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Strengthening forward-looking strategic scenarios in the private sector

Sectoral climate change mitigation scenarios for strategy development and alignment assessment by economic players: Current status and future prospects for taking further account of nature and resilience

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I4CE is a non-profit research organization that provides independent policy analysis on climate change mitigation and adaptation. The Institute promotes climate policies that are effective, efficient and socially fair. Our 40 experts engage with national and local governments, the European Union, international financial institutions, civil society organizations and the media.

Our work covers three key transitions – energy, agriculture, forest – and addresses six economic challenges: investment, public financing, development finance, financial regulation, carbon pricing and carbon certification.

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DISCLAIMERS

This work reflects only the view of I4CE.

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EXECUTIVE SUMMARY

Economic players face growing pressures to transform their business models in response to multiple challenges (sustainability issues, technological supremacy, natural resources security, etc.), while strengthening their competitiveness and resilience. 2024 is the first year to exceed 1.5°C above pre-industrial levels (Copernicus Climate Change Service 2024). The losses associated with all natural disasters worldwide, mainly due to weather catastrophes, are on an upward trend (Munich Re 2024).). Europe has not been spared, with warming twice as fast as the global average and significant costs associated with recent extreme weather events (Copernicus Climate Change Service and World Meteorological Organisation 2024, EEA 2023).

To face uncertain futures and achieve a sustainable economy, economic players could accelerate the transformation of their business models. They would take advantage to further consider the latest scientific insights regarding climate and natural resource constraints to assess the risks and opportunities, in order to elaborate policies that strengthen innovation, the competitiveness [1] and resilience of business models. Collective efforts have so far mainly focused on climate change mitigation. The Paris Agreement sets objectives to limit the increase in global average temperatures, cap greenhouse gas (GHG) emissions and achieve net-zero emissions in the second half of the century. Sectoral climate change mitigation scenarios consistent with the Paris Agreement are central to this, as they incentivise major transformations at the financial asset, firm and sector levels; economic players use these scenarios to set interim targets and measures that convert temperature goals and GHG emission reductions into policy milestones and design strategic plans accordingly.

This paper gives decision-makers an overview of the current thinking on these scenarios that drive sectoral and business transformation, avenues for improvement, and targeted actions towards a sustainable economy [2]. It recommends that economic players and scenario designers explore the wider opportunities that arise from having greater consistency between their approaches to climate and nature [3] to define resilient strategies and increase co-benefits. The broad transition of nature [4] and adaptation [5] frameworks are not the focus of this paper that examines how nature is considered in the earlier climate frameworks and tools.

The main findings and recommendations of this paper are set out below.

1. To reach a sustainable economy, greater inter-operability of overarching science-based frameworks through policy and implementation interlinkages between nature and climate is critical and to better align around consistent objectives and reinforce each other. The scope and relationship between the different frameworks need to be recalled. The United Nations (UN) Sustainable Development Goals (SDGs) set political objectives. The Paris Agreement is a 2015 treaty that establishes binding commitments by all parties. Its goals are also to reach net-zero emissions in a timely manner and promote adaptation in order to foster “climate resilience and low GHG emissions development, in a manner that does not threaten food production”. It requires taking account of nature. Adopted in 2022 at the 15th conference of the parties (COP15), the Global Biodiversity Framework (GBF) is a UN decision to halt and reverse nature loss. Both the Paris Agreement and the GBF are science-based to guide policies; they set goals and targets that are intended to be applicable at the global level, with possible application at the sectoral and entity levels. Besides, the planetary boundaries, developed by the Stockholm Resilience Centre, introduce key processes and thresholds for resilience of the planet and future generations (Röckstrom 2022).

The Paris Agreement and the GBF should not be considered separately (alongside the SDGs) as their effectiveness depends on the other’s success (Streck 2024). Their different timelines and legal status [6] raise questions about the way in which nature is considered in the earlier net-zero transition (modelling; sectoral scenarios, even regional [7] scenarios, as nature has a local scale).

Though climate and nature have largely been addressed in silos, they are interconnected: climate change is a prominent driver of biodiversity loss, while the degradation of ecosystems reduces the options to mitigate or adapt to the climate crisis (IPCC IPBES 2021, IPCC 2023 [2] [3], NGFS [1] 2023). Nature is both a source and a sink of GHG emissions. Natural ecosystems can achieve an estimated 37% of the 2030 net-zero emissions-reduction

1 Competitiveness should be based on a broader approach, including competitive sustainability (CISL 2024). In addition, analyses of competitiveness should encompass the ability to remain competitive in different future scenarios. To this end, the impact of possible limiting factors (e.g. water stress) or the sustainability of transformations (new production tools or long-lasting infrastructures, land use planning), etc., should be taken into account.

2 This paper does not cover financial risk and stress test assessments.

3 All existing systems on Earth including biodiversity, its living element.

4 Beyond climate change, nature frameworks also include other pressures on planetary boundaries and/or the provision of ecosystem services, such as land use, pollution, natural resources exploitation, and invasive species.

5 According to the definition by the Intergovernmental Panel on Climate Change (IPCC), adaptation is any adjustment in response to actual or expected climatic stimuli (NGFS 2024). It differs from resilience. Resilience, according to the IPCC, is the ability to anticipate, absorb, accommodate or recover from a hazardous event in a timely and efficient manner, including through ensuring the preservation, restoration or improvement of the environment (NGFS 2024).

6 Indeed, the States have not endowed the Convention on Biological Diversity (CBD) with legal powers to adopt legally binding decisions. The GBF depends on its incorporation into national laws, and on international cooperation and private finance (Streck 2024).

7 For example, in Europe, the EU Nature Restoration Law is a legal driver that must be incorporated in scenarios.

goals (Griscom 2017 from GFANZ 2024). There are vast areas where land- and ocean-based climate action and biodiversity overlap (Streck 2024).

The scientific outcome of the Intergovernmental Panel on Climate Change (IPCC) and the Intergovernmental Science Policy Platform on Biodiversity and Ecosystem Services (IPBES) workshop on the climate and biodiversity nexus states that "1° policies that simultaneously address synergies between mitigating biodiversity loss and climate change […] offer the opportunity to maximize co-benefits" (IPBES IPCC 2021).

Beyond, the Nexus assessment report [8] by the IPBES, released in December 2024, broadens the analysis to the Interlinkages among Biodiversity, Water, Food and Health. It is the product of three years of work by 165 leading international experts from 57 countries. **It "provides the science and evidence needed to support achievement of the Sustainable Development Goals (SDGs), Kunming-Montreal Global Biodiversity Framework and the Paris Agreement on climate change"**. This Nexus report examines different future scenarios and focuses on identifying a wide range of responses for decision-makers and synergies to maximise co-benefits (IPBES 2024).

The summary for policymakers indicates that "the future scenarios with the widest nexus benefits are those with actions that focus on sustainable production and consumption in combination with conserving and restoring ecosystems, reducing pollution, and mitigating and adapting to climate change" – "and that, focusing on addressing the challenges in just one sector – such as food, biodiversity or climate change in isolation – seriously limits the chances of meeting other goals" (IPCC IPBES 2021, IPBES 2024).

Policies would take advantage to consider the latest scientific developments to capitalise on synergies between the different fields to strengthen their consistency and resilience. The integration and appropriation of scientific expertise is a strategic challenge for organisations. Economic players would benefit from more interoperable science-based transition tools across the different fields.

2. Based on recent climate research, further criteria and assumptions could be considered to assess the consistency of climate change mitigation scenarios with the Paris Agreement, in view of earth resilience. Different interpretations of the terms of the Paris Agreement could lead to considerably different levels of climate change. For example, a long-lasting and high overshoot of the 1.5°C limit would lead to irreversible tipping point crossings [9] (Amstrong McKay *et al.* 2022 from Pouille *et al.* 2023). The OECD has specified criteria [10] that could be further considered (peak and end-of-century temperature outcomes of the scenarios and associated likelihoods, as well as aggregate GHG emissions) (Pouille *et al.* 2023). Very few scenarios used by economic players appear to be consistent with the Paris Agreement, even when considering a slightly less stringent interpretation of the OECD criteria (Noels *et al.* 2023).

Economic players should also pay more attention to some modelling assumptions, such as the discount rate, which may pass on the cost of the transition to future generations. The short-term ambitions of climate change mitigation scenarios should be further considered, as they condition the achievement of long-term temperature goals (The Shift Project *et al.* 2019, UNEP FI and CICERO 2021, NGFS 2023 [2]). Moreover, integrated assessment models (IAMs) are not independent; they use similar hypotheses, simplifications and data sources. They calculate the theoretically optimal trajectory, but not necessarily the most feasible, as they rarely address certain dimensions such as political feasibility. They also have insufficient understanding of second-round effects, non-linearities and tipping points (The Shift Project *et al.* 2019, UNEP FI and CICERO 2021).

3. Fully assessing the consistency of sectoral climate change mitigation scenarios with the Paris Agreement requires an understanding of the way in which nature is considered. Pressures on natural capital can vary across the 1.5°C scenarios, which when significant, can have implications for the level of risk posed by climate change in terms of adaptation, access to water, biodiversity degradation and food security (IPCC 2023 [3], Deprez *et al.* 2019).

There is a need to further consider resource consumption when designing models and scenarios. Based on current modelling, the availability of granular data and progress, scenarios should be further compared on their assumptions regarding the incorporation of nature and the impacts of mitigation policies where land- and ocean-based climate and biodiversity actions overlap (Deprez 2019) (including natural resource use and future demand, such as fresh water, rare earths…).

