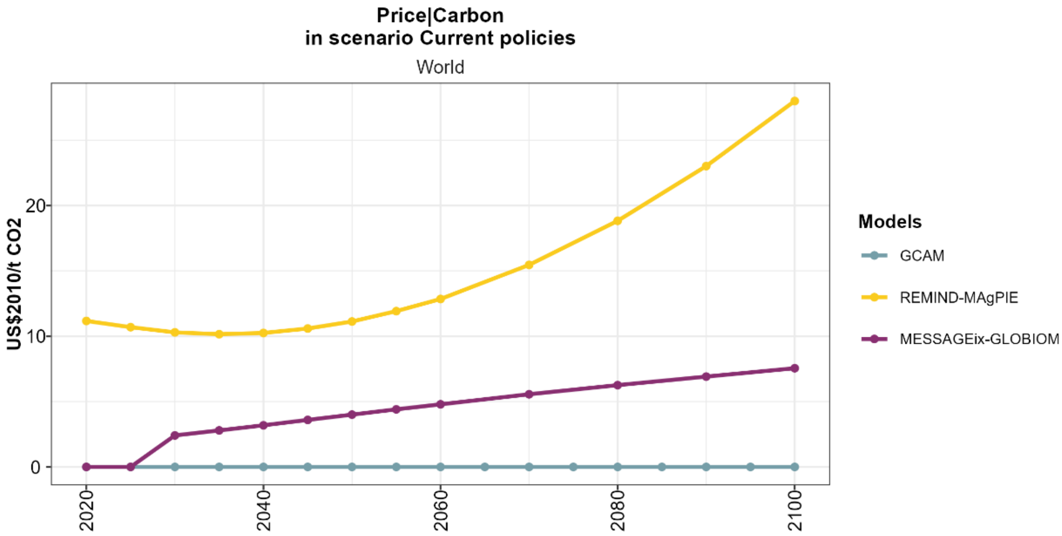


### 3.3.5 Carbon, energy and agricultural prices

#### Shadow carbon price

The main policy lever driving the transition is a (shadow) carbon price that (i) represents the marginal cost of abatement of carbon emissions and (ii) is a proxy for overall climate policy ambition and effectiveness, accounting for a variety of real-world climate policies (carbon tax, subsidies, environmental standards, etc.). In the Current Policies narrative, REMIND-MAgPIE, MESSAGEix-GLOBIOM and GCAM models consider the most important climate policies that have been listed as binding legislation and backed with instruments. All three models assume the carbon price remains low across the century, relatively to orderly scenarios. This approach translates the insufficient action to address climate risks, and the low transition risks in the Current Policies scenario. REMIND-MAgPIE assumes a global convergence of the carbon price to 25US$/t $CO_2$, while GCAM translates that no additional policies are considered by keeping the carbon price to 0US$/t $CO_2$[26]. Section 3.4 of this report will explore the important regional differences.

Figure 3.7 **(Shadow) Price|Carbon, World**




#### Energy prices

Secondary energy prices represent energy costs as the gross price paid by large scale consumers, such as industrial actors or energy suppliers. All IAMs provide price information with a 5-year timestep, indicating the trend for energy prices until the end of the century. The price at the second energy level (i.e. Price|Secondary Energy|Oil) includes the costs of extraction, transport and transformation as well as the carbon tax (applied when converting from primary to secondary energy).[27]

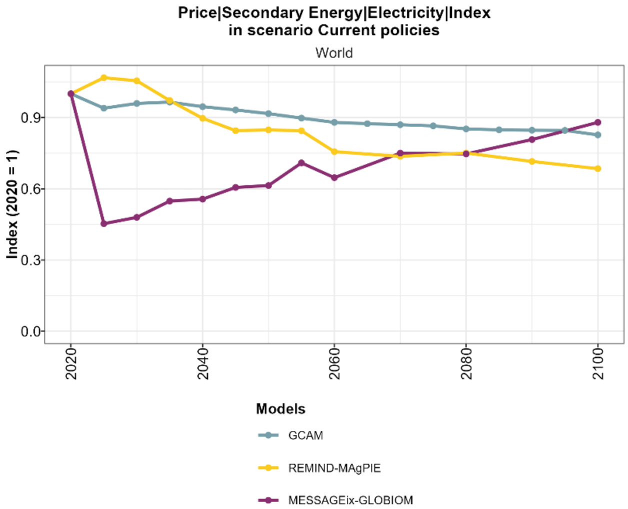
Under the Current Policies scenario, the transition towards low-carbon energy supply and investments is slow and dependence on fossil fuels remains. A slow gradual decrease of the secondary electricity price is expected until the end of the century, as renewable energy is less subject to carbon tax and has low operational costs compared to fossil fuels. MESSAGEix-GLOBIOM prices behaviour in the near-term is due to its region-specific assumptions of coal availability after COVID (slight revival) in 2025.

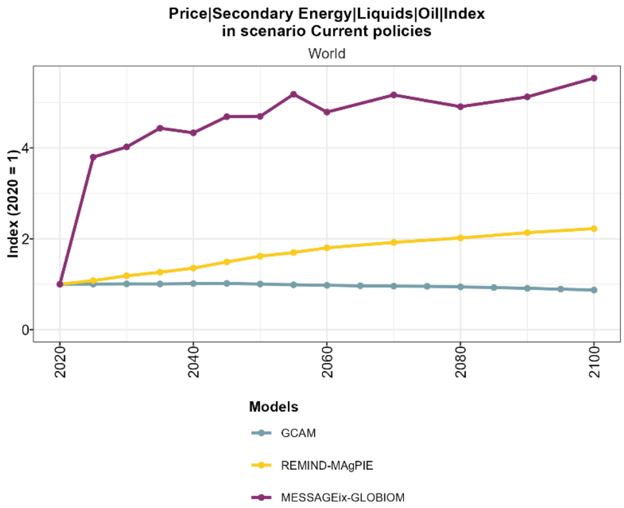
26 GCAM's current policy carbon price acts as a reference for the other scenarios. GCAM has a non-zero carbon price in some regions for calibration purposes, and thus reports the difference to that carbon price for all scenarios as the scenario carbon price (resulting in a zero carbon price in Current Policies).

27 Secondary energy prices provided by IAMs are based on economics fundamentals and driven by extraction costs. They may differ from prices provided by the NiGEM macro-economic model (in particular in the short-term), which takes different assumptions to represent demand and supply dynamics. The use of either results depends on the case study and its assumptions. More information on the IAM and NiGEM models can be found in the Note on Key assumptions and Technical documentation.

Figure 3.8 **Secondary Electricity and Oil index prices, World**

*(USD$2010/t$CO_2$)*



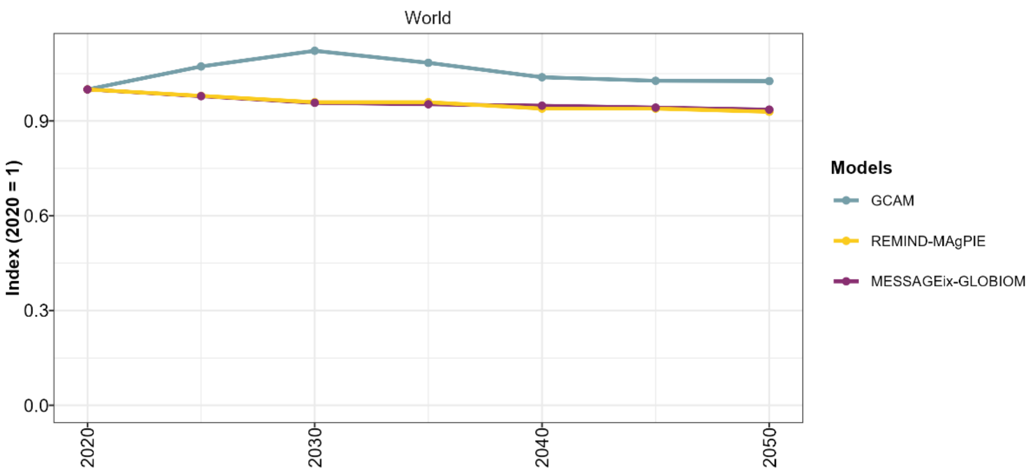

Fossil energy price trends vary across models, as they depend on fossil extraction assumptions and carbon price trends defined by each model. According to REMIND-MAgPIE, as the oil supply is modelled via supply-cost curves, carbon-intensive secondary energy prices (oil, coal and natural gas) are expected to increase until 2050 up to 2.2 times its value in 2020. This is due to both remaining high demand, increasing costs of extraction and carbon taxes.

## Agricultural prices

The Current Policy scenario assumes a continuation of existing agricultural practices without introducing additional measures to halt deforestation or promote afforestation. Under these conditions, there is limited pressure to expand arable land, as food and feed demands are also met through intensification and improved productivity. This dynamic is reflected in the global projections of all IAMs, which show a stable agricultural price index over time in this scenario.

Such price stability carries important implications for both economic performance and food security. From an economic perspective, stable food prices contribute to macroeconomic stability and foster investment. Price volatility, by contrast, tends to harm the most vulnerable populations – especially low-income consumers who spend a large share of their income on food. However, it is important to note that the IAM's transition scenarios projections do not account for the potential effects of climate change and extreme weather events on crop yields, or impacts from broader land degradation processes. These factors could significantly disrupt the projected stability in agricultural prices and pose serious risks to food systems and economic resilience (see Section 3.4).

Figure 3.9 **Price | Agriculture | Non-Energy Crops | Index in scenario Current policies**



## 3.4 Macroeconomic effects

The macroeconomic model NiGEM is used in the NGFS framework to derive impacts from transition and physical risks at the economic and financial level. Unlike the other NGFS scenarios, the Current Policies scenario assumes countries do not implement any new policies and carbon prices remain subdued. Therefore, this scenario does not result in any transition impacts to GDP, inflation, or interest rates in NiGEM. In the Current Policies scenario, the main component of macroeconomic effects is due to the physical damages associated with the emissions trajectory and global temperature rise (see Section 1.2 and 3.2). The estimates for both aggregate GDP damages and impact from climate extremes will be updated in the sixth phase of the NGFS scenarios in 2026.

More on macroeconomic effects from transition risks can be explored in the case of the Net Zero 2050 (Section 2.4) and Fragmented World scenarios (Section 4.4).

## 3.5 Key findings: ineffective and unsustainable current policies

This section provides a detailed analysis of the Current Policies scenario key findings using projections from three leading Integrated Assessment Models (IAMs) – GCAM, MESSAGEix-GLOBIOM, and REMIND-MAgPIE. This scenario demonstrates how current policies are insufficient to limit climate change impacts on natural and human systems, as the conditions for their liveability is jeopardised by the trajectory of greenhouse gas emissions.

Below, Section 3.5.1 describes the ineffectiveness of current policies to mitigate greenhouse gas emissions. Section 3.5.2 demonstrates the slowness of technology shifts, as a cause of projected emissions: renewables are expected to become ever more competitive, while the preserved role of fossil fuels in all sectors will lock emissions for decades to come.

### 3.5.1 Ineffectiveness of current policies to bend the emissions curve

**The near-term $CO_2$ projections suggest that current policies are still not sufficient to bend the global emission curve.** Near-term $CO_2$ emissions from fossil fuels and industry ($CO_2$-FFI) under Current Policies (shown in

Figure 3.10 **Emissions | $CO_2$ | Energy and Industrial Processes in scenario Current Policies, World**

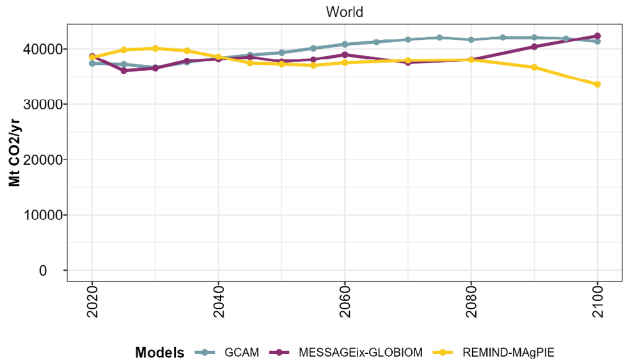



Figure 3.10) provide a realistic picture of where the world is headed without additional action, making them a crucial benchmark for assessing ambition gaps. Unlike total $CO_2$, which includes land-use change and may be influenced by relatively higher long-term uncertainties, $CO_2$-FFI is more directly tied to energy infrastructure, making it a more reliable indicator of near-term risks. High $CO_2$-FFI emissions in the near term can lock in long-term warming and significantly increase the difficulty of meeting global climate targets. All three IAMs show that the world 2025 level may keep around 38 Mt $CO_2$-FFI/yr in 2025, though they show different expectations on near-term green recovery (trend from 2020 to 2025, REMIND-MAgPIE increasing, GCAM and MESSAGEix-GLOBIOM decreasing).

The 2025-2035 emissions are higher than in previous NGFS phases (e.g. NGFS phase II or III), reflecting the fact that emissions have remained high despite the climate policies being implemented. It is also notable that, all models assume that once a policy is implemented, it remains in place indefinitely, although in reality climate policies can be weakened or even backslide. Therefore, the $CO_2$ emissions levels in IAMs could be underestimated, considering enacted policies lose strength over time, even under a scenario without stringent climate policies.

### 3.5.2 Unsustainable trends in the short- and long-term

#### Slow technology shift: supply-side

Looking at both the energy supply side and demand side gives a full system perspective of what lies behind the near-term and long-term $CO_2$ emission trajectories.

Figure 3.11 **Slow technology shift in Current Policy scenarios: share of fossil fuels in power generation mix**

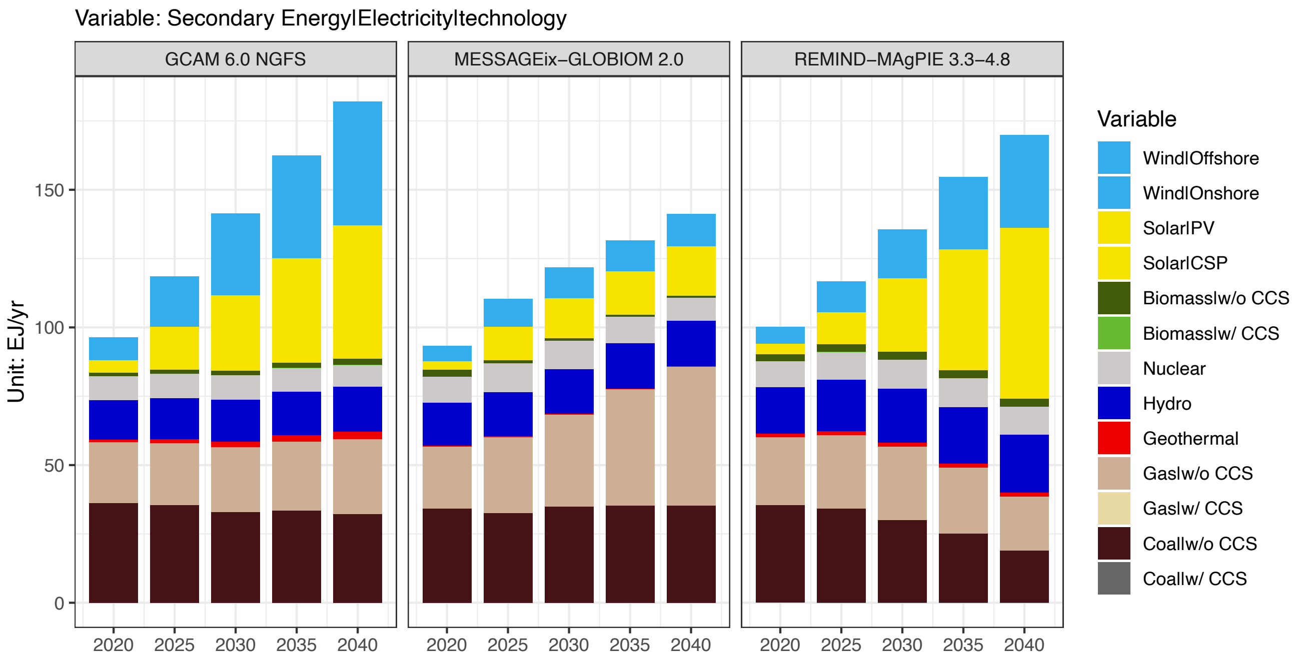



Figure 3.11 illustrates the global power generation under the Current Policy scenario across models. All three models project a steady increase in total electricity generation from 2020 to 2040, highlighting a rising demand for electricity that aligns with trends such as population growth, economic growth, and electrification of end-use sectors.

**Even without stringent climate policy goals, these near-term trends show that low-carbon electricity generation becomes cost-competitive and experiences a significant scale-up** (most fast growth in REMIND-MAgPIE, medium in GCAM, slow but steady growth in MESSAGEix-GLOBIOM). The substantial growth in the power generation from renewable energy technologies is a key observation. Specifically, solar technologies ramp up at a fast rate (although not as fast as under an ambitious mitigation scenario). Similar trends can be observed in the wind power sector (particularly offshore wind), reflecting current expectations of improved cost competitiveness in renewables.

