GUIDANCE ON USE OF

Sectoral Pathways for Financial Institutions

GFANZ
Glasgow Financial Alliance for Net Zero

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Allianz (Workstream co-chair)
BancoEstado
Bank of America
Barclays
BlackRock (Workstream co-chair)
Carbon Tracker Initiative (Advisor)
Industry Tracker (Advisor)
CDP (Advisor)
Citi (Workstream co-chair)
Commercial International Bank Egypt
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RMI (Advisor)
Societe Generale
Storebrand
Sumitomo Mitsui Banking Corporation
UNEP FI (Advisor)
Wellington Management
World Resources Institute (Advisor)

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Important notice

This document is a report of a workstream of the Glasgow Financial Alliance for Net Zero ("GFANZ") which aims to provide non-binding guidance to support financial institutions' use of sectoral pathways (e.g., for the creation of net-zero transition plans, for the alignment of their portfolios, and for engagement with real-economy companies) (the "Report"). For the avoidance of doubt, nothing express or implied in the Report is intended to create legal relations and the Report does not create legally enforceable obligations.

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GFANZ members have signed up to the ambitious commitments of their respective sector-specific alliances and are not automatically expected to adopt the principles and frameworks communicated within this report, although we expect all members to increase their ambition over time.

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Executive summary

Context and objectives of this report

Governments and private-sector firms around the world have committed to achieving net-zero greenhouse gas (GHG) emissions, with the goal of limiting global warming to 1.5 degrees C. According to recent analysis, the transition to net zero will require a significant increase in financing, with global investment in energy infrastructure alone requiring an additional $3 trillion annually over the next decade, including a tripling of current annual clean energy investment.[1] The Glasgow Financial Alliance for Net Zero (GFANZ) was founded because investment of this scale requires the mobilization of the entire financial system.[2]

An orderly transition[3] to net zero entails the continued availability of essential goods and services to the global economy while replacing high-emitting technologies with low-emitting or carbon-free alternatives. This requires reimagining the technologies — and sometimes business models — of certain sectors such that the carbon intensity — and absolute emissions — of those sectors decline over time. The nature of that shift — including its pace and related economic activities — is referred to as a “pathway.”

Sectoral pathways provide the link between the science of the remaining carbon budget and the detailed steps that a specific sector could take to reduce GHG emissions to a particular level in a specified timeframe. Sectoral pathways do this by providing a benchmark on the pace and timing of GHG emissions reductions needed, identifying the interdependencies between sectors, and articulating the underlying actions that can be taken or the changes within the sector that would drive the specified transition (e.g., technology development and/or adoption, regional variations, the retirement of assets, market changes, policy levers, energy mix).

Such pathways provide a useful benchmark for financial institutions to shape their lending, investment, and insurance activities, and related services, in line with the net-zero transition in particular sectors. Critically, these pathways are important for industry to set out a clear target that will drive their investments, operations, and other activities to transition to a low-carbon economy. Debate, discussion, and potential alignment on pathways can facilitate collaboration between industry and the financial services sector, together with policy makers and other stakeholders collaborating to drive decarbonization, and contribute to an accelerated, orderly transition to net zero.

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1 BNEF. Counting Cash in Paris Aligned Pathways, May 2022.

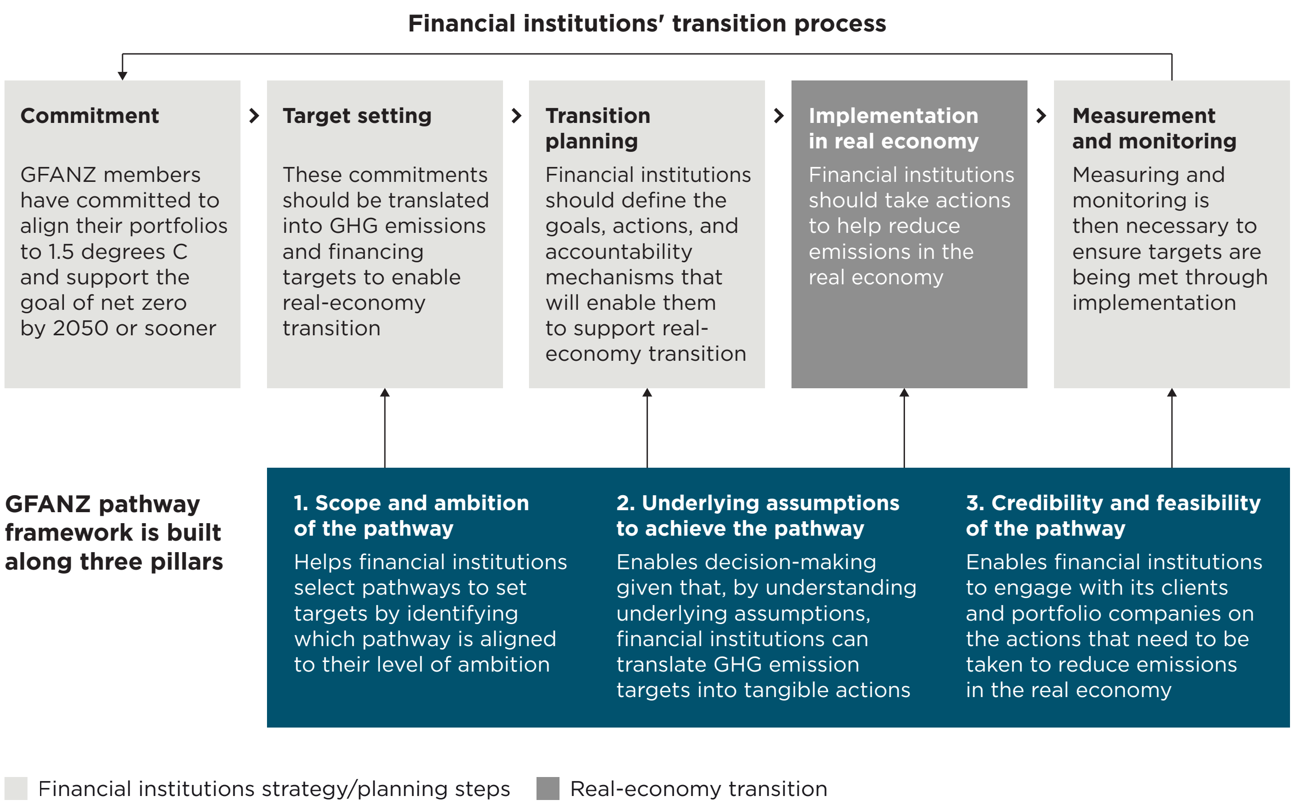
2 GFANZ. The Glasgow Financial Alliance for Net Zero — Our progress and plans towards a net-zero economy, November 2021.

3 GFANZ uses the term "orderly transition" to refer to a net-zero transition in which both private sector action and public policy changes are early and ambitious, thereby limiting economic disruption related to the transition (e.g., mismatch between renewable energy supply and energy demand).

This report is intended to be used as a guide to support financial institutions' use of sectoral pathways, in line with institutional and/or client goals, for the: creation of net-zero transition plans,[4] alignment of their portfolios,[5] and engagement with real-economy firms.[6] Additionally, we encourage pathway developers to use the insights from this report to improve the usability of their pathways.

To achieve these goals, this report introduces the landscape of sectoral pathways (Section 2), and the GFANZ pathway framework, outlined in Figure 1, which aims to drive consistency in the use of pathways for decision-making (Section 3). A comparison using this framework on five 1.5 degrees C global pathways is summarized (Section 4) and derived insights are provided into limitations and areas for further development (Section 5). Developers and users of pathways seeking further details are directed to the appendices for pathway definitions (Appendix A), pathway archetypes (Appendix B), and the comparison exercise (Appendix C).

Figure 1: Financial institutions' transition process and GFANZ pathway framework pillars[7]



4 GFANZ workstream on Financial Institution Net-zero Transition Plans.

5 GFANZ workstream on Portfolio Alignment Measurement.

6 GFANZ workstream on Real-economy Transition Plans.

7 Financial institutions' transition process follows the path that many institutions have followed (i.e. joining a net-zero alliance and making a commitment, and then setting targets and building a transition plan).

This report will be supplemented by sector briefs that go into greater detail for high-emitting and hard-to-abate sectors. Sector briefs for steel, aviation, and oil and gas will be published later this year.[8] These sector briefs are being developed in collaboration with the GFANZ workstream on Real-economy Transition Plans[9] to also outline financial institutions' expectations and provide insights into each sector's decisions, assumptions, and metrics.

Use of sectoral pathways

Financial institutions that are members of sector-specific net-zero alliances have committed to reach net zero by 2050 or sooner, or support the goal of the real economy reaching net zero by 2050, in line with a maximum temperature rise of 1.5 degrees C above pre-industrial levels, according to the latest science.[10] These commitments should translate into specific net-zero targets, and define transition plans that outline their objectives and priorities, the implementation approaches they will use to support the net-zero transition, engagement with clients and portfolio companies, metrics to measure and monitor progress, and governance to ensure accountability for meeting these targets.

Sectoral pathways are useful at each step of a financial institution's transition processes to ensure that targets, transition plans, and actions taken in the real economy are delivering on net-zero commitments (Figure 2):

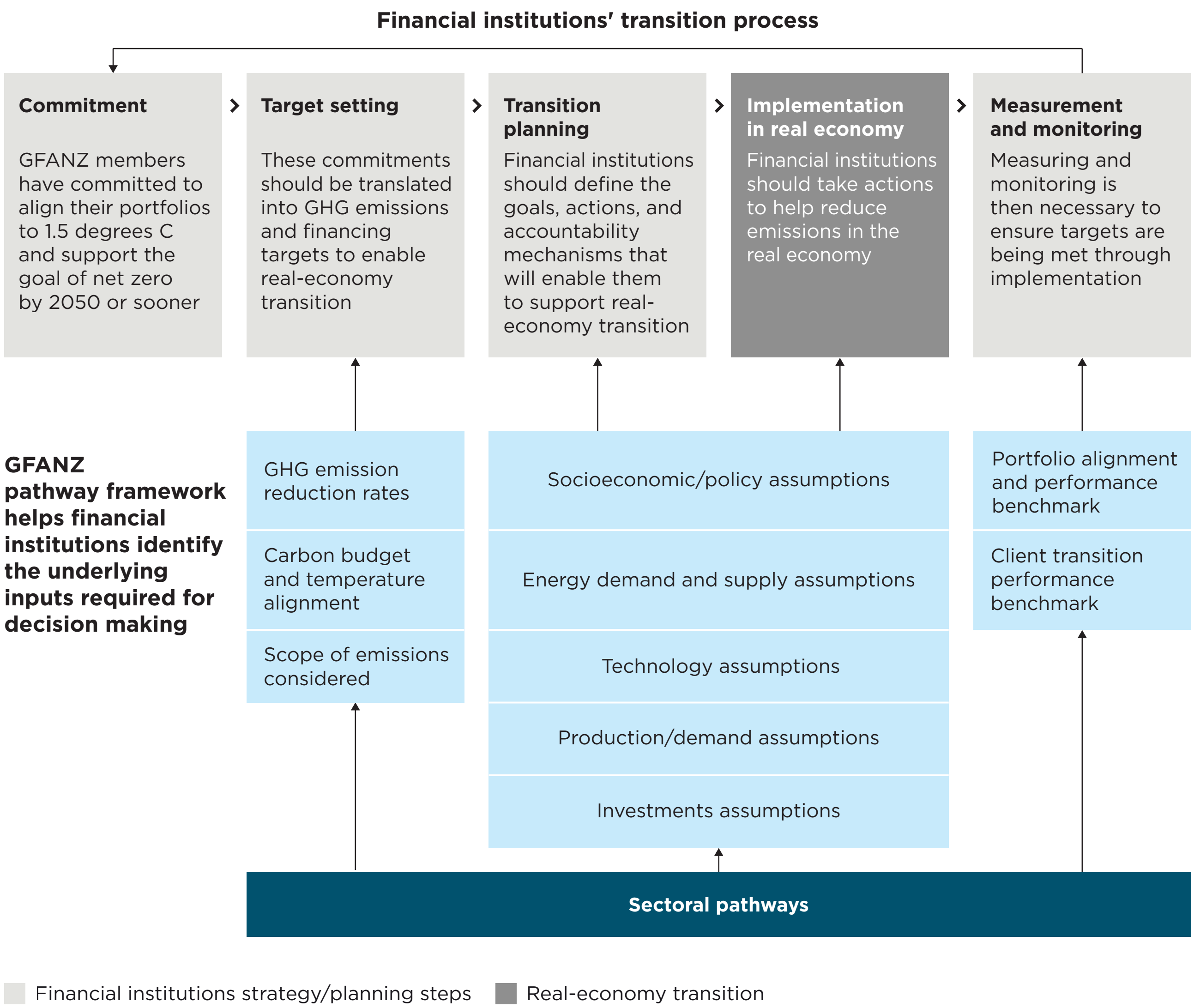
- **Target setting:** Identifying pace of reduction needed for net-zero targets to meet ambition of 1.5 degrees C at an organizational, portfolio, and sector level to enable the transition and drive GHG emissions reductions in the economy as a whole
- **Net-zero transition planning:** Informing transition objectives and approaches for business using sectoral pathways as roadmaps of the socio-economic, technological, and market changes needed to meet targets in each sector's transition
- **Transition plan implementation:** Informing key business decisions (e.g., capital allocation, and provision of other financial services) and providing information to facilitate engagement with companies (e.g., identifying actions that industries consider commercially feasible), to support and accelerate transition activities in the real economy in line with pathways for a client or portfolio company's sector
- **Measuring and monitoring:** Providing benchmarks of companies and overall portfolio performance against sectoral pathways as well as information for building portfolio alignment metrics (when measuring portfolio alignment, financial institutions need pathways to evaluate consistent alignment across sectors in their portfolio — i.e., to ensure that the sum of the targets at sector level accounts for the overall ambition of 1.5 degrees C)

8 The priority sectors were selected based on the materiality of emissions and the extent to which involvement from GFANZ is expected to be additive given the level of consensus and the existing landscape of sectoral pathways.

9 GFANZ. The Glasgow Financial Alliances for Net Zero — Our progress and plans towards a net-zero economy, November 2021.

10 According to the minimum criteria required for participation in the UNFCCC Race to Zero Campaign.

Figure 2: Example of sectoral pathway's input across a financial institution's transition process[11]



11 Financial institutions' transition process follows the path that many institutions have followed by aligning to net-zero alliances (i.e., making commitments) and then setting targets and building transition plans.

Limitations and call to action

Sectoral pathways provide critical information to support the transition to net zero for the whole economy, by helping to inform the actions that real-economy firms, policymakers, and financial institutions should take to achieve their goals. For financial institutions, in particular, pathways help identify where investment can enable the transition, inform how to align portfolios to net zero, in line with institutional and/or client goals, and provide a basis for engagement with clients and portfolio firms to support their transition.

Users should recognize that pathways are models, not predictions, of how the economy and individual sectors may transition. They incorporate simplifications and assumptions about emissions trajectories, policies, technology deployment, etc., for the transition of the economy and industries. In many cases, they provide linear models of change whereas in reality, transformations often follow non-linear trajectories, where exponential growth in technology may suddenly occur in response to a change in market conditions before finding a maximum rate.[12, 13]

Financial institutions are not passive users of pathways; their actions will influence the pace and shape of the transition. Financial institutions should be constructive partners in identifying, enabling, and advocating for the actions (e.g., investment, financing, incentives, policy, regulation) that will bridge the gap between the ambition of a pathway and the transition in the real economy. This is intrinsic to a financial institution's net zero transition plan and implementation.

Pathway users should be aware that there are still opportunities to improve pathways. Potential improvements identified throughout the comparative analysis presented in this report include:

- Standardization and clarity of the definitions that pathway developers use for key assumptions (e.g., carbon price and investments) as well as the scope covered by each pathway (e.g., in terms of sector boundaries, GHG emissions included)
- Access to underlying data and assumptions in a useable format (e.g., International Energy Agency (IEA) Net Zero Emissions by 2050 Scenario (NZE) sectoral pathway for the automotive industry details the stock of cars on the road over time; whilst this may be useful for governments in their policy decision making, for industry and financial institutions the flow of cars sold is a more useful assumption for decision making)
- Additional granularity to cover all sectors, time intervals, and regional/country level breakdowns
- Clarity on where emissions reductions are dependent upon assumptions of decarbonization in other sectors, to verify whether a pathway's alignment to a particular temperature increase holds when applied to the whole economy (i.e., if the sum of sector level efforts reaches the temperature target for the whole economy)
- Provision of information on how and if the pathways have been tested or validated with industry and other key stakeholders to assess their commercial feasibility and with the scientific community to test their credibility in terms of temperature alignment

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12 WRI. Explaining the Exponential Growth of Renewable Energy, September 2021.

13 Cherp, A, et al. National growth dynamics of wind and solar power compared to the growth required for global climate targets, Vol 6, Nature Energy, July 2021.

The evolution of entire sectors and their impact on climate is inherently complex to model, and there are important matters on which informed experts will disagree. However, the more that pathways can be expressed in a common language, with common ways of explaining the gap between what is available today and what relies on future policy changes, future breakthroughs in technology and/or scale up of new technology, the more valuable they will be to financial institutions seeking to use them to inform investing, underwriting, and lending decisions. At the same time, this will also provide a common language and foundation for dialogue between the public and private sectors.

GFANZ urges pathway developers to improve useability and act on the limitations identified in this report to build pathways that are aligned with financial institutions' expectations, following key principles that enable uptake of sectoral pathways:

- Clear and understandable (i.e., transparency on scope, ambition, and assumptions).
- Comparable (i.e., similar scopes and standardized outputs for comparison)
- Granular (i.e., enough detail on market, regions, timeframe, etc.)
- Accessible (i.e., public access to methodology and underlying data)
- Actionable (i.e., commercial and technological feasibility of underlying assumptions)
- Credible (i.e., validation from scientific community around stated temperature alignment)
- Dynamic (i.e., periodical update to reflect recent changes in science and other economic/social/technical conditions)

There is uncertainty around the level of ambition and the commercial feasibility of existing pathways, but financial institutions should still use them now as a tool to help achieve their net-zero goals and help drive dialogue with real economy and policy makers to close the gap between ambition and feasibility. Their limitations should not be a reason to delay climate action by either financial institutions, firms, or policy makers. Moreover, underlying assumptions (e.g., socioeconomic factors, energy demand, technology evolution, policy) are constantly changing and financial institutions should be able to adapt their targets and overall strategies as pathways evolve.

It is important for financial institutions to understand the pathway model assumptions in detail, so they may select pathways that align with an ambition of 1.5 degrees C and enable decision-making. By having clarity on the different scopes and underlying assumptions, financial institutions can leverage available data to tailor pathways to their specific needs (e.g., downscaling global pathways to suit regional granularity needs) and identify where additional action is required to achieve the pathway.

The GFANZ framework developed here can be used to compare, understand, and use pathways. We encourage financial institutions to use the framework as a tool when analyzing pathways and use the comparative analysis provided in this report as an example of the type of insights that users can extract to inform decision-making.

GFANZ pathway framework

This framework aims to support financial institutions in understanding and comparing sectoral pathways, facilitate engagement between financial institutions and their clients and portfolio firms, and communicate pathway needs to developers.

How to use the pathway framework: Users should identify a potential set of pathways that they want to compare. Once these are selected, users should use available underlying data and methodology documents to address each question on the framework. Example of how the framework is applied to a group of cross-sector pathways is available in Appendix C.

1. SCOPE AND AMBITION OF THE PATHWAY	
Scope	• What sectors and sub-sectors does the pathway cover? • How does the pathway consider system interactions (e.g., energy systems and land-based systems)? • What sector system boundaries are considered? • What scopes are considered and how is each scope defined? • What is the timeframe and interval of reported data? • What geographies and regions does the pathway cover? • What GHGs does the pathway consider (e.g., CO_2 or all GHGs)?
Net-zero and temperature alignment	• What is the total emissions pathway to 2050 (both in terms of absolute and intensity)? • What is the global carbon budget from 2020 to net zero? • What is the temperature alignment (degrees C), level of overshoot, and likelihood? • What is the sector share of the global carbon budget? What is the methodology/assumptions to assign carbon budget to each sector? • What are the emissions per scopes 1, 2, and 3?
Reliance on carbon capture and removal	• What technologies does the pathway consider for removals and carbon capture? • To what extent does the pathway rely on removals and carbon capture? • What is the sector share of global carbon captured and removed?

2. UNDERLYING ASSUMPTIONS TO ACHIEVE THE PATHWAY	
Socioeconomic/policy	• What are the key socioeconomic assumptions (e.g., GDP and population growth)? • What are the assumptions for carbon price development from 2020 to 2050? • What are the policy requirements to achieve the pathway?
Energy demand and supply	• What is the assumed energy demand? • What is the rate of energy-intensity improvements? • What is the assumed mix of energy supply through time (fossil fuels, renewables, nuclear)? • What are the assumptions regarding the adoption of hydrogen and biofuels over time?
Technology	• What are the overall technology development assumptions? • What is the assumed timeline for technologies to be developed/ready for use? • What are the assumptions around the lifetime of existing high-emitting assets, and asset retirement timeframes given the development of greener technologies?
Production/demand	• What is the industry's assumed production/demand volume (e.g., tons of steel, passengers/km)?
Investments	• What are the assumptions on investment needed to achieve the pathway? • How are current infrastructure, assets, and their lifetimes considered? • How are the financial flows distributed during the time horizon?

3. CREDIBILITY AND FEASIBILITY OF THE PATHWAY	
	• What was the pathway created for? • Has the pathway been validated by the scientific community for credibility around temperature alignment? • Have the model and scenarios been peer reviewed? What are the current use cases of the scenarios (e.g., alignment, risk)? • Has the pathway been submitted for international model intercomparison exercises (e.g., IPCC database)? • Has the pathway been evaluated by industry and other key stakeholders (e.g., regulators) to assess the commercial feasibility? • How are just transition and fair share considered in regional/country-specific pathways?

1. Introduction

Background and rationale

Governments and private-sector firms around the world have committed to achieving net zero with the goal of limiting global warming to 1.5 degrees C. Nearly 200 countries signed the 2021 Glasgow Climate Pact, through which they resolved to "pursue efforts to limit the temperature increase to 1.5 degree C."[14] At time of writing, 128 countries, representing 90% of global GDP, have made a net-zero commitment,[15] and over 10,000 firms, organizations, or subnational governments have joined the UN Race to Zero, committing to achieve net-zero carbon emissions by 2050 at the latest.[16]

These efforts are driven by the growing understanding of climate impacts. The latest assessment report from the Intergovernmental Panel on Climate Change (IPCC) highlights that, to date, climate change "has caused widespread adverse impacts and related losses and damages to nature and people," and that projected "mid- and long-term impacts are up to multiple times higher than currently observed."[17] This includes substantial risks to human health, cities, infrastructure, ecosystems, food production, and water availability, and is projected to cause significant increases in displacement and premature deaths, in addition to significant economic damages. The IPCC report states that "near-term actions that limit global warming to close to 1.5 degrees C would substantially reduce projected losses and damages related to climate change in human systems and ecosystems, compared to higher warming levels."[18]

Net zero: This term refers to a state when anthropogenic emissions of greenhouse gases to the atmosphere are balanced by anthropogenic removals. Organizations are considered to have reached a state of net zero when they reduce their GHG emissions following science-based pathways, with any remaining GHG emissions attributable to that organization being fully neutralized, either within the value chain or through purchase of valid carbon credits.[19]

1.5 degrees C aligned: A pathway of emissions of greenhouse gases and other climate forcers that provides an approximately one-in-two to two-in-three chance, given current knowledge of the climate response, of global warming either remaining below 1.5 degrees C or returning to 1.5 degrees C by around 2100 following an overshoot.[20] Pathways giving at least 50% probability based on current knowledge of limiting global warming to below 1.5 degrees C are classified as "no overshoot" while those limiting warming to below 1.6 degrees C and returning to 1.5 degrees C by 2100 are classified as 1.5 degrees C "low-overshoot."

14 Conference of Parties. Glasgow Climate Pact, p. 3, 2021.

15 The Net Zero Tracker. Net Zero Tracker Beta, 2022.

16 Global Climate Action. Climate Ambition Alliance: Race to Zero, June 2022.

17 IPCC. Climate Change 2022 Impacts, Adaptation, and Vulnerability: Summary for Policymakers, p. 16-17, March 2022.

18 IPCC. Climate Change 2022 Impacts, Adaptation, and Vulnerability: Summary for Policymakers, p. 15, March 2022.

19 United Nations. Race to Zero Lexicon, April 2021.

20 IPCC. Annex 1: Glossary, 2018.

In order to achieve these commitments and drastically reduce GHG emissions, real-economy firms, supported by clear policy signals from government and capital and related services from the financial sector, must decarbonize their business activities and scale climate solutions to gradually replace GHG-emitting assets, products, and services. According to a recent analysis by BloombergNEF, this will require an unprecedented increase in financing, with global investment in energy infrastructure alone requiring an additional $3 trillion annually over the next decade, including a tripling of current annual clean energy investment.[21] GFANZ was founded because investment of this scale requires the mobilization of the entire financial system.[22]

Real-economy: This refers to economic activity outside of the financial sector. Financial institutions are significant intermediaries that support activity in the real-economy — production and consumption by households, businesses, and government — through their lending, investing, underwriting, and advising activities.

Private finance has the scale to mobilize the necessary capital with more than 500 GFANZ members, representing around 40% of global private financial assets, committed to the goal of net zero by 2050. With deliberate and ambitious action, supported by clear policy signals from governments, the financial sector can enable a global transition to net zero that helps avoid the worst impacts of climate change, minimizes risks to financial stability and stranded assets, and is orderly[23] across countries and communities.

