Insights
ESG

Climate Scenarios
Unpacking the 1.5°C Pathways

Kushal Shah
Climate Specialist, Vice President
ESG Investment Strategy

Mohit Rakyan
Senior Research Analyst
Global Equity Beta Solutions

The 1.5°C Scenario Narratives

In a previous paper (see: Climate Scenarios: an Introduction), we outlined various climate scenarios and models that are provided by major international providers. In this paper, we take a deeper look at the underlying assumptions and outputs of several 1.5°C scenarios, and highlight some key areas of difference among them. The 1.5°C level is a critical limit for climate regulation around the globe, as the landmark 2015 Paris Accord aimed to hold down global warming to well below 2°C above pre-industrial levels, and pursue efforts to limit the temperature increase to 1.5°C.

The three main scenario data providers focusing on 1.5°C scenarios outline different paths to reach that goal, in terms of emissions reduction, timing and other variables. These differences often arise due to the range of assumptions applied to the frameworks, as well as the various ways the integrated assessment models (IAMs) simulate various building blocks and the interactions among them. While understanding the construction of and interactions between the various building blocks is out of scope for this paper, we study how the scenarios differ qualitatively (i.e., in assumptions, high-level modeling choices, etc.), as well as quantitatively (i.e., emissions, energy use, carbon pricing, and other outputs).

Two key takeaways from our analysis include:

- Several data points show a fair degree of agreement across various scenarios. For example, CO_2 and Kyoto emissions, green/brown sources of energy are similar across scenarios.
- However, for other data points like use of carbon removal and the increase in carbon prices, the scenarios show more variation.

Overall, for investors that wish to align their activities with 1.5oC scenarios, we believe these outputs can potentially be used to guide scenario analysis, stress testing, investee company engagements, and portfolio alignment targets.

We focus our attention on scenarios from three providers: the International Energy Agency (IEA), the Intergovernmental Panel on Climate Change (IPCC) and the Network for Greening the Financial System (NGFS). All scenarios considered here are characterised by a temperature outcome of 1.5°C with no or low overshoot (50% probability).[1]

1 **IEA Net Zero Emissions by 2050[2,3] (IEA-NZE)** This scenario aims to achieve net zero CO_2 emissions from energy and industrial processes by 2050. Its primary lever relies on a large shift to renewables, though this follows along with a slower movement away from fossil fuels relative to the other 1.5°C scenarios. The IEA Scenarios are updated biennially, and are an integral part of discussions at the UN Climate Change Conference of Parties (COP).

2 **IPCC Focus on Renewables[4] (IPCC-Ren)** This scenario implies a large focus on climate-related policy to limit global warming, a regulatory shift that could make carbon based fuels very expensive. This scenario, given the decreasing cost of photovoltaics, wind power and battery storage, along with the accelerating progress in solar and wind power technology, and the increase in carbon prices, assumes that electricity will soon be cheaper than carbon based fuels. In addition, demand side innovation is likely to induce a fundamental transformation of energy systems towards a dominance of electricity based end uses. We see a jump in which electricity will account for about 66% of final energy by 2050 (more than 3 times its current value), and renewables will account for about 75% of the primary energy source (nearly 4 times its current value).

3 **IPCC Focus on SDGs[5] (IPCC-SP)** This scenario focuses on economic development, education, technological progress, less-resource-intensive lifestyles, and ambitious climate policies, all geared toward progress on the UN Sustainable Development Goals. Furthermore, the model expands on the existing SDGs, requiring not only strong interventions and lifestyle changes, but also sustainable development packages, redistribution of carbon pricing revenues, and an increased focus on sufficient and healthy nutrition — all of which are likely to aid significant climate action within the framework of the UN 2030 Agenda. Given these assumed policy-driven distributions, the shift to greener sources of energy is slower compared to the other scenarios.

4 **IPCC Low Energy Demand (IPCC-LD)** This scenario focuses on demand-side solutions. It assumes a rapid transition towards producing electricity via low-emission methods and increased use of electricity, instead of other fuels. The scenario looks closely at sectors such as transportation, but it assumes a significant reduction in energy demand across all sectors, resulting in the lowest energy demand across all scenarios considered. In parallel, this scenario also includes substantial reductions in fossil fuels (to the lowest levels across the scenarios considered), higher energy efficiency, and increased use of alternate carriers such as hydrogen. Like the previous scenarios, this also requires significant changes in societal behaviour, including shifts to less-resource-intensive lifestyles and diets. Early action and accelerated demand-side solutions minimize the need for Carbon Dioxide Removal (CDR) technologies.

5 **NGFS Net Zero 2050 (NGFS-NZORD)[6]** Net Zero 2050 is an ambitious scenario that limits global warming to 1.5°C through stringent climate policies and innovation, with the goal of reaching net zero CO_2 emissions around 2050. In this scenario, some jurisdictions such as the US, EU and Japan reach net zero for all greenhouse gases by this point. This scenario assumes that ambitious climate policies are introduced immediately. CDR is used to accelerate the decarbonisation but kept broadly in line with sustainable levels of bioenergy production. In this scenario, physical risks, which broadly encompass the quantification of a company or country's exposure to natural catastrophes that could be reliably tied to climate change and a warming environment, are relatively low. However, transition risks are high.