**However, despite the progress in renewables deployment, fossil fuel-based power generation continues to dominate a large share of the mix through 2040 in all three models.** Coal and gas without carbon capture and storage (CCS) retain significant capacities and contribute heavily to power output. Fossil fuel capacities do not experience early retirement. **Therefore, the energy transition driven by current policies would only be partial and gradual.**

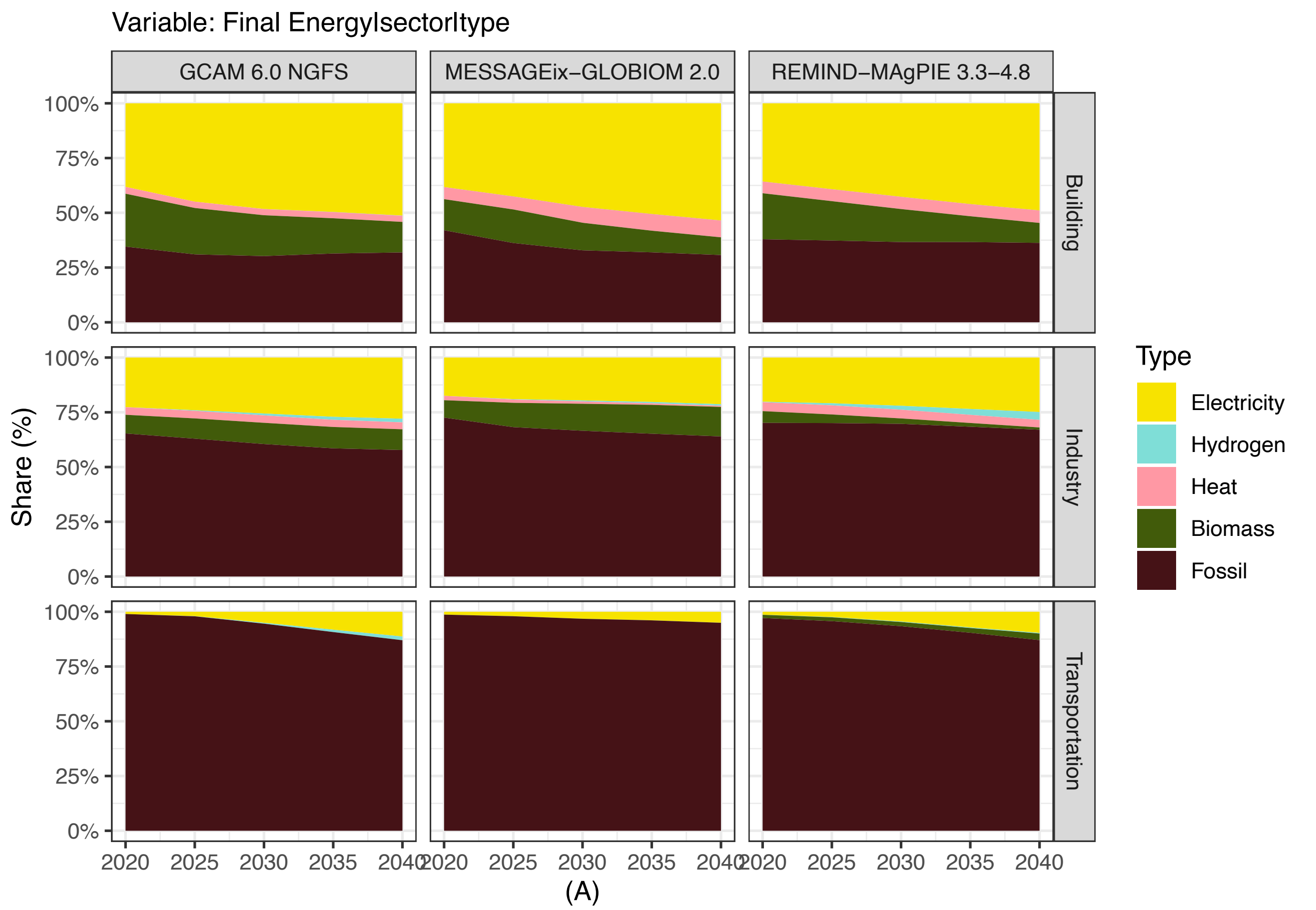
**The future of fossil fuels in the power generation mix varies across IAMs. These differences highlight the large uncertainties of where the current policies may lead the world to.** While the overall share of fossil fuels in the power generation mix remains high across all three models, their trajectories diverge significantly. In GCAM, total fossil-based power generation remains relatively stable from 2020 to 2040. Although renewables grow substantially, they largely meet the increase in electricity demand rather than displacing existing fossil capacity. In contrast, MESSAGEix-GLOBIOM shows a revival of fossil generation, particularly in gas-fired power, over the same period. This trend suggests a reliance on fossil fuels, potentially as a backup to intermittent renewables, given the slower progress in clean energy deployment under current policy assumptions. On the other hand, REMIND-MAgPIE projects a clear decline in total fossil generation, especially in unabated coal, by 2040. The renewables will not only meet demand growth but also actively displace fossil power, signaling a faster technology diffusion compared to the other two models.

**Finally, it is worth noting that fossil fuel investments remain high in all models, and two of the three models exhibit higher near-term fossil power investments (2016-2030). This suggests a high probability of fossil lock-in under the current policy scenario. This continued financial commitment to fossil fuel capacities in the near term (2016-2030) highlights the unsustainable incomplete nature of current policy frameworks.** Such an inertia standing in the way of the decarbonisation transition might be driven by multiple factors: a renewed prioritisation of energy security, the current context of a polycrisis[28], and financial strategies of fossil fuel investors. The relative investments are discussed in detail in the Report on energy investments (2025).

## Slow technology shift: demand-side

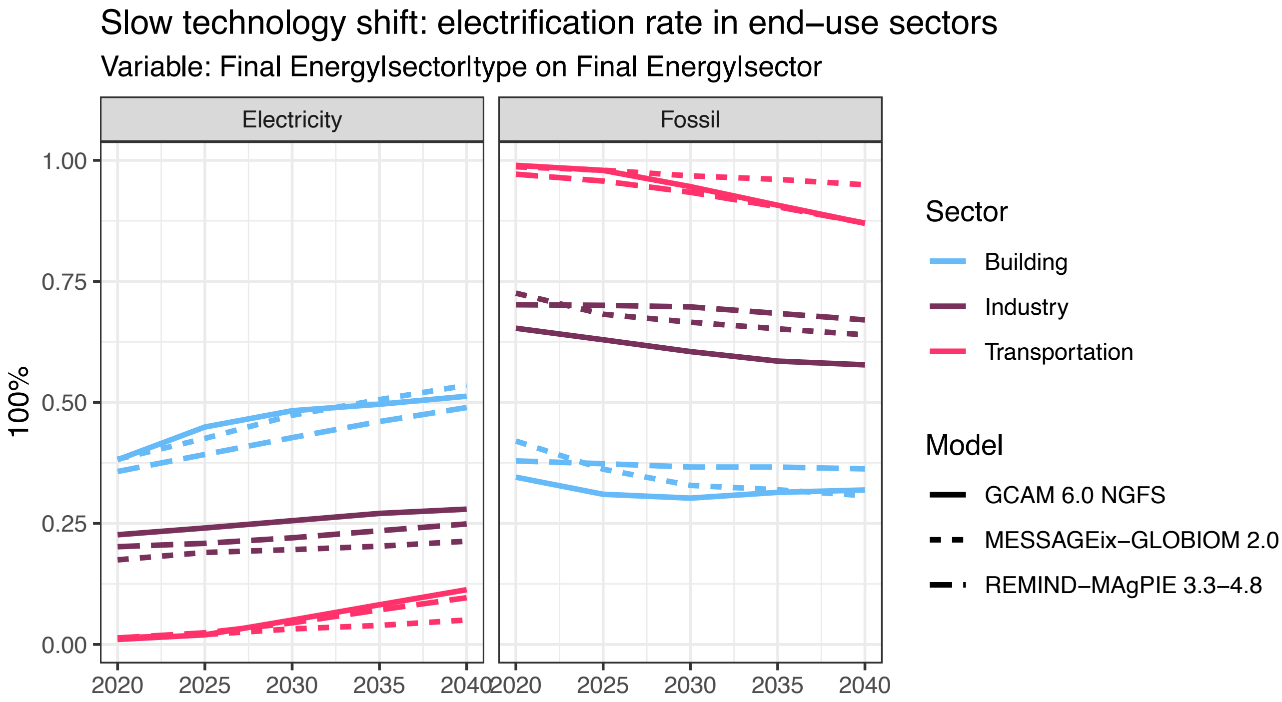
**Demand-side mitigation options, such as electrification, are also essential, as the mild clean transition in the energy supply cannot compensate for unchecked growth in consumption. However, electrification can only contribute to emission reductions if the electricity used is generated from low-carbon sources.** Figure 3.12 shows the structure of final energy in industry, transportation, and buildings (A), as well as the shares of electricity and fossil fuels there (B). The electricity share (in yellow) grows slowly and unevenly across sectors and models, with buildings again showing the most visible shift, but still leaving fossil fuels (dark brown) with a large

Figure 3.12 **Slow technology shift : electrification rate in end-use sectors**




28 IMF. (2023). Gardes-Landolfini, C., Grippa, P., Oman, W., & Yu, S. Energy transition and geoeconomic fragmentation: implications for climate scenario design. International Monetary Fund, 2023, https://doi.org/10.5089/9798400258220.066.

Figure 3.13 **Share of electricity and fossil fuels**




share of the energy mix in 2040. Industrial energy remains heavily fossil-based, with only minor contributions from electricity, biomass, or heat. Transportation shows the slowest transformation, with fossil fuels overwhelmingly dominant in all three models and minimal penetration of alternative energy sources.

**Decarbonising end-use sectors requires stronger demand-side policy intervention, as well as the fast scaling-up of low-carbon demand-side technologies.** A modest rise in electricity share can be observed across all sectors, particularly in buildings where electrification increases to just above 50% by 2040 across most models. In contrast, the electrification rate in industries only increases by about 4% between 2020 and 2040. Up to 12% of the transportation sector could be electrified by 2040. Fossil fuel reliance remains dominant in transportation, staying above 95% in 2030 and declining only marginally by 2040. In the industrial sector, fossil fuel use stays above 68% even in 2030 and remains the primary energy source across all scenarios.

### 3.5.3 Near and long-term risks in a 3 °C world

#### Transition risks: manageable but non-negligeable

**Low carbon prices are characteristic of low transition risk scenarios: the change in carbon price is negligible as current policies continue without upgrading their ambition.** Figure 3.14 shows the carbon price trajectory and primary energy price index under the Current Policy scenario. In the near term, transition risks associated with fluctuations in primary energy use remain relatively modest. Coal price shows minimal variation, reflecting its continued role in the energy mix under current policy trajectories. For gas and oil, the transition risk index increases up to 1.4 in 2040 (Figure 3.15), with the rise driven mostly by extraction costs rather than carbon pricing, suggesting that changes may be underway but are not being disruptive. All these indicate a slow and incremental shift in the energy system, with short-term risks appearing manageable in the absence of stringent policy interventions.

Figure 3.14 **Near-term and long-term transition risk: carbon price**

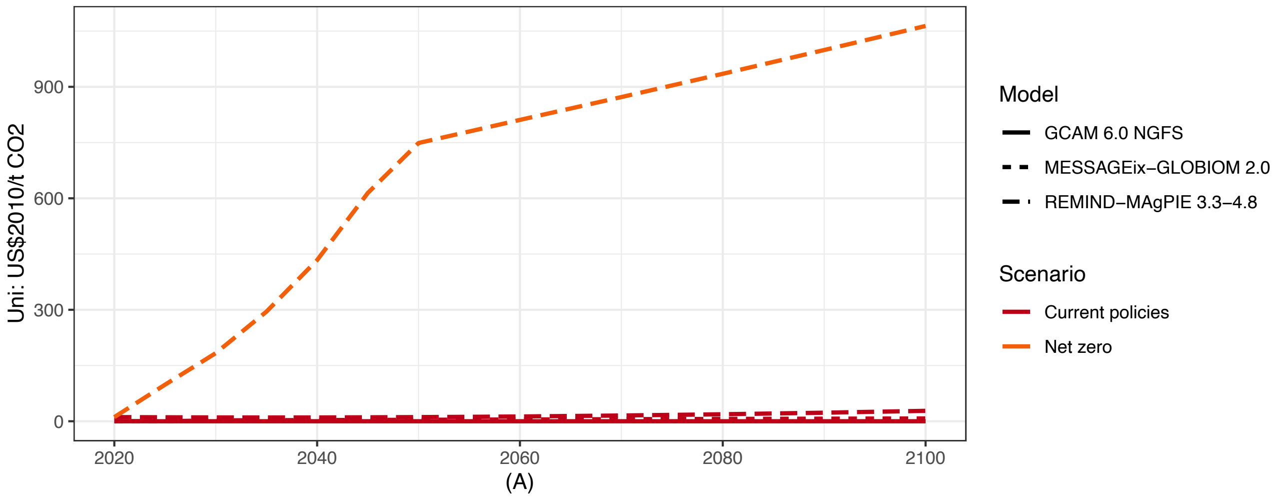
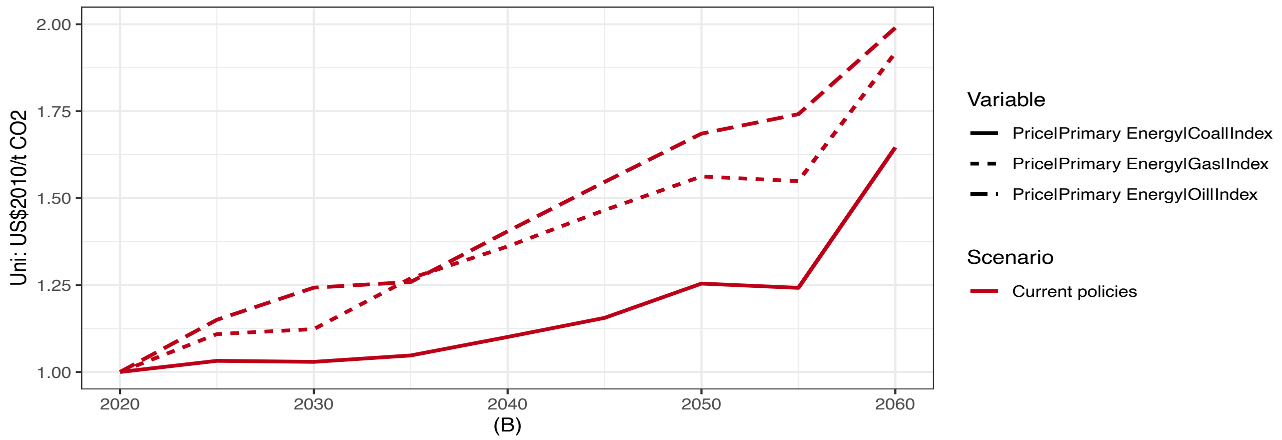



Figure 3.15 **Near-term and long-term transition risk: primary energy price index**




**However, the longer-term economic consequences are more concerning.** The further increase of fossil primary energy signals an economic strain, and emphasises the urgency of measures on both energy supply side and demand side. Under a Current Policy scenario, the most serious longer-term economic effects stem from increasing physical risks due to high global warming, which are explored in the next section.

## Physical risks

The Current Policies scenario shows much higher levels of climate impacts, illustrating the severe consequences of delayed or insufficient mitigation. For example, high heat risk days over Western Europe may be three times more frequent by the end of the century than in a Net Zero 2050 scenario[29].

Societies already today experience an increase in the frequency and intensity of climate extremes, such as heat waves. While "median" projections for climate impacts for the near-term may appear small at first sight, one needs to be aware that the world at atmospheric greenhouse gas concentration levels that are *unprecedented* in human history[30], and under the Current Policies Scenario emission levels would continue to rise steeply, pushing the world further into unknown territory. The response of our climate system to this is subject to considerable

29 Explore climate impacts under NGFS scenarios on the Climate Impact Explorer: https://climate-impact-explorer.climateanalytics.org/.

30 World Meteorological Organization https://wmo.int/news/media-centre/greenhouse-gas-concentrations-surge-again-new-record-2023, Royal Society https://royalsociety.org/news-resources/projects/climate-change-evidence-causes/question-7/.

uncertainty. These large uncertainty ranges are especially relevant for projections on tail risks, i.e. rare high impact extreme events.

The Climate Impact Explorer features a wide range of indicators for both slow-onset and extreme events. Additionally, the report on physical risks in the updated Climate Impact Explorer, 2025, provides a detailed overview of the projected changes in exposure and intensity for drought, heat and extreme precipitation. It moreover explores the questions how projected impacts change when our climate system responds more strongly to greenhouse gas emissions than currently assumed.

## 3.6 Conclusions on Current Policies scenario

In the Current Policy scenario, the world is assumed to keep its current level of policy action for addressing climate change. The scenario results depict an unsustainable and uncertain future: the current policies are shown to be insufficient to limit global warming, and energy consumption trends and investments in fossil fuels are a promise for further pollution for several decades. Regarding the emissions and temperature outcomes, the uncertainty range is large but is definitely disastrous (from 2 °C to 4.4 °C in 2100). Due to this lack of mitigation effort, societies will experience economic instability and unprecedented physical impacts in the long-term.

Further deprioritisation of the climate agenda would have clear negative consequences globally. Past emissions have locked societies to already experience a 1.3 °C World today, with increased frequency and severity of climate extremes. Near-term emissions are decisive for the long-term temperature increase: if they are not mitigated, they will impact ecosystems and livelihood of present and future generations dramatically.

For the financial sector, these scenario findings reveal that the Current Policies scenario leads to the global temperature increase and highest physical risks relative to the other NGFS scenarios. An updated quantification of these impact and damage estimates will be available in NGFS Phase 6, 2026. In case of policy backsliding, these impacts may become greater. The financial sector can support the transition to a greener economy globally by incorporating the long-term costs of inaction in risk management decisions.