In addition, governments and regulators of the world's largest economies are requiring financial institutions and real-economy firms to disclose climate-related risks and opportunities, including the need for forward-looking disclosures on climate strategy.[24] Transition plans are instrumental in guiding, coordinating, and accelerating the transition to net zero. Sectoral pathways are a critical tool to inform development of transition plans, as they provide the detail on where the economy needs to go and how it should get there.

This report is intended as a practical guide for the teams and individuals responsible for developing net-zero targets, transition plans, and strategies within financial institutions. It will help those institutions to steer net-zero alignment of portfolios, and benchmark individual clients and portfolio firms on their transition plans. The report is also targeted for individuals in the front line responsible for engaging with clients and making business decisions in line with the firm's transition plan.

Real-economy firms can use this report to better understand how financial institutions use pathways to set net-zero targets in the sectors in which the company operates. Pathway developers will gain insights into how their pathways are being applied by financial actors and where potential challenges exist that limit their effective use. This will help them to evolve both the pathways and their useability. Governments and policymakers will get insights on the policies that underpin the sectoral and economy-wide changes on which a particular pathway is predicated.

21 Bloomberg New Energy Finance (BNEF). New Energy Outlook, July 2021.

22 GFANZ. The Glasgow Financial Alliances for Net Zero — Our progress and plans towards a net-zero economy, November 2021.

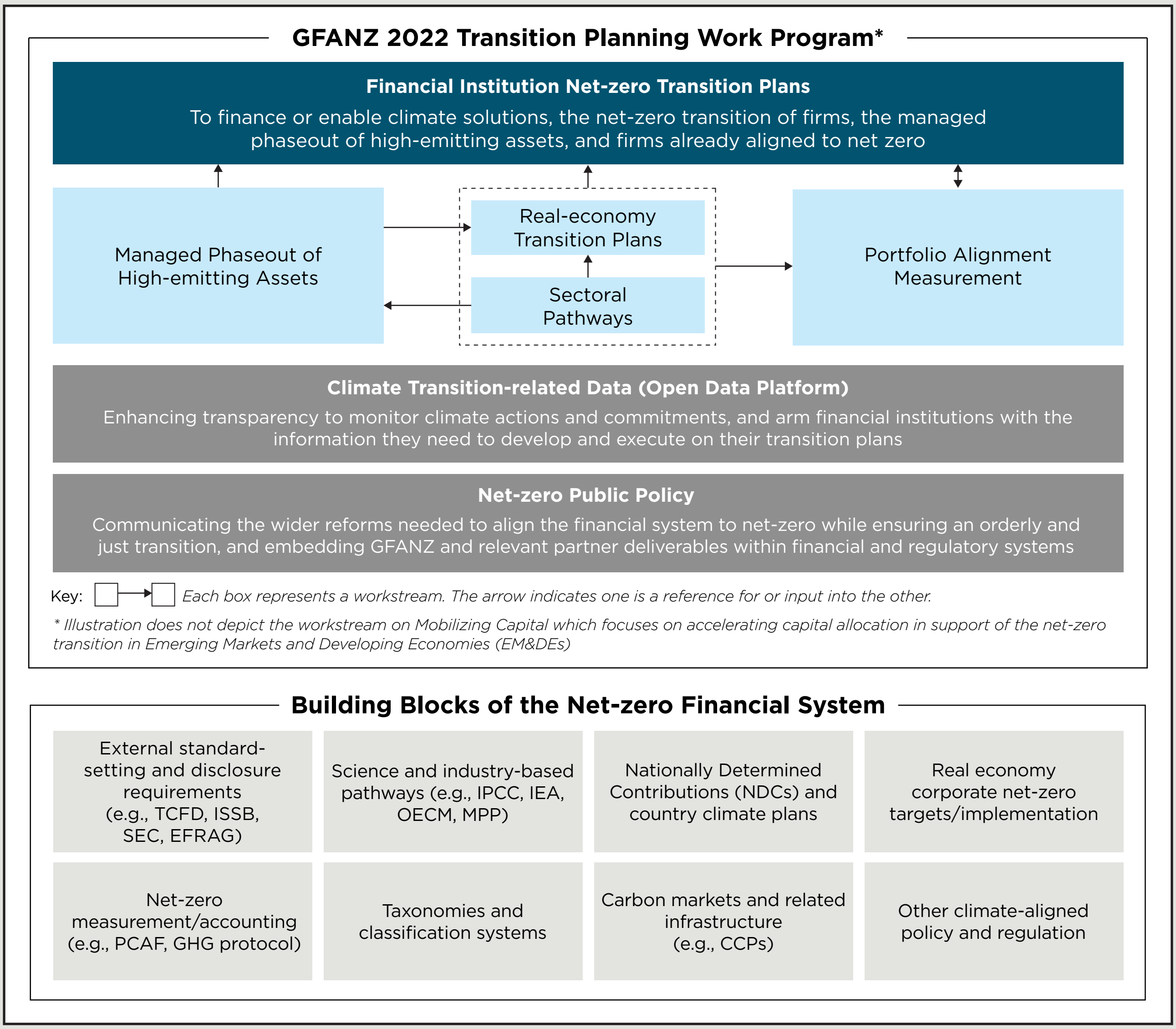
23 GFANZ uses the term "orderly transition" to refer to a net-zero transition in which both private sector action and public policy changes are early and ambitious, thereby limiting economic disruption related to the transition (e.g., mismatch between renewable energy supply and energy demand). For reference, the Network for Greening the Financial System (NGFS), which develops climate scenarios used by regulators and others, defines "orderly scenarios" as those with "early, ambitious action to a net zero CO_2 emissions economy," as opposed to disorderly scenarios (with "action that is late, disruptive, sudden and/or unanticipated"). In an orderly transition, both physical climate risks and transition risks are minimized relative to disorderly transitions or scenarios where planned emissions reductions are not achieved, see here for further information from NGFS.

24 Taskforce on Climate-related Financial Disclosures. 2021 Status Report, p. 5-6, October 2021.

Background on GFANZ work program

The Glasgow Financial Alliance for Net Zero (GFANZ) is a global coalition of leading financial institutions in the UN's Race to Zero that is committed to accelerating and mainstreaming the decarbonization of the world economy and reaching net-zero emissions by 2050. GFANZ brings together seven financial sector net-zero alliances, representing more than 500 members, into one global strategic alliance to address common challenges and elevate best practices across the sector. GFANZ core areas of work are practitioner-led and advised by leading technical civil society organizations.[25]

Figure 3: GFANZ 2022 Transition Planning Work Program[26]



25 The alliances are: the Net Zero Asset Managers initiative, the Net-Zero Asset Owner Alliance, the Net-Zero Banking Alliance, the Net Zero Financial Service Providers Alliance, the Net-Zero Insurance Alliance, the Net Zero Investment Consultants Initiative, and the Paris Aligned Investment Initiative.

26 In this note, orderly is defined as: early, ambitious action to a net zero CO_2 emissions economy, following the definition provided by NGFS. Noting that disorderly is defined as: action that is late, disruptive, sudden and/or unanticipated. NGFS Climate Scenarios for central banks and supervisors, 2020.

The elements of the GFANZ work program under Financial Institution Net-zero Transition Plans are all connected and intended to collectively support financial institutions' net-zero transition planning and implementation efforts. For the provision of finance to be aligned with net-zero goals, financial institutions need to understand and evaluate the transition strategies of their clients and portfolio companies.

GFANZ's work on real-economy transition plans will support this by delineating the financial sector's expectations for real-economy firms' transition plans to ensure that they include specific, consistent information that financial institutions can use in decision-making.

Sectoral pathways help inform transition strategy development for both real-economy firms and financial institutions, providing information on the alignment of real-economy activities with net-zero objectives.

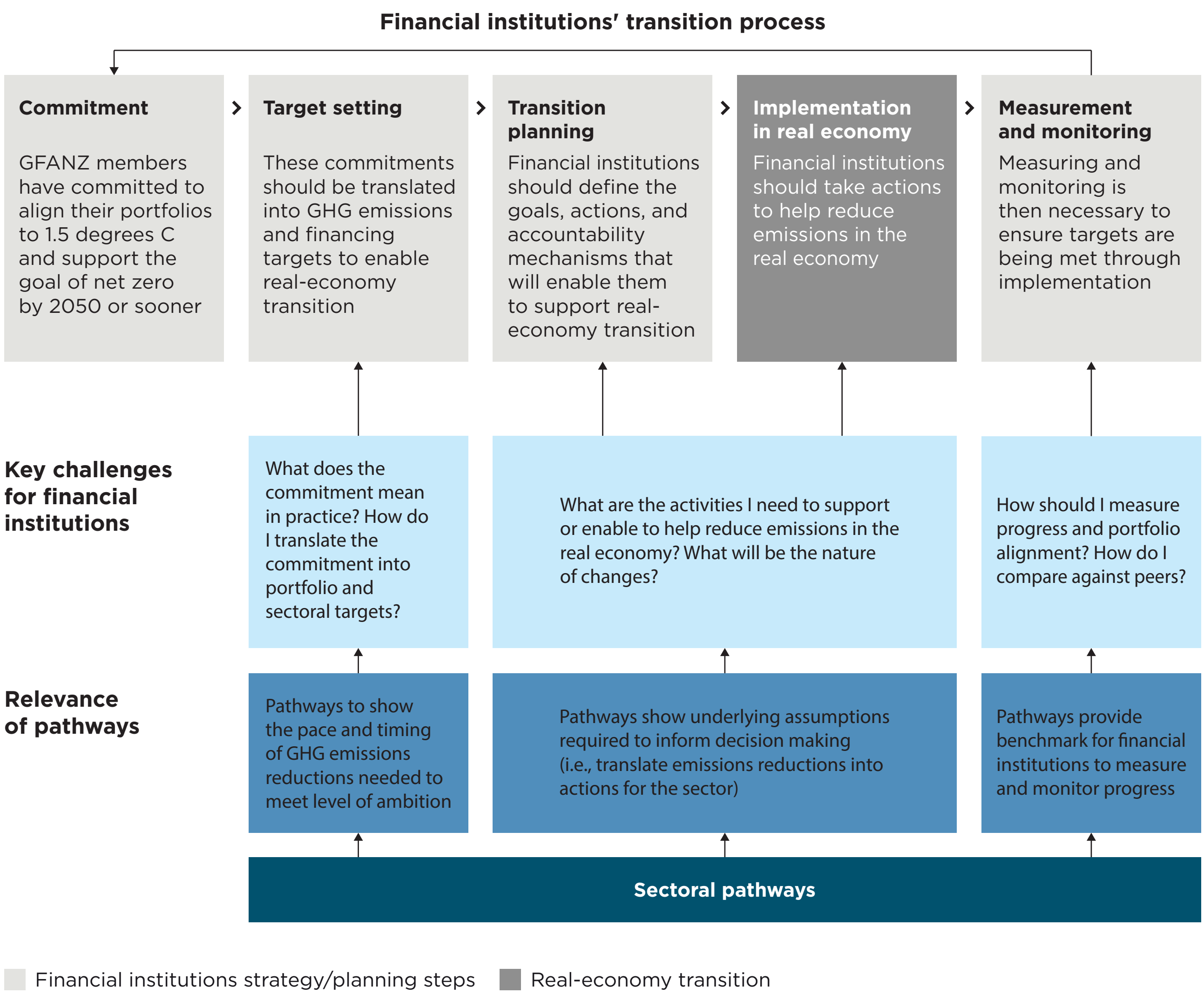
Portfolio alignment metrics contribute to methodologies for evaluating the alignment of financial portfolios with net-zero objectives.

One approach to net zero-aligned finance is financing or enabling the early retirement of high-emitting assets, informed by sectoral pathways. The GFANZ work on Managed Phaseout sets out preliminary thinking and a work plan to support the use of early retirement as part of net-zero transition planning for both financial institutions and real-economy firms.

What is the challenge for financial institutions and why are sectoral pathways relevant?

Financial institutions that are part of the sector-specific net-zero alliances have committed to aligning their portfolios with a maximum temperature rise of 1.5 degrees C above pre-industrial levels, or to support the goal of the real economy reaching net zero by 2050, according to the latest science. These commitments should translate into specific net-zero targets, and define transition plans that outline their objectives and priorities, the implementation approaches they will use to support the net-zero transition, engagement with clients and portfolio companies, metrics to measure and monitor progress, and the governance to ensure accountability for meeting these targets. (Figure 4).

Figure 4: Key challenges and relevance of pathways across financial institutions' transition process[27]



27 Financial institutions' transition process follows the path that many institutions have followed (i.e. joining a net-zero alliance and making a commitment, and then setting targets and building a transition plan).

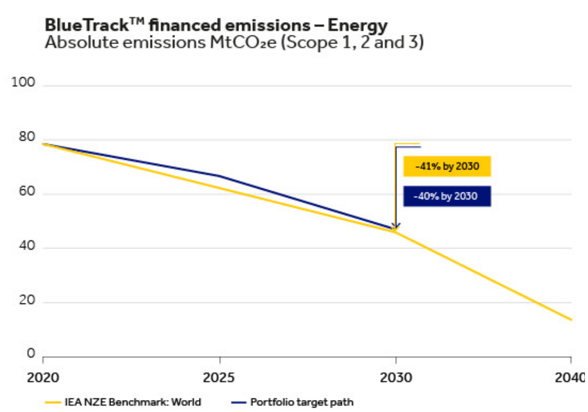
Sectoral pathways are a key tool to help financial institutions meet the challenges in setting targets, building, and implementing their net-zero transition plan. For net-zero commitments to be met, financial institutions should support and enable GHG emissions reductions in the real-economy. Sectoral pathways provide a benchmark on the pace and timing of GHG emissions reductions needed, identify the interdependencies between sectors, and articulate the underlying actions that can be taken or the changes within the sector that would drive the specified transition (e.g., technology development and/or adoption, regional variations, the managed phaseout of assets, market changes, policy levers, and energy mix).

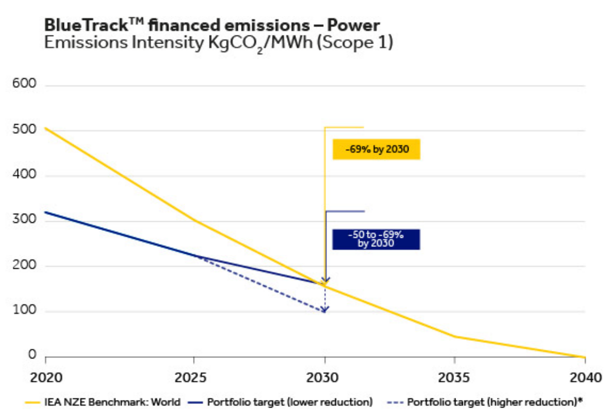
In selecting and using sectoral pathways, financial institutions should ensure that the pathways reflect a level of ambition consistent with 1.5 degrees C, have sufficient sectoral/regional granularity to match their portfolio needs, and are feasible for their clients or portfolio firms to drive decarbonization in the real-economy. Financial institutions can also work with their clients or portfolio firms to benchmark progress.

Use case: Sectoral pathways to set targets and monitor progress (Barclays)[28]

Barclays has developed its own methodology, known as BlueTrack™, for measuring financed emissions and tracking them at a portfolio level against the goals of the Paris Agreement. BlueTrack™ starts by selecting an appropriate benchmark for a sector (i.e., a sectoral pathway), then determining how Barclays' portfolio is performing against it. This determination is made by estimating the emissions that Barclays' clients produce, linking those emissions to the financing provided, and then aggregating those measurements into a portfolio-level metric. The portfolio metric is then compared to the sectoral pathway, allowing Barclays to make active choices to reshape its portfolio within a 'carbon limit'.[29]

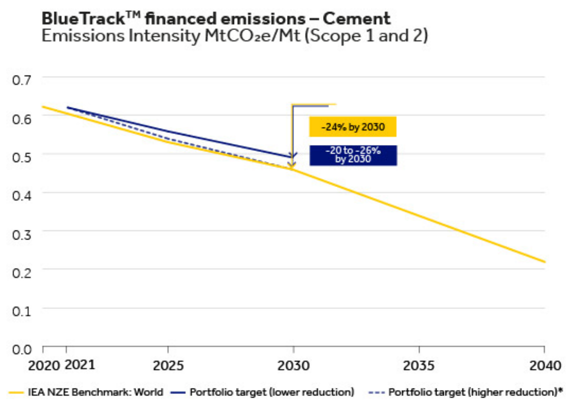
In 2020, Barclays set 2025 targets for two high emitting sectors: Energy and Power.
This year, Barclays has also set 2030 reduction targets for Energy, Power, Cement and Steel.

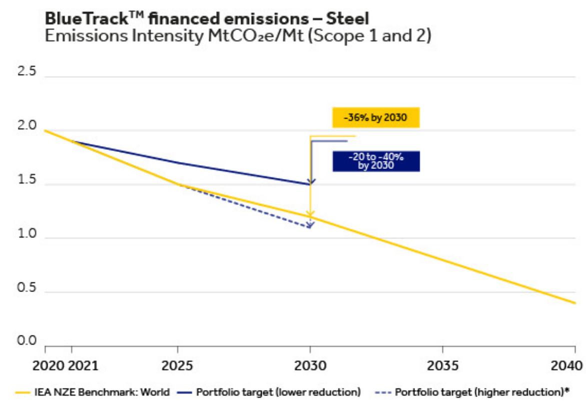




28 The mention of specific financial institutions or pathways in use cases does not imply that they are endorsed by GFANZ or its members in preference to others of similar nature that are not mentioned.

29 Barclays. Blue Track WhitePaper, 2022.





* The higher reduction target path is aligned with the IEA NZE as it follows the same rate of reduction from base year to 2030

Barclays adopted the IEA Sustainable Development Scenario (SDS) when setting its 2025 targets for Energy and Power as the IEA Net-zero Emissions by 2050 (NZE) pathway was not available at that time. In 2022, Barclays adopted the IEA NZE pathway for setting its 2030 targets.

This reflects the bank's commitment to the Net-Zero Banking Alliance (NZBA) which requires all signatories to use science-based decarbonization scenarios that reach net zero by mid-century or sooner, with a maximum temperature rise of 1.5 degrees C above pre-industrial levels by 2100.

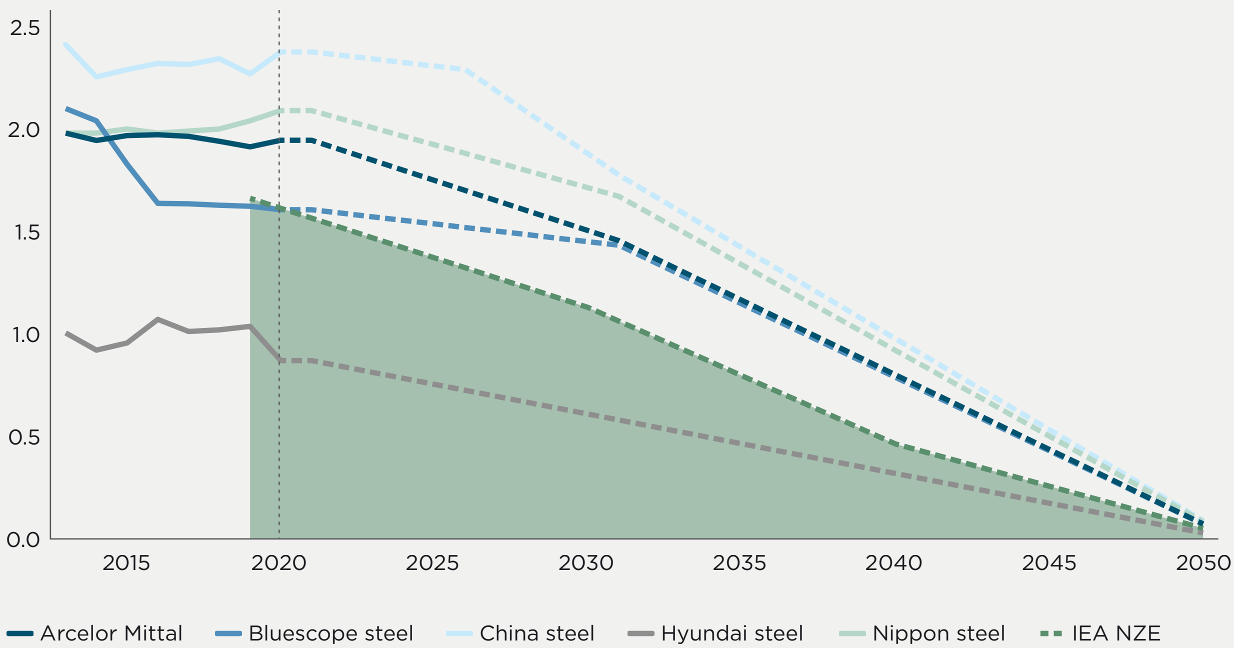
For Power, Cement and Steel, Barclays is using a target range. While the bank is clear on what reduction is required to converge with the IEA NZE pathway, it recognizes that there are additional dependencies and variables outside its control that will determine the pace of the transition and therefore how quickly financed emissions intensity can be reduced. For each target range:

- The lower emissions reduction ambition reflects an estimated emissions reduction trajectory based on Barclays' view of sector and client pathways and commitments;
- The higher emissions reduction ambition is in line with the IEA NZE pathway that is consistent with limiting global warming to 1.5 degrees C. This pathway incorporates an assumption that public policy interventions, shifts in demand and new technologies will enable Barclays' clients to accelerate their transition plans beyond current commitments or expectations.

Use case: Sectoral pathways to benchmark companies' commitments[30]

Sectoral pathways can be used by financial institutions to benchmark the commitments companies have made against specific pathways. Using the steel sector as an example, Figure 5 shows the emission intensity reduction pathways of high-emitting steel companies and compares their trajectory against the IEA NZE pathway providing transparency on whether companies' strategies are in line with the level of ambition of limiting the rise in global temperatures to 1.5 degrees C.

Figure 5: Carbon intensity pathway of major steel manufacturers[31]



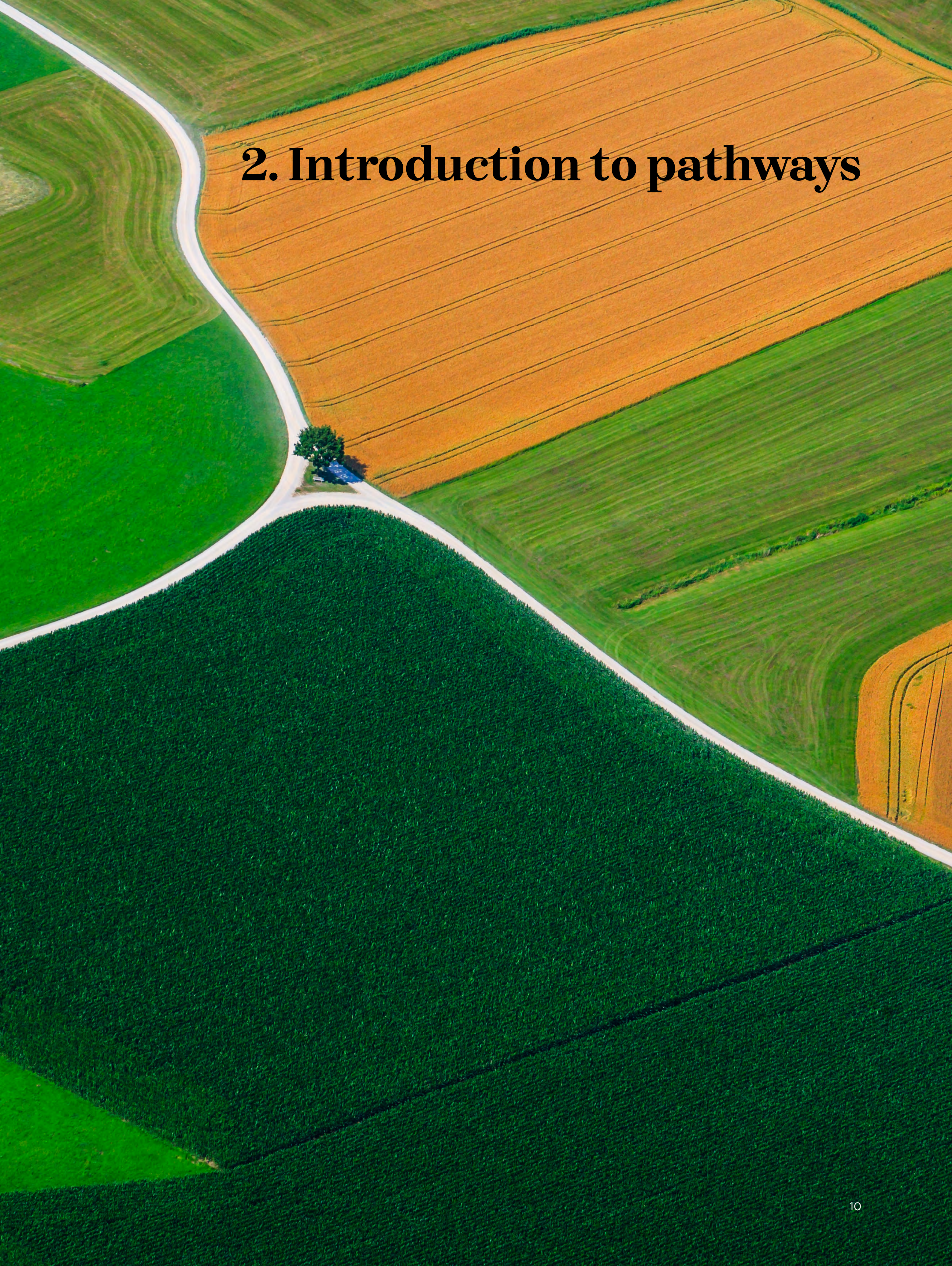
Examples of how financial institutions can use benchmarks of companies against sectoral pathways:

- **Decision-making:** Identify if a company's climate strategy is in line with the level of ambition of the financial institution (i.e., 1.5 degrees C) to inform commercial decisions
- **Client/portfolio firms engagement:** Use information around a company's gap against 1.5 degrees C and gap against peers to engage clients and portfolio firms
- **Portfolio alignment:** Access to climate strategy data of clients can be used to measure how a financial institution's portfolio is aligned with specific sectoral pathways (see the Taskforce for Climate-related Financial Disclosures 2021 report, Measuring Portfolio Alignment)[32]

30 The mention of specific financial institutions or pathways in use cases does not imply that they are endorsed by GFANZ or its members in preference to others of similar nature that are not mentioned.