Comparisons have recently extended to the incorporation of nature in a group of IAMs: the dependence on ecosystem provisioning services that fuel the economy appears to have received more attention than regulating and maintenance services, which are essential for nature's stability. Thus, transition policies may neglect factors beyond climate change and land-use change (e.g. the intensification of ocean use) (Banque de France 2024). Research is also progressing to develop joint climate-nature scenarios and modelling (NGFS 2023 [1], Nature Finance *et al.* 2024).

8 Approved on December 16th by the 11th session of the IPBES plenary, composed of representatives of 147 governments that are member of the IPBES, the publication of the Summary for policymakers last December will be completed by seven chapters and a glossary.

9 The following tipping points may already have been reached: the melting of the Greenland ice cap (which reflected around 90% of solar radiation back into space due to its white surface); the melting of the West Antarctic; the sudden melting of the permafrost; the loss of tropical coral barrier systems; and the collapse of the Labrador Current (Rockström 2024).

10 i) Temperature increase: below 1.5°C by 2100 with limited overshoot (<0.1°C) with a 50% likelihood, and well below 2°C with a very high likelihood (90%) (78% likelihood for less stringent interpretation); and ii) GHG emissions: peak at the latest in 2025 (vs. 2030) and net-zero GHG (C02 with marginal GHG) emissions to be achieved in the second half of the century.

Furthermore, the Nexus report should require further development regarding concepts, models and scenarios (IPBES 2019, IPBES 2024).

4. Faced with complex and uncertain futures, climate change mitigation scenarios could be supplemented with a broader number of strategic options, to strengthen the competitiveness and resilience of business models in the various possible scenarios. Scenarios are not predictions; rather, they seek to enable users to compare different possible versions of the future and to infer levers and actions from these (I4CE 2019). More pathways and options should be explored to strengthen the resilience of alignment strategies. These options should be further grounded in industrial strategies and countries' competitive advantages (for the energy sector, considering a more diversified infra-regional energy mix, exploiting the potential of clean energy[11], with cross-border integrated energy networks). The development of technologies based on the extraction of metals and rare earth elements from the land and ocean requires economic players to further implement eco-design, long-life products, reuse and recycling (IPCC 2023 [3], IEA 2024 [1]). Abundant-material technologies could be researched and incentivised as well.

Beyond the theoretical optimal pathway for the energy sector relying on innovation in the upstream part of the value chain, more scenario options for other sectors should be based on sectoral aspects of IAMs, complemented by sectoral studies (IPCC 2023 [3]). These scenarios should explore changes throughout the rest of the value chain: they should further focus on innovation, the mitigation potential of the demand side, efficiency, end-use optimisation, cross-sector and country cooperation, new circular business models and sustainable infrastructures, all of which allow for greater synergies between climate and nature goals (Bauer *et al.* 2021, WRI *et al.* 2022, EEA 2024). Resource efficiency is a driver of resilience and competitiveness. For natural ecosystem-related sectors, scenarios should further incorporate land- and ocean-based mitigation options (in particular, improved management and restoration of carbon-rich ecosystems, terrestrial and ocean ecosystems, fresh water, and sustainable agriculture and forestry) (IPCC 2023 [1] [2] [3]).

5. Scenario designers should also extend the sectoral and geographical coverage and granularity of scenarios towards greater sector resilience. Scenarios should cover more business sectors for target-setting and alignment assessments–notably, emissions-intensive and nature-related sectors such as mining or food and beverage (Noels *et al.* 2023, WEF 2020). Even from a climate perspective alone, all business sectors will be required to transform their economic models to minimise the drain on nature and mitigate related GHG emissions in order to limit global warming to 1.5°C (IPCC 2023 [1], Röckstrom 2024). As it is, half of GHG emissions come from the extraction and transformation of resources (International Resource Panel 2020).

Scenario designers should also include more geographically specific scenarios (Noels *et al.* 2022). They should also provide more sectoral and geographical granularity to facilitate climate alignment assessment at the entity level, by avoiding the assumptions made by alignment methodologies to disaggregate the carbon budget (Noels *et al.* 2023).

In addition, scenarios should reflect linkages between sectors and common constraints across them (e.g. biomass), local demand for natural resources and critical minerals, but also geopolitical dependencies (IPCC 2023 [2]).

6. Economic player efforts should focus on strengthening their forward-looking strategic analyses, within the planetary boundaries, through new circular business models, for long-term profitability, strategic autonomy and resilience. Corporates and the financial sector should use or conduct more exploratory scenarios with a wider scope, embracing the value chain at the sector and cross-sector levels (TCFD 2020 [1], I4CE 2022). Circularity and relocating supply chains can be levers for economic value and further strategic autonomy. To strengthen their alignment economic players should also encompass physical risk assessments, resilience and adaptation considerations. There is a need to further develop tools and models, including for corporates, that incorporate, for example, possible supply chain disruptions, consistent planning at the county level; some are already under development (TCFD 2020 [1], Carbone 4 2023). Scenario designers should provide more granular data with practical access to help feed exploratory scenarios (UNEP FI and CICERO 2021). Economic players could also consider the Nexus report to guide strategies and policies.

Economic players should also consider using more than one sectoral climate change mitigation scenario for target setting and alignment assessment, as transition pathways for a given sector differ across climate change mitigation scenarios (UNEP FI and CICERO 2021, Noels *et al.* 2023).

7. Scenario designers should further enhance the transparency and comparability of scenarios. They should standardise the disclosure for characterising scenarios and climate outcomes to include all the necessary information to assess the consistency with the Paris Agreement (Pouille *et al.* 2023). They should also standardise the sets of assumptions and narratives used in the scenarios to optimise comparability (GFANZ 2022, Noels *et al.* 2023).

The model documentation, modelling assumptions, scopes, uncertainties and sensitivity of results to certain parameters also need to be made more transparent (GFANZ 2022, Noels *et al.* 2023).

This paper can be supplemented by the study:

Further Transforming Business Models in the Private Sector.

**Methodologies for Target-Setting and Climate Alignment Assessment:
Current Status and Future Prospects for Taking Further Account of Nature and Resilience.**

11 Solar and/or wind power, depending on countries' exposure to these elements, nuclear, etc.

INTRODUCTION

Economic players face growing pressures to transform their business models in response to multiple challenges (sustainability issues, technological supremacy, natural resources security, etc.). 2024 is the first year to exceed 1.5°C above pre-industrial levels (Copernicus Climate Change Service 2024). These levels of warming have not been seen since at least 100,000 years ago and are affecting living conditions (IPCC AR6, 2023). The losses associated with all natural disasters worldwide, mainly due to weather catastrophes, are on an upward trend (Munich Re 2024). The frequency and strength of extreme events will increase over the next 30 to 40 years (Röckstrom 2024). Europe has not been spared, with warming twice as fast as the global average and significant costs associated with recent extreme weather events (Copernicus Climate Change Service and World Meteorological Organisation 2024, European Environment Agency 2023).

To face uncertain futures and achieve a sustainable economy, economic players could accelerate the transformation of their business models. They would take advantage to further consider the latest scientific insights regarding climate and nature to assess the risks and opportunities, in order to elaborate policies that strengthen innovation, their competitiveness and resilience. Collective efforts have so far mainly focused on climate change mitigation. Sectoral climate change mitigation scenarios consistent with the Paris Agreement are central to this, as they incentivise major transformations at the financial asset, company and sector levels. They are used to set interim targets and measures that convert temperature goals and greenhouse gas (GHG) emission reductions into policy milestones and to design resilient strategic plans accordingly.

This paper gives decision-makers an overview of the current thinking on the scenarios that drive sectoral and business transformation, avenues for improvement and targeted actions towards a sustainable economy. It recommends that economic players and scenario designers explore the wider opportunities that arise from having greater consistency between their approaches to climate and nature[12] to define consistent strategies and increase co-benefits. The broad transition of nature[13] and adaptation[14] frameworks are not the focus of this paper that examines how nature is considered in the earlier climate frameworks and tools.

12 All existing systems on earth, including biodiversity its living element.

13 Beyond climate change, nature frameworks include other pressures on planetary boundaries and/or the provision of ecosystem services. Such pressures come, for example, from land use, pollution, natural resources exploitation, and invasive species.

14 According to the definition by the Intergovernmental Panel on Climate Change (IPCC), **adaptation** is any adjustment in response to actual or expected climatic stimuli (NGFS 2024). It differs from resilience. **Resilience**, according to the IPCC, is the ability to anticipate, absorb, accommodate or recover from a hazardous event in a timely and efficient manner, including through ensuring the preservation, restoration or improvement of the environment (NGFS 2024).

1. OVERARCHING INTERGOVERNMENTAL FRAMEWORKS AND THE SECTORAL CLIMATE CHANGE MITIGATION SCENARIOS

1.1. The Paris Agreement, to consider in relation with the Global Biodiversity Framework (GBF)

Adopted by the United Nations (UN) in 2015, the Sustainable Development Goals (SDGs) set political objectives. Economic players must apply science-based frameworks to their risk and opportunity analyses of how to reach the goals of the Paris Agreement and later, in 2022, the GBF, which added biodiversity commitments to the existing climate ones. Both are science-based and set global goals and targets. Contribution to these goals is expected at the sectoral and entity levels.