# 4. Fragmented World: narrative and key findings

## 4.1 Narrative of the Fragmented World Scenario

*Short summary: The Fragmented World scenario assumes delayed and divergent climate policy ambition globally, leading to high physical and transition risks. Countries with net zero targets achieve these only partially (80% of the target), while the other countries follow current policies.*

| Warming at end of century[31] | Policy reaction | Technology change | CDR | Regional policy variation | Physical risks |
|---|---|---|---|---|---|
| 2.1-2.4 °C in 2100 | Delayed to 2030, fragmented | Slow until 2030, then fragmented | Low-medium use | High variation | High in medium-term, increased in the long-term |

### Climate policy ambition and action

**Fragmented World assumes a delayed and divergent climate policy response among countries globally, and a weak international cooperation, leading to heterogeneous pathways across regions. Countries with net zero targets[32] achieve these only partially (80% of the target), while the other countries follow current policies.** As some countries will move towards net-zero emissions with decarbonisation, others will remain dependent on traditional fossil fuels use. This lack of global coordination leads to high variation across regions for modernisation of the energy sector and dependency on international trade of fossil fuel. Due to countries implementing climate neutrality targets, the scenario assumes an increased $CO_2$ price from 2030, reflecting the delayed implementation of policy instruments for emissions reduction. Globally, the shadow carbon price could reach 60-130 US$2010/t $CO_2$ by 2050, and shows high regional variation. This response is shown to be ineffective, as global warming could reach 2.0 °C in the second half of the century, and 2.4 °C by 2100. The delayed and divergent policy response leads to both high transition risks due to a rapid and uncoordinated transition, and high physical risks due to ineffective global response to climate change impacts.

### Socio-economic developments

**Like all other NGFS scenarios, the Fragmented World scenario assumes social, economic, and technological developments that reflect trends observed during the first two decades of the 21st century**, following the assumptions of the Shared Socio-economic Pathway 2 (SSP2)[33]. Countries and international relations are relatively stable, markets are globally connected, although some barriers remain, development and economic growth proceed unevenly (with a global annual average growth rate of 4% for 2020-2030 and 3% for 2030-2050), and global population growth is moderate and levels off at 10 billion people in the second half of the 21st century. Multilateral institutions make only slow progress towards achieving the sustainable development goals and environmental systems continue to degrade gradually. Technological development is moderate. The fragmented action on climate change and associated transformation of energy and land use constitutes a break from these moderate and uneven trends, but such trends persist in other sectors. See also Box 2 on alternative SSP.

### Energy transition and technology trends

**Regions face heterogeneous deployment of technologies, in particular in the energy sector.** As countries with net-zero

31 End-of-century and peak warming values represent the results range across IAMs, and the 50th percentile of the surface temperature variation (AR6 Surface Temperature (GSAT)|MAGICCv7.5.3|50.0th Percentile).

32 Net-zero targets as published by the UNFCCC as of March 2024 for the following countries: Argentina, Australia, Brazil, Canada, Colombia, EU + UK, Japan, New Zealand, South Africa, South Korea and USA in 2050; China, Indonesia and Russia in 2060; and India in 2070. Some jurisdictions such as the US, EU, UK, Canada, Australia, and Japan reach net zero for all GHGs.

33 Riahi *et al.*, 2017, O'Neill *et al.*, 2017.

targets experience a fast technological shift to decarbonise their energy sector and other countries follow current policy trends, the world experiences unbalanced technology markets across regions.

### Food systems and land-use transition

**Delayed and uneven policy actions lead to fragmented progress in transforming food systems and land use, as rising global agricultural demand and regional disparities continue to strain land resources and limit the effectiveness of climate action.** The late implementation of climate mitigation measures slows the adoption of more sustainable land management practice and emissions reduction in the land use sector. In developed countries, patterns of overconsumption and food waste persist, while in many developing economies converge towards Western-styled diets. Regional differences in climate policy ambition result in uneven incentives for bioenergy production and land-based carbon removal.

### Physical risks and climate change impacts

**Most regions are projected to experience increased exposure to climate hazards such as heat stress, drought and heavy precipitation risks.** The lack of stringent emission reduction despite costly, but ineffective climate policy action in some regions results in a strong increase in physical risks in the medium to long run, albeit still reduced compared to a Current Policy scenario.

### Economic transition

Economic impacts due to the transition increase from 2030, adding on existing damages due to physical impacts, as regions with net-zero targets implement further climate policy instruments. Transition impacts begin in 2030 and are considered unanticipated until this point. Policy and long-term interest rates tend to increase in 2030 to curtail the initial spike in inflation in some regions, and settle to higher value compared to baseline in the longer-term.

### Too little, too late

**The Fragmented World scenario belongs to the 'Too little, too late' category of the NGFS Scenario Framework, which encompasses scenarios with a late and uncoordinated transition that fails to limit physical risks.** The Fragmented World scenario faces both short-term and long-term disruptions, due to uneven climate action. This scenario could be used to assess the impacts of a delayed transition and the cost of inaction. It also shows the decrease in efficiency of the transition, when society does not align behind ambitious climate goals.

#### Box 2

### Note on alternative SSP for the Fragmented World scenario

Scenarios built on the assumptions from a chosen SSP can lead to diverse outcomes. For instance, different global warming levels, defined by the end-of-century forcing levels (RCPs), can coherently be attributed to SSP2 scenarios. Indeed, while remaining under the SSP2 assumptions, a wide range of additional assumptions can be made on social, technological and political developments. This broadens the range of possible outcomes within the SSP narrative, as demonstrated by the diversity of trajectories among the NGFS scenarios.

While all NGFS scenarios follow the SSP2, the Fragmented World scenario narrative has some resemblance with the world described in SSP3 "A Rocky Road" narrative. However, overall socio-economic trends of SSP3 remain different from the "Middle of the road" assumptions made in the Fragmented World scenario. The severe fragmentation as described in SSP3 would have severe consequences on regional economies, substantively weaken climate policy ambition and inevitably increase social inequality, and therefore lead to scenarios with less ambitious outcomes. Compared to SSP2, the SSP3 trajectories show a slower GDP increase, energy efficiency improvements, and higher population.

The SSP2 narrative is by definition neither optimistic nor pessimistic, and it is important to compare a wide range of possible outcomes within its limits. However, it would also be relevant to consider recent geopolitical developments (e.g., shift in dominant power and social preferences) within other SSP narratives, such as SSP3 or SSP4.

## 4.2 Narrative quantification

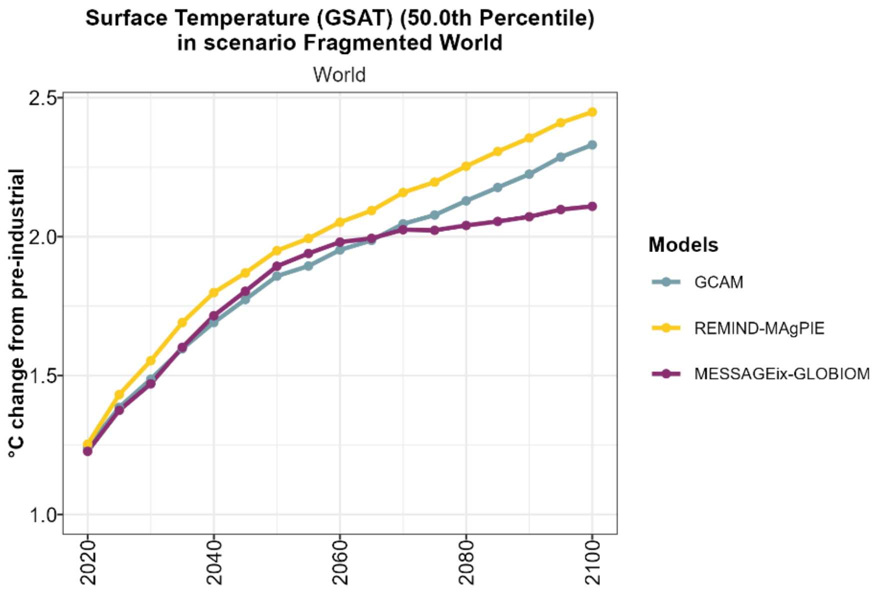
Robust SSP and scenario frameworks allow the translation of the qualitative narrative into quantitative assumptions to the Integrated Assessments Models[34]. The implementation of the following parameters are essential to the Fragmented World scenario.

- **SSP2 assumptions on population and GDP baseline are reflected as exogenous parameters in IAMs.** The GDP then changes semi-endogenously when affected by energy transition costs, and by integrated damages when they are included. SSP2 assumptions enforce moderate rates of socio-economic development on average globally, and moderate convergence between low and high income countries (Annex A).
- **Policy commitments are translated into constraints on the emissions or technology targets and are reflected in the shadow carbon price.** A carbon budget is set to reflect the policy ambition, leading to warming level above 2 °C at the end of the century (Figure 4.1). In the case of Fragmented World, the carbon price varies highly between regions, and reflects the timing for action – which is delayed to 2030.
- Climate change directly affects physical risks and impacts on natural and human systems, and therefore socioeconomic developments.
- **Collaboration within countries impacts how smoothly the transition can occur.** The Fragmented World scenario has high regional differences in policy ambition, which implies a fragmented transition. The scenario also assumes hindered global learning effects on low-carbon technologies.
- The Fragmented World scenario takes **moderate assumptions on innovation and growth constraints**, which only allow for slow technology change and deployment. Specifically, low-to-medium use of CDR is allowed in this scenario.

However, modelling exercises show there are many ways to reflect complex systems, and many strategies to implement a transition. IAMs characteristics and assumptions influence their future projections and pathway towards reaching emission targets. Key assumptions are summarised in the "NGFS Note on Key assumptions, 2025", and more technical details on the models are available in the "NGFS Technical documentation, 2025". When relevant, this report will highlight how model results compare and the drivers behind potential differences.

Figure 4.1 **Surface Temperature Variation**

*(MAGICCv7.5.3, 50.0th Percentile)*




34 Fricko *et al.*, 2017.

## 4.3 Transition risks

This section highlights key characteristics of the climate transition in the Fragmented World scenario, that are of particular relevance for describing the scenario implications in various sectors, as well as for using this scenario for risk assessments. NGFS long-term scenarios offer a multi-model study that is needed to derive robust insights in long-term scenarios. In this section, results from the three IAMs are shown and compared. Key similarities and differences between models are highlighted and crossed with characteristics and assumptions of IAMs.

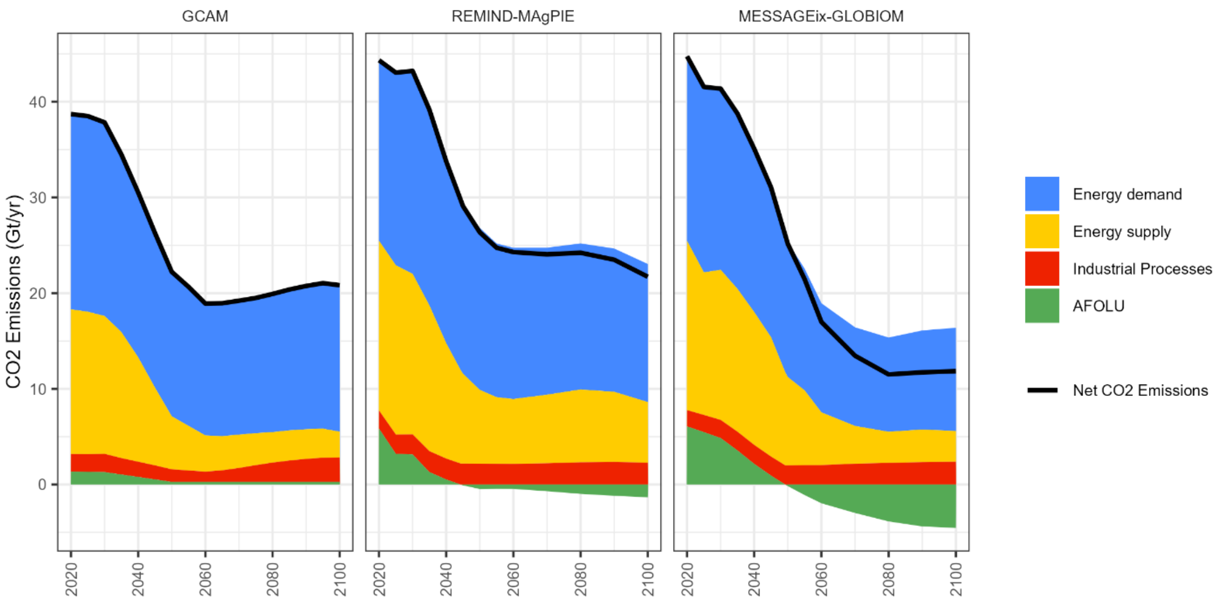
### 4.3.1 Emissions trajectory

Under the Fragmented World scenario, all three IAMs observe a moderate reduction of global yearly $CO_2$ emissions by the end of the century. The yearly emissions decline strongly from 2030, and at most are divided by two by 2060 compared to 2030. Emissions stabilise at the end of the century, around 22Gt/year in REMIND-MAgPIE and GCAM, and at 12Gt/year in MESSAGEix-GLOBIOM thanks to larger negative emissions in the AFOLU sector (agriculture, forestry and other land use). Figure 4.2 shows that despite a decline in $CO_2$ emissions in the energy sector (including some carbon sequestration), total global $CO_2$ emissions remain net positive. Divergent national climate policies result in strong regional variations. These variations in terms of emissions are explored in the Key findings section of this report 4.5.2 "Global emissions and climate change remain high". $CO_2$ emissions in the energy demand sectors (residential and commercial buildings, industry, transportation) only show a slight decline, and the supply-side emissions highlight the importance of electricity decarbonisation.

### 4.3.2 Primary energy mix

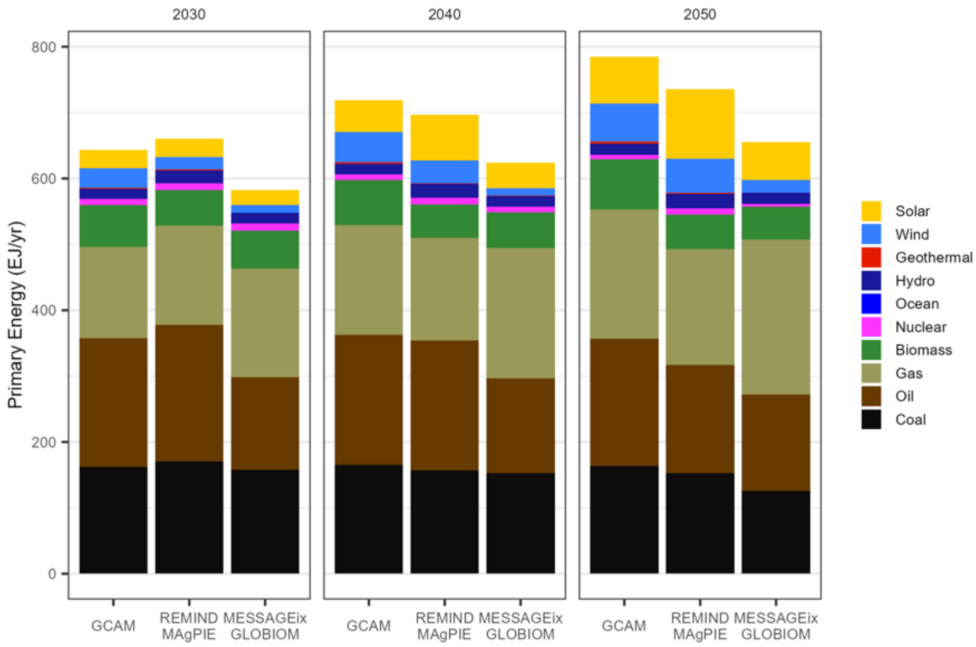
In the Fragmented World scenario, the use of primary energy sees a rather constant trend, despite the mitigation efforts in some jurisdictions. The use of fossil fuel only decreases slightly and remains significant, as new renewable capacities are added to the mix.

Figure 4.2 **Yearly Emissions|$CO_2$ (Mt $CO_2$/yr)**[35]




35 Gross $CO_2$ emissions would allow for better specification of the sectoral transition, in particular to represent the share of carbon capture and storage in energy and industry sectors. These variables will be reported in the next NGFS phase, following the IAM community initiative of aligning their common variables definitions.

Figure 4.3 **Primary energy, World**




## 4.3.3 Final energy and electricity mix

Renewable electricity is the main component of the energy sector decarbonisation. Solar and wind capacities quickly ramp up and become between 50% and 80% of the total mix. However, gas and coal-based electricity remains in the portfolios, which causes electricity to remain a source of high emissions (see Section 4.3.1). All three IAMs project a climbing final energy demand, mostly driven by electricity demand.