31 Data from the Transition Pathway Initiative Tool. Steel companies selected are classified by TPI within the Top 10 large cap emitters. Chart only shows companies that have projected targets up until 2050.

32 Task Force for Climate-related Financial Disclosures. Measuring Portfolio Alignment: Technical Report, 2021.



2. Introduction to pathways

An orderly transition to net zero entails the continued availability of essential goods and services to the global economy while replacing high-emitting technologies with low-emitting or carbon-free alternatives. This requires reimagining the technologies — and sometimes business models — of certain sectors such that the carbon intensity — and absolute emissions — of those sectors decline over time. The nature of that shift — including its pace and related economic activities — is referred to as a "pathway."

Scenario: Projections of what can happen by creating plausible, coherent, and internally consistent descriptions of possible climate change futures. Scenarios are not predictions of the future.[31]

Pathway: A goal-oriented scenario or combination of scenarios answering the question, "What needs to happen?", to accomplish a specific objective (e.g., what are the steps needed to reach net zero by 2050, limit global warming to 1.5 degrees C, with low or no overshoot)

Multiple initiatives have developed models to outline and simulate the numerous societal and economic changes that must take place to limit global warming to 1.5 degrees C. These models have created new terminology that is helpful for users to understand when selecting pathways and using them to define targets and transition plans.

The definition of "1.5 degrees C aligned" used by the UN Race to Zero is a clear example of this new terminology. Figure 6 presents the Race to Zero definition, which introduces concepts including temperature alignment (e.g., below 1.5 degrees C), probability (or likelihood) of achieving a temperature goal, and level of overshoot. These concepts, along with additional relevant terminology, are defined in Appendix A which aims to help standardize the level of climate literacy across readers.

Figure 6: UN Race to Zero definition of 1.5 degrees C aligned[34]

"Target is aligned with scenarios that yield a long-term warming outcome of **below 1.5 degrees C** with some **probability** (e.g., 50%, 67%) and some amount of **overshoot** (e.g., no, low), both of which should be explicitly specified"

Modeling geographic and socioeconomic outcomes is complex, and there are several approaches. Pathways can therefore vary significantly based on their methodology and underlying assumptions. One of the key methodological differences between pathways is whether they are constructed following top-down or bottom-up archetypes.

33 Definition from climatescenarios.org.

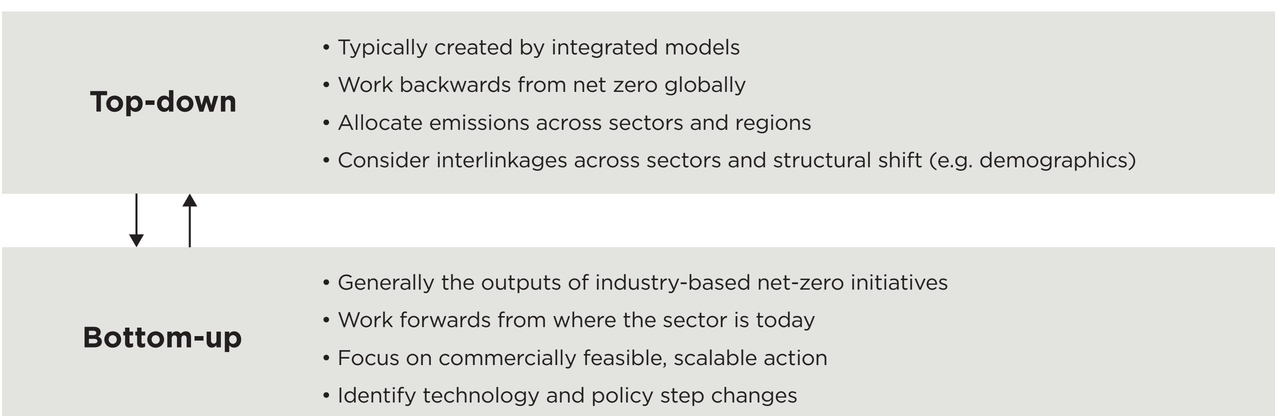
34 UNFCC. Race to Zero Lexicon, April 2021.

Top-down archetypes are typically created by integrated models,[35] which include many variables and, by design, create a pathway for the entire economy to transition to net zero. The top-down archetype focuses on how the global carbon budget is cascaded down to the sector level, determining how much each sector can emit to be in alignment. In other words, top-down models estimate the remaining carbon budget until 2050 to achieve a given degree of warming and splits it across sectors.

Top-down models can produce both sectoral pathways (i.e., pathways that provide the actions underpinning GHG emissions reduction at sector level) as well as cross-sector pathways (i.e., pathways that includes the GHG emissions reduction pace for the whole economy). However, given the size and complexity of these models, they generally provide fewer details for assumptions at sectoral level.

Bottom-up archetypes, in contrast, are generally the outputs of industry-based net-zero initiatives. These pathways typically have less of a focus on interaction effects across the economy (i.e., they do not model the economy as a whole, but rather use impact from other industries as assumptions) and more of a focus on the practical steps that the specified industry can take to align with modeled GHG emissions reductions. The bottom-up archetype is based on detailed sector-specific assumptions, including technology changes, to arrive at a carbon output specific to that sector. In other words, bottom-up pathways start from evaluating where the industry is today and makes assumptions on technology advances and actions that can occur over the following decades to enable GHG emissions reduction.

Figure 7: Examples of features for bottom-up and top-down archetype[36]



35 A method of analysis that combines results and models from the physical, biological, economic, and social sciences and the interactions among these components in a consistent framework to evaluate the status and the consequences of environmental change and the policy responses to it (IPCC).

36 Diagrams shows common examples of features for each archetype, but these are not mutually exclusive (i.e., top-down pathways can have features of bottom-up archetypes and vice versa).

Both archetypes provide valuable insights for financial institutions looking to support real-economy decarbonization. Top-down archetypes allow for cross-sectoral consistency on temperature alignment, providing a holistic view on each sector's role to mitigate climate change (e.g., useful to set targets across sectors to ensure overall alignment to 1.5 degrees C). Bottom-up archetypes represent specific sectors' views of the most feasible steps to get there, providing more detailed underlying assumptions on the technologies and actions needed to reach net zero (e.g., useful for engaging with clients or portfolio firms identify actions needed to reach net zero).

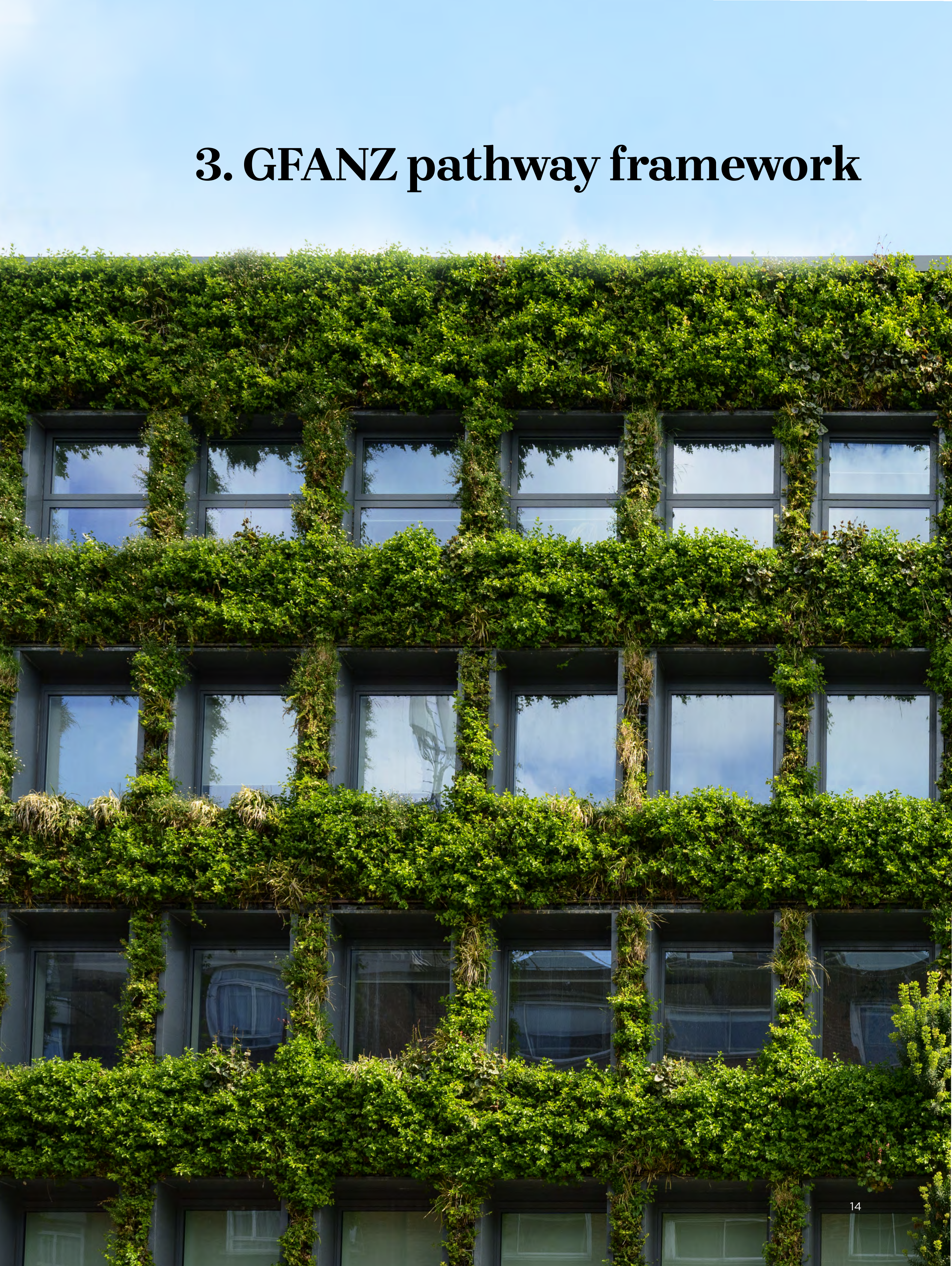
Top-down and bottom-up pathways can be used to address different needs and users should consider the implications of selecting different pathways. When pathways are used for setting targets across sectors in a portfolio, financial institutions should ensure that the total carbon budget used across sectors is in line with a 1.5 degree C ambition. Using bottom-up pathways or a combination of different pathways to set targets at sector level can lead to a misalignment in the total carbon budget for the whole portfolio. This presents a challenge given that not all sectors are considered in each pathway requiring financial institutions to find alternative pathways for specific sectors.

Overall, both bottom-up and top-down pathways present key use cases and challenges that users should understand to better select pathways. Appendix B provides a detailed comparison of the archetypes across key elements.

The evolution of entire sectors and their impact on climate is inherently complex to model, and there are important matters on which informed experts will disagree. However, the more that pathways can be expressed in a common language, with common ways of explaining the gap between what is available today and what relies on future policy changes, breakthroughs in technology and/or the scaling up of new technology, the more valuable they will be to financial institutions seeking to use them to inform investing and lending decisions. While some models are backed by the expertise and reputation of the institutions that produce them, there is a need for information on how and if the pathways have been tested or validated by the scientific community (i.e., temperature alignment), and by industry and other key stakeholders to assess their commercial feasibility.

Given the differences between pathways, users can benefit from a better understanding of the scope and methodology used to build the pathway (i.e., what is included in the pathway and how was it calculated?) along with a detailed understanding of the assumptions underpinning the model. Section 3 presents a framework developed by GFANZ to help financial institutions select pathways and use them for decision-making.

3. GFANZ pathway framework



GFANZ has developed a framework that outlines the considerations that financial institutions should understand about pathways to support selection and decision-making. The framework centers around three main pillars:

- **Scope and ambition of the pathway** to identify differences in scope and ensure the pathway is in line with financial institutions' net-zero commitments.
- **Underlying assumptions to achieve the pathway** to guide financial institutions in transition planning and implementation, including target setting and decision-making.
- **Credibility and feasibility of the pathway** to understand how/if the pathway has been validated by the scientific community (e.g., temperature alignment) and assess the commercial feasibility of the pathway.

Scope and ambition of the pathway

The first pillar of the framework covers three key components:

- **Scope:** Detail of what is included in the pathway to facilitate comparison (i.e., users know what is being compared) and, ultimately, engagement with clients and portfolio firms (e.g., which activities within specific sectors are covered in the pathway?)
- **Net-zero and temperature alignment:** Details on the level of ambition that the pathway is reaching in relation to the remaining carbon budget and temperature alignment. This information enables financial institutions to make informed decisions and ensure that selected pathways are aligned to an ambition of 1.5 degrees C.
- **Reliance on carbon capture and carbon removal:** Assumptions that the pathway developers make on availability and use of technologies for carbon capture and removal and how much the ambition relies on these technologies. This is relevant for users given the uncertainty and opposing opinions within the scientific community on the future availability of these technologies.

Table 1 outlines the detailed list of questions that financial institutions can address to better understand the scope and ambition of different pathways.

Table 1: Pathway framework: scope and ambition

1. SCOPE AND AMBITION OF THE PATHWAY	
Scope	• What sectors and sub-sectors does the pathway cover? • How does the pathway consider system interactions (e.g., energy systems and land-based systems)? • What sector system boundaries are considered? • What scopes are considered and how is each scope defined? • What is the timeframe and interval of reported data? • What geographies and regions does the pathway cover? • What GHGs does the pathway consider (e.g., CO_2 or all GHGs)?
Net-zero and temperature alignment	• What is the total emissions pathway to 2050 (both in terms of absolute and intensity)? • What is the global carbon budget from 2020 to net zero? • What is the temperature alignment (degrees C), level of overshoot, and likelihood? • What is the sector share of the global carbon budget? What is the methodology/assumptions to assign carbon budget to each sector? • What are the emissions per scopes 1, 2, and 3?
Reliance on carbon capture and removal	• What technologies does the pathway consider for removals and carbon capture? • To what extent does the pathway rely on removals and carbon capture? • What is the sector share of global carbon captured and removed?

Underlying assumptions to achieve the pathway

The second pillar of the framework covers the underlying assumptions of the pathways across five components which can help financial institutions translate GHG emissions pathways into tangible decarbonization drivers and metrics that can support transition planning and implementation:

- **Socioeconomic/policy:** Assumptions around GDP, population growth, and relevant policy considerations that can have a direct impact on real-economy GHG emissions (e.g., assumptions around phaseout of coal can help financial institutions define their own lending/investing policies)
- **Energy demand/supply:** Assumptions around demand and the types of energy used to meet that demand. All else equal, those net-zero pathways with higher energy demand will require more zero-carbon power to be provided to both replace fossil fuels and meet energy demand growth (e.g., proportion of energy supply from renewables)
- **Technology:** Assumptions detailed at the sector level, providing insight into the shift from existing technologies to new technology and the pace at which these technologies need to be implemented/developed (e.g., timing of electric and hydrogen propulsion available for airplanes)
- **Production/demand:** Assumptions specific for each sector, providing key insights on actions that are needed to decarbonize the sector (e.g., split between primary and secondary steel production)
- **Investment:** Assumptions providing clarity on the level of investment required to achieve the projected emission reductions by developing and scaling the required technology (e.g., investment into fossil fuels, renewable energy sources, identified technologies such as carbon capture)

Table 2 outlines the detailed list of questions that financial institutions can address to better understand the assumptions behind each component.

Table 2: Pathway framework: underlying assumptions of pathways

2. UNDERLYING ASSUMPTIONS TO ACHIEVE THE PATHWAY	
Socioeconomic/ policy	• What are the key socioeconomic assumptions (e.g., GDP and population growth)? • What are the assumptions for carbon price development from 2020 to 2050? • What are the policy requirements to achieve the pathway?
Energy demand and supply	• What is the assumed energy demand? • What is the rate of energy-intensity improvements? • What is the assumed mix of energy supply through time (fossil fuels, renewables, nuclear)? • What are the assumptions regarding the adoption of hydrogen and biofuels over time?
Technology	• What are the overall technology development assumptions? • What is the assumed timeline for technologies to be developed/ready for use? • What are the assumptions around the lifetime of existing high-emitting assets, and asset retirement timeframes given the development of greener technologies?
Production/ demand	• What is the industry's assumed production/demand volume (e.g., tons of steel, passengers/km)?
Investments	• What are the assumptions on investment needed to achieve the pathway? • How are current infrastructure, assets, and their lifetimes considered? • How are the financial flows distributed during the time horizon?

Credibility and feasibility of the pathway

The third pillar of the framework addresses the credibility and feasibility of the different pathways, to provide financial institutions with details on how the models have been assessed and validated by key stakeholders. Understanding the credibility and feasibility of the pathways will support financial institutions in their engagement with clients and portfolio firms (e.g., does the relevant sector deem the pathway feasible?). The credibility and feasibility of a pathway relates to expert validation of the critical assumptions of the pathway through involvement in the development and/or review processes.

Credibility considerations include validation of the ability of the pathway to deliver net-zero 1.5 degrees C-aligned emissions goals. Feasibility considerations include validation of the commercial feasibility of real-economy firms to scale technologies and take action to achieve the transition. Institutions should understand where gaps occur between these two considerations and consider where unmodeled actions may be needed to bridge them (e.g., policy actions).

Table 3 outlines the detailed list of questions that financial institutions can address to better understand the credibility of each pathway.

Table 3: Pathway framework: credibility and feasibility of the pathway

3. CREDIBILITY AND FEASIBILITY OF THE PATHWAY
• What was the pathway created for? • Has the pathway been validated by the scientific community for credibility around temperature alignment? • Have the model and scenarios been peer reviewed? What are the current use cases of the scenarios (e.g., alignment, risk)? • Has the pathway been submitted for international model intercomparison exercises (e.g., IPCC database)? • Has the pathway been evaluated by industry and other key stakeholders (e.g., regulators) to assess the commercial feasibility? • How are just transition and fair share considered in regional/country-specific pathways?

The following section outlines the key insights extracted from applying the GFANZ pathway framework to a select group of pathways. Appendix C provides a detailed analysis along each component of the framework. The analysis below is intended as an illustration of how to apply the GFANZ pathway framework rather than an exhaustive comparison of the latest pathways.[37]

Use case: Use of detailed underlying pathway assumptions for transition plans[38]
Sectoral pathways generally must embed views on how the use of sector-specific technologies will shift over time to low-carbon alternatives. Transparency into these underlying technology related assumptions can help to shape the transition plans and climate strategies of real-economy firms and financial institutions.

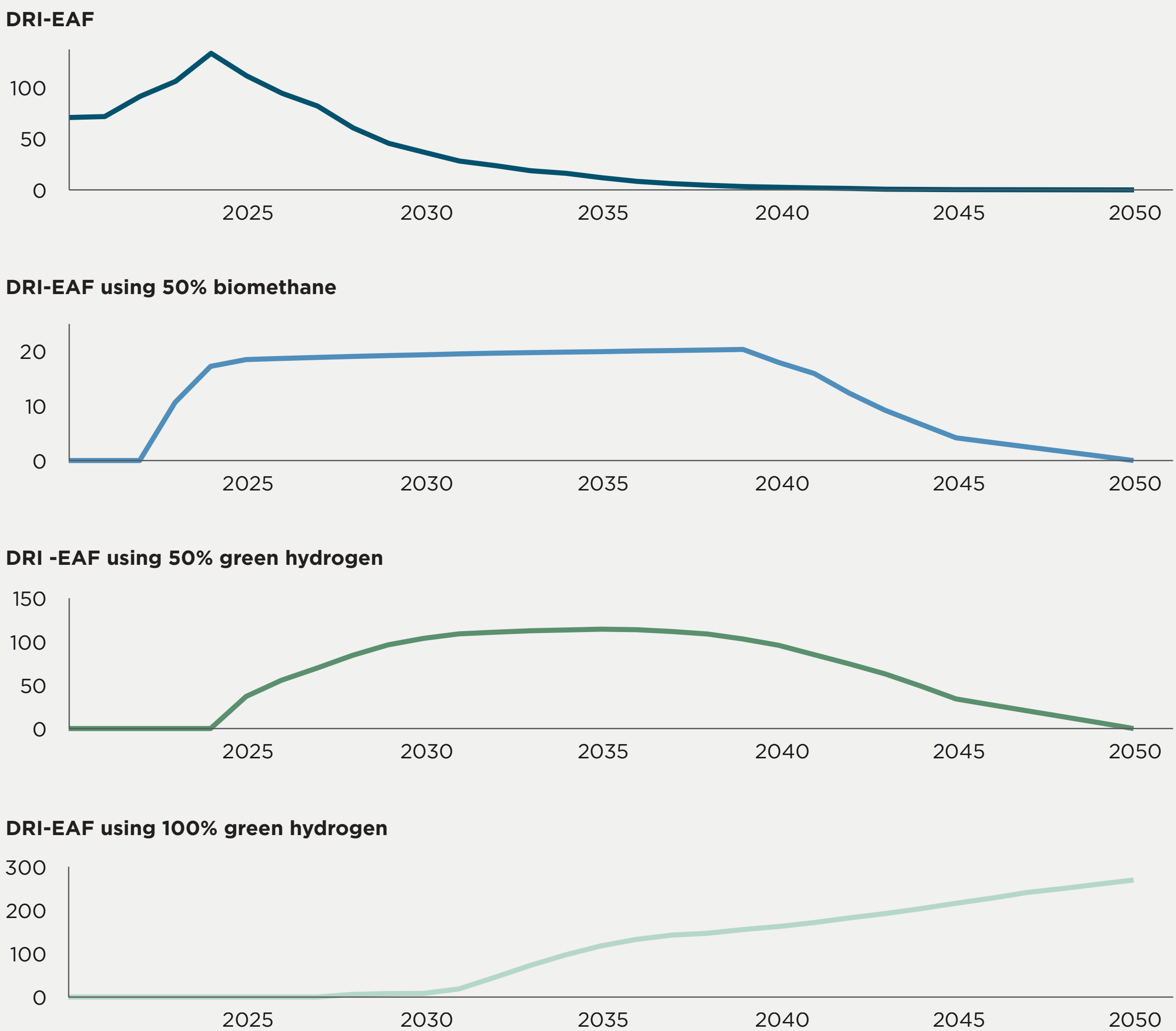
For example, financial institutions can use this information to anticipate investment flows needed to bring on new technologies and to replace existing assets. For example, the Mission Possible Partnership (MPP) pathway on steel provides detailed information on their assumptions around steel production by different types of Direct Reduced Iron (DRI) technology over time (Figure 8). The chart shows how the production of steel using DRI-Electric Arc Furnace (DRI-EAF) should start declining before 2025 and be replaced in the short term by DRI-EAF that uses 50% of Biomethane (CH_4) or 50% of green Hydrogen (H_2). By 2040, all production should start shifting to DRI-EAF that uses 100% Hydrogen. These changes in technology underpin the assumptions needed to achieve the pathway and guide firms on the timing of replacement of existing technologies necessary to adhere to the aggregate 1.5 degrees C aligned carbon budget.

37 The pathways covered are not the only ones aligned to 1.5 degrees C and users may use other pathways aligned to their commitments. The pathways used in this report are the latest available pathways from the IEA, NGFS, and OECM as of May 2022 (see Appendix E for the specific documentation used to conduct this analysis).

38 The mention of specific financial institutions or pathways in use cases does not imply that they are endorsed by GFANZ or its members in preference to others of similar nature that are not discussed.

In addition to the information on timing to scale new technologies, related information on the required retirement timing and profile is also helpful to evaluate and define the managed phaseout of high-emitting assets. One of the key mechanisms to reduce GHG emissions in the real economy is through such managed phase out of high-emitting assets (see GFANZ report on The Managed Phaseout of High-emitting Assets).