The Paris Agreement is a 2015 treaty, adopted by the parties to the UN Framework Convention on Climate Change (UNFCCC), that establishes binding commitments by all parties, considering the work of the Intergovernmental Panel on Climate Change (IPCC). This Agreement refers to the sustainable development goals as it aims to strengthen "the global response to the threat of climate change, in the context of sustainable development and efforts to eradicate poverty" (article 2). It sets commitments to limit the increase in global average temperature (art. 2.1.a), cap GHG emissions, and achieve net-zero emissions in the second half of the century (art. 4) (**Box 1**) (UNFCCC 2015).

BOX 1. THE PARIS AGREEMENT

Article 2.1 sets a global average temperature target:

a) "holding the increase in the global average temperature to well below 2°C above pre-industrial levels [… and] to pursuing the efforts to limit the temperature increase to 1.5°C above pre-industrial levels" in the long term";

b) "increasing the ability to adapt to the adverse impacts of climate change and foster climate resilience and low GHG emissions development, in a manner that does not threaten food production";

c) making "financial flows consistent with a pathway towards low-carbon greenhouse gas (GHG) emissions trajectory and climate-resilient development".

Article 4: in order to achieve the long-term temperature goal set out in article 2, in terms of emissions:

"To reach global peaking of GHG emissions as soon as possible [...and] to undertake rapid reductions thereafter in accordance with best available science, so as to achieve a balance between anthropogenic emissions by sources and removals by sinks of GHG in the second half of the century" (UNFCCC 2015).

Economic players should ensure that their business model and strategy are compatible with the Paris Agreement. Sectoral climate change mitigation scenarios consistent with the Paris Agreement are central to this, for companies to build pathways, set targets to reduce GHG emissions, assess climate alignment (SBTi 2021) and design strategic plans accordingly.

The Paris Agreement also aims at adaptation: "climate resilience and low GHG emissions development in a manner not to threaten food production" (art 2.1.b), and ultimately at carbon neutrality (art. 4). It requires considering nature (and the degradation of biodiversity in particular).

The net-zero transition requires nature to be considered, in terms of its contribution to climate mitigation, but also its role in achieving adaptation and resilience. Economic players should consider the GBF, a UN decision, reached at the 15th Conference of the Parties (COP15), that aims to halt and reverse nature loss. Besides, the planetary boundaries, developed by the Stockholm Resilience Centre[15], introduce key processes and thresholds for resilience of the planet and future generations (Röckstrom 2015 and 2022).

Climate and nature are largely addressed in silos due to the specialisation and complexity of the disciplines involved. However, they are interconnected: climate change is a prominent driver of biodiversity loss, while the degradation of natural ecosystems reduces the options for effective mitigation and adaptation (IPCC IPBES 2021, IPCC 2023 [2] [3], NGFS [1] 2023). Nature is both a source and a sink of GHG emissions: of the global GHG emissions, the agriculture, forestry and other land use (AFOLU) sector accounts for 22% and deforestation

15 In collaboration with several preeminent research institutes and academics.

50% (IPCC 2023 [1]); land sequesters 31% and ocean 26% of total emissions (ESSD 2023). Natural ecosystems can achieve an estimated 37% of the 2030 net-zero emissions-reduction goals (IPCC 2023 [1]), Griscom 2017 from GFANZ 2024).

The Paris Agreement and the GBF should not be considered separately (alongside the SDGs) as their effectiveness depends on the other's success (Streck 2024). Their different legal status [16] and timelines raise questions about the way in which nature is considered in the net-zero transition and earlier related frameworks (modelling and sectoral scenarios; even regional scenarios[17] as nature has a local scale while climate is global).

The scientific outcome of the IPCC and the Intergovernmental Science Policy Platform on Biodiversity and Ecosystem Services (IPBES) workshop on climate and biodiversity shows: "1° Policies that simultaneously address synergies between mitigating biodiversity loss and climate change […] offer the opportunity to maximize co-benefits (IPBES IPCC 2021). 2° Several land- and ocean-based actions to protect, sustainably manage and restore ecosystems have co-benefits for climate mitigation, climate adaptation […] 3° Measures narrowly focused on climate mitigation and adaptation can have direct and indirect negative impacts on nature […] 4° Treating climate, biodiversity and human society as coupled systems is key to successful outcomes from policy interventions" (IPBES IPCC 2021).

The IPBES assessment report, to be fully published in 2025, on interlinkages among biodiversity, water, food, health and also climate change will require further developments (**Box 2**).

To further develop consistent and resilient strategies for alignment, decision-makers would benefit from more interoperable science-based tools.

BOX 2. THE INTERGOVERNMENTAL PLATFORM ON BIODIVERSITY AND ECOSYSTEM SERVICES (IPBES) THEMATIC ASSESSMENT REPORT ON INTERLINKAGES AMONG BIODIVERSITY, WATER, FOOD, HEALTH (publication of the Summary for policymakers in December) (known as the Nexus report)

The Nexus report[18] broadens the analysis to the Interlinkages among Biodiversity, Water, Food and Health. It the product of three years of work by 165 leading international experts from 57 countries. It "provides the science and evidence needed to support achievement of the Sustainable Development Goals (SDGs), Kunming-Montreal Global Biodiversity Framework and the Paris Agreement on climate change". This Nexus report examines different future scenarios and focuses on identifying a wide range of responses for decision-makers and synergies to maximise co-benefits (IPBES 2024).

The summary for policymakers indicates that "the future scenarios with the widest nexus benefits are those with actions that focus on sustainable production and consumption in combination with conserving and restoring ecosystems, reducing pollution, and mitigating and adapting to climate change" – "and that, focusing on addressing the challenges in just one sector – such as food, biodiversity or climate change in isolation – seriously limits the chances of meeting other goals" (IPBES 2024).

1.2. Sectoral climate change mitigation scenarios for strategy development and alignment assessment

The main climate change mitigation scenarios consistent with the Paris Agreement used by the financial and non-financial sectors for their transition have been developed by international institutions, research organisations or communities. They may also be commissioned by public institutions or industrial alliances. Unlike the IPCC's physical climate scenarios[19], the climate change mitigation scenarios introduce policies (I4CE 2021).

Climate change mitigation scenarios consistent with the Paris Agreement are usually made public, include a description of the methodology, and allow for sectoral granularity (PAT 2020, GFANZ 2022, Noels *et al.* 2023, Institut Louis Bachelier *et al.* 2024). In addition to the shared socio-economic pathways (SSP) of the **IPCC** (IPCC 2018), they include the following scenarios:

- **IEA**: the International Energy Agency has developed global and regional net-zero transition (NZE) scenarios for public authorities for the decarbonisation of the energy sector (IEA 2023 [1]). The IEA uses the Global Energy and Climate Model (GEC Model), a hybrid model that relies on the World Energy Model

16 The States have not endowed the Convention on Biological Diversity (CBD) with legal powers to adopt legally binding decisions. The GBF depends on its incorporation into national laws, and on international cooperation and private finance (Streck 2024).
17 For example, in Europe, scenarios must incorporate the 2024 EU Nature Restoration Law.
18 Approved on December 16th by the 11th session of the IPBES plenary, composed of representatives of 147 governments that are member of the IPBES, the publication of the Summary for policymakers last December will be completed by seven chapters and a glossary.
19 These GHG emission and concentration trajectories, known as "Representative Concentration Pathways", show the climatic response to a change in atmospheric GHG concentrations (I4CE, 2021).

(WEM) and the Energy Technology Perspectives (ETP) (IEA 2023 [2] [3])[20]. The scenarios developed by the IEA aim to meet the Paris Agreement and energy-related SDGs.

- **UTS-ISF**: the University of Technology Sydney's Institute for Sustainable Futures has developed a net-zero climate change mitigation scenario, initially for use by governments and the energy industry, and then at the request of the financial sector. UTS-ISF uses an integrated global sectoral model (One Earth Climate Model -OECM) covering the entire economy, broken down into primary and secondary forms of energy and end-users. This model breaks down the global carbon budget by geographical area with sectoral granularity. Key performance indicators (KPIs) are used for short-, medium- and long-term investment decisions (UTS 2022).
- **NGFS**: the Network of Central Banks and Supervisors for Greening the Financial System[21] has developed contrasting scenarios with the aim of assessing financial sector risks and enhancing comparability. Three scenarios illustrate an orderly transition ("net zero 2050", "below 2°C", "low demand") (NGFS 2022), while other scenarios are used for stress tests ("delayed transition" or "hot house world").
- **JRC**: the European Commission's joint research centre has developed scenarios based on the POLES model, producing global, long-term analyses of mitigation policies and energy market trends (Noels *et al.* 2023).

In addition to the IPCC and NGFS climate change mitigation scenarios, the banking sector tends to use the IEA scenarios, while institutional investors tend to use the UTS-ISF scenarios for target-setting and alignment assessments (scenarios on which the sections below will rather now focus) (ECB 2023 [1]).

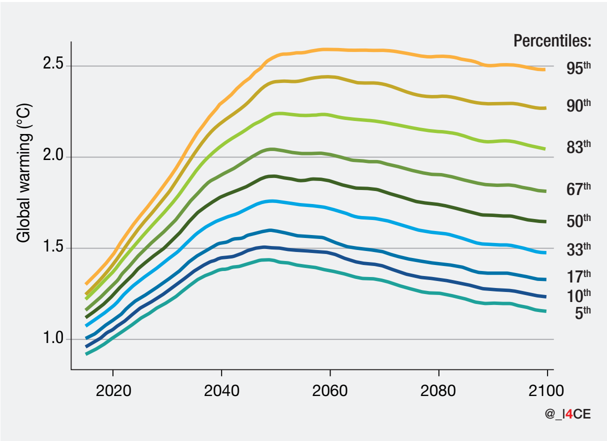
1.3. Climate change mitigation scenario modelling, including taking into account nature

Using scenarios provides robust references for strategic thinking, which implies understanding the modelling framework and assumptions. This understanding enables the results to be interpreted appropriately, and does not generate undesirable environmental, political or strategic consequences (The Shift Project *et al.* 2019, GFANZ 2022). Scenarios correspond to "a plausible description of future development, based on a coherent and intrinsically homogeneous set of assumptions about driving forces and their relationships" (IPCC 2014). They constitute neither a prediction nor a forecast.