Figure 4.4 **Sources of Electricity, World**

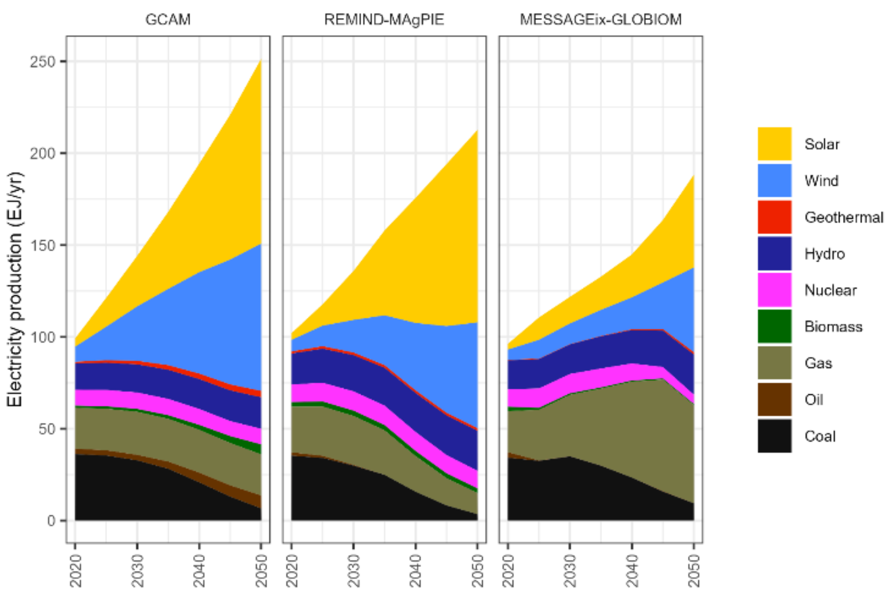
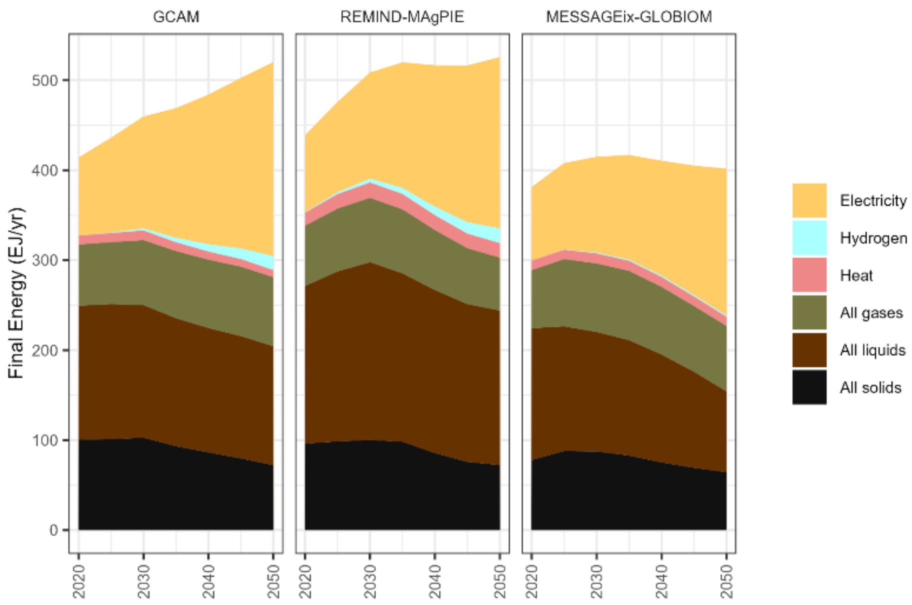


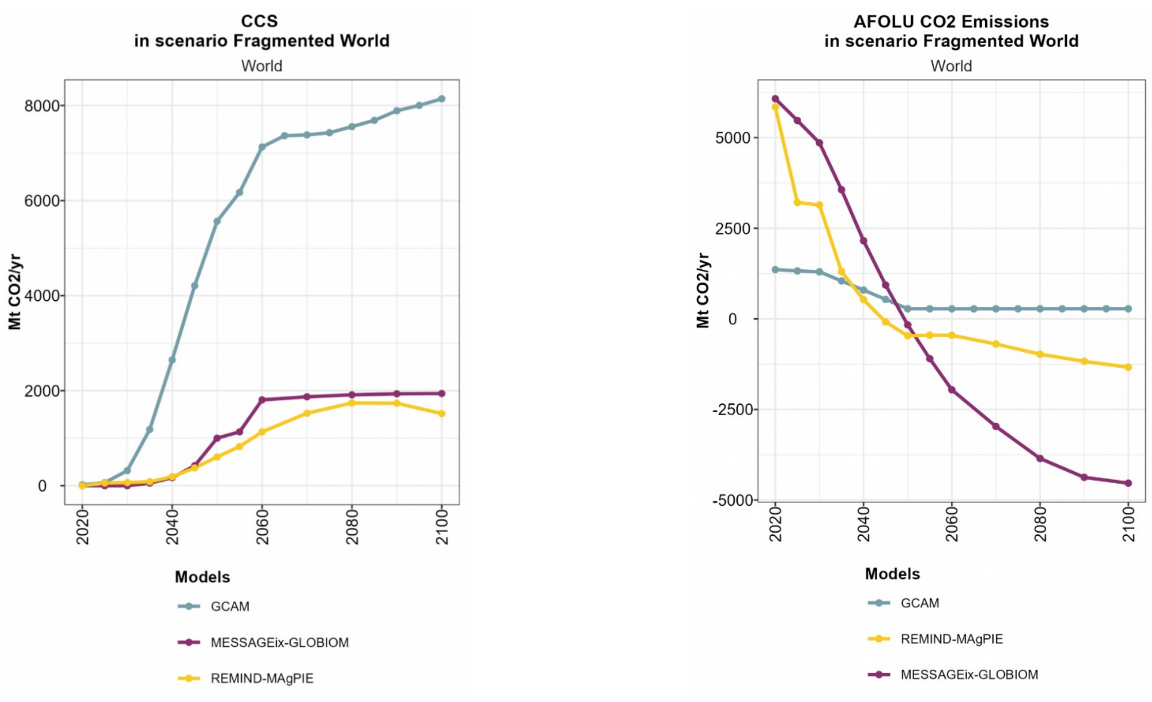
Figure 4.5 **Final Energy, World**




## 4.3.4 Carbon storage and land use

Carbon sequestration includes processes to *capture* $CO_2$, either at the outlet of a plant or through biomass growth, and to *store* the $CO_2$ into geological deposits (such as in depleted oil and gas fields) or through land-based sinks (such as afforestation). In the Fragmented World scenario, the use of carbon sequestration to limit emissions play a varied role across models, depending on their CCS cost and deployment assumptions. GCAM takes more optimistic

Figure 4.6 **Carbon Sequestration|CCS (left), Emissions|$CO_2$|AFOLU (right)**



assumptions on CCS costs and adoption rates, while MESSAGEix-GLOBIOM rather complements residual emissions with higher negative emissions in the AFOLU sector. In total, land-based and technological carbon sequestration could sum to 2-8Gt of $CO_2$ per year in the second half of the century. This represents a low-medium use compared to less ambitious NGFS scenarios (e.g. the Current Policies scenario sees CCS capacities to only 0-1.2Gt $CO_2$/year in 2050). Section 4.5.1 of this report discusses in more detail the opportunity of land-based mitigation.

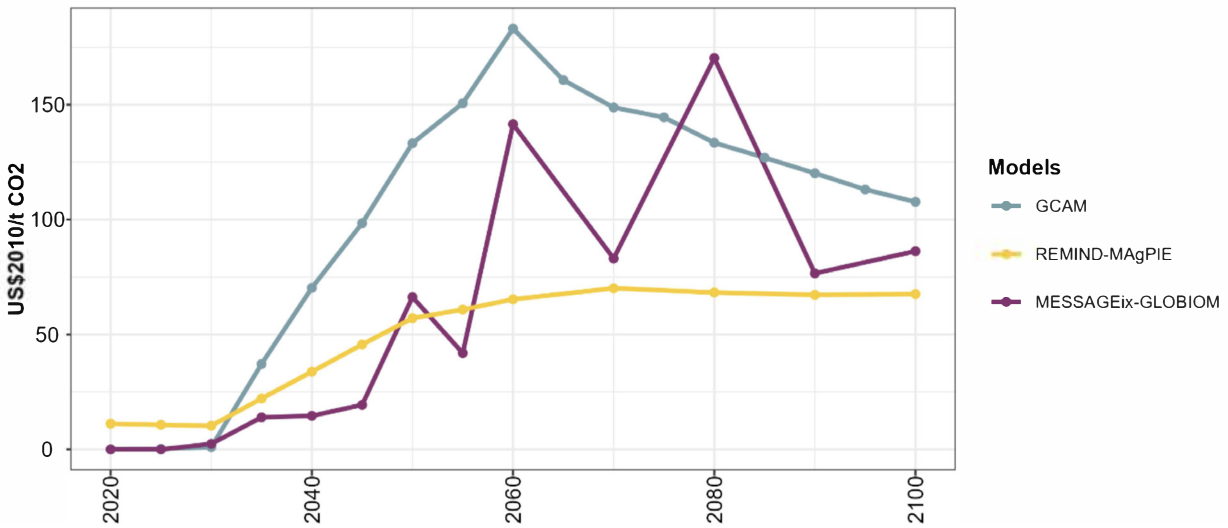
### 4.3.5 Carbon, energy and agricultural prices

#### Shadow carbon price

The main policy lever driving the transition is a (shadow) carbon price that (i) represents the marginal cost of abatement of carbon emissions and (ii) is a proxy for overall climate policy ambition and effectiveness, accounting for a variety of real-world climate policies (carbon tax, subsidies, environmental standards, etc.). In the Fragmented World scenario, the global carbon price remains relatively low (55-130$US/t $CO_2$ in 2050) compared to orderly scenarios as most countries follow a low-ambition current policy trajectory (translating into low carbon prices <10$US/t $CO_2$ in 2030). Section 4.4 of this report will explore the important regional differences.

Under the Fragmented World scenario, the MESSAGEix-GLOBIOM model exhibits a fluctuating long-term trajectory for the global carbon price (which is derived as a weighted average of regional prices). The scenario narrative assumes that each region achieves its climate targets according to its own timeline, without a coordinated and phased implementation strategy. Moreover, with MESSAGEix-GLOBIOM, once net-zero targets are met, regional carbon prices tend to decline. As a result of regionally fragmented efforts, elevated carbon prices emerge in different regions at different periods, leading to a fluctuating trend in the global carbon price trajectory.

Figure 4.7 **Shadow Price|Carbon in scenario Fragmented World**

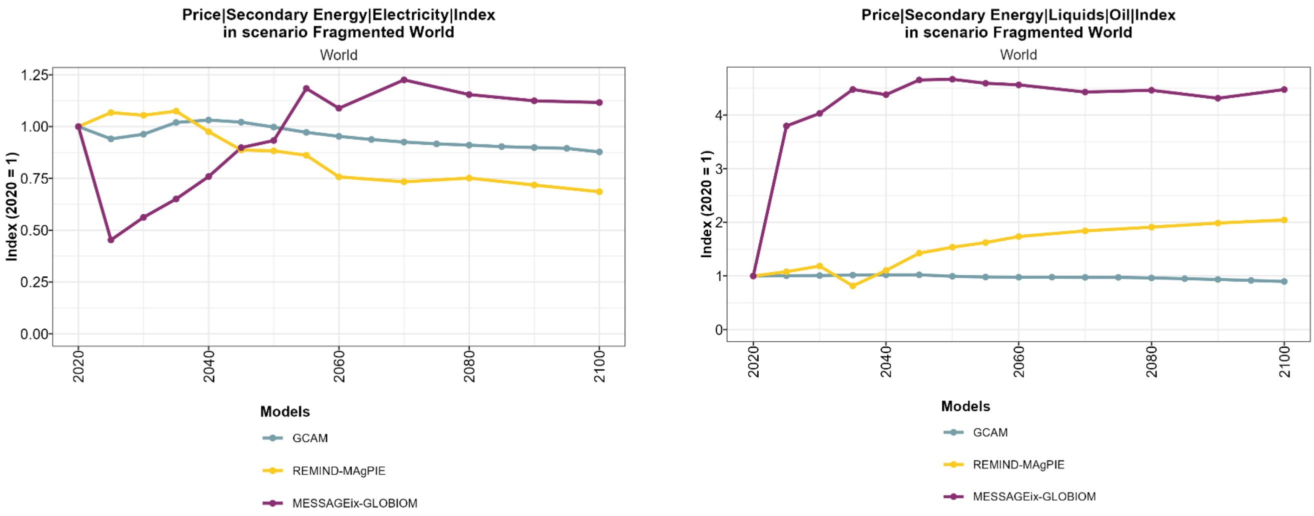



#### Energy prices

Secondary energy prices represent energy costs as the gross price paid by large scale consumers, such as industrial actors or energy suppliers. All IAMs provide price information with a 5-year timestep, indicating the trend for energy prices until the end of the century. The price at the second energy level (i.e. Price|Secondary Energy|Oil) includes the costs of extraction, transport and transformation as well as the carbon price (applied when converting from primary to secondary energy).[36]

36 Secondary energy prices provided by IAMs are based on economics fundamentals and driven by extraction costs. They may differ from prices provided by the NiGEM macro-economic model (in particular in the short-term), which takes different assumptions to represent demand and supply dynamics. The use of either results depends on the case study and its assumptions. More information on the IAM and NiGEM models can be found in the Note on Key assumptions and Technical documentation.

Figure 4.8 **Secondary Electricity and Oil index prices (USD\$2010/t$CO_2$)**



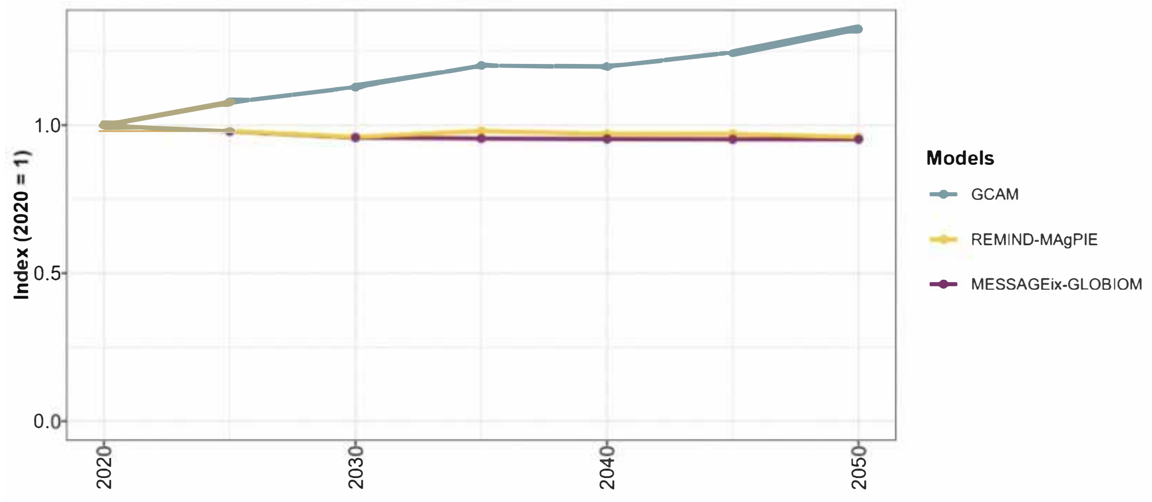

Under the Fragmented World scenario, the transition towards decarbonised energy production is delayed, and fossil fuels remain a large share of the global primary energy consumption. As electricity production is mostly decarbonised by 2050, secondary electricity prices fall, as renewable energy is low-carbon and has low operational costs compared to fossils. Fossil energy price trends vary across models, as they depend on fossil extraction assumptions and carbon price trends defined by each model. REMIND-MAgPIE expects carbon-intensive energy prices (oil, coal and natural gas) to increase up to 2 times the 2020-value by the end of century, due to both remaining high demand, increasing costs of extraction and carbon taxes. MESSAGEix-GLOBIOM prices behaviour in the near-term is due to its region-specific assumptions of coal availability after Covid (slight revival) in 2025.

## Agricultural prices

Under the Fragmented World scenario, GCAM projects a more pronounced increase in agricultural prices compared to MESSAGEix-GLOBIOM and REMIND-MAgPIE. While GCAM shows steadily rising prices through mid-century, mainly driven by regional disparities in productivity, land availability, trade barriers, and emissions pricing, REMIND-MAgPIE and MESSAGEix-GLOBIOM display relatively stable global agricultural price indices over time. This price stability reflects their more flexible treatment of cropland expansion, yield improvements and trade flows to meet food and feed and bioenergy demand at minimum cost, thereby smoothing price spikes.

Although the narrative of Fragmented World includes delayed and uncoordinated climate action, weak international cooperation, and regionalised policy responses, these assumptions do not disrupt global food price trends equally across models. However, in such a fragmented policy landscape, small and trade-dependent economies could be especially exposed to agricultural price volatility, even if global averages remain relatively contained due to offsetting effects between constrained supply and ongoing demand growth.

Figure 4.9 **Price|Agriculture|Non-Energy Crops|Index in scenario Fragmented World**




## 4.4 Macroeconomic effects from transition risks

The following section presents results and trends for key macroeconomic variables from the model NIGEM. Regional GDP damages from transition risks are discussed and compared with other scenarios from the NGFS framework.

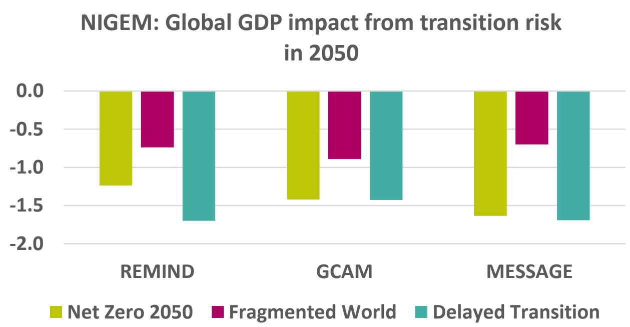
Another important component of macroeconomic changes is due to the physical damages associated with the emission-driven climate change and global mean temperature increase (see Section 1.2 and 4.2).

For the calibration of climate scenarios, NiGEM takes inputs from different modules of the NGFS modelling framework. The trends for all macroeconomic variables (from NiGEM) in this section are presented relative to a climate neutral forecast baseline (see Annex B). The IAMs provide data for a new baseline forecast and climate transition risk scenarios.