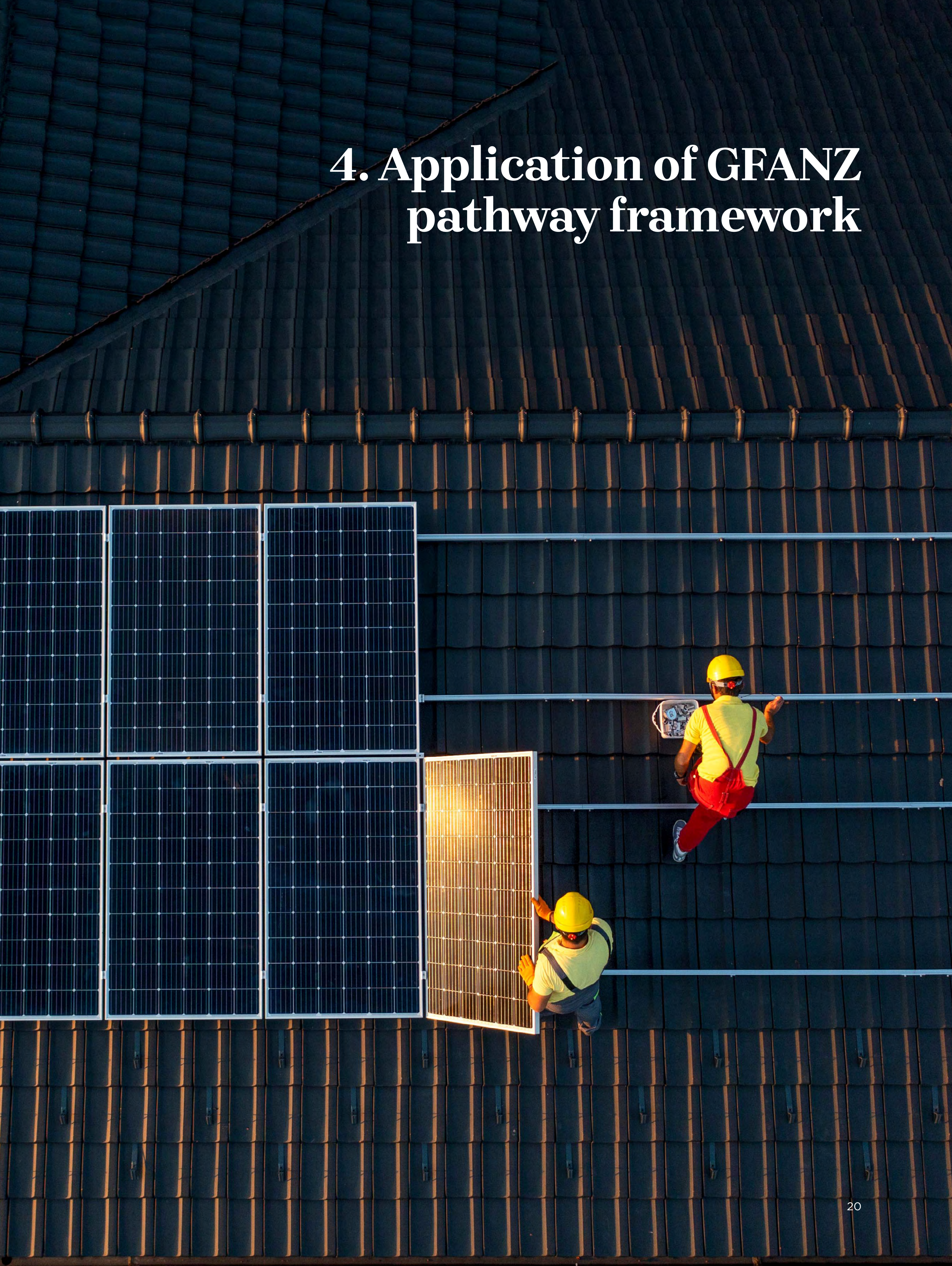
Figure 8: Steel production from different DRI-EAF technologies[39]
Millions of tones of steel



Source: Mission Possible Partnership, Net Zero Steel Sector Transition Strategy, 2021

39 Mission Possible Partnership. Net-Zero Steel Sector Transition Strategy, Tech Moratorium pathway, October 2021.

4. Application of GFANZ pathway framework



While there are many pathways available, this section focuses on five cross-sectoral pathways to illustrate how the framework can be applied and the conclusions derived from the comparison that can inform decision-making. The five pathways, described in Table 4, come from the International Energy Agency (IEA), the University of Technology Sydney (UTS), and the modelers supporting the development of climate scenarios for the Network for Greening the Financial System (NGFS).[40]

These pathways and modelers have been selected based on the following criteria:

- They have detailed methodology and public access to data/assumptions
- They provide some sector-level granularity
- They are in line with the required level of ambition of 1.5 degrees C
- They are widely used/recognized or supported by financial institutions
  - IEA and NGFS are globally used by the scientific community, the financial sector, and the industry
  - UTS is a new model backed by the Net-Zero Asset Owners Alliance

This is not an exhaustive list of pathways but rather a selection that is intended to be used to exemplify how the GFANZ pathway framework can be applied. Users can leverage this guidance as an example to replicate the analysis for other pathways.

Additionally, it is important to mention that there are other initiatives that build upon existing pathways to fit specific user requirements. The Science Based Targets Initiative (SBTi) or the Transition Pathway Initiative (TPI) are examples of initiatives widely used by the investor community for target setting and decision-making. Both SBTi and TPI use the Sectoral Decarbonization Approach (SDA)[41] to translate the IEA pathways into appropriate benchmarks, against which the performance of individual firms can be compared. For example, the pathway presented by TPI for aviation is derived from the IEA NZE pathway but presented as a benchmark of passenger and freight air travel in revenue tonne kilometers (RTK) assuming an industry accepted factor of 95 kilograms per passenger, which is a metric that can be used to assess company level performance.[42] This document focuses on helping financial institutions have a better understanding of the pathways that underpin these types of initiatives.

40 The outputs consider the model versions as follows: GCAM5.3_NGFS; MESSAGEix-GLOBIOM 1.1; REMIND-MAgPIE 2.1–4.2; World Energy Model as described in World Energy Model Documentation, October 2021; OECM V2.0.

41 SBTi. SECTORAL DECARBONIZATION APPROACH (SDA): A method for setting corporate emission reduction targets in line with climate science, Version 1, May 2015.

42 Transition Pathway Initiative. Sectoral Decarbonisation Pathways, 2022.

Table 4: Overview of selected cross-sectoral pathways

INTERNATIONAL ENERGY AGENCY (IEA)

The IEA is an autonomous inter-governmental organization created in 1974 to help coordinate a collective response to major disruptions in the supply of oil. Oil security remains a key aspect of its work, but the IEA has evolved and expanded significantly since its foundation: it takes an all-fuels, all-technology approach to recommend policies that enhance the reliability, affordability, and sustainability of energy.

Model	Pathway
The IEA Net Zero Emission by 2050 scenario (NZE) is based on a hybrid modelling approach developing and combining the relative strengths of the World Energy Model (WEM) and the Energy Technology Perspectives (ETP) models. The WEM is a large-scale simulation model designed to replicate how competitive energy markets function and to examine the implications of policies on a detailed sector-by-sector and region-by-region basis. The ETP model is a large-scale partial-optimization model with detailed technology descriptions of more than 800 individual technologies across the energy conversion, industry, transport, and buildings sectors.	IEA NZE sets out a narrow but achievable pathway for the global energy sector to achieve net-zero CO_2 emissions by 2050. It does not rely on, or account for, GHG reductions from outside the energy sector to achieve its goal. It is consistent with limiting the global temperature rise to 1.5 degrees C with no temperature overshoot (with a 50% probability).

UNIVERSITY OF TECHNOLOGY SYDNEY (UTS)

UTS is a public research university located in Sydney, Australia. UTS was commissioned by the Net-Zero Asset Owners Alliance (NZAOA) to develop pathways that account for sector granularity to enable investors' use of pathways (consistent with the Global Industry Classification Standard, Bloomberg Industry Classification Systems, and Statistical Classification of Economic Activities in the European Community classifications).

Model	Pathway
The One Earth Climate Model (OECM) is an Integrated Energy Assessment Model (IEAM) that develops net-zero targets based on science for all major industries in granularity and with the key performance indicators (KPI) needed to make short-, mid-, and long-term investment decisions.	The 1.5 degrees C emissions pathways with 67% likelihood (400 $GtCO_2$ 2020-2050) developed by UTS are no/low overshoot scenarios. A carbon budget overshoot is avoided and already released CO_2 is not assumed to be 'removed' by unproven technologies still under development such as carbon capture and storage (CCS).

NETWORK FOR GREENING THE FINANCIAL SYSTEM (NGFS)

NGFS is a network of over 100 central banks and financial supervisors that aims to accelerate the scaling up of green finance and develop recommendations for central banks' role in climate change.

Model	Pathway
NGFS Global Change Analysis Model (GCAM) is a global Integrated Assessment Model (IAM) that is produced by the Pacific Northwest National Laboratories (PNNL) and the University of Maryland. It represents the behavior of and complex interactions between systems. **NGFS Regional Model of Investment and Development (RM)** (REMIND) is an IAM that is produced by the Potsdam Institute of Climate Impact Research. It incorporates the economy, the climate system, and a detailed representation of the energy sector. **NGFS MESSAGEix-GLOBIOM (MG)** is an IAM designed by the International Institute for Applied Systems Analysis (IIASA). It is used to assess the transformation of the energy and land systems vis-à-vis the challenges of climate change and other sustainability issues.	NGFS Net-zero 2050 assumes that ambitious climate policies are introduced immediately. Carbon Dioxide Removal (CDR) technology is used to accelerate the decarbonization but kept to the minimum possible and broadly in line with sustainable levels of bioenergy production. A 1.5 degrees C target is imposed, such that the median temperature is required to return to below 1.5 degrees C in 2100, after a limited temporary overshoot.

This section provides an overview of the key differences between selected cross-sector pathways. Appendix C provides a full comparison of the same pathways across the question presented in the GFANZ framework. Sector specific pathways will be considered in sector briefs, which will provide a comparison between top-down and bottom-up pathways using components of the GFANZ framework.

Scope and ambition of the pathway

As discussed in Section 3, the first pillar of the framework covers three key components that will help financial institutions select the pathways that are in line with their commitments of achieving 1.5 degrees C.

Scope

The first component is scope, which outlines what is included in the different pathways to facilitate comparisons and allow financial institutions to select the pathway that meets its specific needs

- **Sector coverage:** All selected pathways provide granular breakouts of industry, transport, buildings, and the energy sector. IEA NZE and UTS OECM are generally more granular in detailing sub-sectoral pathways than the NGFS models
- **System interactions:** All five pathways model interactions between systems (e.g., energy system and land-use interactions), with overlap in the models used (e.g., IEA NZE and NGFS MG use the same model for land use, GLOBIUM).[43] These overlaps lead to similar modeling of key interactions (i.e., for overlapping systems, the underlying assumptions of each pathway are modeled in the same way)
- **Timeframe and time intervals:** While most scenarios are modeled on an annual basis, the information for users is only available in specific time intervals. UTS OECM and NGFS pathways provide output data in five-year intervals while the IEA data is reported in ten-year intervals, with five-year time steps in the extended dataset. Moreover, all NGFS pathways provide information up to 2100 while the others have projections up to 2050
- **Geographical granularity:** All NGFS pathways provide granularity at regional level and downscale a limited set of variables to over 180 countries. By comparison, the IEA NZE only provides global-level outputs, and the UTS OECM only provides regional output for OECD Europe and OECD North America, with more regions due to be published in the future. Financial users of these latter pathways may need to conduct their own downscaling to ensure that outputs are relevant for operations in specific regions or countries
- **GHGs covered:** IEA NZE only models CO_2 for the global cross-sectoral pathway.[44] In contrast, NGFS and UTS OECM pathways capture all other GHG emissions — Methane (CH4), Nitrous oxide (N2O), Hydrofluorocarbons (HFCs), Perfluorocarbons (PFCs) and Sulphur hexafluoride (SF6).

43 Note that while the IEA NZE does not report emissions from land-use, land-use is modeled in the IEA World Energy Model used to produce the IEA NZE pathway.

44 The IEA also models CH4 and other emissions, but only for the energy sector.

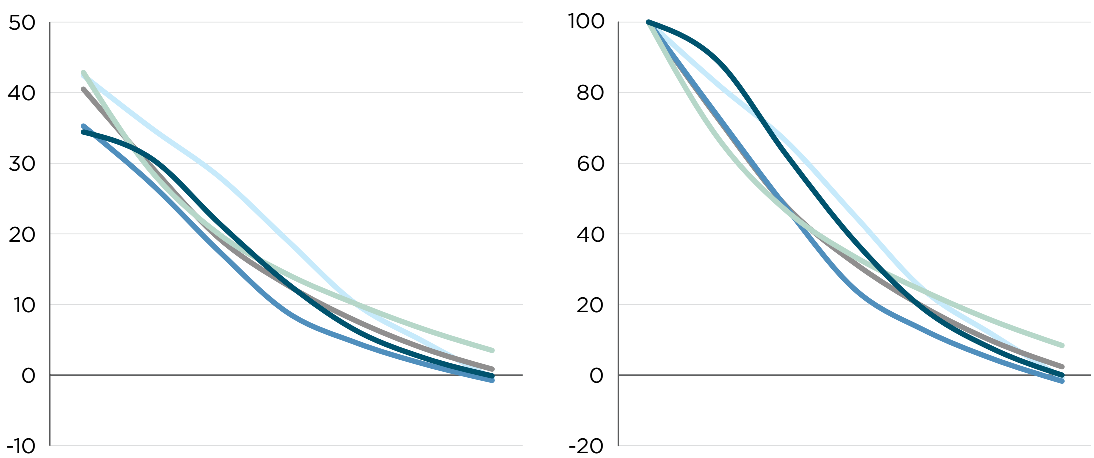
Net-zero and temperature alignment

The second component of the pillar is net-zero and temperature alignment, which provides a detailed view of the rate of reduction (Figure 9) and outlines the level of ambition of each pathway.

Figure 9: CO_2 emission pathways absolute and indexed[45]

Absolute CO_2 emission pathway
Gt CO_2, 2020-2050

CO_2 emission pathway indexed to 2020
Index = 100, 2020-2050



	2020	2030	2040	2050	2020	2030	2040	2050
IEA NZE	34	21	6	0	100	62	19	0
UTS OECM	35	17	5	-1	100	50	13	-2
NGFS GCAM	42	28	10	0	100	66	24	-1
NGFS RM	40	19	8	1	100	48	19	2
NGFS MG	42	20	10	4	100	47	24	8

Source: International Energy Agency, 'Net Zero by 2050: A roadmap for the global energy sector', 2021; University of Technology Sydney One Earth Climate Model, 2021; Network for Greening the Financial System

By design, all pathways compared in the analysis have a maximum temperature of 1.5 degrees C with at least 50% probability. Moreover, all pathways except for NGFS GCAM are classified as having low/no overshoot. NGFS GCAM is classified as high overshoot, which is not in line with the level of ambition stated in the Race to Zero minimum criteria.

45 The delta in 2020 between IEA and UTS OECM pathways and NGFS pathways in 2020 can be explained by the type of CO_2 emissions included. NGFS numbers displayed include CO_2 emissions from energy and industrial processes as well as CO_2 emissions from agriculture, forestry, and other land use (AFOLU). Exclusively energy-related CO_2 emissions in the NGFS pathways range from 34-35 Gt CO_2/year in 2020, in the range of IEA and UTS OECM figures.

Reliance on carbon capture and removal

The final component of the pillar is the **reliance on carbon capture and removal**, which outlines the assumptions that pathway developers make on availability and use of technologies for carbon capture and removal and how much the emission reduction relies on these technologies.

Table 5: Type of carbon removal solution incorporated into the considered pathways

TYPE OF REMOVAL		IEA NZE	UTS OECM	NGFS GCAM	NGFS RM	NGFS MG
Land-based		No	Yes	Yes[46]	Yes	Yes
	BECCS	Yes	No	Yes	Yes	Yes
Technology-based	DAC	Yes	No	No	No	No

- IEA NZE focuses on reaching net-zero CO_2 emissions from energy and industrial sources. It, thereby, does not consider carbon removal from outside the energy sector, e.g., from nature-based solutions, as it does not model land use
- UTS OECM only relies on nature-based removals (carbon sinks) such as forests, mangroves, or seaweed to compensate for emissions that will not be eliminated by 2050, such as some that may remain in heavy industry (this is because it does not deem the technology of CCS to be reliable)
- NGFS assumes both nature-based as well as technology-based removals to meet net-zero targets. Moreover, NGFS GCAM and NGFS RM show significant dependency on technology-based removals from 2030 to 2050 (2.5 times higher than IEA NZE)

The assumption that large-scale carbon removal solutions will be technologically and commercially feasible has been called into question by scientists and economists in recent years. Though there are several operating CCS facilities today, there is uncertainty around whether this technology can be deployed at the pace and scale required, in a cost-effective way. IPCC comments in their Sixth Assessment Report (AR6) report that “Implementation of CCS currently faces technological, economic, institutional, ecological-environmental and sociocultural barriers. Currently, global rates of CCS deployment are far below those in modelled pathways limiting global warming to 1.5°C or 2°C. Enabling conditions such as policy instruments, greater public support and technological innovation could reduce these barriers.”[47]

Beyond alignment of pathways to financial institutions' commitments based on temperature, probability and level of overshoot, users should consider other assumptions that impact the level of ambition implied by the pathway. In particular, it is important that users define their posture around technology-based solutions to drive carbon removal which will influence their pathway selection.

46 Although carbon removals come from land-based system in the GCAM pathway, it is not possible to retrieve precise data on the extent of removals.

47 IPCC. AR6. Working Group III, 2022.

Key limitations identified

- Different scopes across pathways (e.g., consideration of carbon removal from energy sector and/or nature base solutions)
- Different level of granularity across pathways both for sector and geographical granularity but also on the level of available public data to enable analysis (e.g., spreadsheet with selected variables vs open-source models)

By having clarity on scope and available data, financial institutions can adapt current pathways to make use of them (e.g., interpolate between years, downscale global pathways to regional needs).[48]

Underlying assumptions to achieve the pathway

The second pillar of the framework covers the underlying assumptions of the pathways along five components that help financial institutions translate GHG emissions pathways into tangible decarbonization drivers and metrics that can be used to engage with clients and portfolio firms, and enable decision-making.

Socioeconomic/policy

Assumptions around GDP growth vary slightly between pathways, with NGFS having more conservative compound annual growth rates (CAGR) of 2.5%–2.6% up to 2050 vs. IEA and UTS OECM that assume a CAGR of 3.1%–3.2%. In terms of population, assumptions across pathways are similar, driving a CAGR of 0.6%-0.8% from 2020 to 2050.

The carbon price, and its evolution over time, is a fundamental economic and policy assumption in shaping financial institutions' net-zero planning as it has the potential to incentivize movement away from high-carbon activities. Pathway developers use different definitions for carbon prices, leading to significant differences in assumptions. For NGFS, the price acts as a proxy for all direct and indirect mitigation policies leading to prices per ton in 2050 of between \$550 and \$780. In contrast, the IEA considers carbon price more narrowly as the direct cost of carbon emissions when they occur, leading to lower carbon prices of \$250 by 2050 in advanced economies and around \$55/tCO2 by 2050 in most emerging market and developing economies.

Overall, policy assumptions are typically defined at sector level given that sector decarbonization and technology deployment needs are defined at sector level (e.g., required phaseout of coal, bans on internal combustion engine vehicles). Where relevant, GFANZ will detail the policy assumptions for main pathways in upcoming sector briefs. The detailed deep dive in Appendix C provides an example of global milestones/policies used by IEA across different sectors.

48 Where financial institutions are adapting pathways, it is important that they disclose precisely how and why this has been done.

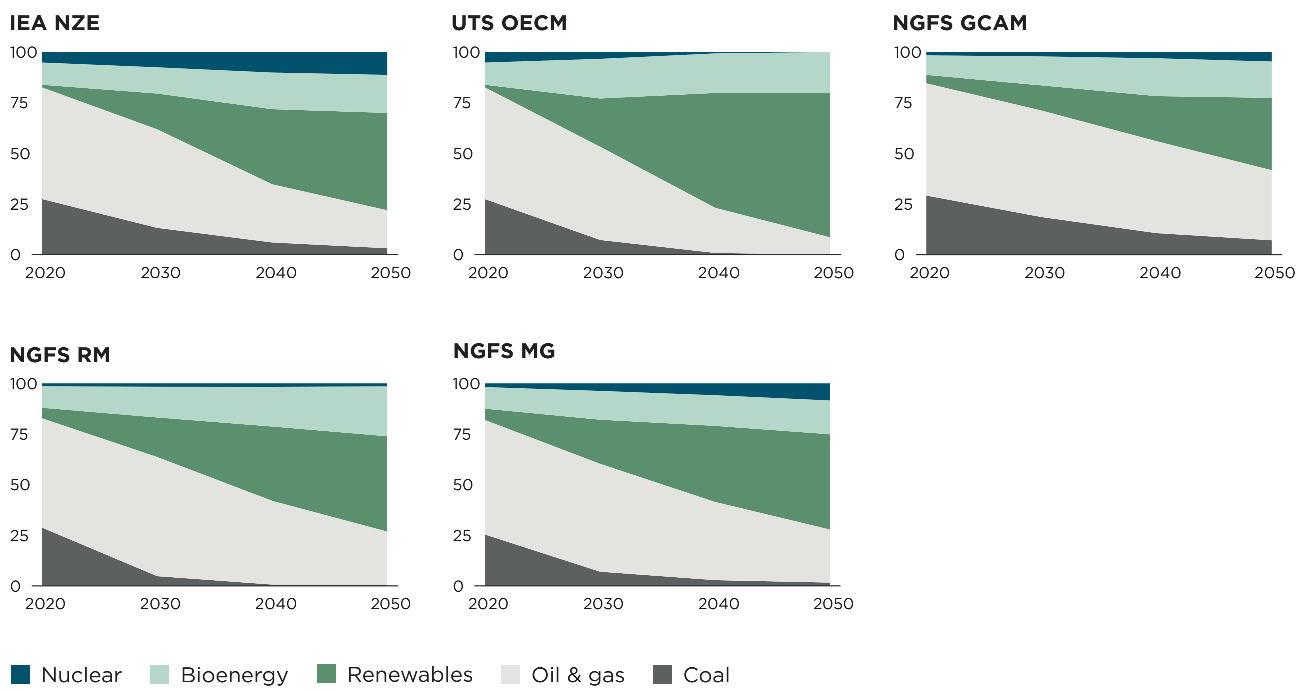
Energy demand/supply

There is significant difference in assumptions around energy demand across selected pathways. On one end, NGFS GCAM shows the most conservative decrease in annual demand of 3% between 2020 and 2050. On the other hand, NGFS RM pathway assumes a decrease in annual demand of 20% in the same period. Given that all pathways foresee significant economic growth, reductions in primary energy demand can only be obtained through stringent commitments to energy efficiency and change of consumer behaviors.

Beyond energy demand, pathways make different assumptions on technology mix throughout the next three decades. As shown in Figure 10, all pathways assume significant reductions in coal, oil, and gas, and a massive rise in renewable energy production. The pathways differ in the scale and rate of growth or decline of these energy technologies, with NGFS GCAM tending towards higher rates of coal, oil, and gas than the other pathways. UTS OECM, IEA, and NGFS MG have the highest rates of decline of fossil fuels as well as highest growth of renewables and nuclear energy. In 2050, the UTS OECM pathway assumes over 70% renewable generation of total primary energy.

Figure 10: Primary energy mix[49]

% of primary energy supply, 2020-2050



Source: International Energy Agency, 'Net Zero by 2050: A roadmap for the global energy sector', 2021; University of Technology Sydney One Earth Climate Model, 2021; Network for Greening the Financial System

49 Note that remaining fossil fuel use in 2050 is for non-energy use in most pathways, e.g., for plastics production.

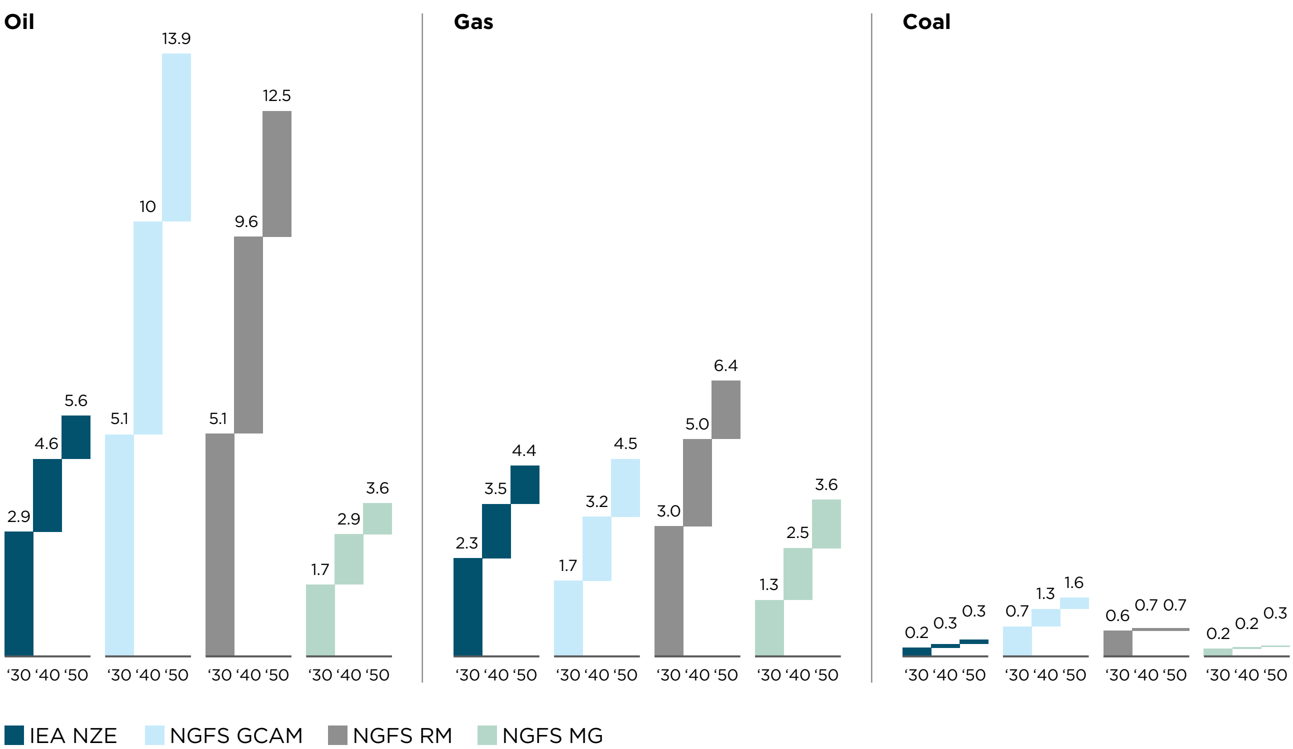
Investment

There are substantive differences between pathways regarding fossil-fuel investments, especially for oil and gas. An important difference for financial institutions to be aware of is whether a pathway allows for investment in new oil and gas fields. Both the IEA NZE and the UTS OECM pathways explicitly assume zero investment in new oil and gas fields from 2022. The NGFS pathways do not distinguish between investments in new vs. existing oil and gas projects, though assumptions are made about annual additional energy production capacity: all NGFS pathways assume the capacity for generating electricity from gas increases after 2020, and the NGFS GCAM pathway also has additional capacity from oil, after 2020.