Different categories of integrated assessment models (IAMs) (The Shift Project *et al.* 2019, UNEP FI and CICERO 2021): scenarios are produced using complex IAMs that combine several fields (energy, economics and climate science) and different modelling schemes. Models can be: i) partial equilibrium (one sector); ii) general equilibrium (several markets and sectors); or iii) large-scale energy system models. The latter are divided into i) least-cost optimisation models at the energy system level, considering various constraints, and ii) simulation models that consider economic dynamics (*e.g.* the IEA WEM). Models combining energy and macroeconomics are referred to as hybrids.

Modelling pathways (Pouille *et al.* 2022): pathways are normative scenarios that set ex ante the final temperature (1.5°C with zero or limited overshoot[22] at a given date with a given probability[23]). Several scenarios can lead to a given temperature level. For example, the IPCC, in its special report on 1.5°C warming, drew up four scenarios (entitled P1 to P4) (IPCC 2018). Conversely, each scenario reaches different temperature levels (1.5°C or 2°C) associated with different probabilities that must be specified (**Figure 1**).

FIGURE 1. PROBABILISTIC TEMPERATURE ASSESSMENT FOR A MITIGATION SCENARIO



Source: Pouille et al. *2022.*

20 The NZE IEA scenario does not include all GHGs so a formula is applied to take them into account.
21 The NGFS includes Banque de France, as a founding member, and other central banks and supervisors from several countries.
22 Trajectories with at least a 50% probability of keeping global warming below 1.5°C by 2100 are said to have zero overshoot, and those limiting warming below 1.6°C and returning to 1.5°C by 2100 are said to have limited overshoot.
23 The likelihood of reaching a temperature level should also be considered. The IEA's NZE scenario has a 50% probability of keeping temperature increase below 1.5° by 2100, while the UTS-ISF scenario has a 67% probability.

Purpose of models: models aim to represent interactions between the environment and human activities, which inform public policy decisions; they do not provide circumstantial answers to specific contexts or sectors (The Shift Project and AFEP 2019). They focus on the long-term implications or the likelihood of certain choices to achieve a given temperature level, and are particularly adapted to conduct "what if?" analyses (UNEP FI and CICERO 2021). Scenarios answer general questions[24] by providing general answers (Nikas *et al.* 2021). For example, they do not quantify the exact market share of a technology, but a reading across the different scenarios may lead to the conclusion that the share of renewables must be increased significantly, and that the share of fossil fuels, particularly coal, must be reduced rapidly (UNEP FI and CICERO 2021).

Modelling assumptions: climate models are not independent; they tend to be based on a similar design, using similar simplifications and data sources (The Shift Project *et al.* 2019). As such, reality may deviate from the modelled scenarios. Climate models do not calculate the most likely or even the most feasible pathway; and they rarely address dimensions such as political feasibility and energy security, non-linear changes in consumer preferences, or, related to technology deployment, granular demand side or lifestyle changes (The Shift Project *et al.* 2019, UNEP FI and CICERO 2021).

The multiple layers of assumptions in the relevant fields (energy, climate, economics) together with insufficient transparency can make the interpretation of the results difficult. Some modelling assumptions are worth recalling, while others are not cited so often in the literature. As the equations and structuring parameters tend to be calibrated using historical data, this could lead to bias, such as overestimating the extent to which the future will resemble the past (The Shift Project *et al.* 2019). On an economic level, agents, considered as rational, optimise the use of resources without waste, which differs from reality (The Shift Project *et al.* 2019). The discount rate, which can lead to the cost of transition being deferred to future generations[25], is an important parameter of models, although it is less talked about in the literature on scenario comparisons (UNEP FI and CICERO 2021). In the case of energy models, the modeller's choices can influence the models used and their results; they may be based on disruptive technologies that defer efforts (The Shift Project *et al.* 2019).

Nature considerations: a working paper covers nature modelling in a group of IAMs along the following axes: (i) different aspects of nature, including feedback between natural elements; (ii) economic dependencies upon nature, regarding provisioning services and regulating and maintenance services; (iii) economic impacts upon nature; and (iv) policy interventions to mitigate nature loss, regarding drivers of biodiversity loss (Banque de France 2024). The comparison shows that the IAMs mainly capture the ecosystem provisioning services that fuel the economy and under-represent most regulating services that maintain nature's stability. Moreover, these models focus on land-use change (*e.g.* with little consideration of the ocean) and climate change, so that transition policies may neglect other factors (including *e.g.* ocean-use intensification). (**Appendix 1**).

Modelling tipping points: climate change mitigation scenarios struggle to assess tipping points, sudden and/or simultaneous shocks, unexpected events, non-linear effects, and the impacts of physical and transition risks and their interactions (The Shift Project *et al.* 2019, UNEP FI and CICERO 2020, Armstrong McKay 2022). Science is required to make further progress in this area.

24 *e.g.* if we reduce energy demand, is it possible to reach 1.5° without using carbon capture and storage? (UNEP FI and CICERO, 2021).
25 The discount rate is 5% in general, with variations between 2% and 8% (Forster *et al.* 2018).

2. FURTHER CRITERIA TO COMPARE A SET OF CLIMATE CHANGE MITIGATION SCENARIOS (INCLUDING NATURE CONSIDERATIONS)

2.1. Considerations and criteria to compare climate change mitigation scenarios

Given that different assumptions and modelling lead to different results, the climate change mitigation scenarios should be compared along the following criteria (The Shift Project and AFEP 2019, PAT 2020, UNEP FI and CICERO 2021, GFANZ 2022, Pouille 2023, Institut de la Finance Durable 2024) (**Figure 2**):

- **Objectives**, the purposes for which the scenario is developed;
- **Credibility**: validation by the scientific community;
- **Ambition in terms of consistency with the Paris Agreement**: emissions trajectories, temperatures, associated probabilities, extent of use of carbon-capture solutions, etc.;
- **Coverage and granularity**:
  - Sectors and geography;
  - GHGs included, distinguishing between long-lived gases around 100 years (CO_2, nitrous oxide) and short-lived climate-forcing gases (methane and hydrofluorocarbons); scopes 1, 2 and 3 coverage;
  - Time horizons and time intervals; start date;
- **Mitigation policies and assumptions**:
  - Mitigation policies (energy mix, use of CCS solutions, etc.);
  - Assumptions: i) SSP standardised by the IPCC[26] (changes in population, GDP, energy supply and demand, carbon prices[27], or changes in energy intensity, rebound effects, etc.); and ii) technologies (very sensitive assumptions in terms of costs, lead times, lifespan);
  - Models used;
- **Feasibility**: the IPCC provides an assessment framework in its 2022 report (IPCC, 2022, Appendix 2).

26 SSP1 Sustainability: Taking the Green Road (Low challenges to mitigation and adaptation); SSP2 Middle of the Road (Medium challenges to mitigation and adaptation).

27 Carbon prices often represent climate policies and are outputs to reach a climate target.

FIGURE 2. IEA AND UTS ISF NET-ZERO SCENARIO MAIN CRITERIA

Paris Agreement Article	IEA NZE	UTS ISF
Organisation, Models, Objectives, credibility		
Organisation	International Energy Agency	University Technology of Sydney
Models (energy)	Global energy and climate model, 2022 (Energy system model, partial equilibrium model)	One earth climate model, 2020 (integrated energy assessment model, partial equilibrium model)
Objective	Pathway of the energy sector (responsible of 75% of GHG emissions) which achieves net-zero without offsets from other sectors, for policy makers	For the financial sector (aligned with sector classification -NACE, BICS GICS-, granularity sector specific, all GHG, with KPI)
Collaboration and peer reviews	IIASA, IMF, NREL, Grantham Resarch Institute on Climate change and the Environment, Cambridge University, Governmental organizations, industry experts	Energy Transition Commission, the Postdam Institute for Climate Impact Research, SBTI, CRREM
Ambition		
Timeframe	2050	2050
Temperature (likelihood)	< 1.5° no overshoot (50%) in 2100	1.5° no/low (67%) in 2100
Peak warmnig the century (50% likelyhood)	~1.6°C	1.67°C
Carbon budget (Gt CO_2) leading to an annual average reduction of 4-7% till 2030	460 (+40 AFOLU)	400
GHG	CO_2	Main GHG
Year of net-zero CO_2 emissions	2050	2050
Scope and granularity		
Temporal scope	2010-2050	2019-2050
Interval of disclosed emissions pathways	10 years	5 years up to 2040, and 10 years 2040-2050
Scopes	No disaggregated 1, 2, 3 emissions	1, 2, 3 (based on WRI 2013)
Regional granularity (number of disclosed emissions pathways)	**7 regions, 8 sub-regions, 6 countries** (USA, Brazil, EU, Russia, China, India, Japan, Southeast Asia)	**10 regions, 19 countries** (Argentina, Australia, Brazil, Canada, China, France, Germany, India, Indonesia, Italy, Japan, Mexico, Russia, Saudi Arabia, South Africa, South Korea, Turkey, UK, US)
Sectoral net zero pathways	**Energy** (combustion activities, electricity and heat sectors, other energy sector); **Industry** (iron and steel, chemicals, cement); **Transport** (road, aviation, shipping); building (residential, services)	**Energy** (coal, oil, gas); **Industry** (transport, aviation, shipping, road); **Buildings**; **Utilities** (power, gas, water utilities); **Materials** (fishing industry, forestry and woods products, chemical industry, textile & leather, aluminium, steel, iron&steel, cement); **Consumer Staples** (agriculture, food processing & tabacco)
Mitigation strategies and assumptions		
GIEC Scenario based	SSP2	SSP1
Narrative	Global access to electricity and clean cooking achieve by 2030; rapid and major reductions of methane; adoption of ambitious policies; global collaboration	Social, business and technological innovations result in lower energy demand, living standards rise in the South, downsized energy system and decarbonisation
Carbon price by 2050 ($/t$CO_2$) advanced	250	180
Energy mix	More than 90% renewable of electricity consumption, immediate cessation of investments in new oil, coal and gas projects	
Energy intensity	-3 to -4% per year up to 2030 and -2 to -3% up to 2050 (-1% per year historically)	
Reforestation/Aforestation, other land sinks	No	Yes
BECCS	Yes	No
DAC	Yes	No

Source : I4CE based on GFANZ 2022 OECD 2023.