### 4.4.1 GDP damages from transition risks

**The Fragmented World scenario assumes a delayed and divergent climate policy action globally, resulting in one of the highest peak warming temperatures among NGFS scenarios by the end of the century (2.4 °C). This higher warming leads to higher physical risks not just in comparison to the orderly Net Zero 2050[37] scenario but also the disorderly Delayed Transition[38] scenario.**

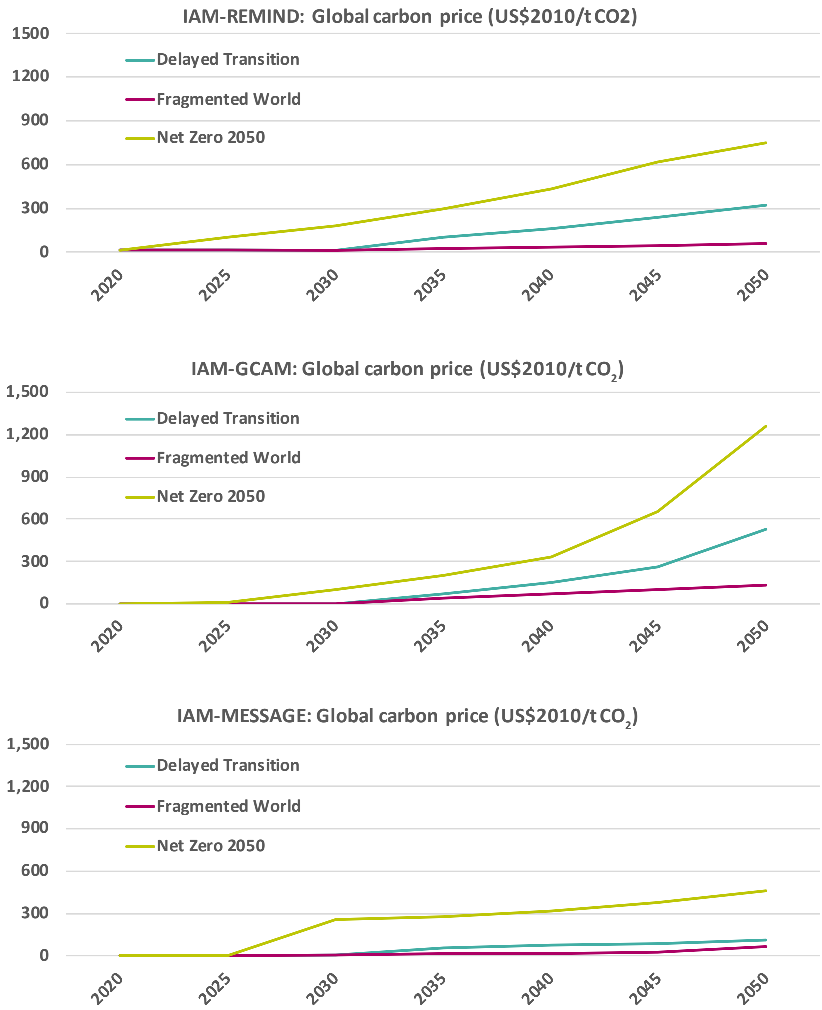
Figure 4.10 **World GDP losses (%) due to transition risks wrt baseline levels in 2050 (NiGEM output)**




37 The Net Zero 2050 scenario limits global warming to 1.5 °C by 2100, with a peak warming up to 1.7 °C, through stringent climate policies and innovation, reaching global net zero $CO_2$ emissions around 2050. This scenario assumes that ambitious climate policies are introduced immediately (see Section 2).

38 Delayed Transition assumes global annual emissions do not decrease until 2030. Strong policies are then needed to limit warming to below 2 °C. Negative emissions are limited. This scenario assumes new climate policies are not introduced until 2030 and the level of action differs across countries and regions based on currently implemented policies.

Figure 4.11 **Global carbon prices (IAM outputs)**

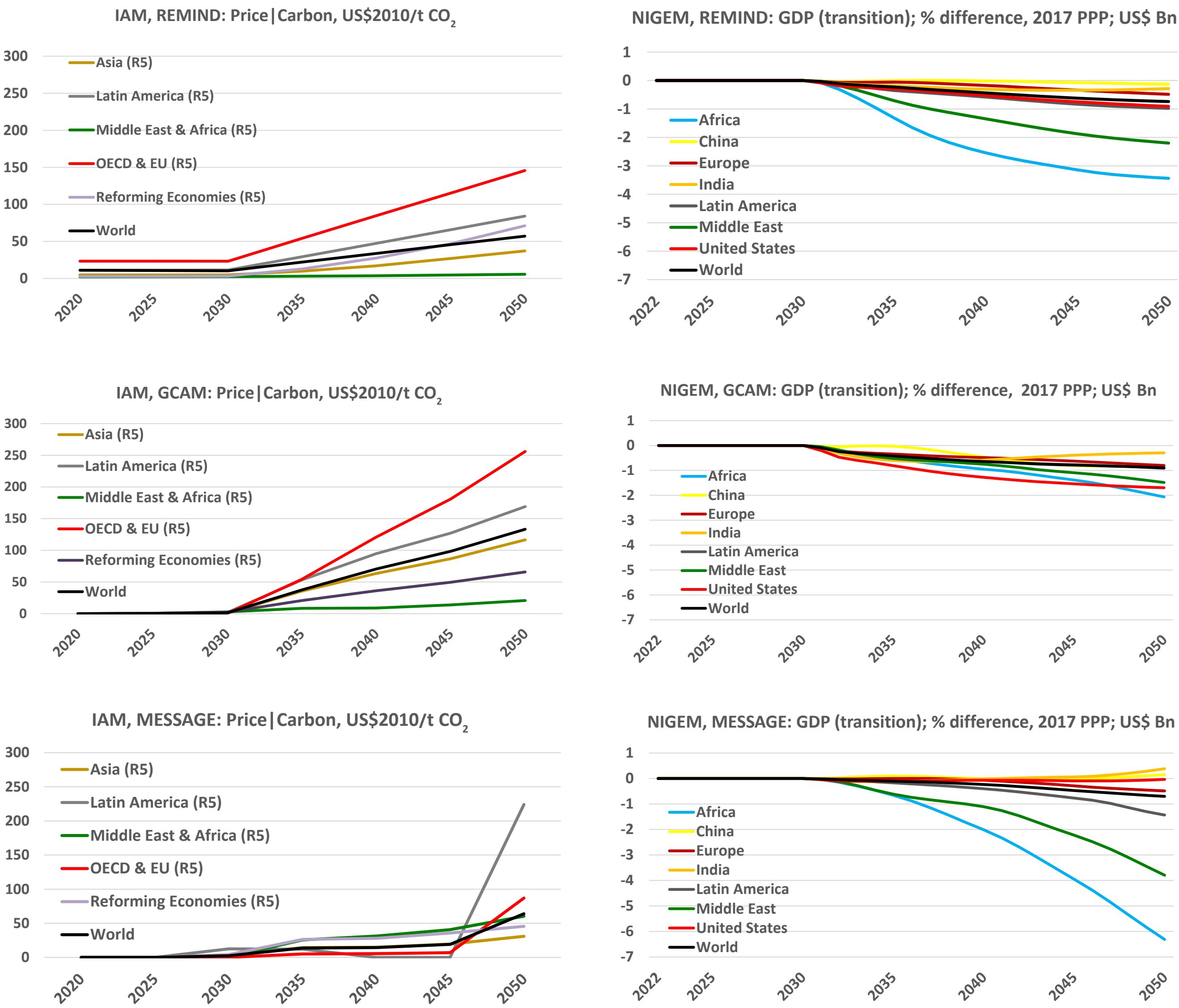



**Transition risk, however, remains more contained in Fragmented World since the scenario assumes limited climate policy action as compared to Net Zero and Delayed transition.** As shown in Figure 4.11, carbon prices in Fragmented World remain consistently lower as compared to Net Zero 2050 and Delayed Transition, right until 2050. Therefore, the resulting GDP losses due to transition risk are slightly lower in the Fragmented world scenario, ranging from 0.7% to 0.9% by 2050 among the three models, while in Net Zero and Delayed transition GDP losses are projected to increase to 2% by 2050 (Figure 4.10).

## GDP impact across jurisdictions

**The GDP impact of transition risks varies across jurisdictions depending on how ambitious the climate transition policy is, meaning how stringent the carbon prices are.** Figure 4.12 below shows the carbon prices and GDP impacts from transition across key regions. Across the three models, R5 OECD + EU region shows a meaningful increase in carbon prices, ranging from $90 to $260 per ton of $CO_2$ by 2050. In Asia, Latin America, Middle East and Africa carbon prices either remain flat or show a minimal increase until 2050, ranging from $6 to $230 per ton of $CO_2$ among the three regions and models, even though these regions remain most vulnerable to physical risks. As a result, Asian economies such as China and India face one of the lowest impacts on GDP, ranging from -1% to 0.2% across the models by 2050. In contrast, the United States sees higher GDP impacts, ranging from -2% to -0.3% by 2050 across the three models.

Figure 4.12 **Regional carbon prices (IAM outputs) and GDP losses from transition risks (NiGEM output) in the Fragmented World scenario**

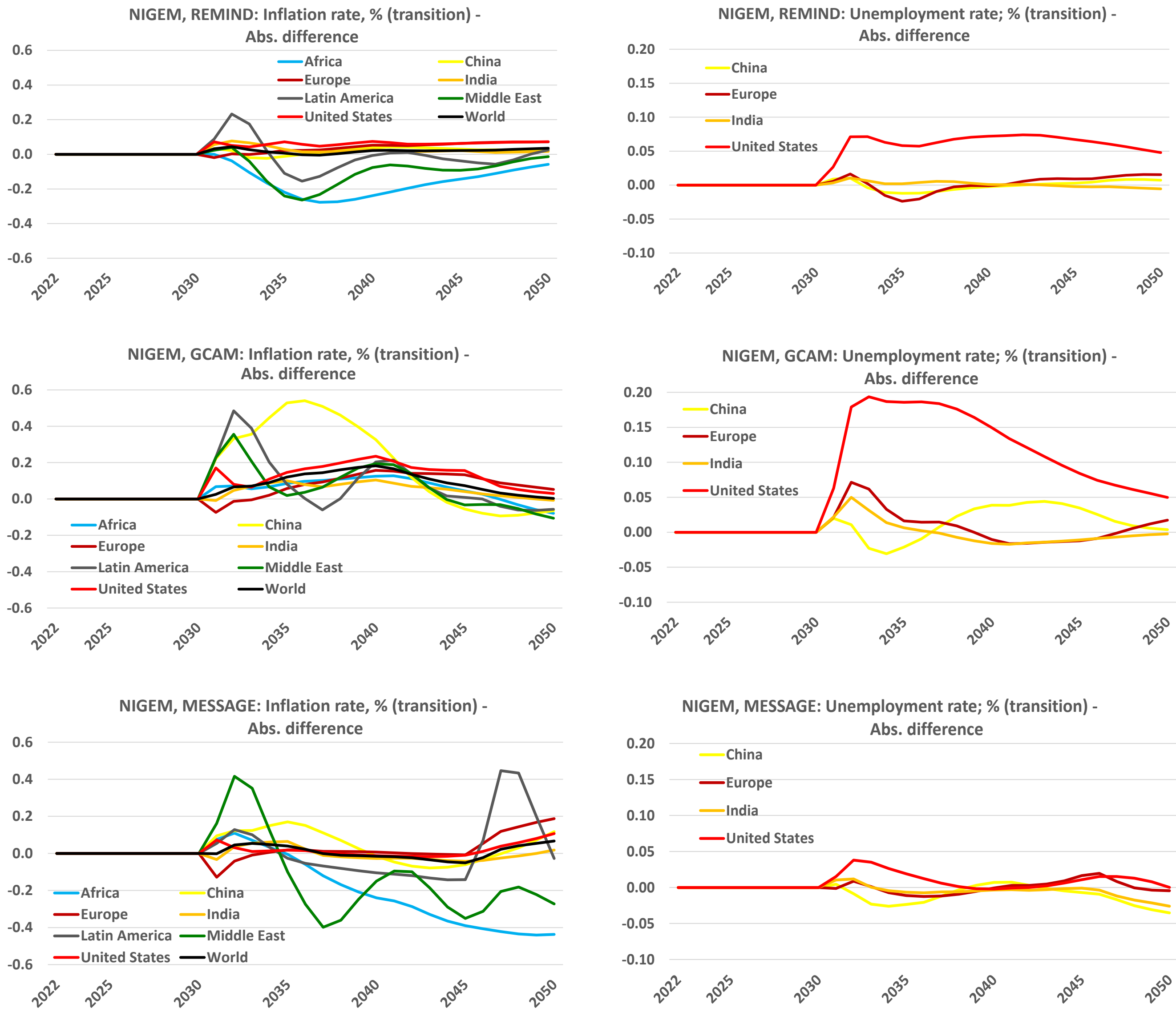



## 4.4.2 Inflationary strain and unemployment

**Regions face an initial inflationary strain as carbon policies are suddenly implemented in 2030. This is accompanied by an increase in unemployment.** Inflation and unemployment trends vary across regions. Figure 4.13 shows the inflation and unemployment trends across regions for the three models. Most regions face an initial inflationary spike in 2031-2032 driven by the increase in carbon taxes that are collected and subsequently recycled into the economy[39]. Inflationary pressures subside in subsequent years as final energy demand declines in Fragmented World (relative to baseline). As shown in Figure 4.13, central banks raise policy rates to tame inflation, despite signals of weakening labour markets. As a result, inflation tempers down and converges to baseline in later years. For regions such as China and India that are net importers of fossil fuel primary energy, a decline in fossil fuel primary energy prices could potentially offset inflation further.

39 In the Fragmented World scenario, revenues are recycled entirely through tax reductions.

Figure 4.13 **Inflation and unemployment rates impacts due to transition risks (NiGEM output)**

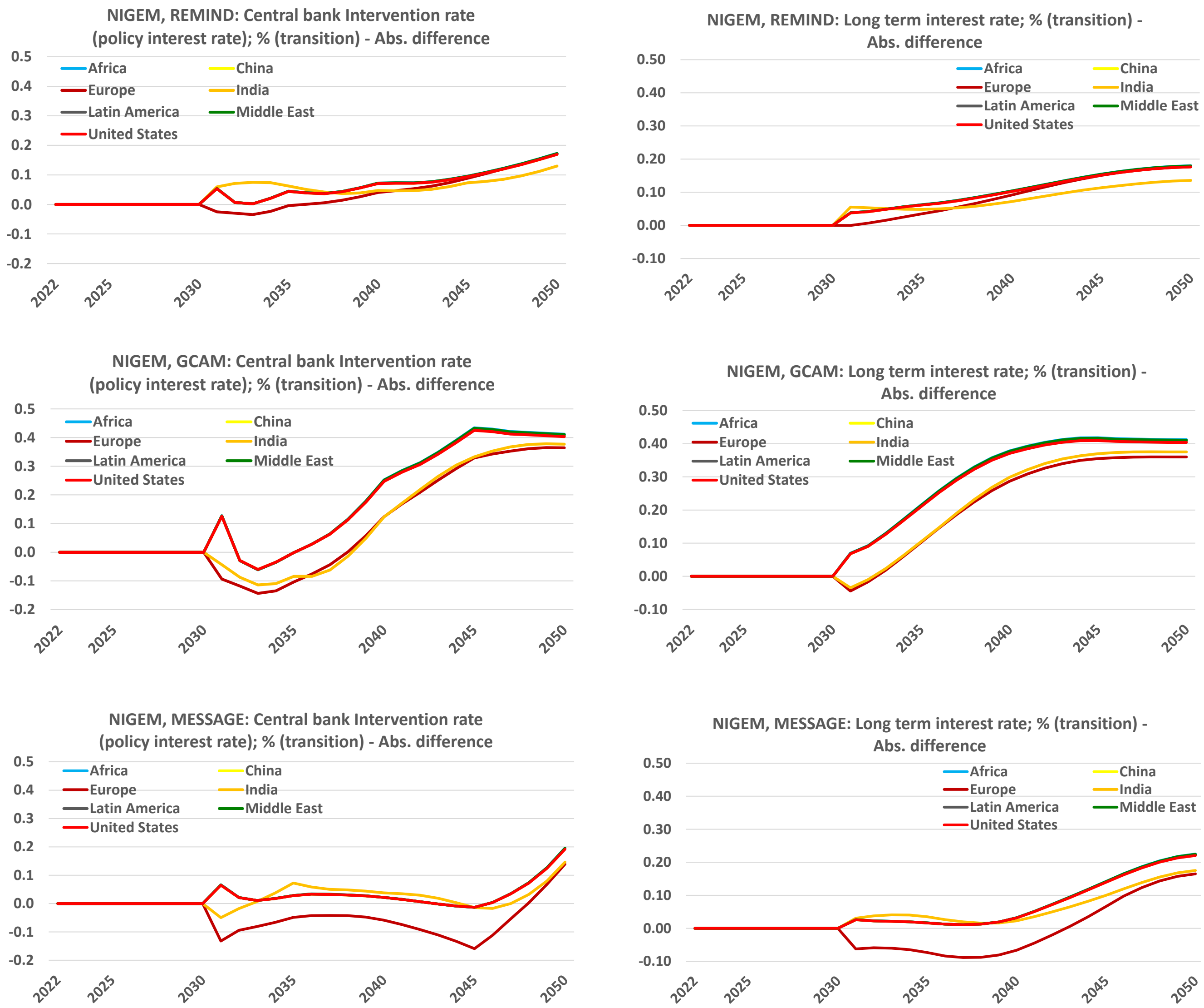



Unemployment spikes in 2033 across US, Europe and key Asian economies such as India. The US faces the highest spike, reaching as high as 0.2 pp above the baseline levels, while China sees a decline in unemployment initially, but it increases in the later years. As Central banks respond by raising interest rates, inflation and unemployment temper down in the late years. **It is also notable that both inflation and unemployment impacts from transition risk remain lower in the Fragmented World scenario as compared to the more ambitious Net Zero 2050 scenario.**

### 4.4.3 Policy interest rates and long-term interest rates

**The Middle East, Africa, Latin America, and China see a slight initial jump in policy interest rates (ranging from 0.05 pp to 0.1 pp above baseline levels in 2031) to curtail the initial spike in inflation in these regions.** Policy rates then decline briefly 2032 to 2035, and then increase until 2050 (Figure 4.14). On the other hand, policy rates decline initially in Europe and India, consistent with the initial decline in inflation in 2031 for these regions.