UTS OECM does explicitly assume negative net investment,[50] but it does not explicitly model investment in fossil fuels, as other pathways do. Figure 11 shows the investment in fossil fuels assumed in other pathways. Cumulative investment by 2050 in oil spans from $3.6 trillion in NGFS MG to $13.9 trillion in NGFS GCAM pathway. Similarly, investment assumptions in gas span from a cumulative spend of $2.5 trillion by 2050 in IEA to $6.4 trillion in NGFS RM pathway. Despite the difference in investment assumptions, there is consensus on the need to reduce the investment on gas and coal. In the 2040s, there is a significant reduction in gas investment in all pathways, and there is almost no scope for any coal investments. The managed phaseout of assets as part of the transition to net zero is explored in detail in the GFANZ Managed Phaseout of High-emitting Assets paper.

Figure 11: Cumulative fossil-fuel investments

Trillion (US$ 2019), 2020-2050



Source: International Energy Agency, 'Net Zero by 2050: A roadmap for the global energy sector', 2021; University of Technology Sydney One Earth Climate Model, 2021; Network for Greening the Financial System

50 Net investment defined as investment in excess of the amount required to offset depreciation of existing infrastructure and extraction projects.

Some of the differences in assumptions stem from higher fossil fuel use on the NGFS pathways. However, the biggest difference comes from estimation methods. NGFS states in their documentation that "investments into fossil fuel extraction are estimated based on constant investment intensity assumption of fuel use, and so likely overestimate the required investments where declining demand can be met with existing projects requiring less investments than new ones".[51]

Assumptions around investment in low-carbon electricity show a similar behavior with a significant span between the IEA NZE, which estimates cumulative investment by 2050 of $33 trillion, and NGFS RM, which assumes almost double the investment, reaching $61 trillion by 2050. Similarly, there is no consensus between pathway developers on investment assumptions for energy efficiency and for electricity supply where pathways[52] assume cumulative investment ranges by 2050 of between $12–20 trillion and $33-51 trillion respectively.

There is consensus on the need to shift from fossil fuels to renewable energy sources, but the pace and scale of change varies between pathways. The NGFS GCAM and NGFS RM pathways have the highest levels of investment needed in oil, gas, and coal by 2050. All five pathways assessed see a scale of low-carbon and energy-efficiency investments multiple times larger than those identified for fossil fuels in the next three decades. Users should evaluate which pathway is in line with their own assumptions and how these assumptions compare with clients' and portfolio firms transition plans, to enable decision-making.

Key limitations identified
There is limited standardization on the definitions that pathway developers use for key assumptions (e.g., carbon price, investment in fossil fuels)

Note: Technology and production/demand components of the framework are defined at a sector level. GFANZ will include these components to compare bottom-up vs. top-down pathways at a sector level in upcoming sector briefs.

51 NGFS. Climate Scenarios for central banks and supervisors, June 2021.

52 UTS OECM does not explicitly model energy efficiency investments.

Credibility and feasibility of the pathway

The third pillar of the framework addresses the credibility and feasibility of the different pathways to provide financial institutions with details on how the models have been assessed and validated by key stakeholders. Overall, all selected pathways are built using deep expert knowledge and are backed by the credibility of each institution and the organizations that they collaborate with.

- **IEA:** The Net Zero by 2050 report is a combined effort from the IEA's World Energy Outlook team and Energy Technology Perspectives team. IEA reports all undergo extensive external peer review by governments, real-economy firms, and think tanks. For each sector and for most specific energy sources, IEA enlists contributing industry experts. As IEA links its energy modeling outputs to other models beyond the scope of the energy system (e.g., GHG emissions from land use), they collaborate with the International Institute for Applied Systems Analysis (IIASA). For macroeconomic analysis, IEA partners with the International Monetary Fund (IMF).
- **UTS OECM:** The 2020 model documentation developed for the NZAOA states that the pathway has undergone peer review by an expert group consisting of representatives from the Energy Transition Commission (ETC), the Exponential Roadmap Initiative, and the Potsdam Institute for Climate Impact Research, and additional input and review were provided by Science-Based Targets Initiative (SBTi), Carbon Disclosure Project (CDP), the Carbon Risk Real Estate Monitor (CRREM), and the World Wildlife Federation (WWF). In addition, NZAOA member financial institutions such as Allianz, Aviva, and Storebrand provided input. The UTS OECM also derives input from discussions with real-economy firms at sectoral level.
- **NGFS:** The NGFS pathways have been generated with GCAM, MESSAGEix-GLOBIOM, and REMIND-MAgPIE. These models are well-established IAMs, included in hundreds of peer-reviewed scientific studies on climate change mitigation. The NGFS Net Zero by 2050 scenario is in partnership with an academic consortium from the Potsdam Institute for Climate Impact Research, International Institute for Applied Systems Analysis, University of Maryland (UMD), Climate Analytics (CA), Swiss Federal Institute of Technology in Zurich (ETHZ), and National Institute of Economic and Social Research (NIESR).

Key limitations identified

While some models are backed by the expertise and reputation of the institutions that produce them, there is limited information on how and if the pathways have been tested or validated by the scientific community (i.e., temperature alignment), and by industry and other key stakeholders to assess their commercial feasibility (including evaluation of current policies in place vs ambition level needed).

5. Limitations and call to action

Sectoral pathways provide critical information to support the transition to net zero for the whole economy, by helping to inform the actions that real-economy firms, policymakers, and financial institutions should take to achieve their goals. For financial institutions, pathways help identify where investment can enable the transition, inform how to align their portfolios to net zero, and provide a basis for engagement with clients and portfolio firms to support their transition.

Pathway users should understand the scope and ambition of pathways to select the pathway that aligns with 1.5 degrees C. Users should also recognize that pathways are models, not predictions, of how the economy and individual sectors may transition. They incorporate simplifications and assumptions about emissions trajectories, policies, technology deployment, etc. for the transition of the economy and industries. In many cases, they provide linear models of change whereas in reality, transformations often follow non-linear trajectories, where exponential growth in technology may suddenly occur in response to a change in market conditions before finding a maximum rate.[53, 54]

Financial institutions are not passive users of pathways; their actions will influence the pace and shape of the transition. Financial institutions should be constructive partners in identifying, enabling, and advocating for the actions (e.g., investment, financing, incentives, policy, regulation) that will bridge the gap between the ambition of a pathway and the transition in the real economy. This is intrinsic to a financial institution's net zero transition plan and implementation.

Furthermore, financial institutions should understand the underlying assumptions behind the pathways to identify where actions need to be taken and drive decision-making. The GFANZ pathway framework provides a tool for financial institutions to navigate the existing pathway landscape and choose those pathways that help achieve their net-zero commitments and objectives.

The comparison analysis using this framework highlights some of the limitations in today's pathway landscape. Users can benefit from understanding these limitations and their implications so they can adopt workarounds themselves to enable the use of pathways today while pathway developers implement solutions or improvements to their pathways.

Table 6 outlines the key limitations of pathways that create hurdles for adoption, summarized under five broad themes.

53 World Resources Institute. Explaining the Exponential Growth of Renewable Energy, September 2021.

54 Aleh Cherp, Vadim Vinichenko, Jale Tosum, Joel A. Gordon, and Jessica Jewell. National growth dynamics of wind and solar power compared to the growth required for global climate targets, July 2021.

Table 6: Current limitations for pathway users

LIMITATIONS	EXAMPLES	IMPLICATIONS FOR FIs
1. Access to data	No open access to underlying data and models for users restricting the information to specific publications with limited data (e.g., time intervals only available on five or ten-year periods)	Multiple sources required to extract information (e.g., methodology documents, spreadsheets, online portals), and users required to make assumptions to fill in information gaps (e.g., interpolate data between time periods, regional granularity from global models)
2. Standardization of scope, terminology, and formatting	Pathways cover different scopes (e.g., CO_2 vs. GHG emissions) and also provide different definitions for key concepts like carbon price and investments	Difficult to make like-for-like comparisons across pathways produced by different providers without adjusting/standardizing key concepts into common metrics
3. Geographical granularity	Limited number of pathways with output variables available at regional/country level	Varying level of applicability of pathway to specific institutions depending on portfolio and geographical footprint (e.g., regional financial institutions may need to use assumptions to regionalize pathways)
4. Sub-sector granularity	Different level of sector-specific granularity available among pathways and varying level of detail/granularity of data available among sectors	Difficulty for financial institutions to apply consistent pathways from the same provider to all firms in a portfolio, leading to the risk of inconsistencies among sector-specific and cross-sector pathways
5. Cross-stakeholder credibility/feasibility assessment	Limited disclosure on how validation processes, including experts from industry, policy, and finance, have been involved on assessing pathway feasibility	Uncertainty on the level of credibility (i.e., temperature alignment) and commercial feasibility of pathways from different stakeholders' perspectives (e.g., scientific community vs. industry vs. financial institutions)

Pathway developers are continuously working to improve the accuracy and usability of pathways and improvements are underway. However, as climate action is required immediately, financial institutions can adapt pathways to make use of them in the short term, accepting that key factors like climate science, policies, accounting, and innovation are rapidly evolving.

Call to action

Financial institutions

There is uncertainty around the level of ambition and the commercial feasibility of existing pathways, but financial institutions should still use them now as a tool to help achieve their net-zero goals and help drive dialogue with the real economy and policy makers to close the gap between ambition and feasibility. Their limitations should not be a reason to delay climate action by either financial institutions, firms, or policy makers. Moreover, underlying assumptions (e.g., socioeconomic factors, energy demand, technology evolution, policy) are constantly changing and financial institutions should be able to adapt their targets and overall strategies as pathways evolve.

It is important for financial institutions to understand the pathway model assumptions in detail, so they may select pathways that align with an ambition of 1.5 degrees C and enable decision-making. By having clarity on the different scopes and underlying assumptions, financial institutions can leverage available data to tailor pathways to their specific needs (e.g., downscaling global pathways to suit regional granularity needs) and identify where additional action is required to achieve the pathway.

The GFANZ framework developed here can be used to compare, understand, and use pathways. We encourage financial institutions to use the framework as a tool when analyzing pathways and use the comparative analysis provided in this report as an example of the type of insights that users can extract to inform decision-making.

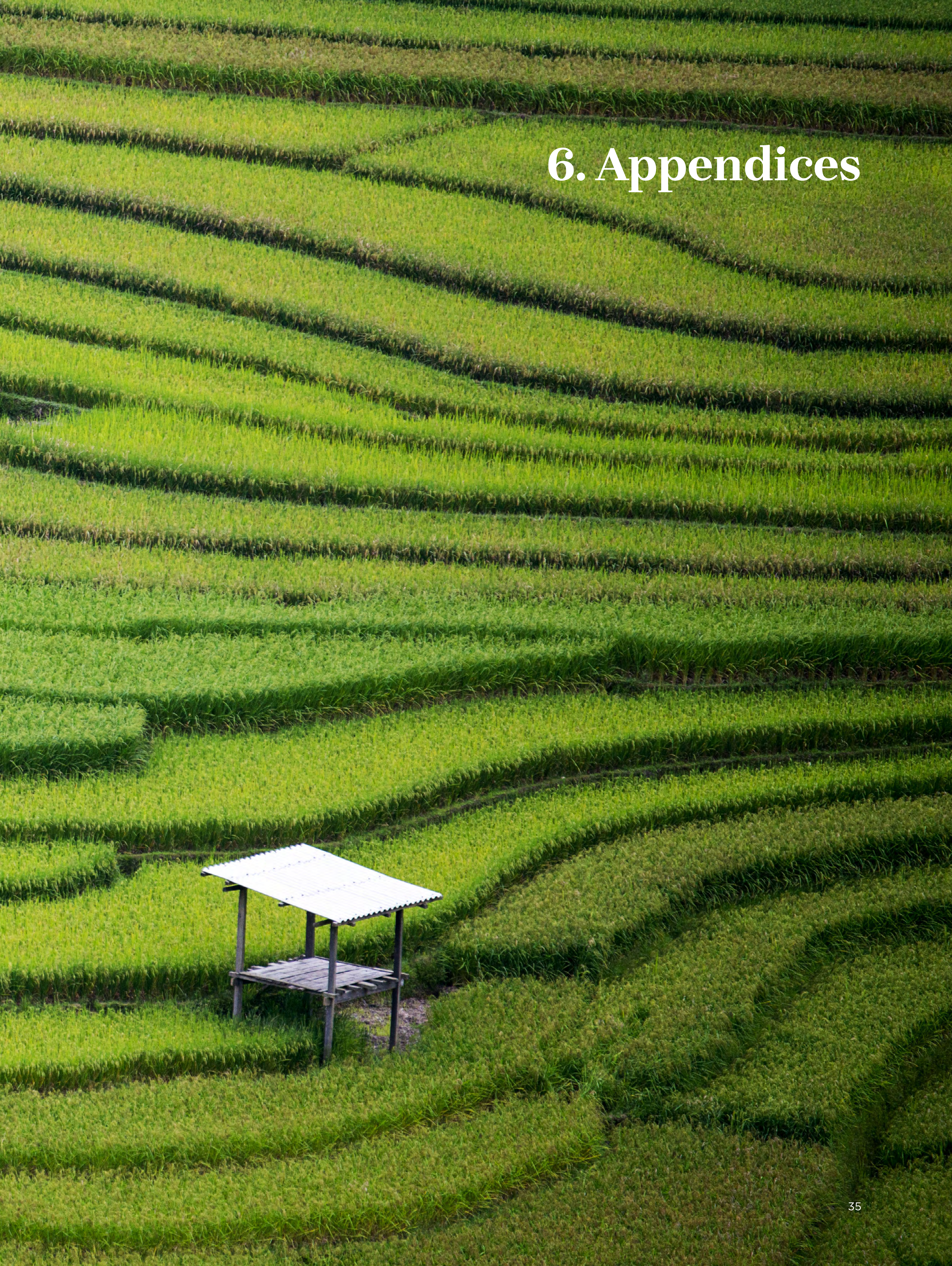
Pathway developers

GFANZ urges pathway developers to improve useability and act on the limitations identified in this report to build pathways that are aligned with financial institutions' expectations, following key principles that enable uptake of sectoral pathways:

- Clear and understandable (i.e., transparency on scope, ambition, and assumptions)
- Comparable (i.e., similar scopes and standardized outputs for comparison)
- Granular (i.e., enough detail on market, regions, timeframe, etc.)
- Accessible (i.e., public access to methodology and underlying data)
- Actionable (i.e., commercial and technological feasibility of underlying assumptions)
- Credible (i.e., validation from scientific community around stated temperature alignment)
- Dynamic (i.e., periodical update to reflect recent changes in science and other economic/social/technical conditions)

The net-zero transition requires decarbonization of firms in a range of sectors, with different pathways for each, and financial institutions should have a clear understanding of sectoral pathways to enable decision-making for particular sectors. Moreover, sectoral analysis is required to understand the gap between pathways that may be considered more feasible by industry (i.e., bottom-up) and pathways that may be considered more ambitious by other stakeholders. GFANZ will work with pathway developers, industry groups, real-economy firms, and other stakeholders to develop sector briefs to provide further comparison of sectoral pathways.

6. Appendices



APPENDIX A.

Definitions and key concepts

Below is a description of key concepts for financial institutions to understand in order to effectively evaluate transition pathways. It is important to note that GFANZ is not creating new definitions but instead leveraging existing ones from credible sources such as the IPCC, to the extent possible.

Scenario vs. forecast vs. pathway

- Scenario: Projections of what can happen by creating plausible, coherent, and internally consistent descriptions of possible climate change futures, scenarios are not predictions of the future.[55]
- Forecast: When a projection is branded "most likely," it becomes a forecast or prediction. A forecast is often obtained by using deterministic models — possibly a set of such models — outputs of which can enable some level of confidence to be attached to projections.[56]
- Pathway: A pathway is a goal-oriented scenario or combination of scenarios answering the question "What needs to happen?" to accomplish a specific objective (e.g., what are the steps needed to reach net zero by 2050, limit global warming to 1.5 degrees C with low or no overshoot)

Net zero and temperature alignment

- **1.5 degrees C-aligned pathway:** A pathway of GHG emissions and other climate forces that provides approximately a one-in-two to two-in-three chance, given current knowledge of the climate response, of global warming either remaining below 1.5 degrees C or returning to 1.5 degrees C by around 2100 following an overshoot.[57]
- **Net zero:** Net-zero emissions are achieved when emissions of greenhouse gases to the atmosphere are balanced by anthropogenic removals.[58] Organizations are considered to have reached a state of net zero when they reduce their GHG emissions following science-based pathways, with any remaining GHG emissions attributable to that organization being fully neutralized, either within the value chain or through purchase of valid offset credits.[59]
- **Timing of net-zero emissions:** In the IPCC AR6, global net-zero CO_2 emissions is achieved in the early 2050s in modeled pathways that limit warming to 1.5 degrees C (>50%) with no or limited overshoot. The same pathways reach net-zero GHG emissions later in the 21st century, between 2095-2100 (2055 — N/A),[60] and about half do not reach net-zero GHG emissions by 2100.[61]

55 Senses. Primer to Climate Scenarios, 2022.

56 IPCC. TAR Climate Change 2001: Impacts, Adaptation, and Vulnerability, 2001.

57 IPCC. Special Report on 1.5, Annex I: Glossary, 2018.

58 IPCC. Special Report on 1.5, Annex I: Glossary, 2018.

59 UNFCC. Race to Zero Lexicon, April 2021.

60 Refers to the 50th and (5th-95th) percentile values. The 95th percentile cannot be deduced from the scenario database as more than 5% of pathways do not reach net-zero GHG emissions by 2100.

61 IPCC. AR6. Working Group III, 2022.

Carbon dioxide (CO_2) vs greenhouse gases (GHG)

- **CO_2:** A naturally occurring gas, CO_2 is also a by-product of: burning fossil fuels (such as oil, gas, and coal), burning biomass, land-use changes (LUC), and industrial processes (e.g., cement production). It is the principal anthropogenic greenhouse gas that affects the Earth's radiative balance.[62]
- **GHG:** Greenhouse gases encompass the six categories defined in the Kyoto protocol[63] including Carbon dioxide (CO_2), Methane (CH_4), Nitrous oxide (N_2O), Hydrofluorocarbons (HFCs), Perfluorocarbons (PFCs) and Sulphur hexafluoride (SF_6).[64]

Carbon budget

As mentioned above, the carbon budget is the amount of additional emissions that can be released into the atmosphere before a temperature threshold is likely to be breached. The carbon budget provides two important areas of guidance:

- **Remaining emissions to limit warming to 1.5 degrees C:** Cumulative global CO_2 emissions from the start of 2020 to the time that CO_2 emissions reach net zero that would result in a given level of global warming (1.5 degrees C).[65]
- **Likelihood[66] of reaching a given emissions target:** Climate sensitivity (the response of climate system to additional emissions) is dependent on a variety of complex factors and cannot be definitively known. This means that the carbon budget associated with a given temperature target cannot be known for certain. As a result, scientists use a range of carbon budgets associated with varying probabilities of reaching a given temperature target. Lower budgets are more conservative (i.e., harder to achieve) and, thus, are more likely to result in the desired temperature outcome (higher probability). In comparison, higher budgets are more likely to exceed the desired temperature (lower probability of hitting the target). As noted above, pathways need at least a 50% chance of hitting a 1.5 degrees C target to be considered a 1.5 degrees C pathway.

62 IPCC. Special Report on 1.5, Annex I: Glossary, 2018.

63 Kyoto Protocol operationalizes the United Nations Framework Convention on Climate Change by committing industrialized countries and economies in transition to limit and reduce greenhouse gases (GHG) emissions in accordance with agreed individual targets (UNFCCC, 2022).

64 IPCC. Special Report on 1.5, Annex I: Glossary, 2018.

65 IPCC. Special Report on 1.5, Annex I: Glossary, 2018.

66 IPCC (2018) defines likelihood as:" the chance of a specific outcome occurring, where this might be estimated probabilistically".

Figure 12: Carbon budget and likelihood for different temperature scenarios[67]

Global Warming Between 1850–1900 and 2010–2019 (°C)		Historical Cumulative CO_2 Emissions from 1850 to 2019 ($GtCO_2$)					
1.07 (0.8–1.3; likely range)		2390 (± 240; likely range)					
Approximate global warming relative to 1850–1900 until temperature limit (°C)[a]	Additional global warming relative to 2010–2019 until temperature limit (°C)	Estimated remaining carbon budgets from the beginning of 2020 ($GtCO_2$) *Likelihood of limiting global warming to temperature limit*[b]					Variations in reductions in non-CO_2 emissions[c]
		17%	*33%*	*50%*	*67%*	*83%*	
1.5	0.43	900	650	500	400	300	Higher or lower reductions in accompanying non-CO_2 emissions can increase or decrease the values on the left by 220 $GtCO_2$ or more
1.7	0.63	1450	1050	850	700	550	
2.0	0.93	2300	1700	1350	1150	900	

Note: Modified from source - IPCC, 2018

In the latest Working Group III Report,[68] the IPCC categorized over 1,200 pathways based on temperature alignment, level of overshoot and likelihood. In the most ambitious category (C1) the IPCC groups global pathways that limit warming to 1.5 degrees C (>50%) with no or limited overshoot. These pathways have a carbon budget of 500 Gt CO_2 (330–710)[69] from 2020 until they reach net zero.

To put these numbers in perspective, using the remaining carbon budget based on 66% likelihood of limiting warming to 1.5 degrees C, AR6 reports that the world has a remaining carbon budget of 360 Gt CO_2 from 2021. This is equivalent to about nine years of current emission levels.

Temperature overshoot

The IPCC defines overshoot pathways as: "Pathways that exceed the stabilization level (concentration, forcing, or temperature) before the end of a time horizon of interest (e.g., before 2100) and then decline towards that level by that time. Once the target level is exceeded, removal by sinks of greenhouse gases is required."[70]

Pathways that allow emissions to temporarily drive a significant rise in temperature over 1.5 degrees C will need high levels of emissions removals to hit the 1.5 degrees C target by 2100. The assumption that large-scale carbon removal solutions will be technologically and economically viable has been called into question by scientists and economists in recent years. IPCC comment in their latest AR6 report that

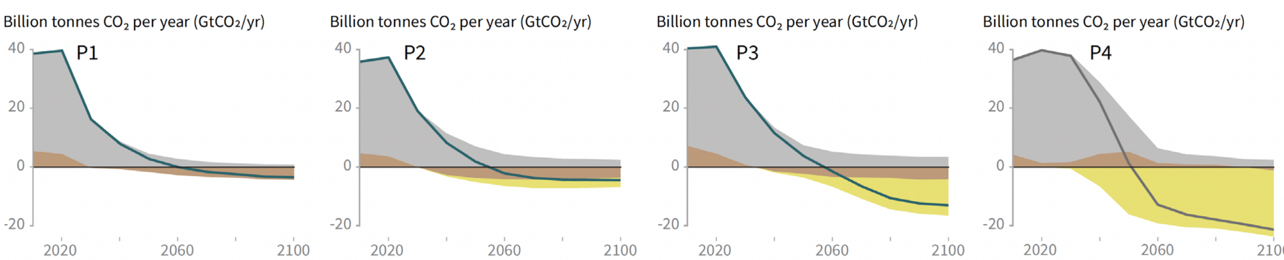
67 Table from IPCC. Special Report on 1.5, Annex I: Glossary, 2018.
68 IPCC. AR6. Working Group III, 2022.
69 Refers to the 50th and (5th-95th) percentile value.
70 IPCC. Special Report on 1.5, Annex I: Glossary, 2018.

"*implementation of CCS currently faces technological, economic, institutional, ecological-environmental and sociocultural barriers. Currently, global rates of CCS deployment are far below those in modelled pathways limiting global warming to 1.5°C or 2°C. Enabling conditions such as policy instruments, greater public support and technological innovation could reduce these barriers.*"[71] In addition, the physical consequences of climate change worsen at higher temperatures so that an overshoot may increase the risks of climate harm. In 2018, the IPCC explored the effects of 1.5 degrees° C of warming in a special report (SR15) and found that many of the worst effects of climate change could become far less manageable above 1.5 degrees° C. For these reasons, many financial sector net-zero alliances have explicitly called for their members to avoid using "high overshoot" pathways for net-zero target setting.

High overshoot pathways assume the large-scale use of carbon capture and storage technologies and carry potentially high risk of irreversible harm to the climate through pushing physical systems past their tipping points.

The IPCC has outlined four illustrative pathways (P1-P4) to describe the range of potential mitigation approaches. Figure 13 shows the differences in removals required using IPCC's P1–P4 scenarios. All four pathways limit global warming to 1.5 degrees C but with varying degrees of overshoot and different assumptions on the dependency of carbon capture and removal technologies. P1 to P3 are classified as no/low overshoot, whereas P4 is classified as high overshoot. Moreover, both P3 and P4 rely on bioenergy with carbon capture and storage (BECCS) to a high degree which is not currently proven as feasible leaving them out of the scope for some alliances (e.g., NZBA states that scenarios should rely conservatively on negative emissions technologies).