2.2. More criteria to assess the consistency of the climate-mitigation scenarios with the Paris Agreement, and to further consider nature

Consistency with the Paris Agreement: a recent OECD research paper shows that the terms of this Agreement should be considered jointly with their scientific translation[28] (*e.g. "well below"*) and consequently proposes criteria to conduct this assessment (Pouille *et al.* 2023) (**Figure 3**). Different interpretations of this Agreement are possible and could lead to considerably different levels of climate change. For example, a long-lasting and high overshoot of the 1.5°C limit could lead to irreversible tipping point crossings (Armstrong McKay *et al.* 2022 referenced by Pouille *et al.* 2023). Based on recent studies, of the 16 tipping points identified, 4 are likely to be crossed[29] even with an average global surface temperature of 1.5°C. 1.5°C does not appear to be a target, but a "physical limit" (Rockström 2024).

Very few of the climate change mitigation scenarios used by economic players appear to be consistent with the Paris Agreement when considering the OECD slightly less stringent interpretation (Noels *et al.* 2023).

Nature's contribution to the net-zero transition in the scenarios, and its role in relation to adaptation and resilience: fully assessing the consistency of climate change mitigation scenarios with the Paris Agreement also means looking at how nature is incorporated. Climate change is a prominent driver of biodiversity loss, and the degradation of ecosystems reduces mitigation and adaptation policy options (IPCC 2023 [2] [3], NGFS [3] 2023, Streck 2024). Based on recent studies, the level of risk posed by climate change depends on demand for natural resources across the scenarios; few 1.5°C scenarios manage to reduce the conversion of land use, which, when significant, has negative impacts on the ability to adapt, access to water, biodiversity, and, ultimately, food security (IPCC 2023 [3]). Some studies show that returning to a temperature of 1.5°C by the end of the century after overshoot requires decarbonisation at a record pace and a return to all the planetary boundaries providing the earth with its resilience (Röckstrom 2024).

Based on the current scenarios, the availability of granular data and future progress, climate change mitigation scenarios should be further compared on their incorporation of natural ecosystems and the impact of mitigation policies where biodiversity and land- and ocean-based climate actions overlap (*e.g.* land[30] and ocean use) (Hof 2018, Deprez *et al.* 2019, IPCC 2023 [2] and [3]). Comparisons should also extend to the use of natural resources (*e.g.* water, rare earths. etc) and recycling rates in the scenarios.

Collective efforts should be pursued to develop climate and nature joint scenarios and related modelling (NGFS 2023 |1], Nature Finance *et al.* 2024).

FIGURE 3. CONSIDERATION AND CRITERIA FOR ASSESSING THE PARIS CONSISTENCY OF GLOBAL CLIMATE CHANGE MITIGATION SCENARIOS

Paris Agreement Article	Paris Agreement mitigation goal and objectives	Possible criteria for mitigation scenarios: More stringent interpretation	Possible criteria for mitigation scenarios: Less stringent interpretation	Scenario data required for consistency assessment
2.1	"Pursuing efforts to limit the temperature increase to 1.5 °C"	CRITERION 1 1.5°C in 2100 In 2100 the scenario must hold global warming below 1.5°C with at least **50%** chance.		• Likelihood of staying below 1.5°C in 2100 • Or global warming in 2100 at the 50% likelihood level
		CRITERION 2 no or limited overshoot of 1.5°C Throughout the century, the scenario must hold global warming below **1.6°C** with at least 50% chance.		• Likelihood of staying below 1.5°C during the century • Or peak global warming during the century at the 50% likelihood level
2.1	"Holding the increase in global average temperature to well below 2 °C"	CRITERION 3 well-below 2°C throughout the century Throughout the century, the scenario must hold global warming below 2°C with at least a **90%** chance.	CRITERION 3 well-below 2°C throughout the century Throughout the century, the scenario must hold global warming below 2°C with at least an **78%** chance.	• Likelihood of staying below 2°C during the century
4.1	"Aim to reach global peaking of greenhouse gas emissions as soon as possible [...and) achieve a balance between anthropogenic emissions by sources and removals by sinks of greenhouse gases in the second half of this century"	CRITERION 4 peak GHG emissions The scenario must ensure that global GHG emissions peak before **2025**.	CRITERION 4 peak GHG emissions The scenario must ensure that global GHG emissions peak before **2030**.	• Year of peak GHG emissions
		CRITERION 5 Net-zero emissions The scenario must achieve global **net-zero GHG emissions** in the second haif of the 21st century.	CRITERION 5 Net-zero GHG emissions The scenario must achieve global net-zero CO_2 emissions, accompanied by marginal net-zero GHG emissions *i.e.* very strong GHG emissions reductions resulting in residual net GHG emissions in 2100 of **5 Gt** or less.	• Year of net-zero global GHG and CO_2 emissions • GHG emissions in 2100
Number of scenarios in the IPCC AR6 database		26	55	

Source : Pouille et al *2022.*

28 And that the reference to 1.5°C or 2°C scenarios should not be considered without further information.

29 The following tipping points may already have been reached: the melting of the Greenland ice cap (which reflected around 90% of solar radiation back into space due to its white surface); the melting of the West Antarctic; the sudden melting of the permafrost; the loss of tropical coral barrier systems; and the collapse of the Labrador Current (Rockström 2024).

30 In particular, deforestation, logging, forest degradation, reforestation, afforestation, natural generation of forests, clearing and conversion to pasture or cropland, agriculture practices that increase carbon in the soil, large-scale monoculture, and large-scale bioenergy crops.

2.3. Overview of the comparisons of mitigation strategies for the energy sector

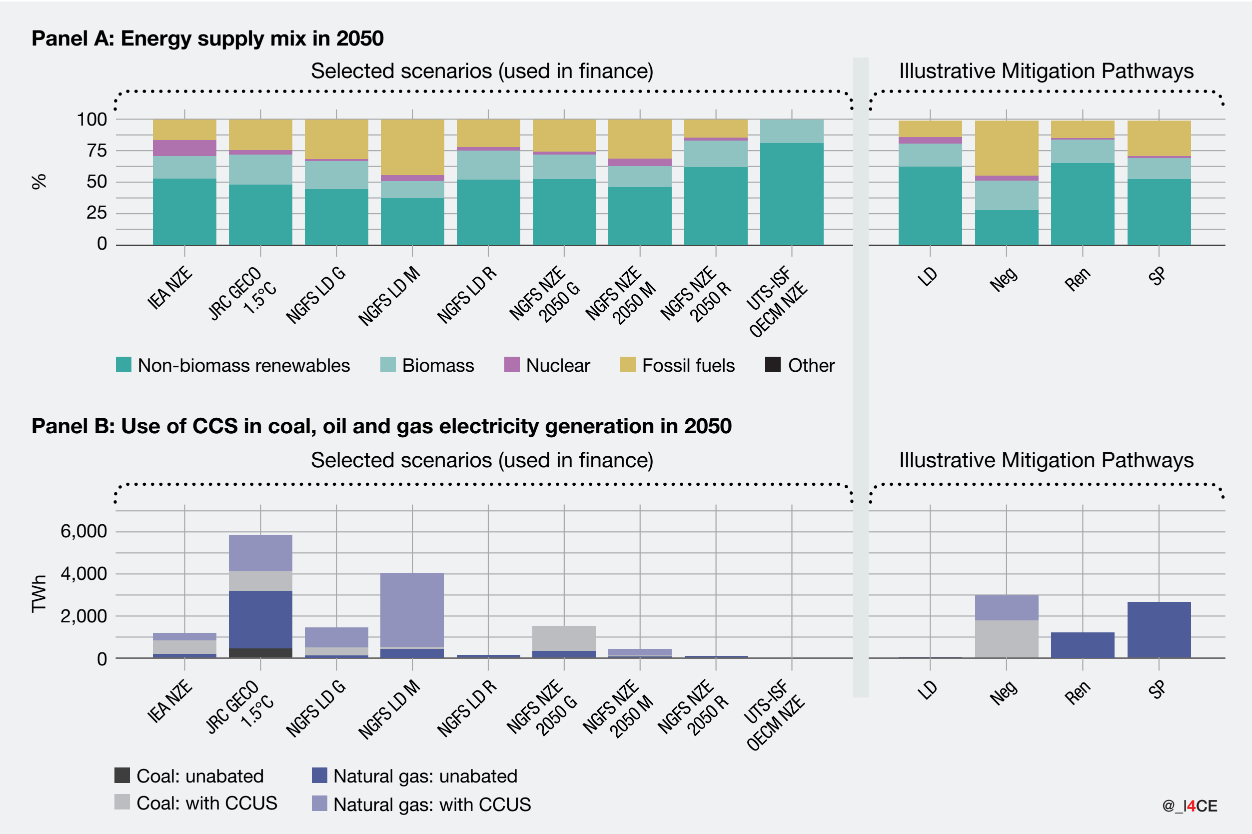
Energy decarbonisation: the energy mix varies according to SSP and mitigation policies, and, within the same pathway, according to the models used (UNEP FI and CICERO 2021) (**Figure 4**). The IEA and UTS-ISF NZE scenarios are both based on a large-scale deployment of renewable energy, of the order of 90% and 100% of electricity generated in 2050 (IEA 2023, UTS 2022). In the UTS-ISF scenario (UTS 2022), renewable energy will account for more than 75% of the total energy supply in 2050, which some studies consider to be realistic, even if some debate remains over this (Noels *et al.* 2023). The share of fossil fuels in 2050 falls sharply, particularly for coal, in both scenarios. In the IEA scenarios, 80% of the solutions needed to reach the 2030 targets are already available, and half of them are at the prototype stage to reach the 2050 targets (more efficient batteries, electrolysers, carbon-capture techniques, etc.) (IEA 2023, Noels *et al.* 2023).