Figure 4.14 **Long-term and policy interest rates impacts due to transition risks (NiGEM output)**

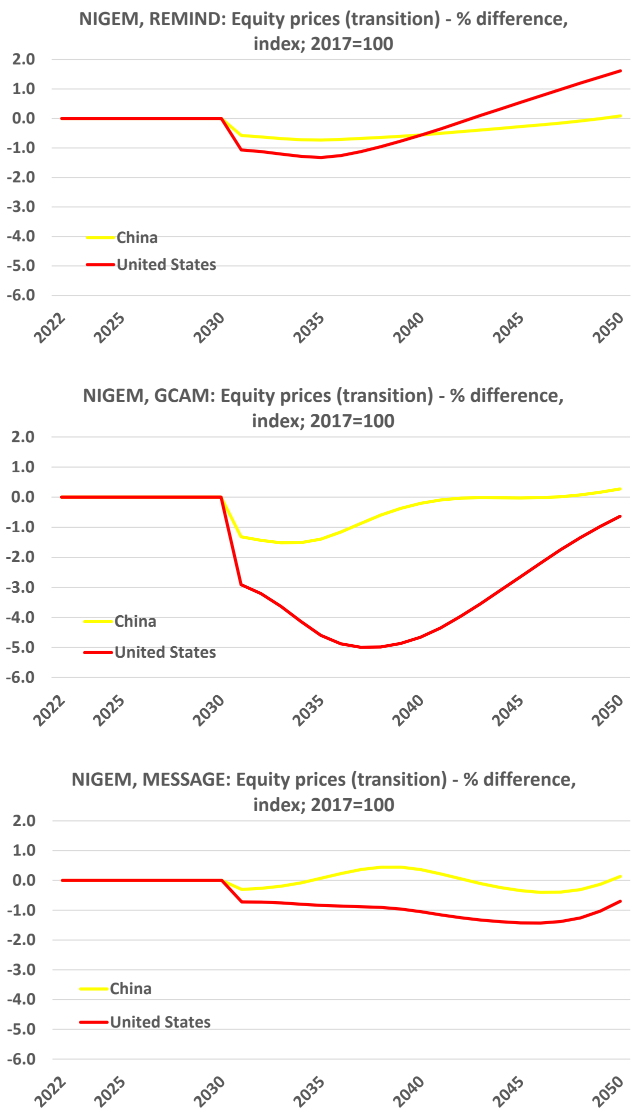



**As a result of the increase in policy interest rates, long-term interest rates also rise, reflecting the inflationary pressure created by shadow carbon prices.** As shown in the plots below, the regional variation in the trends of long-term interest rates is consistent with that of policy rates, with Europe and India reflecting the lowest increase in policy rates. Similarly to GDP, inflation and unemployment, the impacts on interest rates under the Fragmented World scenario are milder as compared to the Net Zero scenario.

### 4.4.4 Equity market disruptions

**Carbon pricing also introduces policy uncertainty, leading to sudden disruptions in equity markets.** This is reflected in an initial decline in equity prices in 2030 when carbon pricing is finally introduced. The initial shock is followed by a gradual decline and subsequently a gradual rebound as investors continue to form and revise their expectations. As shown in Figure 4.15 below, the equity market drop is more severe in the US (ranging from -2% to -5% across the three

Figure 4.15 **Equity prices impacts due to transition risks (NiGEM output)**




models) compared to China (-0.3% to -2%), consistent with the trend of carbon prices applied in these regions. As investors revise their expectations, the subsequent recovery is also much sharper in the US as compared to China. Equity shocks are also driven by the energy tax rate which impacts profits and the long-term interest rate which is derived as a forward convolution of the short-term rates. Consistent with its more ambitious policy objectives, the Net Zero scenario features substantially higher energy tax rates. Inflationary impacts are also higher which feeds through short-term rates into the long-term rate. **Accordingly, equity market reactions in both regions are relatively muted under the Fragmented World scenario, in contrast to the Net Zero scenario, where market impacts are more pronounced, declining by as much as 15% in the US and 10% in China.**

## 4.5 Key findings: uncoordinated and delayed climate transition

This section of the report provides a detailed analysis of the Fragmented World scenario. Using projections from three leading Integrated Assessment Models (IAMs) – GCAM, MESSAGEix-GLOBIOM, and REMIND-MAgPIE – it examines energy demand, carbon pricing, forest area change, fossil fuel trade, carbon sequestration, and primary energy mix under conditions of delayed and regionally inconsistent climate ambition. While some countries partially implement net-zero targets, others stagnate under current policies, resulting in a world that fails to meet the goals of the Paris Agreement. This analysis underscores the risks of partial transition, the inefficiencies of delayed action, and the uneven burden of decarbonisation across global regions.

In this "Too Little, Too Late" future, countries pursue climate action unevenly, with partial achievement of net-zero targets and continued reliance on existing policies. IAM projections reveal a consistent story: energy demand grows, emissions persist, and decarbonisation unfolds slowly and inefficiently. While some progress occurs, especially in the OECD + EU, the global energy system remains dominated by fossil fuels, and carbon sequestration remains regionally constrained. Carbon pricing signals are too weak to trigger systemic change, and land-based mitigation plays only a marginal role.

This scenario illustrates not the absence of transition, but the costs and the dual risks of an uncoordinated, delayed one. The energy and land systems evolve – but not quickly or widely enough to avoid a 2.4 °C warming trajectory, bringing heightened physical and transition risks.

### 4.5.1 Effects of fragmentation: large divergence between regions in terms of carbon pricing, energy and land use leads to international distortions

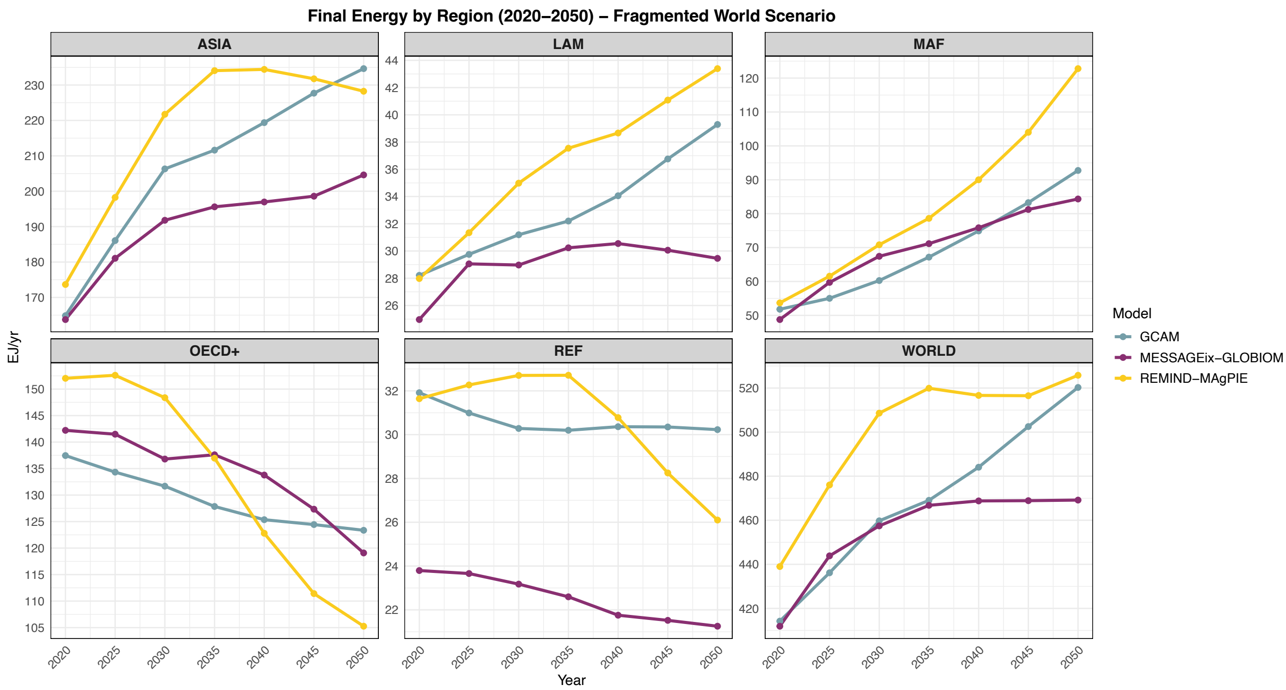
#### Fossil-fuel dependant, climbing energy demand

In the context of climate scenarios, changes in final energy demand help illuminate not only efficiency improvements and technology shifts, but also the broader impact of policy ambition, economic structure, and behavioural change. In the Fragmented World scenario, final energy demand trajectories offer a window into the implications of delayed and regionally inconsistent climate action. Because this scenario assumes only partial implementation of net-zero targets (80%) in some countries, and a continuation of current policies in others, final energy trajectories provide insight into how ambition asymmetries shape global and regional energy use over time.

All three IAMs project that global final energy demand continues to rise steadily through 2050 under the Fragmented World scenario. However, the pace, shape, and implied consequences of that growth differ subtly between models depending on service growth assumptions, technology diffusion, land use competition, and feedback loops between the macroeconomic structure and energy system transformations assumed in each model. All models agree on the direction of change: global energy demand does not fall; instead, it continues to climb. That consensus underscores the central conclusion that delayed ambition does not significantly suppress energy needs, even if mitigation ambition is weak or fragmented.

The R5 regional disaggregation highlights stark contrasts in energy demand trends. Whether due to demographic momentum (population growth and the expanding number of households and urban residents), industrial expansion, or incomplete energy efficiency uptake, Asia continues to see rising final energy use, even as some countries only partially implement net-zero goals. China, India, and Southeast Asia dominate this trend, especially under assumptions of limited behavioural shifts or electrification progress. R5 LAM (Latin America) and R5 MAF (Middle East & Africa) show modest but persistent increases, although MESSAGEix-GLOBIOM flattens demand significantly in later decades. R5 OECD + EU, representing advanced industrial economies, sees flat or slightly declining demand across all three models. This reflects greater historical investment in energy efficiency, market saturation in major end-use sectors, and some mitigation progress despite incomplete

Figure 4.16 **Final energy demand to 2050**



net-zero implementation. However, the decline is not steep, confirming that even these regions do not transform their energy systems quickly enough to meaningfully reduce global demand. Reforming Economies (including Russia and Eastern Europe) shows sluggish but positive demand growth, hinting at economic inertia and fossil-fuel path dependence.

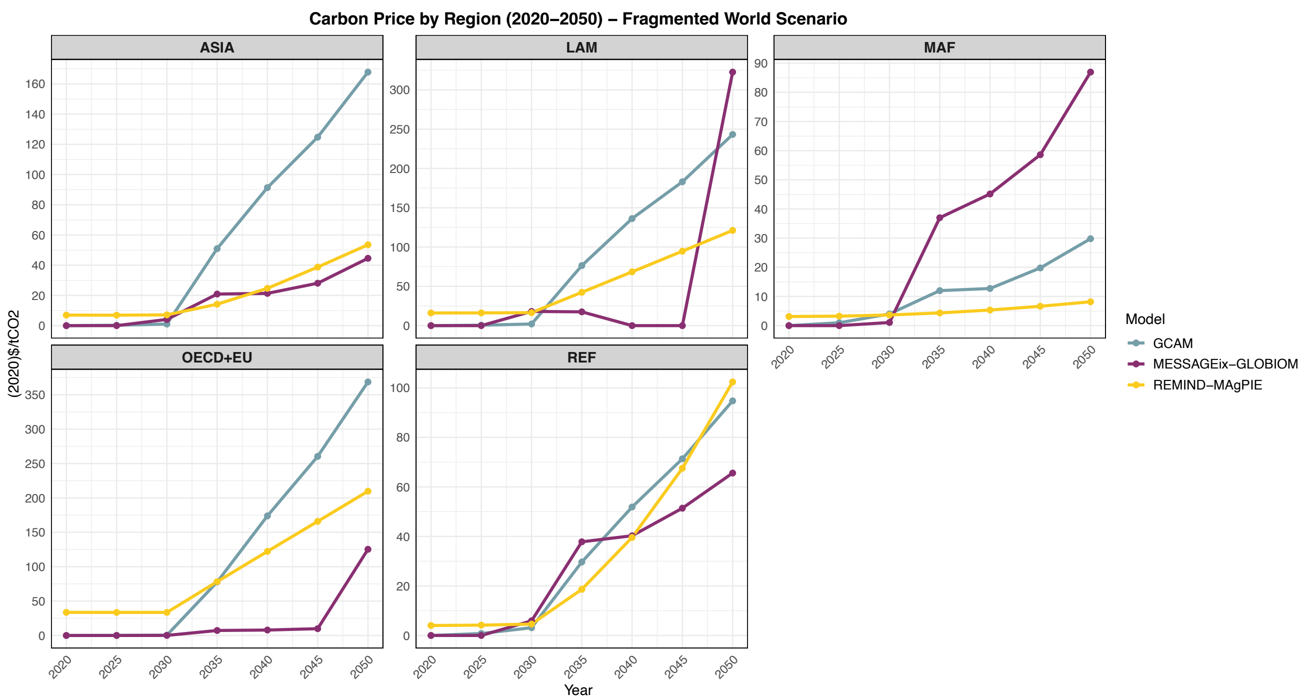
**The continued rise in final energy demand, even in a fragmented and under-ambitious climate world, suggests that energy infrastructure investment will remain high across most regions, especially in Asia and Africa. If this investment favors fossil systems, it risks locking in emissions for decades to come.** Additionally, the inefficiency of the transition becomes more pronounced in this scenario. Instead of a smooth or optimised decarbonisation pathway, final energy demand grows in ways that are more costly, more carbon-intensive, and less equitable than in more coordinated transitions. **Regional inequalities in demand growth mirror disparities in policy ambition and institutional capacity.** Without significant efforts to mobilise clean technologies in high-growth regions, global emissions will continue to climb regardless of progress made in OECD + EU or other high-capacity jurisdictions. The Fragmented World scenario ultimately underscores the limits of partial ambition.

## Regionally divergent and underwhelming mitigation efforts

Shadow carbon prices are a central diagnostic output of IAMs. Unlike explicit policy-based carbon prices (such as those observed in real-world emissions trading systems), shadow prices represent the implied marginal cost of abatement – the cost of reducing one additional tonne of $CO_2$ within the model's internal optimisation, under the given scenario constraints. These prices indicate the level of policy stringency: higher values suggest more aggressive emissions reductions or more costly marginal mitigation measures. In the Fragmented World scenario, shadow carbon prices serve as a proxy for the efficiency and reach of climate mitigation.

**Across all three IAMs (GCAM, MESSAGEix-GLOBIOM, and REMIND-MAgPIE), shadow carbon price trajectories are consistently low and regionally divergent. The general pattern reflects underwhelming mitigation effort, with carbon prices rising modestly in some high-capacity regions and remaining negligible elsewhere.** R5 OECD + EU is the only region where all models project a meaningful increase in shadow prices by 2050. In R5 ASIA, LAM, MAF, and REF, shadow prices either remain flat or rise only marginally, indicating weaker mitigation

Figure 4.17 **Regional carbon price to 2050 across 3 models**



ambition. While the direction of price trends is consistent across models, the size and steepness of price increases vary depending on how each model handles marginal abatement costs and technology substitution. Shadow prices remain low not because emissions are under control, but because the system faces insufficient policy constraints.

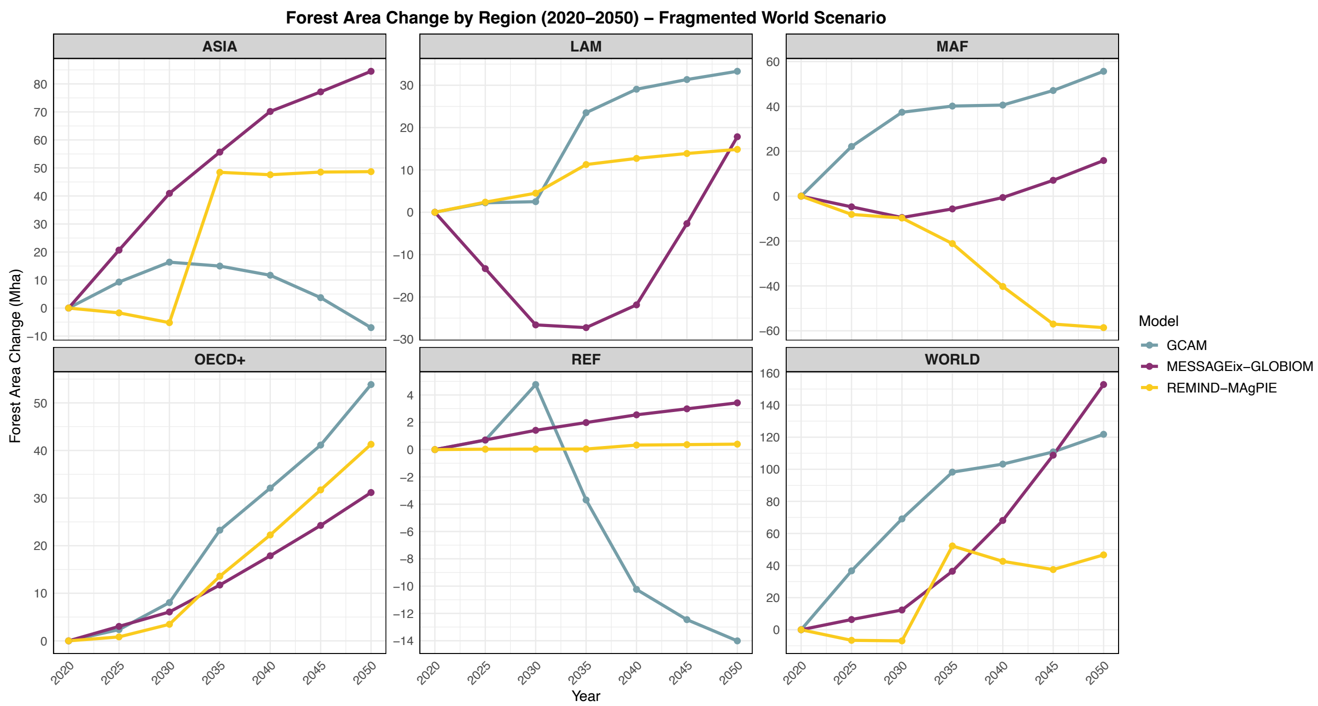
**The regional divergence in carbon prices both reflects and reinforces inequalities in mitigation costs and opportunities. High-income countries may take on more expensive decarbonisation strategies, while low- and middle-income countries remain locked into low-effort, high-carbon pathways – even as these same regions often face the greatest physical climate risks.** Weak carbon pricing signals also imply that fossil fuels remain cost-competitive, making the clean energy transition harder to justify on purely economic grounds in the absence of strong policy support. This dynamic means that partial ambition does not simply slow global decarbonisation; it also makes the transition more inefficient and costly. Furthermore, the failure to generate meaningful shadow prices even where partial net-zero targets exist points to a deeper governance gap. Without stronger institutional capacity, financing, and international trust, the pricing frameworks needed for effective climate action will remain fragmented and ineffective. This fragmentation not only delays progress – it fundamentally distorts it, leaving carbon prices too low in too many places, and where they do rise, the signal often arrives too late to steer meaningful change.