Figure 13: IPCC characteristics of four illustrative model pathways[72]



P1: A scenario in which social, business and technological innovations result in lower energy demand up to 2050 while living standards rise, especially in the global South. A downsized energy system enables rapid decarbonization of energy supply. Afforestation is the only CDR option considered; neither fossil fuels with CCS nor BECCS are used.

P2: A scenario with a broad focus on sustainability including energy intensity, human development, economic convergence and international cooperation, as well as shifts towards sustainable and healthy consumption patterns, low-carbon technology innovation, and well-managed land systems with limited societal acceptability for BECCS.

P3: A middle-of-the-road scenario in which societal as well as technological development follows historical patterns. Emissions reductions are mainly achieved by changing the way in which energy and products are produced, and to a lesser degree by reductions in demand.

P4: A resource- and energy-intensive scenario in which economic growth and globalization lead to widespread adoption of greenhouse-gas-intensive lifestyles, including high demand for transportation fuels and livestock products. Emissions reductions are mainly achieved through technological means, making strong use of CDR through the deployment of BECCS.

Low/no overshoot | High overshoot

Fossil fuel and industry | AFOLU | BECCS

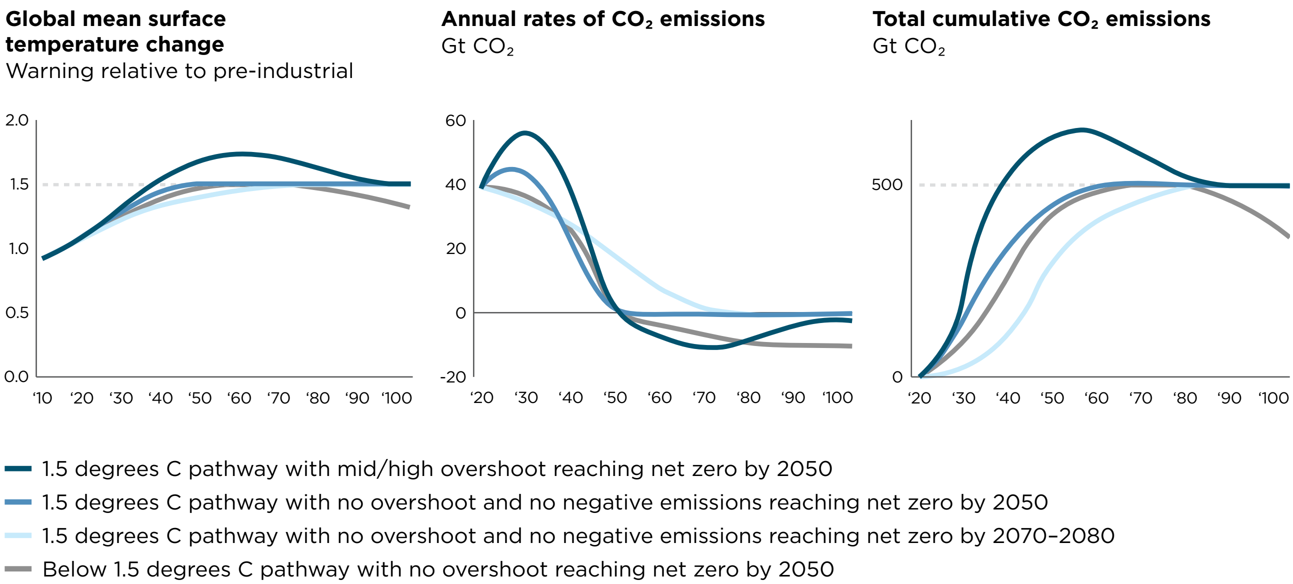
Note: Modified from source — IPCC, 2018

71 IPCC. AR6. Working Group III, 2022.

72 IPCC Special Report on 1.5C, Summary for Policymakers, Figure SPM.3b, 2018.

To illustrate these concepts, Figure 14 shows graphically how different scenarios can be defined as net zero but have different carbon budgets leading to different levels of overshoot.

Figure 14: Illustration of relationship between temperature, emissions, and carbon budget[73]



Note: Modified from source — IPCC, 2018

73 Adapted from the IPCC. Special Report on 1.5, Chapter 1 — Figure 1.4, 2018.

APPENDIX B.

Pathway archetypes

Table 7: Differences of top-down and bottom-up pathway archetypes by element

ELEMENT	TOP-DOWN	BOTTOM-UP
Overall approach	Focus on interlinkages across sectors and structural shifts leading to global, fully consistent pathways across all sectors	Focus on identifying technology and policy step changes for each sector and modeling incremental feasible steps to make progress
Development process	Typically focus on the expertise of the scientific and modeling community with industry players consulted to validate the outputs	Typically focus on input from the industry on feasible actions, technologies, and economics
Commercial feasibility	Primary focus on modeling and optimizing distribution of carbon budget across sectors	Primary focus on ensuring commercial feasibility and building assumptions in collaboration with industry
Carbon budget	Work backward from global carbon budget and allocate across sectors and regions	Work forward from sector-specific assumptions and arrive at a carbon output specific to that sector
Representation of technology	Low technological specificity	High granularity and consideration of specific technologies to capture substitution possibilities of energy efficiency and technological development
Common applications	Reference when assessing temperature alignment across sectors (e.g., portfolio alignment for financial institutions)	Reference when building bottom-up strategies for change (e.g., for engaging clients and portfolio firms)

APPENDIX C.

Application of GFANZ pathway framework (deep-dive analysis)

This section details the questions of the pathway framework, outlining why the different components are relevant for financial institutions and comparing specific pathways along the different components to highlight the use of the framework. The analysis below is intended as an example on how to apply the GFANZ pathway framework rather than an exhaustive comparison of the latest pathways.[74] Some questions will only be relevant for sector-specific pathways — for instance, the question on the assumptions of an industry's assumed production/demand volume. Such sector-specific questions will be explored in further detail in the GFANZ sector briefs.

1. Scope and ambition of the pathway

Scope

What sectors and sub-sectors does the pathway cover?

Relevance for financial institutions: Financial institutions should set targets at sector level while also ensuring that their overall portfolio is aligned to a 1.5 degrees C, with low/no overshoot. To enable this, financial institutions need to understand the sector granularity of the available pathways and how interdependencies and spillovers between sectors are reflected. Pathway selection should have appropriate sector coverage aligned to the sector exposure in the financial institution transition plans and targets.

Example for selected pathways: All selected pathways provide granular breakouts of industry, transport, buildings, and the energy sector. IEA and UTS OECM are generally more granular in detailing sub-sectoral pathways compared to the NGFS pathways. Table 8 summarizes the current state of sectoral pathways across key sectors.

74 The pathways covered are not the only ones aligned to 1.5 degrees C, and user may use other pathways aligned to their commitments. The pathways used in this report are the latest available pathways from the IEA, NGFS, and UTS OECM as of May 2022 (see Appendix E for the specific documentation used to conduct this analysis).

Table 8: Overview of the current state of sectoral net-zero pathways as of Q2 2022

SECTOR[75]		IEA NZE	UTS OECM	NGFS GCAM	NGFS RM	NGFS MG
Industry		✓	✓	✓	✓	✓
Sub-sectors	Iron/Steel	✓	✓	✓	✓	X
	Chemicals	✓	✓	✓	✓	X
	Cement	✓	✓	✓	✓	X
	Aluminum	X[76]	✓	✓	✓	X
Transport		✓	✓	✓[77]	✓	✓
Sub-sectors	Autos	✓	✓	✓	✓	✓
	Trucks	✓	✓	X	X	X
	Aviation	✓	✓	X	X	X
	Shipping	✓	✓	X	X	X
Buildings		✓	✓	✓	✓	✓
Sub-sectors	Residential	✓	✓	✓	X	X
	Services	✓	✓	✓	X	X
Energy		✓	✓	✓	✓	✓
Sub-sectors	Power	✓	✓	✓	✓	✓
	Oil and gas	✓	✓	X[76]	X[76]	X[76]
	Coal	✓	✓	X[76]	X[76]	X[76]
Other	Agriculture	X[76]	✓	✓	✓	✓

How does the pathway consider system interactions (e.g., energy systems and land-based systems)? Defining a decarbonization pathway for a sector or the whole economy requires making assumptions about policies, economies, and technologies. Many of these underlying assumptions can be modeled through interconnected sub-models or "modules." The interactions between these models aim to mirror the interactions between the real-world systems that they represent.

Relevance for financial institutions: The use of different modules can lead to differences in pathways given that the scope or emphasis on specific components varies.

Example for selected pathways: All five pathways consider some degree of interactions between systems, although the models vary in their assessments of specific systems. For example, as a leading energy modeler, the IEA focuses on modeling the complex dynamics of the energy system and focuses less on land-use dynamics, instead coupling their energy system output with outputs from IIASA's GLOBIOM model (i.e., the models used for IEA are similar to those from NGFS MG). Table 9 shows the modules used by the selected pathway developers and the interactions considered in their pathways. As can be seen, similar modules are being used among the five pathways.

75 The 1-0 dichotomy is a simplification of the sector granularity. As an example, oil, gas, and coal are represented in the NGFS models, however not at the granularity of IEA of UTS OECM.

76 IEA does model the aluminum sector but reports aluminum as "other" industry.

77 GCAM splits transport into two categories: passenger and freight.

Table 9: Overview of system interactions considered in selected pathways

MODULES[78]	CONSIDERATIONS	IEA NZE	UTS OECM	NGFS GCAM	NGFS RM	NGFS MG
Energy system	Detailed modeling of energy supply, energy transformation, and energy demand	WEM & ETP	One Earth Climate Model 2.0	GCAM	REMIND	MESSAGEix
Land use	Analyze competition for land use between agriculture, forestry, and bioenergy	GLOBIOM	Simplified land-based sequestration model	GCAM	MAgPIE	GLOBIOM
Climate	Converts emissions to global mean temperature	MAGICC	MAGICC	Hector[79]	MAGICC	MAGICC
Air pollution and GHG	Atmospheric pollution to relevant health and environmental impacts	GAINS	Not included	GCAM	REMIND	GAINS
	Atmospheric pollution to relevant health and environmental impacts	GAINS	Not included	GCAM	REMIND	GAINS
Macroeconomic	Market-based economy functions	WEM & ETP, with GIMF model from IMF	DLR-EM	GCAM	REMIND	MACRO

What is the timeframe and interval of reported data?

Relevance for financial institutions: Financial institutions need to understand both the scope and the limitations of the timeframe they cover and the interval of available modeled data. They may need to interpolate the pathway to provide year on year modeled data or extrapolate beyond the pathway if its timeframe is shorter than the institutional net-zero timeframe.

Example for selected pathways: While most scenarios are modeled on an annual basis, the information for users is only available in specific time intervals. UTS OECM and NGFS provide output data in five-year intervals while IEA provides public data in ten-year intervals. Moreover, NGFS is the only pathway that provides information up to 2100 while others have projections up to 2050.

78 Other models included are: Power System Model, Transport Model, Resource Model, and Water System Model.

79 While GCAM uses Hector for standard climate/temperature evaluation, the temperature/climate information for GCAM on the NGFS explorer is based on harmonized MAGICC runs.

Table 10: Temporal scope of considered pathways[80]

	IEA NZE	UTS OECM	NGFS GCAM	NGFS RM	NGFS MG
Time intervals	10 years[81]	5 years	5 years	5 years (2005–2060) and 10 years (2060–2100)	5 years (2005–2060) and 10 years (2060–2100)
Time horizon	2050	2050	2100	2100	2100

What geographies and regions does the pathway cover?
The geographic granularity speaks to the different rates and nature of the net-zero transitions between regions. These differences derive from various factors including the local policy environment, existing energy infrastructure, agricultural methods, and products. Local and regional outputs allow users to better understand the different drivers required to decarbonize specific sectors. This is important, as drivers that apply in one location may not be relevant in another.

Relevance for financial institutions: Need for regional granularity will depend upon portfolio exposure and alignment. In choosing between sectoral pathways, financial institutions should select pathway models for appropriate alignment of geographical granularity. Models may vary in the nuanced views of how assumptions regarding global supply chains, regional infrastructure, and aggregate demand may evolve in a sector.

Example for selected pathways: There are 26 regions represented in the World Energy Model (WEM) used by IEA and between 11 and 32 regions in the Integrated Assessment Models (IAMs) used to generate the NGFS pathways. UTS OECM models 10 regions, of which three (Global, OECD Europe, OECD North America) are currently open access.

In terms of output data, NGFS pathways provide granularity for each modeled region and downscale a limited set of variables to over 180 countries. By comparison, the IEA and UTS OECM pathways only provide global-level outputs. Financial users of these latter pathways may need to conduct their own downscaling to ensure that outputs are relevant for local operations. Table 11 gives an overview of the modeled regions and the granularity of output variables for each pathway.

80 NGFS data is based on NGFS Climate Scenarios Technical Documentation Phase 2, June 2021.

81 IEA results are reported in 10-year intervals in publicly available data and in 5-year time steps in the extended dataset.

Table 11: Modeled geographic granularity of considered pathways

PATHWAY	NUMBER OF MODELED REGIONS (INPUT)	MODELED REGIONS (INPUT)	REGIONAL GRANULARITY (OUTPUTS)
IEA NZE	26 regions on the demand-side; on supply-side, all countries modeled individually	Asia-Pacific is split into 8 regions; Europe into 6; North America into 3; Central and South America into 3; Africa into 3; Eurasia into 2; and the Middle East is a single region	Global
UTS OECM	10 regions	OECD North America, OECD Pacific, OECD Europe, Eastern Europe/Eurasia, Middle East, Latin America, China, Africa, India, Non-OECD Asia	Global, OECD Europe, OECD North America
NGFS GCAM	32 regions	Africa (Eastern), Africa (Northern), Africa (Southern), Africa (Western), Argentina, Australia & New Zealand, Brazil, Canada, Central America and the Caribbean, Central Asia, China, Columbia, EU-12, EU-15, European Free Trade Association, Europe (Non-EU), India, Indonesia, Japan, Mexico, Middle East, Pakistan, Russia, South Africa, South America (Northern), South America (Southern), South Asia, Southeast Asia, South Korea, Taiwan, USA	180 countries
NGFS RM	12 regions	CAZ (Canada, Australia and New Zealand); China; European Union; India; Japan; Latin America; Middle East and North Africa; non-EU member states; other Asia; reforming countries; Sub-Saharan Africa; United States	180 countries
NGFS MG	11 regions	Sub-Saharan Africa; Centrally Planned Asia; Central and Eastern Europe; Former Soviet Union; Latin America and the Caribbean; Middle East and North Africa; North America; Pacific OECD; Other Pacific Asia; South Asia; Western Europe	180 countries

What GHGs does the pathway consider (e.g., CO_2 or all GHGs)?

Relevance for financial institutions: Financial institutions need to understand whether all GHG emissions are covered or not in each pathway to understand differences between pathways. Moreover, when considering sectors where non-CO_2 GHGs make up a significant share of GHGs (e.g., methane from agriculture), financial institutions may want to explore the emissions trends of these other GHGs in the pathway.

Example for selected pathways: IEA only models CO_2 for the global cross-sectoral pathway (for some sectors, additional GHGs are modeled). In contrast, NGFS and UTS OECM pathways capture all other GHGs — Methane (CH_4), Nitrous oxide (N_2O), Hydrofluorocarbons (HFCs), Perfluorocarbons (PFCs) and Sulphur hexafluoride (SF_6).

Table 12: GHGs considered in pathway

GREENHOUSE GASES	IEA NZE	UTS OECM	NGFS GCAM	NGFS RM	NGFS MG
Carbon dioxide (CO_2)	✓	✓	✓	✓	✓
Methane (CH_4)	~[82]	✓	✓	✓	✓
Nitrous oxide (N_2O)	~[82]	✓	✓	✓	✓
Hydrofluorocarbons (HFCs)		✓	✓	✓	✓
Perfluorocarbons (PFCs)		✓	✓	✓	✓
Sulphur hexafluoride (SF_6)		✓	✓	✓	✓

82 Methane and nitrous oxide emissions are modeled for the energy sector only.

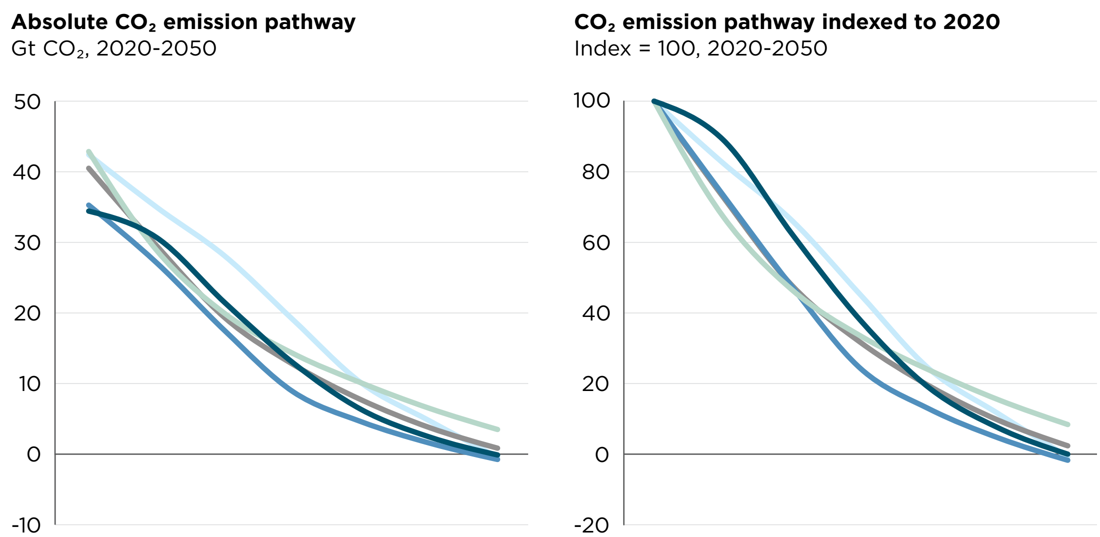
Net-zero and temperature alignment

What is the total emissions pathway to 2050 (both in terms of absolute and intensity)?

Relevance for financial institutions: The total carbon emissions pathways help financial institutions understand what level of reductions are required and by when for the global economy in order to achieve net zero. This rate of decarbonization will identify ambition and portfolio steering decisions. Steeper drops in emissions up to 2030 may demand more significant shifts in current portfolios, investment decisions and restrictions. Declines later in the pathway may still require investments now in technologies and solutions that will scale later.

Example for selected pathways: Figure 15 illustrates the carbon emissions trajectories up to 2050 for each pathway.

Figure 15: CO_2 emission pathways, absolute and indexed[83]



	Absolute 2020	Absolute 2030	Absolute 2040	Absolute 2050	Indexed 2020	Indexed 2030	Indexed 2040	Indexed 2050
IEA NZE	34	21	6	0	100	62	19	0
UTS OECM	35	17	5	-1	100	50	13	-2
NGFS GCAM	42	28	10	0	100	66	24	-1
NGFS RM	40	19	8	1	100	48	19	2
NGFS MG	42	20	10	4	100	47	24	8

Source: International Energy Agency, 'Net Zero by 2050: A roadmap for the global energy sector', 2021; University of Technology Sydney One Earth Climate Model, 2021; Network for Greening the Financial System

83 The delta in 2020 between IEA and UTS OECM pathways and NGFS pathways in 2020 can be explained by the type of CO_2 emissions included. NGFS numbers displayed include CO_2 emissions from energy and industrial processes as well as CO_2 emissions from agriculture, forestry, and other land use (AFOLU). Exclusively energy-related CO_2 emissions in the NGFS pathways range from 34-35 Gt CO_2/year in 2020, in the range of IEA and UTS OECM figures.

IEA and UTS OECM achieve net-zero CO_2 emissions by 2050, while the NGFS pathways have remaining net CO_2 emissions in 2050 between 0.3-3.5 $GtCO_2$. Regardless of the pathway chosen, deep emissions cuts will be required immediately to put the world on track to limit global warming to 1.5 degrees C. All pathways require an annual average reduction of 4%–7% until 2030. To provide context for the scale of these reductions, the COVID-19 pandemic reduced global emissions by around 6%–7% in 2020, although emissions have rebounded, hitting their highest ever levels in 2021.

What is the global carbon budget from 2020 to net zero? What is the temperature alignment (degrees C), level of overshoot, and likelihood?

Relevance for financial institutions: When selecting a pathway, financial institutions need to understand the consistency of the pathway with the firm's climate commitment. To align with UN Race to Zero minimum entry criteria, financial institutions need to have clarity, at a minimum, on the temperature alignment, the probability of reaching the temperature, and the level of overshoot of each pathway.

Example for selected pathways: All selected pathways align to 1.5 degrees C (by construct). UTS OECM and IEA do this with a 67% and 50% likelihood, respectively. The alignment to the remaining carbon budget is explicitly outlined in their technical documentation. In contrast, the NGFS scenarios have no built-in formal alignment with the remaining carbon budget from 2020. However, NGFS presents MAGICC output (based on all GHG emissions) to ensure >50% likelihood below 1.5 degrees C.

Table 13: Level of ambition of considered pathways[84, 85]

	UTS OECM	IEA NZE	NGFS RM	NGFS MG	NGFS GCAM
Carbon budget ($Gt\ CO_2$)	400	460 (+40 AFOLU)	~480	~540	~600
Stated temperature alignment (degrees C)	1.5	1.5	1.5	1.5	1.5
Likelihood (%)	67%	50%	52%	54%	57%
Overshoot	No/low	No/low	No/low	No/low	High[86]

Reliance on carbon capture and removal

What technologies does the pathway consider for removals and carbon capture? To what extent does the pathway rely on removals and carbon capture?

The use of removals can increase the overall emissions budget by taking emissions out of the atmosphere. Carbon removal technologies such as Direct Air Capture (DAC) and Bioenergy with Carbon Capture and Storage (BECCS)[87] are presently untested at a global scale due to economic and technological challenges. All else equal, the less a pathway relies on carbon removal technologies, the more conservative the pathway will be, as it demands sharper emissions reductions.

84 The carbon budgets of NGFS pathways have been calculated using linear interpolation based on reported figures.

85 Table in increasing order of carbon budget.

86 Based on AR6 categorization. GCAM falls under "C2: return warming to 1.5°C (>50%) after a high overshoot" and REMIND and MESSAGE are in "C1: Limit warming to 1.5°C (>50%) with no or limited overshoot"

87 DAC = Chemical process by which CO2 is captured directly from the ambient air, with subsequent storage; BECCS = Carbon dioxide capture, and storage (CCS) technology applied to a bioenergy facility (IPCC, 2018).

Relevance for financial institutions: Financial institutions need to understand the dependency of the pathway on DAC and BECCS technologies to make a judgment regarding their comfort with assumptions on future availability/use of these technologies.

Example for selected pathways: Carbon removal solutions are broadly defined by two categories: nature-based solutions and technology-based solutions (DAC and BECCS). Table 14 presents the type of removals used in the selected pathways.

Table 14: Type of carbon removal solution incorporated into the considered pathways

TYPE OF REMOVAL		IEA NZE	UTS OECM	NGFS GCAM	NGFS RM	NGFS MG
Land-based		No	Yes	Yes[88]	Yes	Yes
Technology-based	BECCS	Yes	No	Yes	Yes	Yes
	DAC	Yes	No	No	No	No

The IEA NZE focuses on reaching net-zero CO_2 emissions from energy and industrial sources. It, thereby, does not consider carbon removal from outside the energy sector, such as nature-based solutions. Instead, it includes technology-based solutions to achieve net zero by 2050.

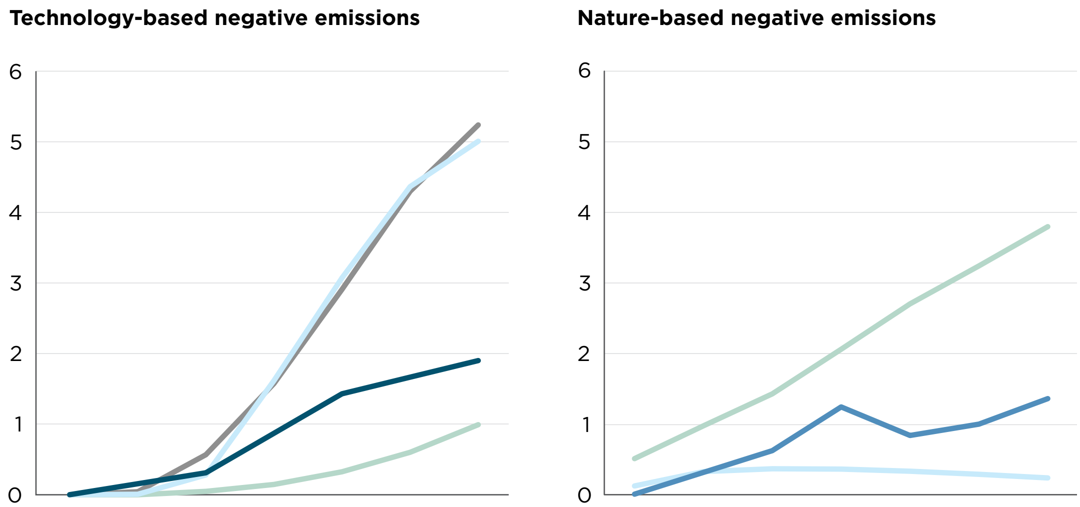
UTS OECM relies on nature-based removals (carbon sinks) such as forests, mangroves, or seaweed to compensate for emissions that will not be eliminated by 2050, such as some that may remain in heavy industry.