Demand-side mitigation levers: these levers are based on electrification of the various sectors (up to 50% of energy consumption for the IEA and 60% for the UTS-ISF by 2050), efficiency gains, and sobriety measures (IEA 2023, UTS 2022). The first two levers are widely used, particularly in the UTS-ISF scenarios, with efficiency gains higher than historical rates (Noels *et al.* 2023).

Carbon capture utilisation and storage (CCUS) and removal options for residual emissions: of these, bioenergy with CCS, and reforestation and afforestation are the most widely used (Noels *et al.* 2023). The use of CCS post-2050 is retained in most scenarios, and particularly in the IEA scenario. Only the UTS-ISF scenario uses carbon sinks (UTS 2022).

The share of negative emissions is dictated by residual emissions (methane in agriculture, melting permafrost, abandoned fossil-fuel sinks and emitting industries) and the level of overshoot (UNEP FI and CICERO 2021). If it is not possible to resort to CCS to the same extent modelled in the scenarios (mostly because of uncertainties about the impact on land and ocean), a further reduction in emissions will be necessary (Noels *et al.* 2023).

FIGURE 4. MITIGATION STRATEGIES ACROSS SCENARIOS



Source: OECD 2024.

2.4. Overview of the comparisons of mitigation strategies for non-energy sectors

Sector coverage: climate change mitigation scenarios for the primary energy sector offer analysis at a greater depth and include emitting non-energy industrial sectors. Some transition scenario designers cover a wider range of sectors (**Figure 5**).

FIGURE 5. OVERVIEW OF SECTORS AND GRANULARITY OF DISCLOSED EMISSIONS PATHWAYS AND MODELS

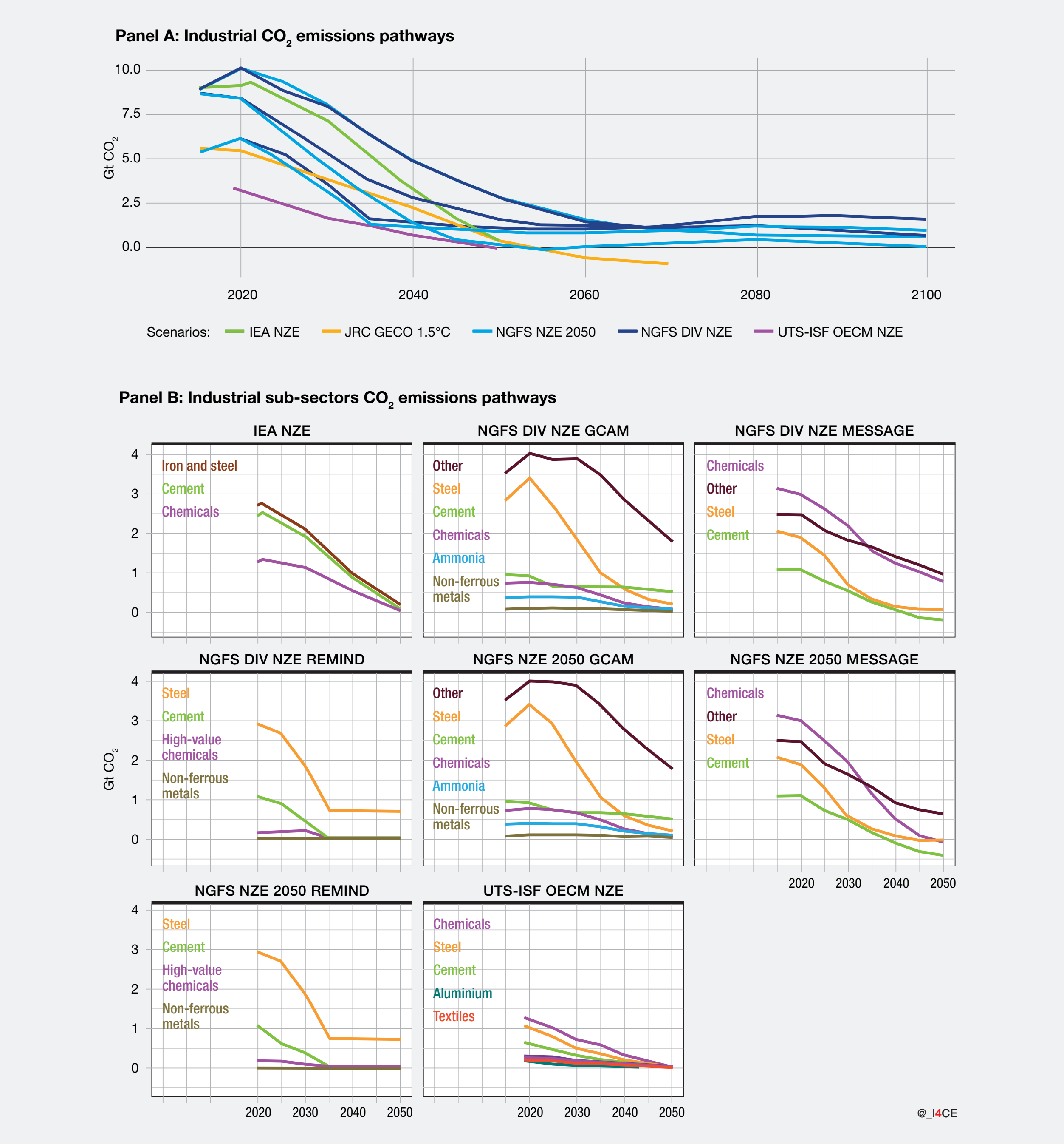
Paris Agreement Article	IEA GEC 2022	POLES-JRC 2022	NGFS GCAM	NGFS MESSAGE	NGFS REMIND	UTS-ISF OECM
Model coverage of IPCC standard sectors	Energy system	Energy system	Energy system	Energy system	Energy system	Energy system
	Industry	Industry	Industry	Industry	Industry	Industry
	Transport	Transport	Transport	Transport	Transport	Transport
	Buildings	Buildings	Buildings	Buildings	Buildings	Buildings
	AFOLU	AFOLU	AFOLU	AFOLU	AFOLU	AFOLU
Model sectoral resolution	35+ sub-sectors	15+ sub-sectors	14 sub-sectors	10 sub-sectors	14 sub-sectors	17 sub-sectors
Sectoral granularity for emissions pathways output data	4 sectors, 11 sub-sectors • Energy (3) • Industry (3) • Transport (3) • Buildings (2)	6 sectors, 10 sub-sectors (sectoral data upon request) • Energy (4) • Industry (4) • Buildings (2) • Agriculture • Transport • Other	5 sectors, 14 sub-sectors • Energy (5) • Industry (5) • Transport (2) • Buildings (2) • AFOLU	5 sectors, 10 sub-sectors • Energy (5) • Industry (4) • Transport (1) • Buildings • AFOLU	5 sectors, 14 sub-sectors • Energy (5) • Industry (5) • Transport (2) • Buildings (2) • AFOLU	6 sectors, following GICS classification, 17 sub-sectors • Energy (3) • Utilities (3) • Buildings Industrials / Transport (3) • Materials (8) • Consumer staples (food processing)

Source: Noels 2023.

■ Covered ■ Complementary data source ■ Not included

Sector transition pathways differ across scenarios. Differences in the magnitude and pace of emission reductions over time reflect differing modelling, assumptions and ambitions for a sector (initial emissions level, emissions reduction, technological options, etc.) (Noels *et al.* 2023) (**Figure 6**). Considering the multiple possible futures and the influence of a scenario on the alignment assessment for a financial asset or company (*e.g.* Noels *et al.* 2022), the use of more than one scenario should be considered to refine the analysis (UNEP FI and CICERO 2021, Noels *et al.* 2023). However, using several scenarios through the warming function approach[31] is more complex and assumes several technical prerequisites (PAT 2021, GFANZ 2022, CDP -WWF 2024).