## Land-based mitigation as a lost opportunity

Forest area change, often used as a proxy for afforestation, reforestation, or land-use conversion, is a critical component of climate mitigation strategies. Expanding forest cover not only sequesters carbon but also supports biodiversity, water regulation, and rural livelihoods. In IAMs, changes in forest area reflect the interplay of land-use policy, carbon pricing, institutional strength, and competition with agriculture or bioenergy. In the Fragmented World scenario, forest area change indicates how much and where land-based mitigation efforts can be mobilised in a context of delayed and uneven climate ambition. Since some countries partially pursue net-zero targets while others maintain current policies, forest change is expected to be uneven, limited, and highly dependent on regional governance capacity.

All three IAMs agree that forest area increases only modestly at the global level, with limited regional ambition and weak governance beyond a few high-capacity regions. This reflects a world in which land-based mitigation exists but

Figure 4.18 **Forest area changes indicating afforestation & reforestation across R5**



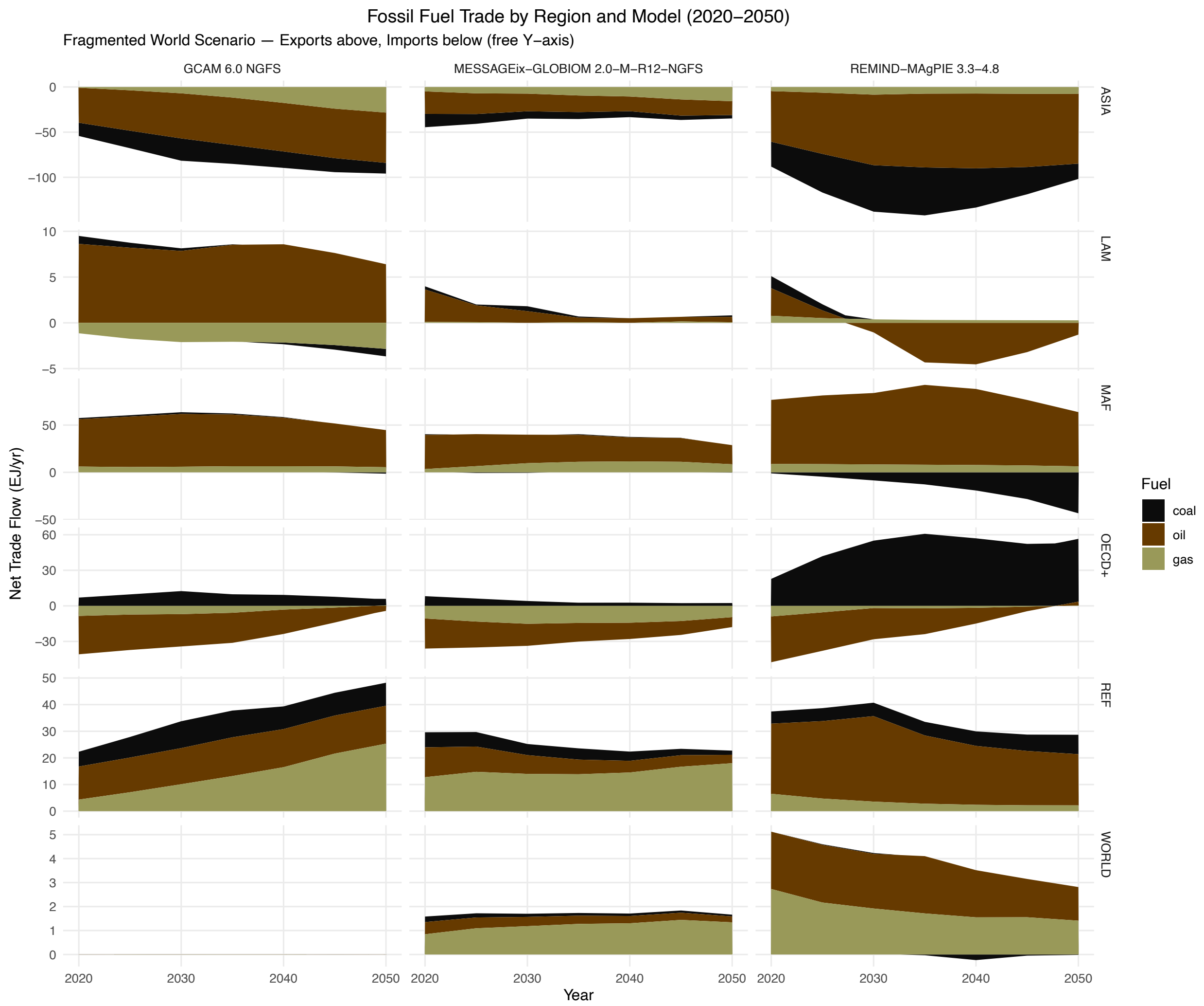
remains significantly underutilised. OECD + EU and parts of Asia see moderate gains in forest cover, while Latin America and Africa show sharp divergence across models. Only GCAM projects meaningful reforestation in these latter regions, driven by more optimistic assumptions around policy incentives and institutional capacity. MESSAGEix-GLOBIOM and REMIND-MAgPIE, in contrast, are more conservative, reflecting tighter land competition and lower policy effectiveness.

**Globally, land-sector mitigation fails to scale, hindered by policy shortfalls and competition with food or bioenergy production. This highlights the limited effectiveness of voluntary or partial land-sector climate action.** In a fragmented world, forests are not mobilised as a coordinated global carbon sink, weakening one of the most cost-effective climate mitigation pathways. Without stronger incentives, institutional support, and safeguards for land rights, forest-sector mitigation becomes an afterthought rather than a central pillar of climate strategy. For financial actors, this limits the viability of land-based offsets. For policymakers, it signals an urgent need to invest in rural development, secure land tenure, and develop equitable frameworks for carbon finance that go beyond headline net-zero pledges.

## Unstable fossil fuel trades and global energy security at risk

Fossil fuel trade volumes capture the international movement of oil, gas, and coal, flows that are central to global energy security, geopolitical stability, and balance-of-payments positions. Changes in trade volumes reflect shifts in energy demand, domestic production, pricing, infrastructure development, and policy alignment.

Figure 4.19 **Fossil fuel trade, including current level**



All three IAMs project a steady contraction in global fossil fuel trade, but with fuel-specific variations. Coal trade sees the sharpest and most consistent decline across all models. This is driven by a combination of regulatory disincentives, falling global demand, and reduced infrastructure investment. Oil trade declines more slowly, reflecting persistent transport-sector demand and existing infrastructure, especially in Asia and OECD + EU. Gas trade trends diverge slightly: GCAM and REMIND-MAgPIE allow gas to play a bridging role through mid-century, while MESSAGEix-GLOBIOM curtails gas trade earlier due to infrastructure constraints and delayed investment.

Asia (R5 ASIA) remains a key importer of oil and gas through 2040 in GCAM and REMIND-MAgPIE, though MESSAGEix-GLOBIOM projects a plateau as domestic production expands and electrification picks up. MAF and REF (Middle East & Africa and Reforming Economies) face major trade contraction risks. As net fossil exporters, they are exposed to price volatility, stranded asset risk, and declining fiscal revenues. OECD + EU imports decline across all fuels, driven by modest decarbonisation and declining energy demand.

**In a world with partial net-zero implementation, fossil trade becomes unstable.** Exporters are especially vulnerable to fiscal collapse, balance-of-payments crises, and asset stranding, while importers face energy security risks. For financial institutions and regulators, this highlights the need for transition stress-testing in fossil-exposed economies and attention to geopolitical energy risks. For governments, it underscores the need for diversification, regional energy self-sufficiency, and strategic clean infrastructure investment.

## Partial and uncoordinated decarbonisation

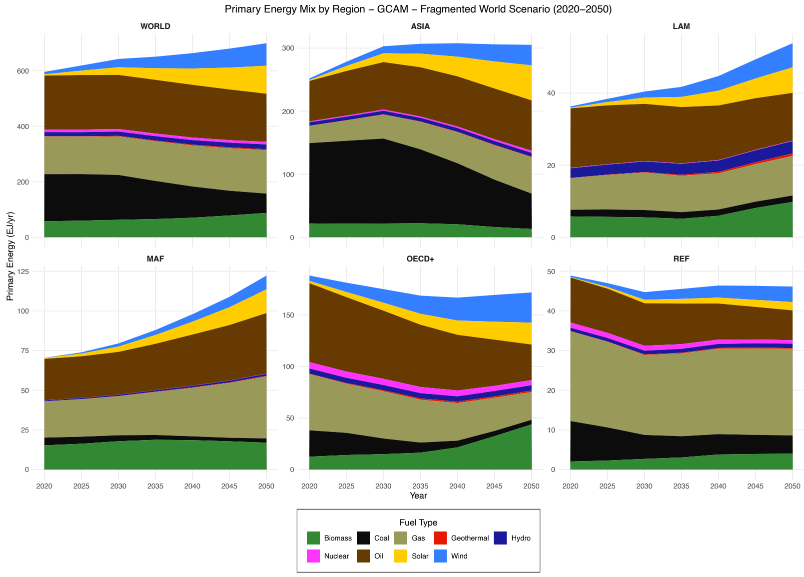
The primary energy mix describes the composition of a region's total energy supply, including fossil fuels (coal, oil, gas) and non-fossil sources (nuclear, hydro, renewables, bioenergy). It is one of the clearest indicators of an energy transition's depth and pace. In climate scenarios, shifts in the mix signal whether economies are decarbonising or remaining reliant on carbon-intensive energy systems. In the Fragmented World scenario, the mix reflects partial and uncoordinated decarbonisation. The picture is not one of stasis, but of slow, regionally uneven transformation, insufficient to prevent warming from exceeding 2 °C.

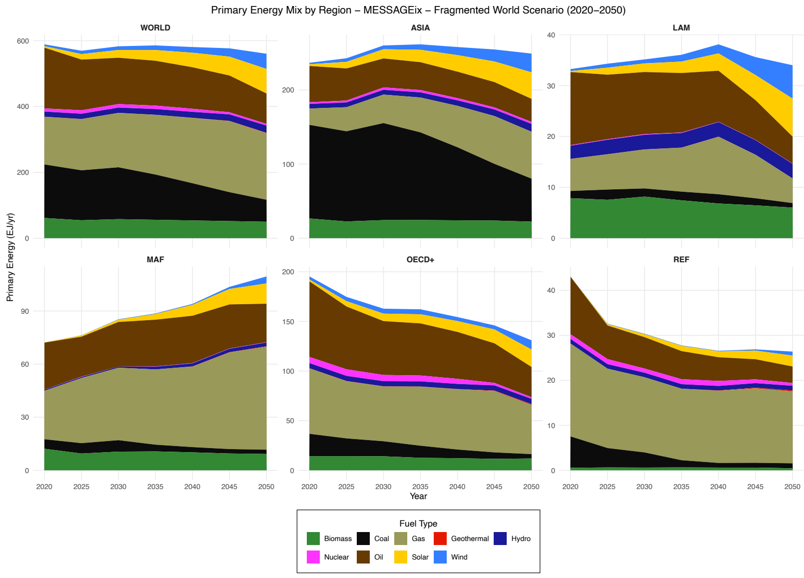
At the global level, all models show fossil fuels maintaining a dominant role in the energy mix through 2050, despite modest increases in renewables. Coal and oil use decline slowly, especially in OECD + EU, but remain strong in Asia and REF. Natural gas shows some resilience, especially in GCAM and REMIND-MAgPIE, as a transitional fuel. Renewables (wind, solar, hydro) grow, but not quickly or broadly enough to achieve deep decarbonisation. Nuclear and modern bioenergy are stable or growing in OECD regions but remain marginal elsewhere.

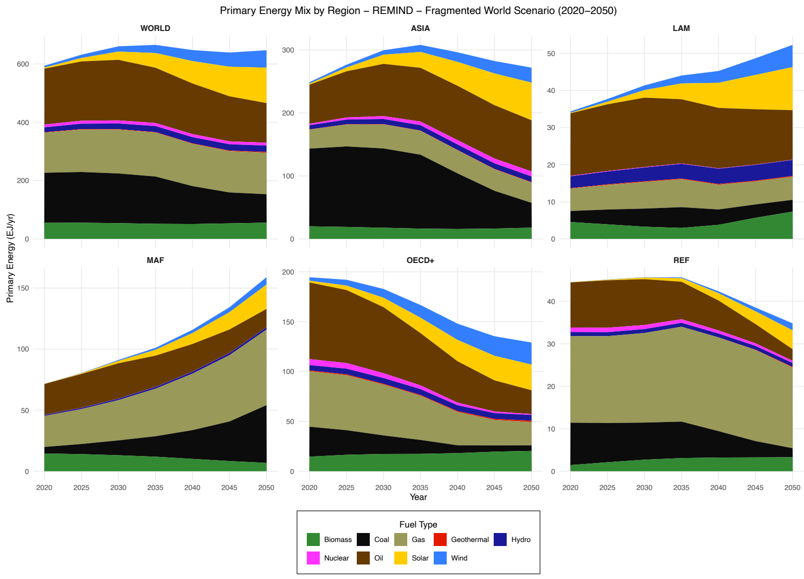
OECD + EU shows the strongest transition, with renewables gaining share and coal nearly phased out in some model trajectories. R5 ASIA) sees growth in renewables, but fossil fuels – especially coal and oil – remain deeply embedded. LAM, REF and MAF exhibit entrenched fossil-heavy energy systems with slow renewable penetration, indicating policy inertia and low policy ambition.

**This scenario demonstrates that even partial climate ambition fails to meaningfully reconfigure global energy systems. Fossil fuels remain entrenched, and renewables are concentrated in already-wealthy regions. The risk is twofold: countries that act too slowly face infrastructure lock-in, and those that act alone face competitive imbalances and higher transition costs. Without robust global coordination, the world ends up with inefficient, inequitable transitions that miss the opportunity for systemic transformation.**