NGFS has split sequestration into two categories: land-based sequestration (i.e., nature-based) and CCS. The former includes both planting trees (afforestation) and restoring forests. CCS consists of all technologies that capture CO_2 from flue gases (the CO_2-rich outputs of power and industrial processes) and store it safely underground in suitable geologic formations. NGFS further splits the CCS category into "fossil," "industry," and "bioenergy." The latter is what is referred to as BECCS and is treated as a carbon removal technology in this analysis. The former ones (fossil and industry) are treated as forms of reducing carbon but not removing it. Other CDR technologies such as DAC are not included.

Figure 16 illustrates the extent of removals that each of the pathways entails. The NGFS pathways' combined technology-based and nature-based carbon removal solutions in 2050 range from 4.8–5.6 Gt CO_2. These levels are higher than UTS OECM and IEA, which reach 1.4 Gt and 1.9 Gt CO_2 removals per year in 2050, respectively. Hence, the NGFS models have a much higher reliance on carbon removals than IEA or UTS OECM to reach net zero.

88 Although carbon removals come from land-based system in the GCAM pathway, it is not possible to retrieve precise data on the extent of removals

Figure 16: Removed emissions from technology- and nature-based approaches
Gt CO_2/year, 2020-2050



	Technology-based 2020	2030	2040	2050	Nature-based 2020	2030	2040	2050
IEA NZE	0	0.3	1.5	1.9	0	0	0	0
UTS OECM	0	0	0	0	0	0.6	0.8	1.4
NGFS GCAM	0	0.3	3.1	5.1	N/A	N/A	N/A	N/A
NGFS RM	0	0.6	3.0	5.3	0.1	0.4	0.3	0.2
NGFS MG	0	0	0.3	1.0	0.5	1.4	2.7	3.8

2. Underlying assumptions to achieve the pathway

Socioeconomic/policy

What are the key socioeconomic assumptions (e.g., GDP and population growth)?
Socioeconomic assumptions have direct impact on real-economy emissions given that they drive the shift in demand/supply of products. Population and GDP growth assumptions can compound over a long pathway and may result in significantly different energy needs and emissions. All else equal, more people will require more energy, more food, and more land, likely increasing emissions. Likewise, wealthier societies have higher levels of consumption and may consume more carbon-intensive goods (e.g., eating more meat, driving more cars), resulting in higher emissions.

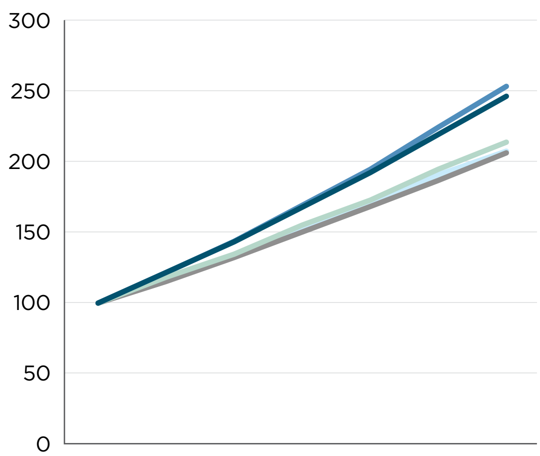
Relevance for financial institutions: These are fundamental assumptions that financial institutions will use in their own projections on future macroeconomic growth when building their net-zero strategy. Alignment of these assumptions to the financial institution's own strategic planning will allow for ease of use.

Example for selected pathways: Figure 17 shows the assumptions on socioeconomic factors that are applied to each of the pathways.

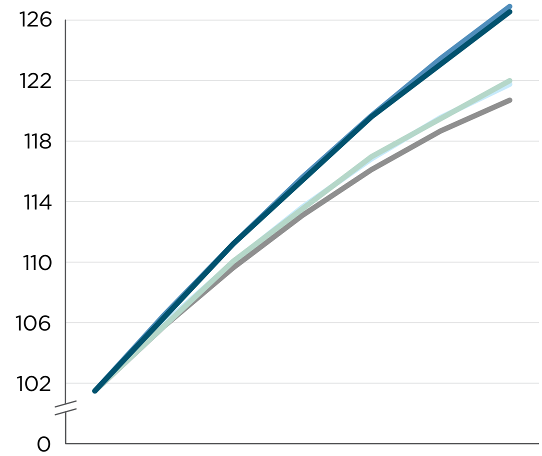
Figure 17: Socioeconomic factors: GDP and population development

Index: 2020 = 100, 2020-2050

Relative GDP growth



Relative population growth



	2020	2030	2040	2050	2020	2030	2040	2050
IEA NZE	100	143	193	247	100	110	118	125
UTS OECM	100	144	195	254	100	110	118	125
NGFS GCAM	100	135	172	208	100	108	115	120
NGFS RM	100	132	168	207	100	108	115	119
NGFS MG	100	135	173	214	100	109	115	120

Source: International Energy Agency, 'Net Zero by 2050: A roadmap for the global energy sector', 2021; University of Technology Sydney One Earth Climate Model, 2021; Network for Greening the Financial System

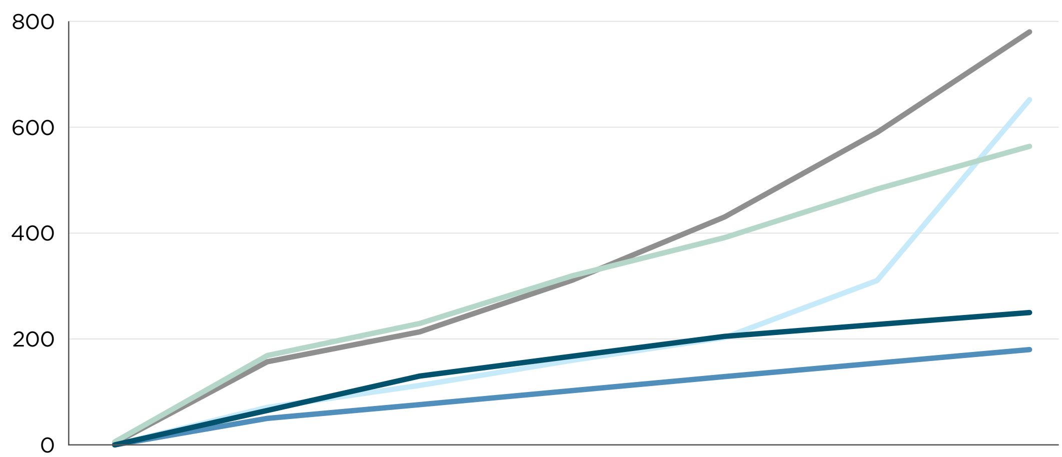
All pathways assume that the world economy will more than double in size by 2050. Overall, GDP is assumed to grow at a compound annual growth rate (CAGR) of between 2.5% and 3.2%. IEA and UTS OECM project a higher growth with a CAGR of 3.1%–3.2%, resulting in 2.5x GDP compared with 2020. NGFS has more conservative assumptions, projecting annual average growth at 2.5%–2.6% versus 2020. In terms of population, IEA and UTS OECM have a similar population trajectory toward 2050, assuming a global population CAGR of 0.7%–0.8%, while the NGFS pathways assume an annual average growth of 0.6%. This results in a population increase of between 1 billion and 2 billion, reaching a total population of 9 billion to 10 billion by 2050.

What are the assumptions of carbon price development from 2020 to 2050?
A carbon price is often presented as a critical driver of decarbonization throughout the economy. Putting a price on carbon impacts the demand for energy by altering the relative costs of using different fuels. Carbon prices can also affect the price of intermediate goods and finished products and influence consumption behavior.

Relevance for financial institutions: Carbon price evolution is a fundamental economic and policy assumption in shaping a financial institution's net-zero planning as it has the potential to incentivize movement away from high-carbon activities.

Example for selected pathways: There are two fundamentally different ways pathway developers define the carbon price. The first is a broader definition, used by NGFS, where the price acts as a proxy for all direct and indirect mitigation policies. Examples of mitigation policies include a carbon tax, emissions permits, and renewable-energy subsidies. The second definition considers carbon price more narrowly as the direct cost of carbon emissions when they occur, as in the case of IEA and UTS OECM. As a result of these divergent definitions, NGFS pathways see a steeper rise in carbon prices and reach a much higher final price of between $550 and $780 in 2050, compared to UTS OECM and IEA, assuming a carbon price of $180 to $250 in 2050.

Figure 18: Carbon price development
(US$ 2019), 2020-2050



	2020	2030	2040	2050
IEA NZE	0	130	205	250
UTS OECM	0	76	129	180
NGFS GCAM	0	112	203	652
NGFS RM	0	214	431	780
NGFS MG	0	229	392	564

Source: International Energy Agency, 'Net Zero by 2050: A roadmap for the global energy sector', 2021; University of Technology Sydney One Earth Climate Model, 2021; Network for Greening the Financial System

What are the policy requirements to achieve the pathway?
Relevance for financial institutions: By comparing the different pathways on policy assumptions, financial institutions may gain insight to sensitivity of a transition to policy engagement. This may help also shape the organization's strategy around policy engagement to support the net-zero transition.

Example for selected pathways: Overall policy assumptions are defined at sector level (e.g., phaseout of coal, bans on internal combustion engine vehicles). GFANZ will detail the policy assumptions for main pathways in upcoming sector briefs. Table 15 serves as an example from IEA to illustrate how pathway developers consider different milestones/policies along the different sectors. UTS OECM and NGFS are not included as they do not include the same level of detail for policy milestones compared to IEA.

Table 15: Policy milestones by sector in IEA NZE

SECTOR	IEA NZE POLICY MILESTONES
Energy/ electricity	**2021:** No new unabated coal plants approved for development. **2021:** No new oil and gas fields approved for development; no new coal mines or mine extensions. **2030:** 1,020 GW annual solar and wind additions and phaseout of unabated coal in advanced economies. **2030:** Target 150 Mt low-carbon hydrogen and 850 GW electrolysis **2035:** Overall net-zero emissions electricity in advanced economies. **2040:** Net-zero emissions electricity globally and phaseout of all unabated coal- and oil-fired power plants. **2045:** Targets of 435 Mt low-carbon hydrogen and 3 000 GW electrolysis. **2050:** Almost 70% of electricity generation globally from solar PV and wind. **2050:** Target of 7.6 Gt CO2 captured.
Buildings	**2025:** No new sales of fossil fuel boilers. **2030:** Universal energy access and all new buildings are zero-carbon ready. **2035:** Most appliances and cooling systems sold are "best in class." **2040**: 50% of existing buildings retrofitted to zero carbon-ready levels. **2045:** 50% of heating demand met by heat pumps. **2050:** More than 85% of buildings are zero-carbon ready.
Industry	**2030:** Most new clean technologies in heavy industry demonstrated at scale. **2035:** All industrial electric motor sales are "best in class." **2040:** Around 90% of existing capacity in heavy industries reach end of investment cycle. **2050:** More than 90% of heavy industrial production is low emissions.
Transport	**2030:** 60% of global car sales are electric vehicles. **2035:** 50% of heavy truck sales are electric and there are no new ICE car sales. **2040:** 50% of fuels used in aviation are low emissions.

Energy demand and supply

What is the assumed energy demand? What is the rate of energy intensity improvements?

Energy demand and the types of energy used to meet that demand have major implications for the level of global emissions. All else equal, those net-zero pathways with higher energy demands modeled will require more zero-carbon power to be provided to both replace fossil fuels and meet energy demand growth. Further fossil fuel use may meet short-term higher energy demand in some regions. The additional need for low-carbon energy and retirement of even more fossil fuel assets alongside rising energy demand demonstrate why energy efficiency measures are necessary.

When financial users examine energy use in pathways, they should understand a couple of key definitions commonly used by energy modelers. These are:

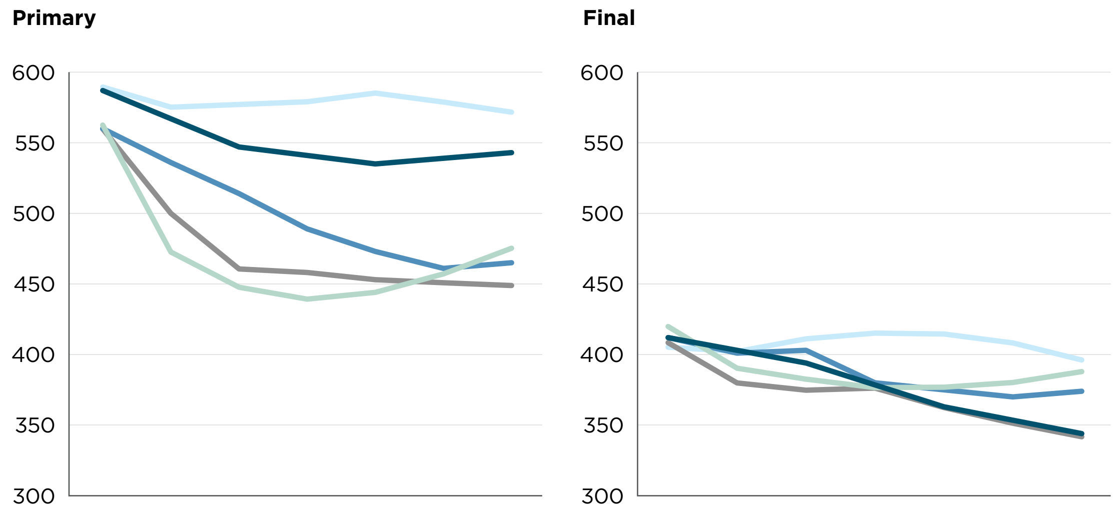
- Primary energy demand: This is the demand for energy in its raw form before it has been converted into other forms of energy like electricity, heat, or transport fuels. An example of primary energy is oil extracted before refining and conversion into fuels or electricity.
- Final energy demand: All energy supplied to the end consumer. Final energy demand can be further disaggregated into end-use sectors: industry, transport, households, services, and agriculture

Relevance for financial institutions: Financial institutions need to understand the future energy demand (primary and final) to understand the scale and scope of investment in energy infrastructure, energy efficiency, and energy production assets (including fuels) required to meet net-zero targets and to benchmark progress.

Example for selected pathways: Across the pathways, primary energy demand falls by between 3% and 20% by 2050 when compared with 2020 levels. Given that all pathways foresee significant economic growth between now and 2050, reductions in primary energy demand can only be obtained through stringent commitments to energy efficiency. Figure 19 shows how primary and final energy develop in the selected pathways from 2020 to 2050.

Figure 19: Primary and final energy demand

EJ/year, 2020-2050



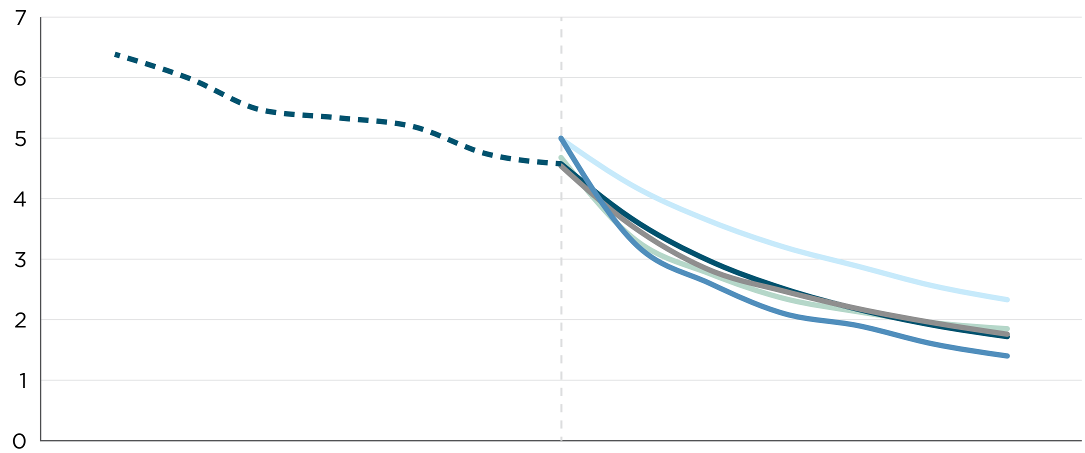
	Primary 2020	Primary 2030	Primary 2040	Primary 2050	Final 2020	Final 2030	Final 2040	Final 2050
IEA NZE	587	547	535	543	412	394	363	344
UTS OECM	560	514	473	465	412	403	375	374
NGFS GCAM	590	577	585	572	405	411	415	396
NGFS RM	560	461	453	449	408	375	362	342
NGFS MG	563	448	444	475	420	383	377	388

Source: International Energy Agency, 'Net Zero by 2050: A roadmap for the global energy sector', 2021; University of Technology Sydney One Earth Climate Model, 2021; Network for Greening the Financial System

The energy intensity of GDP is an indicator to track progress on global energy efficiency. To illustrate the challenge, Figure 20 shows the historical energy intensity of GDP[89] and how the pathways require decoupling of GDP growth and energy use. Under all assessed pathways, the aggressive deployment of efficiency measures produces a fall in primary energy intensity of 3%–4% per year until 2030 and 2%–3% annually thereafter. Some decoupling has occurred in the past few decades, but it has been on the order of 1% per year, demonstrating the acceleration needed to meet the ambition of the intensity reductions required in all pathways.

89 Historical energy and GDP data from IEA.

Figure 20: Historical and future energy intensity of GDP
EJ/GDP, Billion (US$ 2019), 2020-2050



	1990	2000	2010	2020	2030	2040	2050
IEA NZE	-	-	-	4.6	3.0	2.2	1.7
UTS OECM	-	-	-	5.0	2.6	1.9	1.4
NGFS GCAM	-	-	-	5.0	3.6	2.9	2.3
NGFS RM	-	-	-	4.5	2.8	2.2	1.8
NGFS MG	-	-	-	4.7	2.8	2.1	1.9
Historical	6.4	5.5	5.2	-	-	-	-

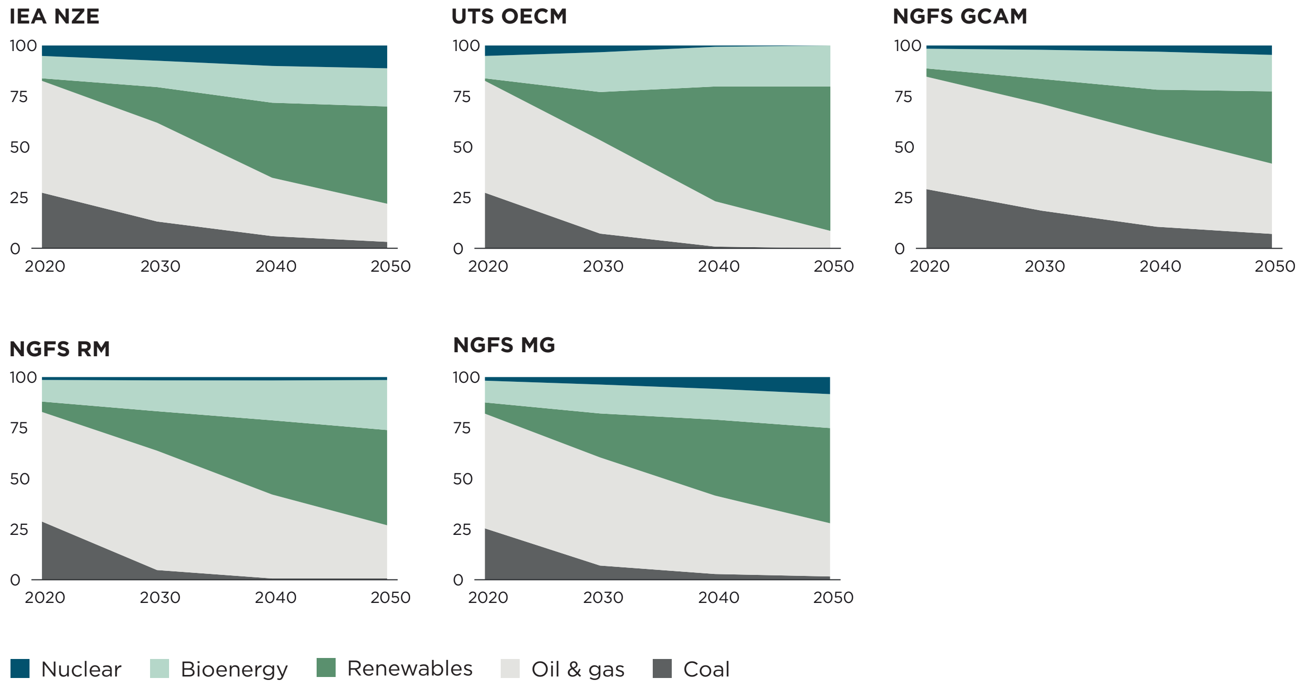
Source: International Energy Agency, 'Net Zero by 2050: A roadmap for the global energy sector', 2021; University of Technology Sydney One Earth Climate Model, 2021; Network for Greening the Financial System

What is the assumed mix of energy supply through time?
The energy landscape will look considerably different in 2050 to support a net-zero future, and financial institutions must be aware of the shifts in energy supply to support this change so that they can align finance appropriately. The assumptions on energy supply illustrate the dependency of different pathways on the different types of energy supply.

Relevance for financial institutions: Financial institutions need to understand the future energy mix to plan investments to support net-zero targets and to benchmark progress.

Example for selected pathways: Renewable energy starts as a small share of global energy production across pathways and grows many times over to power a sustainable global economy. Coal, which makes up nearly one-quarter of global primary energy demand today, reduces to a negligible share of primary energy demand in 2050 for all pathways except NGFS GCAM. Other fossil fuels are also modeled as declining to 2050, albeit by different amounts between the models, with remaining use needing to be abated by natural climate solutions or carbon capture and storage.

Figure 21: Primary energy mix



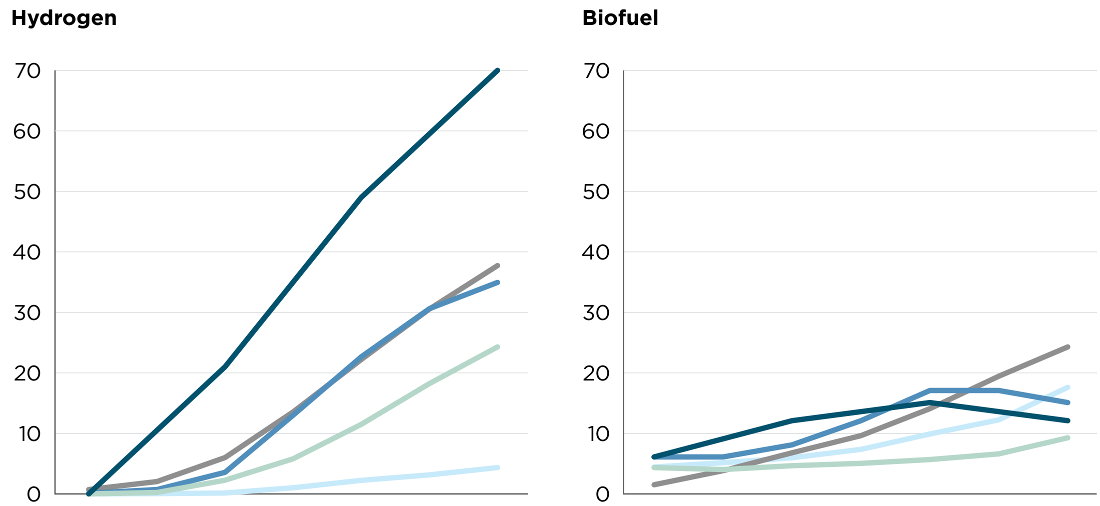
Source: International Energy Agency, 'Net Zero by 2050: A roadmap for the global energy sector', 2021; University of Technology Sydney One Earth Climate Model, 2021; Network for Greening the Financial System

What are the assumptions on adoption of hydrogen and biofuels over time?
Both hydrogen and biofuels, as part of the energy mix, are key assumptions in each model to decarbonize the economy by substituting for fossil fuels.

Relevance for financial institutions: It is helpful for financial institutions to understand the underlying assumptions of new technologies to assess the commercial feasibility of the pathways and their dependency on the development or adoption of alternative energy sources. This helps financial institutions to plan investments to support net-zero targets and to benchmark progress.

Example for selected pathways: Hydrogen produced through electrolysis using renewable energy (green hydrogen) can be used as a transportation fuel for large vehicles and as an energy supply in industrial processes. Biofuels also may have a role to play in the net-zero transition, especially given their potential to replace fossil fuels in transportation. The extent to which hydrogen and biofuel plays a role in the net-zero energy transition varies across pathways. Figure 22 shows that the IEA assumes the biggest role for hydrogen, with production reaching 70 EJ/year by 2050, while NGFS RM assumes the largest increase in biofuels.

Figure 22: Hydrogen and biofuel production
EJ/year, 2020-2050



	Hydrogen 2020	Hydrogen 2030	Hydrogen 2040	Hydrogen 2050	Biofuel 2020	Biofuel 2030	Biofuel 2040	Biofuel 2050
IEA NZE	0	21	49	70	6	12	15	12
UTS OECM	0	4	23	35	6	8	17	15
NGFS GCAM	0	0	2	4	4	6	10	18
NGFS RM	1	6	22	38	1	7	14	24
NGFS MG	0	2	11	24	4	5	6	9

Source: International Energy Agency, 'Net Zero by 2050: A roadmap for the global energy sector', 2021; University of Technology Sydney One Earth Climate Model, 2021; Network for Greening the Financial System

Investments

What are the assumptions on investment needed to achieve the pathway? How are the financial flows distributed during the time horizon?