FIGURE 6. INDUSTRY SUB-SECTORAL ENERGY-RELATED CO_2 EMISSIONS PATHWAYS ACROSS SCENARIOS[32]



Source: Noels et al. *2023.*

31 The warming function is a linear regression model used to project the impact of GHG emissions-reduction rates on global warming by the end of the century.

32 The IPCC AR6 Illustrative Mitigation Pathways (IMPs) scenarios provide reference points in the analysis, showing the possible range of mitigation strategies: heavy reliance on renewables (IMP-Ren), on energy demand reduction (IMP LD), on the use of CDRs (IMP-Neg), on sustainable development (IM-SP), implications of slower, progressively hardening short-term actions (IMP GS).

CONCLUSION

Recent cross-sectional studies have highlighted several developments that could further improve the use by economic players of scenarios to assess their alignment with the Paris Agreement. This paper recommends that economic players explore the wider opportunities that arise from greater consistency between their approaches to climate and nature, to define resilient strategies and increase co-benefits.

3.1. To reach a sustainable economy, greater interoperability of overarching science-based frameworks through policy and implementation links between nature and climate is critical to better align around consistent objectives and reinforce each other (see also Appendix 3 for the climate and biodiversity nexus). Policies could take further account of the latest scientific developments, building on the IPBES Nexus assessment report, which broadens the analyses to the interlinkages among biodiversity, water, food, health and also climate change. It would require development regarding concepts, models and scenarios (IPBES 2019, IPBES IPCC 2021, IPBES 2024).

Decision-makers would benefit from further climate and nature interoperable tools to ensure consistent and resilient strategies of alignment. Policies should seek competitiveness in the various possible scenarios[33]; they should aim to be sustainable in the long run, given the scale of transformation (long-lifetime new production tools, infrastructures, and territorial planning, etc.); they should also incorporate territorial, resilience and adaptation dimensions regarding access to natural resources.

3.2. Further criteria are necessary to compare and assess the consistency of climate change mitigation scenarios with the Paris Agreement, considering earth resilience (peak and end-of-century temperature outcomes and their associated likelihood, as well as aggregate GHG emissions) (Pouille *et al.* 2023, Noels *et al.* 2023).

3.3. Faced with complex and uncertain futures, climate change mitigation scenarios could be supplemented with a broader number of strategic options to strengthen competitiveness and resilience, in the various possible scenarios within the planetary boundaries. Scenarios are not predictions; they rather, seek to enable users to compare different possible versions of the future and to infer levers and actions from these (I4CE 2019). More pathways and mitigation policy options should be explored to strengthen resilience given the various envisaged futures (The Shift Project *et al.* 2019).

These options should be grounded in industrial strategies and countries' competitive advantages (including, for the energy sector, considering a more diversified infra-regional energy mix, exploiting the potential of renewables[34], with cross-border integrated energy networks). The development of technologies based on the extraction of metals and rare earth elements from land and ocean requires economic players to further implement eco-design, long-life products, reuse and recycle (IPCC 2023 [3], IEA 2024 [1]). Abundant-material technologies could be researched and incentivised as well.

In terms of sustainability, there is also a need to further consider natural resource consumption when designing models and scenarios. Beyond the theoretical optimal pathway for the energy sector relying on innovation in the upstream part of the value chain, more scenario options for other sectors should be based on sectoral aspects of IAMs, complemented by sectoral studies (IPCC 2023 [3]). These scenarios should explore changes throughout the rest of the value chain and further focus on the mitigation potential of the demand side, efficiency, end-use optimisation, cross-sector cooperation, circular models and green infrastructures, all of which allow for greater synergies between climate and nature goals (Bauer *et al.* 2021, WRI *et al.* 2022). For natural ecosystem-related sectors, scenarios should further incorporate and be compared in terms of land- but also ocean-based mitigation options (in particular, improved management and restoration of carbon-rich ecosystems, terrestrial and ocean ecosystems, fresh water and sustainable agriculture and forestry) (IPCC 2023 [1] [2] [3]).

3.4. Scenario designers should extend the sectoral and geographical coverage and granularity of scenarios. Scenarios should cover more business sectors, including priority sectors for nature (*e.g.* mining, food and beverage, etc.) (Noels *et al.* 2023, WEF 2020). Even from a climate perspective, all business sectors will be required to transform their economic model to minimise the drain on nature and mitigate related GHG emissions in order to limit global warming to 1.5°C (IPCC 2023 [1], Röckstrom 2024). As it is, half of GHG emissions come from the extraction and transformation of resources (International Resource Panel 2020).

Scenario designers should also include more geographically specific scenarios (Noels *et al.* 2022). Public authorities could develop scenarios at the national and sectoral level, which could feed into global models. This would make it possible to integrate the full range of public policy instruments (subsidies, regulation, and taxation) and identify the factors that most influence the transition (UNEP FI and CICERO 2021).

33 Which also requires considering possible limiting factors (*e.g.* water stress).
34 For example, solar and/or wind power, depending on countries' exposure to these elements, etc.

Scenarios designers should provide more sectoral and geographical granularity to facilitate climate alignment assessment at the financial asset or company level, by the limiting assumptions required from alignment methodology providers to disaggregate the carbon budget (Noels *et al.* 2023). They could match the classifications and granularity used in the finance sector's scenarios (GFANZ 2022, Noels *et al.* 2023). This increased granularity would be helpful for feeding exploratory scenarios with practical access to granular scenario data (UNEP FI and CICERO 2021) and would require more regular updates (TCFD 2020, GFANZ 2022).

Scenarios should further reflect linkages between sectors and common constraints across them (*e.g.* biomass), local demand for natural resources and critical minerals, but also geopolitical dependencies (IPCC 2023 [2]).

3.5. Economic player efforts should focus on strengthening their forward-looking strategic analyses, including new circular business models, for greater competitiveness, autonomy and resilience. They should consider the Nexus report to guide strategies and policies. Businesses and the financial sector should also deploy more exploratory scenarios with a wider scope to include the value chain, sector and cross-sector levels (TCFD 2020 [1], I4CE 2022). They should explore more business model transformations grounded in industrial strategies and a bottom-up approach (for example, taking into account the risks of supply chain disruptions, consistent planning at the county level, circularity etc.) (McKinsey 2022, European Environment Agency 2024, Carbone 4 2023). Circularity and relocating supply chains can be levers for value creation. Physical risk assessments, resilience and adaptation should also be considered to strengthen alignment to climate goals (OECD 2024). There is a need to develop more suitable exploratory models, including for corporates, and provide easier access to more granular data from the scenario designers in order to feed into exploratory scenarios (TCFD 2020 [1], UNEP FI and CICERO 2021, Carbone 4 If Initiative 2024).

Given the various possible pathways for a given sector across scenarios, economic players should consider using more than one scenario for target setting and alignment assessment in order to capture all the different options (UNEP FI and CICERO 2021, Noels *et al.* 2023).

3.6. Short-term implications and regular updates of the scenarios should be further compared. The long-term horizons of the IAMs make it difficult to capture processes operating to 5–10-year timescales (UNEP FI and CICERO 2021). Scenarios must be compared on their short-term ambitions, as these condition the long-term structural transformations and the achievement of temperature targets (IPCC 2023 [3]).

Moreover, developing scientifically robust short-term scenarios within the framework of long-term scenarios is necessary for economic players to steer activity and assess risks; short-term scenarios enable macroeconomic and geopolitical shocks, transition and physical risks to be incorporated (GFANZ 2022, ECB 2023 [2], NGFS 2023 [2], UNEP FI and NIESR 2024).

3.7. Scenario providers should further enhance the transparency and comparability of sectoral climate change mitigation scenarios to ensure optimal use by economic players. Scenario designers should disclose climate outcomes with as the necessary information to assess the consistency with the Paris Agreement (peak and end-of-century temperature outcomes and associated likelihoods, as well as aggregate GHG emissions) (Pouille *et al.* 2023).

Scenario designers should provide more transparency on the model documentation, modelling assumptions, scopes, uncertainties and sensitivity of results to certain parameters (UNEP FI and CICERO 2021, GFANZ 2022, Noels *et al.* 2023). They should provide more information on the commercial and technological feasibility of underlying assumptions (UNEP FI and CICERO 2021, GFANZ 2022, IPCC 2023 [3]).

Finally, standardising the definitions of key concepts and harmonising the input assumptions and scopes would optimise comparability so that economic players can better select which scenarios to use, given their specificities (GFANZ 2022, Noels *et al.* 2023).

APPENDIX 1A. REPRESENTATION, IN THE REVIEWED MODELS, OF (I) THE SUPPLY OF ECOSYSTEM SERVICES AND (II) THE ECONOMIC DEPENDENCY ON ECOSYSTEM SERVICES

		How is (i) the supply of the ecosystem service (background colour) and (ii) the dependency of the economy on the ecosystem service (symbols) represented in:					
	Ecosystem services	GTAP-InVEST	REMIND-MAgPIE	AIM Hub	IMAGE MAGNET	MESSAGE GLOBIOM	GCAM
Provisioning services	Surface and Ground-Water provision		▲		▲	▲	✔
	(Food) crop provision	✔	✔	✔	✔	✔	✔
	(Food) livestock provision	✔	✔	✔	✔	✔	✔
	Fish provision	✔		✔	✔		
	Timber provision	✔	✔	✔	✔	✔	✔
	Fibres provision	✔	✔		✔	✔	✔
	Bioenergy		✔	✔	✔	✔	✔
	Genetic material						
Maintenance and regulation services	Pollination	✔	▲		▲		
	Climate regulation	▲	✔		▲	▲	▲
	Mass stabilisation and erosion control		▲		▲	▲	
	Soil quality		▲		▲	▲	
	Flood and storm protection						
	Water flow maintenance		▲		▲	▲	✔
	Water quality						
	Pest control						
	Disease control						
	Dilution by atmosphere & ecosystems						
	Filtration						
	Ventilation						
	Buffering and attenuation of mass flows						
	Bioremediation						
	Maintain nursery habitats						
	Mediation of sensory impacts						
	Protection against fires						
Cultural	Tourism						

(i) Supply of ecosystem services by nature:
■ Modelled in quite detailed way ■ Modelled in less detailed way □ Not modelled

(ii) Economic dependency on ecosystem services:
✔ Multiple and/or direct transmission mechanisms included ▲ Incomplete compared to other models, or indirect mechanism

Blank: Not included

NB: assessment is relative to the other models.