Figure 4.20 **Stacked area chart primary energy mix by region**



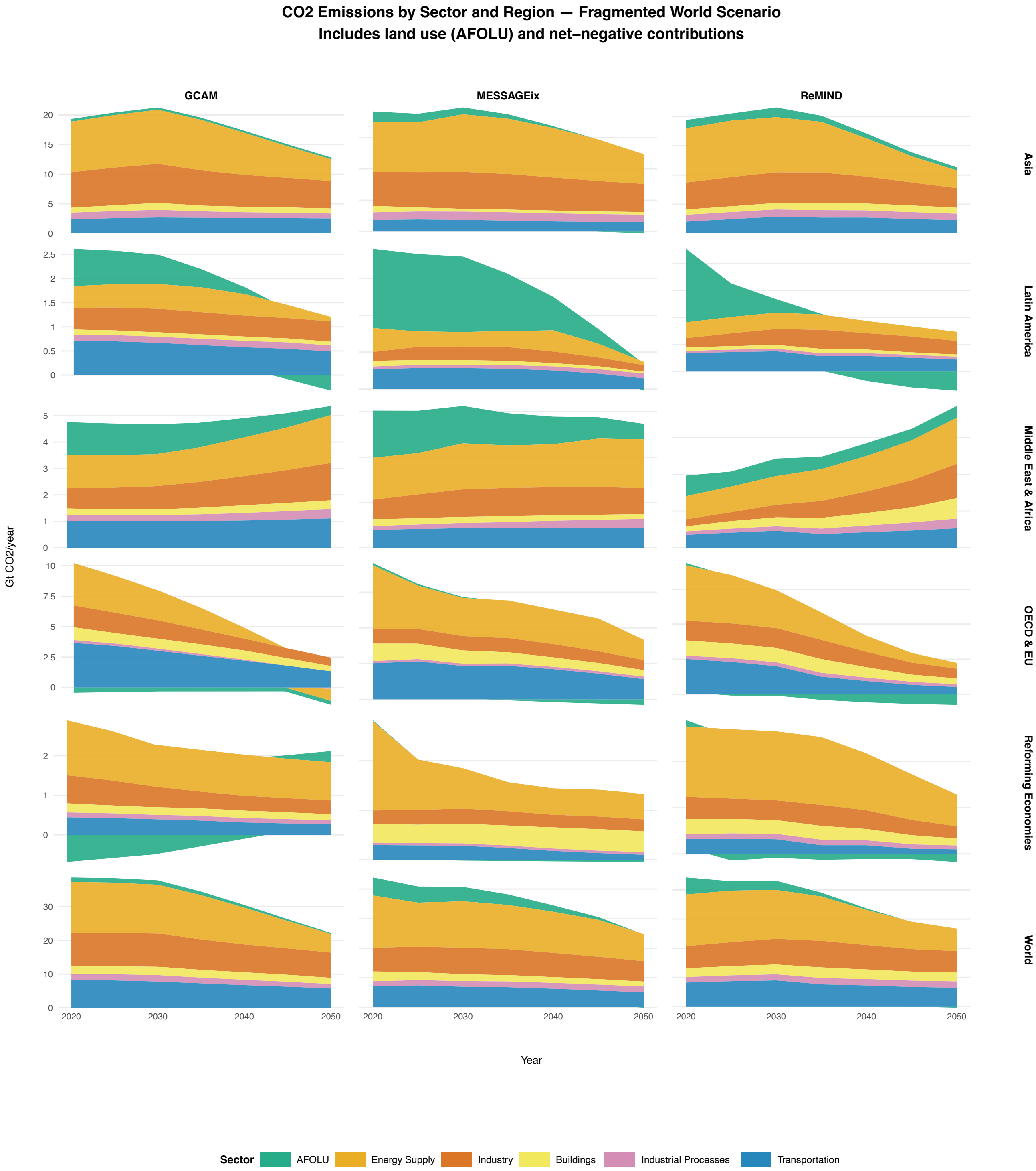



## 4.5.2 Global emissions and climate change remain high

### Emission reduction efforts in some regions are offset in others

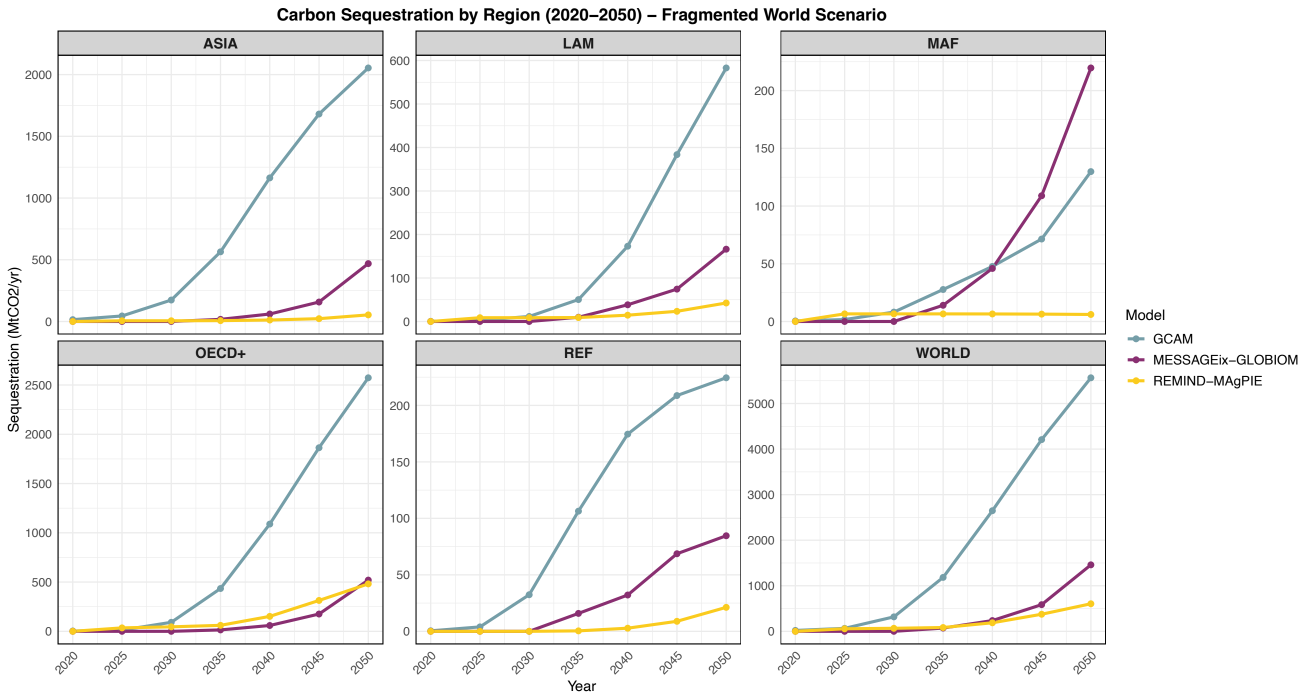
Figure 4.21 **Stacked area chart of emissions to 2100**



**Global greenhouse gas emissions remain persistently high, not because no action is taken, but because action is partial, delayed, and unevenly distributed. This fractured mitigation effort leads to a global temperature rise of approximately 2.4 °C by 2100, well beyond the limits established in the Paris Agreement.** The scenario captures a sobering dynamic: while a few economies do make progress in reducing emissions – particularly parts of Europe and North America – those gains are largely offset by increasing emissions in other regions, especially in parts of Asia, Africa, and the reforming economies of Eastern Europe. These disparities are driven not only by differences in policy ambition, but also by structural realities: fossil fuel dependency, limited access to clean technologies, and the absence of international support mechanisms.

## CCS: a theoretical lever rather than a practical tool

Figure 4.22 **Carbon capture & sequestration**




Carbon sequestration in IAMs typically refers to engineered removals of $CO_2$ from the atmosphere. These strategies are often seen as critical for offsetting hard-to-abate emissions and for achieving net-zero goals. In more ambitious scenarios, sequestration scales rapidly; in fragmented or delayed-action scenarios, its role becomes far less transformative. In the Fragmented World scenario, carbon sequestration levels reflect how delayed ambition and institutional fragmentation constrain the deployment of negative emissions technologies (NETs). It reveals whether nations can still "clean up after the fact" – and the answer appears to be: only modestly and unevenly.

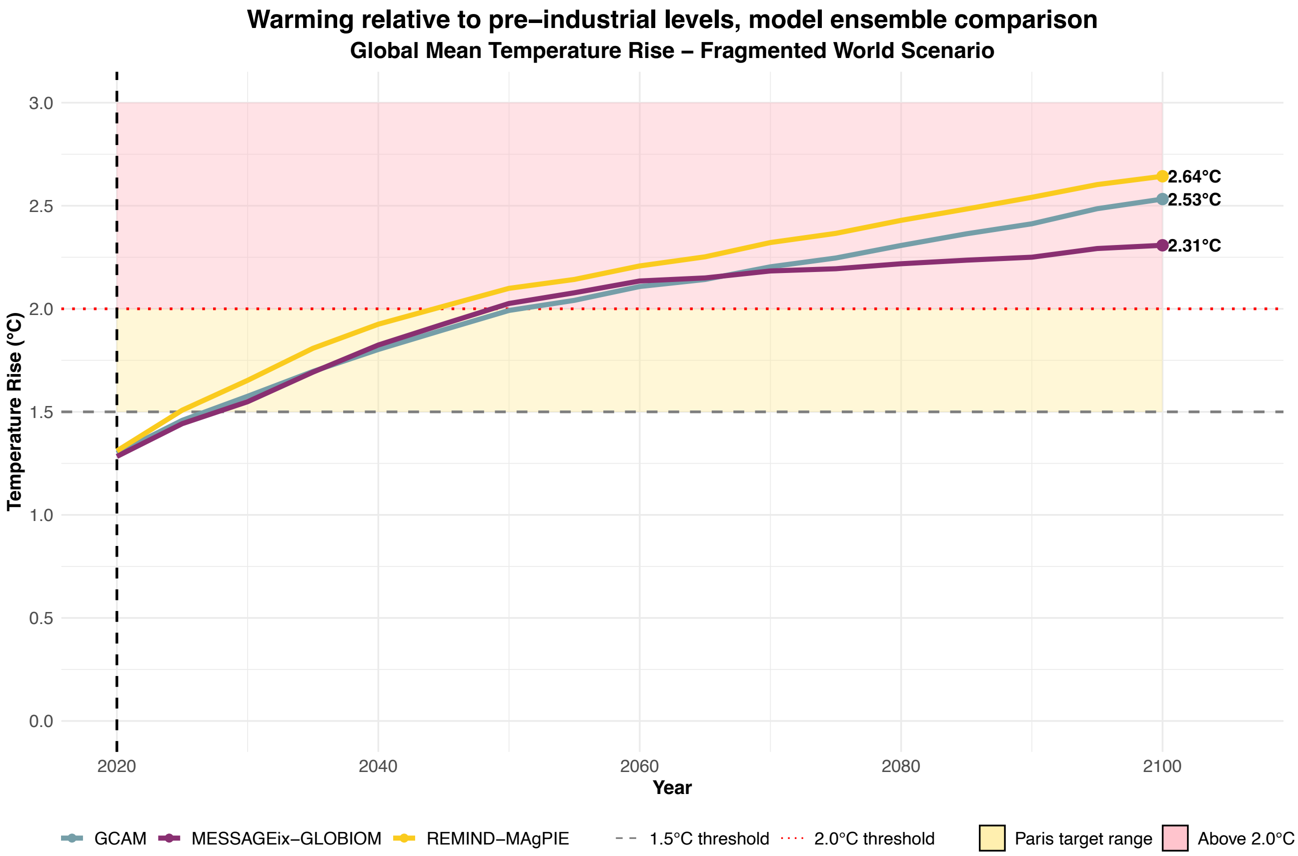
At the global level, sequestration grows slowly and modestly, with all three models projecting limited net removals by 2050. The trends underscore that even partial net-zero ambition is insufficient to drive a scaled-up carbon removal agenda. GCAM projects the highest global sequestration, consistent with its flexible treatment of land use and technology access assumptions.

OECD + EU leads across all models in sequestration deployment, owing to greater institutional capacity, availability of capital, and policy continuity. R5 ASIA shows some CCS deployment in GCAM and REMIND-MAgPIE, but MESSAGEix-GLOBIOM suggests minimal contribution. LAM and MAF are potentially rich in land and biomass and hence see little CCS in MESSAGEix-GLOBIOM and REMIND-MAgPIE. REF remains largely absent from the sequestration narrative in all models.

The modest levels of CCS in this scenario indicate that NETs cannot be treated as a fallback or delay tactic. Without coordinated finance, land governance, and technological trust, negative emissions remain a theoretical lever rather than a practical tool. Policymakers banking on post-2050 cleanup mechanisms will find little to rely on unless stronger action is taken early – especially in regions outside the OECD + EU.

## Insufficient efforts to avoid global physical risks

Figure 4.23 **Temperature rise across all 3 models**




**The scenario underscores that piecemeal decarbonisation, even if real, is insufficient to limit global risk exposure. The failure to coordinate robust action in the near term could hardwire systemic vulnerability into the climate system for the long term.** Temperature outcomes in the Fragmented World scenario reflect the delayed and insufficient nature of global climate ambition. Across all three IAM implementations, global mean temperatures overshoot 1.5 °C by the early 2030s and cross the 2 °C threshold well before mid-century, despite partial mitigation efforts in high-income regions. This trajectory stabilises around 2.3 to 2.5 °C of warming by 2100, with slight variations depending on the model's sensitivity to emissions and feedback. Crucially, this level of warming places the world on a path of significantly elevated physical risks, including more intense and frequent extreme weather events, irreversible ecosystem damage, and chronic stress on food and water systems.

## 4.6 Conclusions on Fragmented World

The NGFS Fragmented World scenario models a future where global climate ambition is delayed, regionally inconsistent, and ultimately insufficient. Across all three IAMs, the analysis reveals a world in which fossil fuels remain entrenched, clean energy diffusion is uneven, and land-based mitigation remains underutilised. Final energy demand continues to rise, driven by growth in Asia and developing economies, while mature economies flatten or slightly reduce demand – an offset that proves insufficient. Shadow carbon prices remain uneven, offering divergent cost signals for deep decarbonisation. Afforestation and carbon removal efforts remain modest and regionally concentrated. Fossil fuel trade declines, particularly coal, exposing exporters to stranded asset risks and importers to transition volatility. Meanwhile, the primary energy mix remains fossil-heavy, with renewables growing too slowly outside the OECD + EU to shift the system trajectory. Fragmented World pathway reinforces regional inequalities in mitigation costs and opportunities, compared to a more ambitious and coordinated Net Zero 2050 scenario. The Fragmented World's reduced policy costs must be weighted out with climate damages under a 2.4 °C by end of century. An updated quantification of these impact and damage estimates will be available in NGFS Phase 6.

For the NGFS, central banks, and the financial sector, these findings emphasise that fragmentation amplifies financial and systemic risks. As mitigation pathways diverge, so too does regional exposure to stranded assets, climate-linked volatility, and investment uncertainty. Diverging carbon pricing signals in different regions of the world and scattered land-sector responses undermine investor confidence, further slowing down the green transition and the reduction of global emissions. In such a world, climate risk supervision is faced with both high transition risk and high physical risk.

# Annex A: Shared socioeconomic assumptions

The assumptions on key socio-economic drivers, such as population and economic developments, are common to all NGFS scenarios. These assumptions are aligned with the Shared Socioeconomic Pathways SSP2 (updated version 3.0 of the SSP scenarios). Population trajectory (Figure A1) and GDP baseline (Figure A2), as well as the country-level growth rate, are equal across IAMs. The variation in trends in the Figures below is due the difference in regional aggregation (R5) across three IAMs.

Figure A1 **Population (billion), including World Development Indicators (WDI, World Bank)**

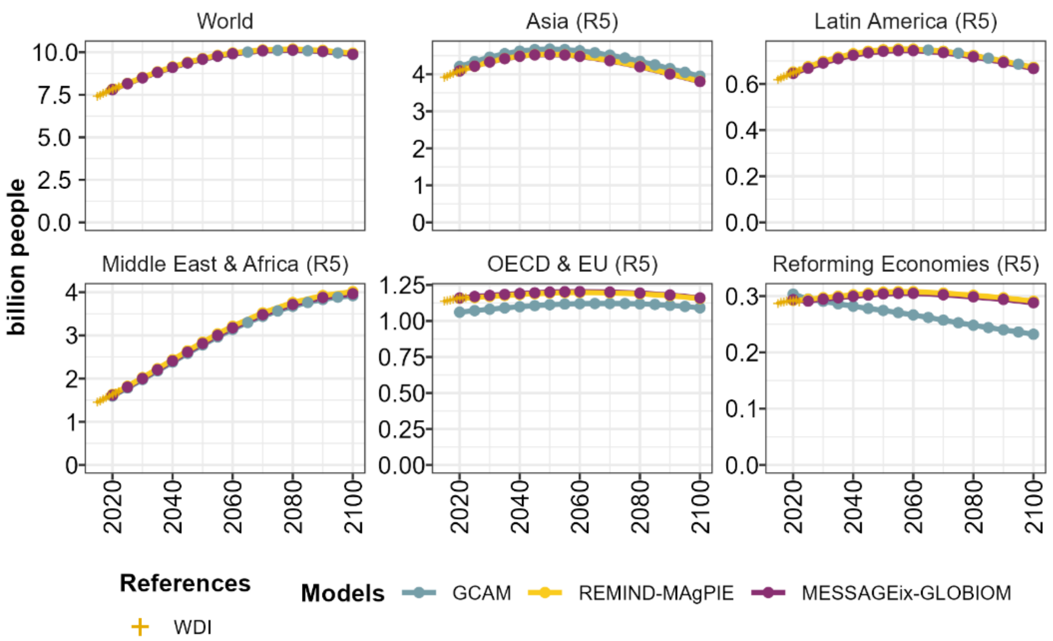
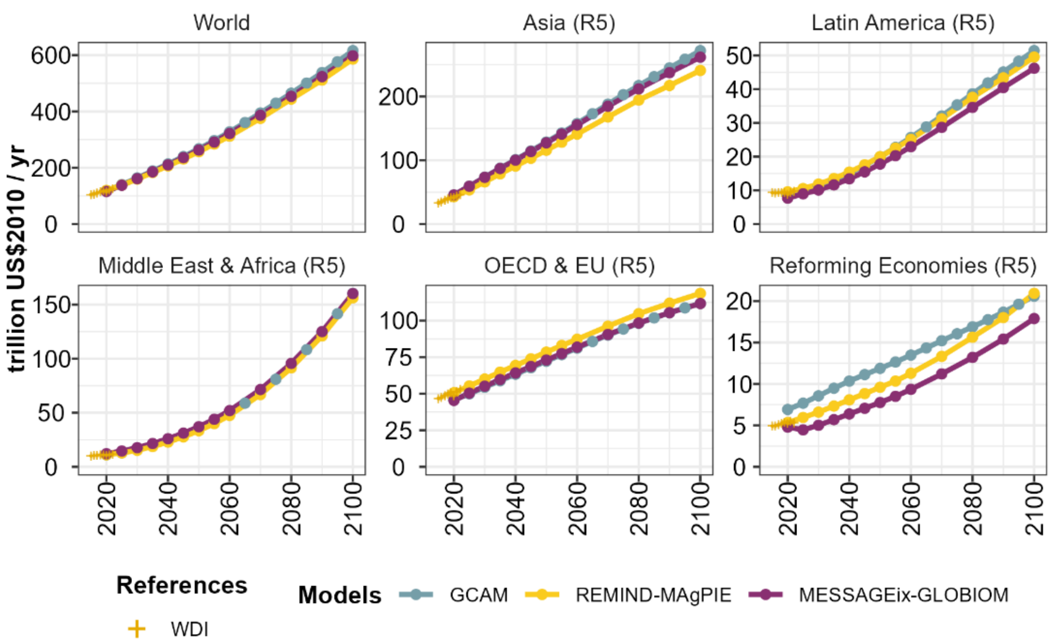



Figure A2 **GDP (PPP) (billion US$2010/yr), including World Development Indicators (WDI, World Bank)**



# Annex B: NiGEM neutral forecast baseline

**The trends for all macroeconomic variables (from NiGEM) are presented relative to a *climate neutral forecast baseline*.** The combination of transition and physical risk shocks, when executed as NiGEM scenarios, provide the output for the NGFS macro-economic variables. The various climate scenarios often use the same economic channels in the model, and therefore, cannot be imposed as a singular shock. Instead, individual scenarios are run as a "stacked" series, which ensures the output of the stack provides the same output as though all shocks being considered were run simultaneously.

To ensure NiGEM and the IAMs are using an equivalent starting point for their investigations into climate risk, particularly in the energy sector, we use a combination of the NIESR v1.24-2 forecast coupled with IAM data from the NGFS current policies scenario to create a *climate neutral forecast baseline*. Climate neutral refers to the fact that projected data values do not reflect any climate transition or physical risks. More information on the NiGEM integration into the NGFS scenarios in the NGFS Phase V Technical Documentation.

BANQUE DE FRANCE
EUROSYSTÈME

NGFS
Secretariat