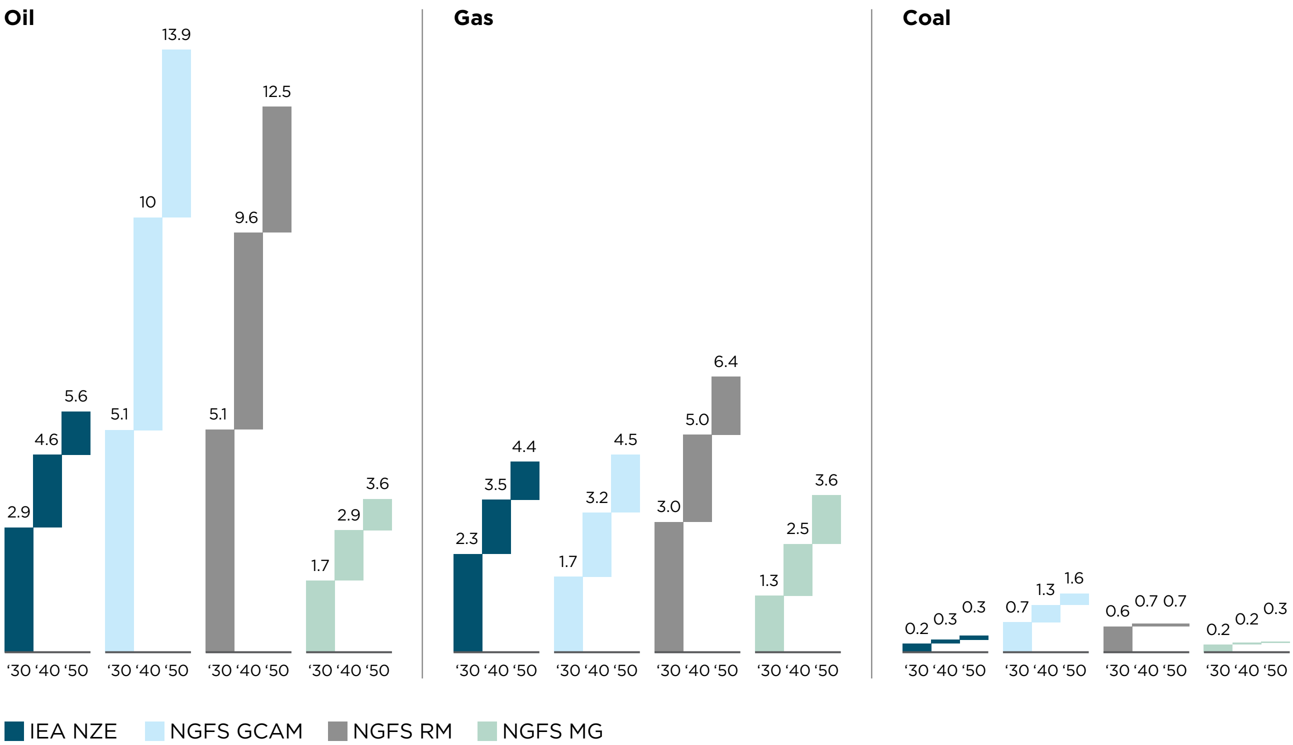
Not only do the pathways provide assumptions on energy demand and energy mix, but the pathway providers have also included the scale of investments needed to achieve these assumed energy models.

Relevance for financial institutions: It is important for financial institutions to understand the required level of investment assumed for each pathway to identify potential gaps and opportunities to support firms in the transition and benchmark their net-zero performance. When considering the remaining fossil fuel investments within the pathways, financial users should understand how these investment variables are defined.

Example for selected pathways: Both IEA and NGFS investment figures focus on capital expenditures and do not include costs such as operating expenses. Not all pathways consider fossil fuel investment, and different pathways also consider different types of assets when estimating fossil fuel investment. Figure 23 gives an overview of implied fossil fuel investment in the pathways.

Figure 23: Cumulative fossil fuel investments

Trillion (US$ 2019), 2020-2050



Source: International Energy Agency, 'Net Zero by 2050: A roadmap for the global energy sector', 2021; University of Technology Sydney One Earth Climate Model, 2021; Network for Greening the Financial System

Substantive differences exist between pathways regarding fossil fuel investments. Some of the differences stem from higher fossil fuel use on the NGFS pathways. However, the biggest difference comes from estimation methods. NGFS states in their documentation that "investments into fossil fuel extraction are estimated based on constant investment intensity assumption of fuel use, and so likely overestimate the required investments where declining demand can be met with existing projects requiring less investments than new ones".[90]

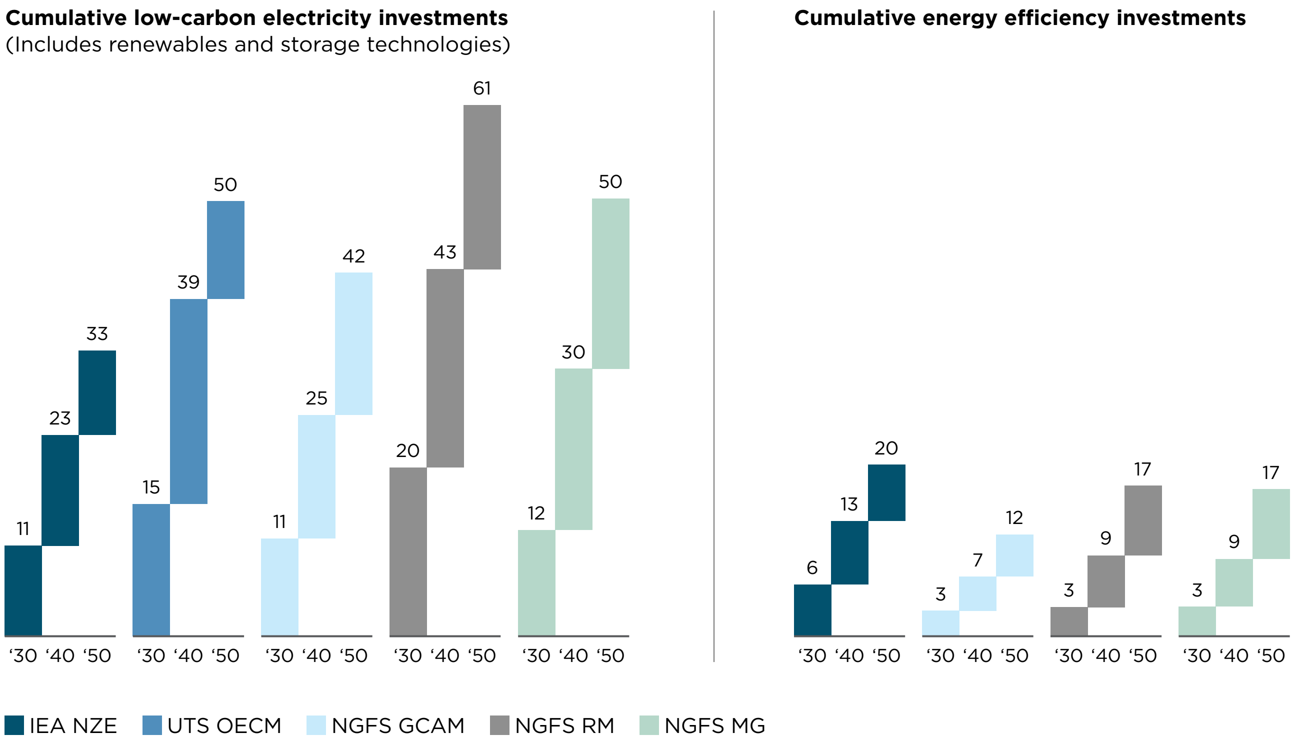
Nonetheless, there seems to be consensus on the need to reduce the investment in all fossil fuels. In the 2040s there is a significant reduction in gas investment in all pathways and almost no scope for coal investments.

In addition to major investments in energy efficiency measures noted previously, capital must flow into the development and deployment of low-carbon solutions.[91] Figure 24 shows the cumulative low-carbon investments until 2050. In all pathways, the scale of this investment is multiple times larger than fossil-fuel investment in the next three decades. Energy efficiency investment is not explicitly modeled in the UTS OECM, but in all other pathways this investment is comparable to the investment in fossil fuel supply.

90 NGFS Climate Scenarios for central banks and supervisors. June 2021.

91 Low-carbon solutions include all renewable energy and electricity storage investments; NGFS pathways also include investments in electricity transmission and distribution.

Figure 24: Low-carbon and energy-efficiency investments[92]
Trillion (US$ 2019), 2020-2050



Source: International Energy Agency, 'Net Zero by 2050: A roadmap for the global energy sector', 2021; University of Technology Sydney One Earth Climate Model, 2021; Network for Greening the Financial System

Within low-carbon investments, electrification is of particular relevance. It will play a critical role in reaching net zero, as zero-emissions power generated from wind and solar can be used to replace fossil fuels in transportation, heating, and certain industries. The automotive sector is perhaps the best-known example of the advance of electrification, as electric vehicles begin to replace internal-combustion vehicles.

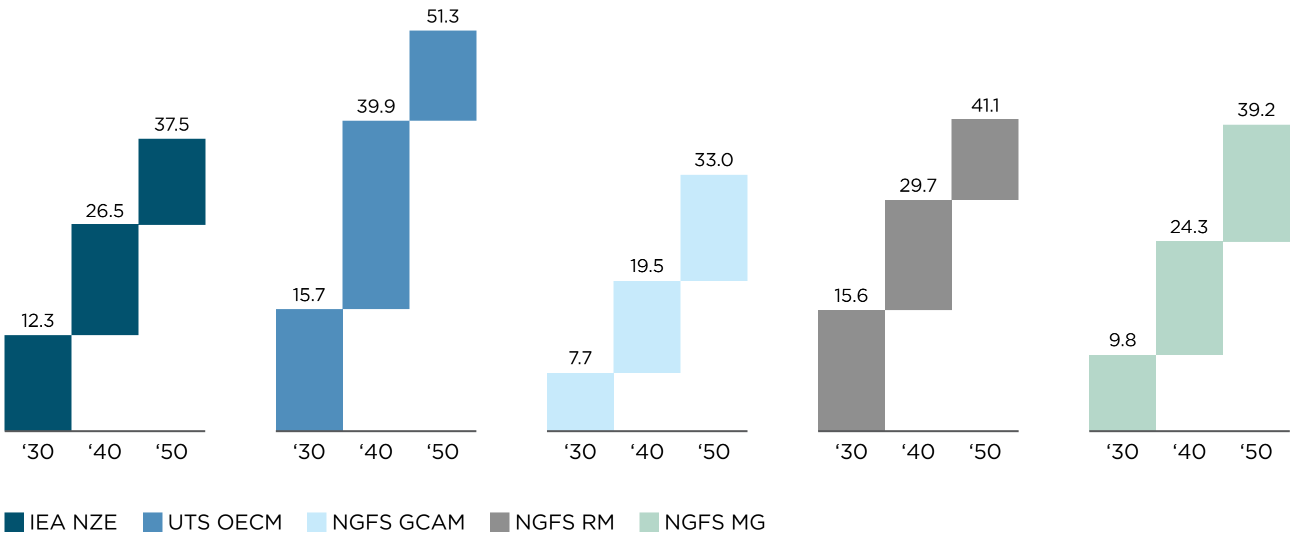
All pathways see electrification alongside energy-efficiency measures as fundamental to decarbonization throughout the global economy. Major investments are required to scale up demonstration technologies to electrify industry and generate electricity to meet expanding needs for green hydrogen, electric vehicles, and numerous other uses. Such electrification is crucial to decarbonizing hard-to-abate sectors, where often transitioning away from fossil fuels implies a significant increase in electricity demand, either for processes that use electricity or for electrification of process heat. Only 2% to 9% of the total cumulative electricity investments by 2050[93] are directed toward fossil fuels across all pathways.

92 Energy efficiency investment data is not available in the UTS OECM pathway.

93 Of the grand total of electricity investments into renewables, nuclear, fossil fuels, and storage.

Figure 25: Electricity supply investment

Trillion (US$ 2019), 2020-2050



Source: International Energy Agency, 'Net Zero by 2050: A roadmap for the global energy sector', 2021; University of Technology Sydney One Earth Climate Model, 2021; Network for Greening the Financial System:

3. Credibility and feasibility of the pathway

What was the pathway created for?
Example for selected pathways:
IEA: The Net Zero by 2050 report is a combined effort from IEA's World Energy Outlook team and Energy Technology Perspectives team. It was primarily created to understand the pathway for the energy sector (e.g., the trajectory of coal, oil, and natural gas production).

UTS OECM: The UTS OECM pathway was commissioned by the UN-convened Net-Zero Asset Owner Alliance (NZAOA) to provide better granularity on the sector-specific emissions pathways, aligned with GICS, BICS, and NACE classifications for system boundaries, and including all GHG emissions.

NFGS: The NGFS pathways were adapted from climate scenarios originally designed to provide policymakers with advice on the risks from climate change and identify possible solutions; NGFS pathways were created to help central banks and supervisors explore the possible impacts, of physical climate change risk and transition risk, on the economy and financial system.

Has the pathway been evaluated by industry and other key stakeholders (e.g., regulators) to assess the commercial feasibility?
Example for selected pathways:
IEA: For each sector and for most specific energy sources, IEA enlists contributing industry experts. As IEA links its energy modeling outputs to other models beyond the scope of the energy system (e.g., GHG emissions from land use), they collaborate with the International Institute for Applied Systems Analysis. For macroeconomic analysis, IEA partners with the International Monetary Fund (IMF).

Moreover, many senior government officials and international experts provided input and reviewed preliminary drafts of the NZE report.

- Examples of organizations from the scientific community include: National Renewable Energy Laboratory (NREL); Grantham Research Institute on Climate Change and the Environment, UK; Cambridge University; International Renewable Energy Agency NREL; Lawrence Berkeley National Laboratory.
- Governmental organizations include US Department of Energy; Ministry of Ecology and Environment of People's Republic of China; the Institute of Energy Economics, Japan; Korea Energy Economics Institute.
- Industry experts from Volkswagen, Hitachi ABB Power Grids, EDF, Iberdrola, Toyota, Shell, World Steel.

UTS OECM: The 2020 model documentation developed for the NZAOA states that the pathway has undergone peer review by an expert group consisting of representatives from the Energy Transition Commission (ETC), the Exponential Roadmap Initiative, and the Potsdam Institute for Climate Impact Research, and additional input and review were provided by Science-Based Targets Initiative (SBTi), Carbon Disclosure Project (CDP), Rocky Mountain Institute (RMI), the Carbon Risk Real Estate Monitor (CRREM), and the World Wildlife Federation (WWF). In addition, NZAOA member financial institutions such as Aviva, Storebrand, and Allianz provided input.

NGFS: The NGFS pathways have been generated with GCAM, MESSAGEix-GLOBIOM, and REMIND-MAgPIE. These models are well-established IAMs, included in hundreds of peer-reviewed scientific studies on climate change mitigation.

The NGFS Net Zero by 2050 scenario is in partnership with an academic consortium from the Potsdam Institute for Climate Impact Research, International Institute for Applied Systems Analysis, University of Maryland (UMD), Climate Analytics (CA), Swiss Federal Institute of Technology in Zurich (ETHZ), and National Institute of Economic and Social Research (NIESR).

Have the model and scenarios been peer reviewed? What are the current use cases of the scenarios (e.g., alignment, risk)? Has the pathway been submitted for international model intercomparison exercises (e.g., IPCC database)?

Example for selected pathways: Various actors have used the global pathways assessed in this report. For example, the NZAOA commissioned the UTS OECM pathway for target-setting purposes but allows for other pathways. Financial institutions and the real economy widely use IEA's various pathways for target setting. NGFS pathways are produced by modelers and organizations involved in authoring the IPCC's Working Group III report. Furthermore, the specific storylines and variables were also selected in consultation with NGFS members (central banks) and are used by supervisors worldwide, primarily for risk assessments and climate stress-testing exercises. The NGFS models are well documented across peer-reviewed publications and included in IPCC assessment reports.

APPENDIX D.

Glossary and abbreviations

Table 16: Glossary

TERMINOLOGY	DESCRIPTION	SOURCE
1.5 degrees C-aligned	Target is aligned with scenarios that yield a long-term warming outcome of <1.5 degrees C with some probability (e.g., 50%, 66%) and some amount of overshoot (no/low), both of which should be explicitly specified.	Race to Zero, Race to Zero Lexicon, April 2021.
Afforestation	Planting of new forests on lands that historically have not contained forests.	IPCC, Global Warming of 1.5 degrees C, 2018
Anthropogenic emissions	Emissions of greenhouse gases (GHGs), precursors of GHGs and aerosols caused by human activities. These activities include the burning of fossil fuels, deforestation, land use and land use changes (LULUC), livestock production, fertilization, waste management, and industrial processes.	IPCC, Global Warming of 1.5 degrees C, 2018
Anthropogenic removals	Anthropogenic removals refer to the withdrawal of GHGs from the atmosphere as a result of deliberate human activities. These include enhancing biological sinks of CO_2 and using chemical engineering to achieve long term removal and storage. carbon dioxide capture and storage (CCS) from industrial and energy-related sources, which alone does not remove CO_2 in the atmosphere, can reduce atmospheric CO_2 if it is combined with bioenergy production (BECCS).	IPCC, Global Warming of 1.5 degrees C, 2018
Bioenergy	Energy derived from any form of biomass or its metabolic by-products.	IPCC, Global Warming of 1.5 degrees C, 2018
Biofuels	A fuel, generally in liquid form, produced from biomass. Biofuels currently include bioethanol from sugarcane or maize, biodiesel from canola or soybeans, and black liquor from the paper manufacturing process.	IPCC, Global Warming of 1.5 degrees C, 2018
Biomass	Living or recently dead organic material.	IPCC, Global Warming of 1.5 degrees C, 2018
Bioenergy with carbon dioxide capture and storage (BECCS)	Carbon dioxide capture and storage (CCS) technology applied to a bioenergy facility. Note that depending on the total emissions of the BECCS supply chain, carbon dioxide can be removed from the atmosphere.	IPCC, Global Warming of 1.5 degrees C, 2018
Carbon dioxide (CO_2)	A naturally occurring gas, CO_2 is also a by-product of burning fossil fuels (such as oil, gas, and coal), of burning biomass, of land use changes (LUC) and of industrial processes (e.g., cement production). It is the principal anthropogenic greenhouse gas (GHG) that affects the Earth's radiative balance.	IPCC, Global Warming of 1.5 degrees C, 2018
Global carbon budget	The estimated cumulative amount of global carbon dioxide emissions that is estimated to limit global surface temperature to a given level above a reference period, taking into account global surface temperature contributions of other GHGs and climate forcers	IPCC, Global Warming of 1.5 degrees C, 2018
Deforestation	Conversion of forest to non-forest.	IPCC, Global Warming of 1.5°C, 2018

TERMINOLOGY	DESCRIPTION	SOURCE
Direct air capture and storage (DAC)	Chemical process by which CO2 is captured directly from the ambient air, with subsequent storage.	IPCC, Global Warming of 1.5 degrees C, 2018
Fossil fuels	Carbon-based fuels from fossil hydrocarbon deposits, including coal, oil, and natural gas	IPCC, Global Warming of 1.5 degrees C, 2018
GHG	Greenhouse gases are those gaseous constituents of the atmosphere, both natural and anthropogenic, that absorb and emit radiation at specific wavelengths within the spectrum of terrestrial radiation emitted by the earth's surface, the atmosphere itself, and by clouds. This property causes the greenhouse effect.	IPCC, Global Warming of 1.5 degrees C, 2018
Kyoto Protocol	The Kyoto Protocol to the United Nations Framework Convention on Climate Change (UNFCCC) is an international treaty adopted in December 1997 in Kyoto, Japan, at the Third Session of the Conference of the Parties (COP3) to the UNFCCC.	IPCC, Global Warming of 1.5 degrees C, 2018
Integrated Assessment Model (IAM)	Integrated assessment models (IAMs) integrate knowledge from two or more domains into a single framework. They are one of the main tools for undertaking integrated assessments.	IPCC, Global Warming of 1.5 degrees C, 2018
Carbon removal	Removal of greenhouse gases (GHGs) from the atmosphere by deliberate human activities, i.e., in addition to the removal that would occur via natural carbon cycle processes. For CO_2, removals can be achieved with direct capture of CO_2 from ambient air, bioenergy with carbon capture and sequestration (BECCS), afforestation, reforestation, biochar, and ocean alkalinization, among others.	IPCC, Global Warming of 1.5 degrees C, 2018
Net-zero CO_2 emissions	Conditions in which any remaining anthropogenic carbon dioxide (CO_2) emissions are balanced globally by anthropogenic CO_2 removals. Net-zero CO_2 emissions are also referred to as carbon neutrality.	IPCC, Global Warming of 1.5 degrees C, 2018
Offsetting	Reducing GHG emissions (including through avoided emissions) or increasing GHG removals through activities external to an actor, in order to compensate for GHG emissions, such that an actor's net contribution to global emissions is reduced. Offsetting is typically arranged through a marketplace for carbon credits or other exchange mechanism. Offsetting claims are only valid under a rigorous set of conditions, including that the reductions/removals involved are additional, not over-estimated, and exclusively claimed. Further, offsetting can only be used to claim net-zero status to the extent it is "like-for-like" with any residual emissions.	Race to Zero, Race to Zero Lexicon, April 2021.
Overshoot	The temporary exceedance of a specified level of global warming, such as 1.5°C. Overshoot implies peak followed by a decline in global warming, achieved through anthropogenic removal of CO_2 exceeding remaining CO_2 emissions globally.	IPCC, Global Warming of 1.5 degrees C, 2018
Paris Agreement	The Paris Agreement under the United Nations Framework Convention on Climate Change (UNFCCC) was adopted on December 2015 in Paris, France, at the 21st session of the Conference of the Parties (COP) to the UNFCCC.	IPCC, Global Warming of 1.5 degrees C, 2018
Stranded assets	Assets exposed to devaluations or conversion to 'liabilities' because of unanticipated changes in their initially expected revenues due to innovations and/or evolutions of the business context, including changes in public regulations at the domestic and international levels	IPCC, Global Warming of 1.5 degrees C, 2018
United Nations Framework Convention on Climate	The UNFCCC was adopted in May 1992 and opened for signature at the 1992 Earth Summit in Rio de Janeiro. It entered into force in March 1994 and as of May 2018 had 197 parties (196 States and the European Union). The Convention's ultimate objective is the "stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system." The provisions of the Convention are pursued and implemented by two treaties: the Kyoto Protocol and the Paris Agreement	IPCC, Global Warming of 1.5 degrees C, 2018

Table 17: Abbreviations

ABBREVIATION	FULL NAME
AR6	IPCC's Sixth Assessment Report
BECCS	Bioenergy with Carbon Capture and Storage
CA	Climate Analytics
CCS	Carbon Capture and Storage
CDP	Carbon Disclosure Project
CDR	Carbon Dioxide Removal
CH4	Methane
CO2	Carbon Dioxide
COP	Conference of the Parties (United Nations Climate Change Conference)
CRREM	Carbon Risk Real Estate Monitor
DAC	Direct Air Capture
DE	Developed Economies
EM	Emerging Markets
ETC	Energy Transition Commission
ETHZ	Swiss Federal Institute of Technology in Zurich
ETP	Energy Transition Partnership
FI	Financial Institution
GAINs	Greenhouse Gas and Air Pollution Interactions and Synergies
GCAM	Global Change Analysis/Assessment Model
GHG	Greenhouse Gas
GIMF	Global Integrated Monetary and Fiscal Model
GLOBIOM	IIASA's Global Biosphere Management Model
Gt	Gigatonne
Hector	A Physical Earth Simulator
HFCs	Hydrofluorocarbons
IAM	Integrated Assessment Model
IEA	International Energy Agency
IEAM	Integrated Energy Assessment Model
IGSM	Integrated Global System Model
IIASA	International Institute for Applied Systems Analytics
IMAGE	Integrated Model to Assess the Global Environment
IMF	International Monetary Fund
IPCC	Intergovernmental Panel on Climate Change
MAGICC	Model for the Assessment of Greenhouse Gas Induced Climate Change
MAgPIE	Model of Agricultural Production and its Impact on the Environment
MESSAGE	Model for Energy Supply Strategy Alternatives and their General Environmental Impact
MG	MESSAGE-GLOBIOM
N20	Nitrous Oxide
NGFS	Network for Greening the Financial System
NIESR	National Institute of Economic and Social Research
NREL	National Renewable Energy Laboratory
NZAM	Net-Zero Asset Managers Initiative

ABBREVIATION	FULL NAME
NZAOA	Net-Zero Asset Owner Alliance
NZBA	Net-Zero Banking Alliance
NZE	Net-Zero Emissions
NZFSPA	Net-Zero Financial Service Providers Alliance
NZIA	Net-Zero Insurance Alliance
NZICI	Net-Zero Investment Consultants Initiative
OECD	Organization for Economic Co-operation and Development
OECM	One Earth Climate Model
p# (e.g., P3)	Pathway # (e.g., Pathway 3)
PAII	Paris Aligned Investment Initiative
PFCs	Perfluorocarbons
PNNL	Pacific Northwest National Laboratories
REMIND	Regionalized Model of Investments and Technological Development
RM	REMIND-MAgPIE
RMI	Rocky Mountain Institute
SF6	Sulphur Hexafluoride
SR# (e.g., SR15)	Special Report # (e.g., Special Report 15)
UMD	University of Maryland
UNFCCC	United Nations Framework Convention on Climate Change
UTS	University of Technology Sydney
WEM	World Energy Model
WWF	World Wildlife Federation

APPENDIX E.

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