Source: Banque de France 2024.

APPENDIX 1B. REPRESENTATION, IN THE REVIEWED MODELS, OF (I) THE IMPACTS OF THE ECONOMY ON NATURE AND (II) POLICIES TO MITIGATE THE DRIVERS OF NATURE LOSS

		How are (i) the impacts of the economy on nature (background color) and (ii) the policies to mitigate these drivers of nature loss (symbols) represented in:					
	Drivers of biodiversity loss	GTAP-InVEST	REMIND-MAgPIE	AIM Hub	IMAGE-MAGNET	MESSAGE-GLOBIOM	GCAM
Land and sea use change	Expansion of cropland and pastureland	✔	✔	✔	✔	✔	✔
	Expansion of managed forests	✔	✔	✔	✔	✔	✔
	Expansion of cities						
	Fragmentation						
	Land use intensification		✔		✔	✔	✔
	Sea use intensification				▲		
	Land degradation		▲		✔		
Resource extraction	Rates of extraction of living materials from nature (*e.g.* biomass)	✔	▲	▲	✔	▲	▲
	Rates of extraction of non-living materials (*e.g.*, metals, minerals)		▲	▲	▲	▲	▲
	Freshwater withdrawals		▲		✔	▲	✔
Climate change	Greenhouse gas (GHG) emissions	▲	✔	✔	✔	✔	✔
Pollution	NOx				▲	▲	▲
	S02				▲	▲	▲
	PM2.5				▲	▲	▲
	Mercury						
	Nitrogen/nutrient runoffs				✔	▲	▲
	Noise						
	Untreated wastewater				✔		
	Pesticides						
	Pharmaceutical residues						
	Plastics				▲		
	Dissolved metals						
	Oil spills						
	Salinization						
Invasive	alien species						

(i) Supply of ecosystem services by nature:
■ Modelled in quite detailed way ■ Modelled in less detailed way □ Not modelled

(ii) Economic dependency on ecosystem services:
✔ Multiple and/or direct transmission mechanisms included ▲ Incomplete compared to other models, or indirect mechanism

Blank: Not included

NB: assessment is relative to the other models.

Source: Banque de France 2024.

APPENDIX 2. IPCC FRAMEWORK FOR ASSESSING THE FEASIBILITY OF MITIGATION SCENARIOS

Feasibility dimensions, associated indicators and thresholds for the onset of medium and high concerns about feasibility

Indicators	Computation	Medium	High	Source
Solar potential	Total primary energy generation from solar in a given year	1,600 EJ	50,000 EJ	Rogner *et al.* (2012); Moomaw *et al.* (2011)
Wind potential	Total secondary energy generation from wind in a given year	830 EJ	2,000 EJ	Deng *et al.* (2015); Eurek *et al.* (2017)
Nuclear scale up	Decadal percentage point increase in the nuclear share in electricity generation	5 pp	10 pp	Brutschin *et al.* (2021); Markard *et al.* (2020); Wilson *et al.* (2020)
Wind/solar scale up	Decadal percentage point increase in the wind/solar share in electricity generation	10 pp	20 pp	Brutschin *et al.* (2021); Wilson *et al.* (2020)
Fossil CCS scale up	Amount of CO_2 captured in a given year	3.8 $GtCO_2$	8.8 $GtCO_2$	Budinis *et al.* (2018)
Energy demand decline	Decadal percentage decrease in demand	10%	20%	Grubler *et al.* (2018)
Biomass potential	Total primary energy generation from biomass in a given year	100 EJ	245 EJ	Frank *et al.* (2021); Creutzig *et al.* (2014)
BECCS scale up	Amount of CO_2 captured in a given year	3 $GtCO_2$	7 $GtCO_2$	Warszawski *et al.* (2021)
Forest cover increase	Decadal percentage increase in forest cover	2%	5%	Brutschin *et al.* (2021)

Source: IPCC 2022, Noels et al. *2023.*

APPENDIX 3. SANKEY DIAGRAM ON THE POSITIVE AND NEGATIVE EFFECTS OF CLIMATE MITIGATION POLICIES ON BIODIVERSITY AND ON CLIMATE MITIGATION POLICIES FOR BIODIVERSITY LOSSES

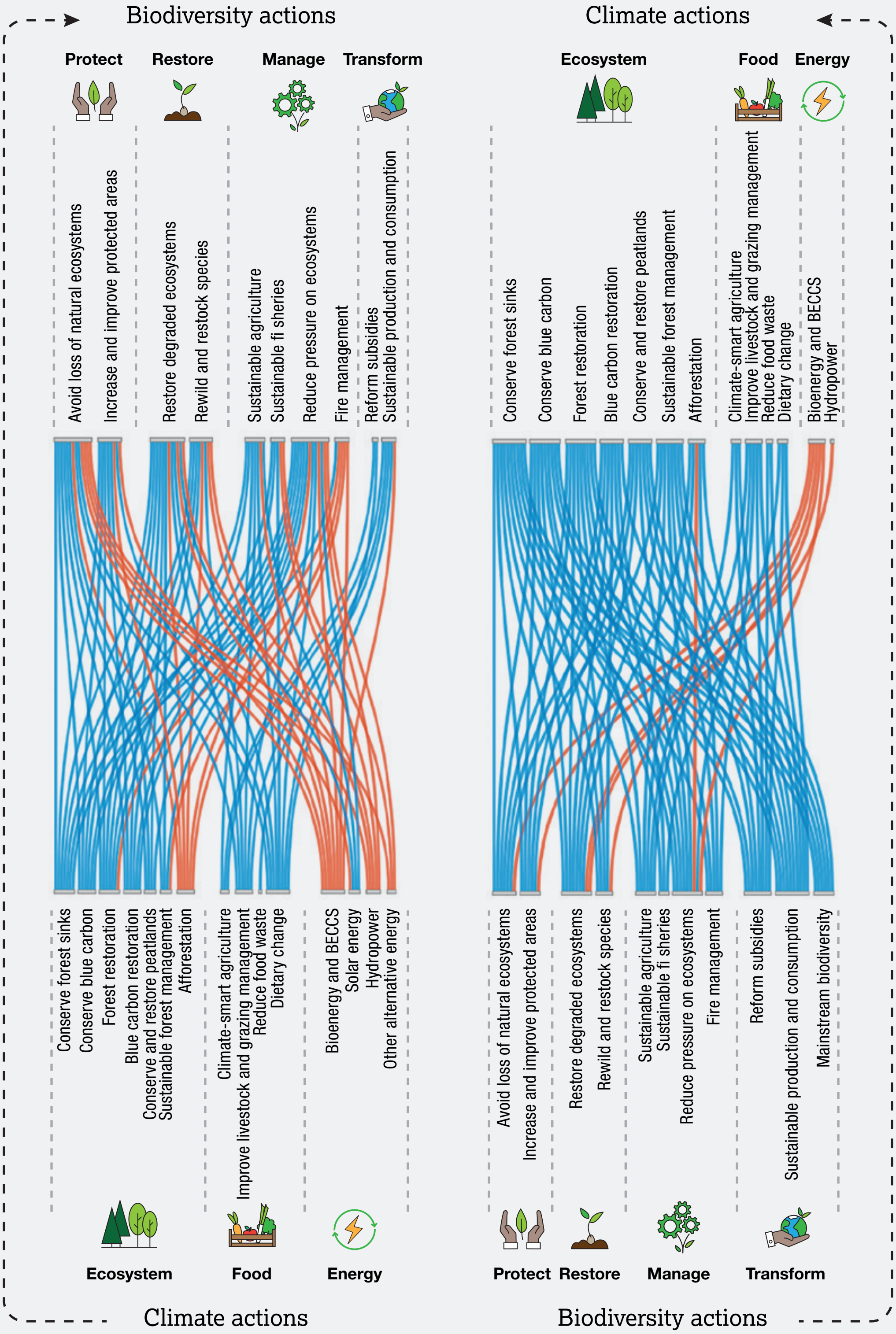


Figure 7 2 Sankey diagram mapping the effects (positive and negative) of actions to mitigate climate change on actions to mitigate biodiversity loss (top), and of actions to mitigate biodiversity loss on actions to mitigate climate change (bottom).

Blue lines represent positive effects, while orange lines represent negative effects. This network of interaction is evolving as many of the solutions are still in the ideation phase or have not yet been deployed at any sizable scale. Likewise, the strength of interactions may shift over time as the scale of solutions moves beyond the threshold at which unforeseen interactions, positive or negative, may occur.

@_I4CE

Source : IPCC IPBES 2021.

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