6 **NGFS Divergent Net Zero 2050 (NGFS-NZDIS)**[7] Divergent Net Zero is based on the goal to reach net-zero by 2050, but it assumes higher costs due to divergent policies introduced across sectors, and a quicker phase out of fossil fuels. This scenario differentiates itself from NGFS-NZORD by assuming that climate policies are more stringent in the transportation and buildings sectors. This illustrates a potential situation in which the failure to coordinate policy stringency across sectors results in a high burden on consumers, but industry and energy supply is still not efficiently regulated. Furthermore, the availability of CDR technologies is assumed to be lower than in NGFS-NZORD. This scenario leads to considerably higher transition risks than NGFS-NZORD but overall the lowest physical risks among NGFS scenarios.

Comparing the Six Scenarios

To begin with, all scenarios assume that socioeconomic parameters are in line with current economic and population trends, with the exception of IPCC-SP (which assumes low population growth). As for the regulatory backdrops, the scenarios include policies such as carbon taxes, economic incentives, and subsidies. These policies are quantified, then converted and manifested into carbon prices. Policies are assumed to be introduced immediately in all scenarios; however the strength of the policies varies across sectors/regions.

The scenarios differ in their analysis of the world's path toward net zero CO_2 emissions. IEA-NZE reaches the target earliest (in 2050), while IPCC-SP hits the goal latest (in 2060–2070). The use of CDR varies; IEA-NZE and NGFS-NZORD have high usage, while IPCC-LD has minimal usage. Not surprisingly, carbon prices increase over time across all scenarios. However, IEA-NZE and IPCC-SP display relatively lower carbon prices, while IPCC-Ren and NGFS-NZDIS output the highest prices.

Green energy use[8] increases sharply by 2030, with IPCC-Ren, NGFS-NZORD and NGFS-NZDIS showing the highest uptick. Brown energy use[9] decreases at a moderate pace by 2030, with IPCC-LD showing the largest drop. The use of all three main fossil fuel sources decreases; however, coal use falls at the fastest pace, followed by gas use. Oil use shrinks at the slowest pace.

Figures 1 and 2 outline some of the key metrics that are derived from the six scenarios.

Figure 1
Emissions, CDR and Carbon Pricing Outputs Across Six Scenarios

Scenario Code	Provider	Scenario Name	Model	Update Frequency	Year Net Zero CO_2 is achieved	CO_2 Removal (Gt CO_2 annual by 2050)	Carbon Prices by 2050 (USD 2010 per tonne)
IEA-NZE	IEA	NZE by 2050	Global Energy & Climate (GEC)	Biennial	2050	High Usage — 7.6 Gt CO_2	Low Prices — $290
IPCC-Ren	IPCC	DeepElec_SSP2_HighRE_budg900 (Ren)	REMIND-MAgPIE 2.1–4.3	5–7 years	2050–2060	Low-Medium Usage — 3.6 Gt CO_2	High Prices — $673
IPCC-SP	IPCC	SusDev_SDP-PkBudg1000 (SP)	REMIND-MAgPIE 2.1–4.2	5–7 years	2060–2070	Low Usage — 2.1 Gt CO_2	Low Prices — $332
IPCC-LD	IPCC	LowEnergyDemand_1.3_IPCC (LD)	MESSGAEix-GLOBIOM 1.0	5–7 years	2050–2060	No Usage	High Prices — $629
NGFS-NZORD	NGFS	Net Zero 2050 (Orderly)	REMIND-MAgPIE 3.0–4.4	Annual	2050–2060	High Usage — 7.8 Gt CO_2	Medium Prices — $451
NGFS-NZDIS	NGFS	Divergent Net Zero 2050 (Disorderly)	REMIND-MAgPIE 3.0–4.4	Annual	2050–2060	Medium Usage — 5.3 Gt CO_2	High Prices — $701

Source: State Street Global Advisors, IEA, NGFS, IPCC as of December 2023.
For CO_2 Removal and Carbon Prices by 2050 columns, Low-Medium-High scale is relative to the six scenarios considered.

Figure 2
Expected Changes in Primary and Secondary Energy Use: Green/Brown Sources

Scenario Code	Secondary Energy		Primary Energy from Fossil Fuels		
	Green Energy Use by 2030 (Relative to 2020 Levels)*	Brown Energy Use by 2030 (Relative to 2020 Levels)**	Coal Use by 2030 (Relative to 2020 Levels)	Oil Use by 2030 (Relative to 2020 Levels)	Gas Use by 2030 (Relative to 2020 Levels)
IEA-NZE	High Increase (+78%)***	Low Reduction (-21%)***	Moderate reduction (-53%)	Low Reduction (-21%)	Very low reduction (-6%)
IPCC-Ren	Very High Increase (+98%)	Moderate Reduction (-31%)	Very High reduction (-90%)	Very Low Reduction (-3%)	Moderate reduction (-33%)
IPCC-SP	High Increase (+76%)	Low Reduction (-18%)	High reduction (-76%)	Very Low Reduction (-4%)	Very Low reduction (-2%)
IPCC-LD	High Increase (+65%)	Moderate Reduction (-51%)	High reduction (-75%)	Moderate reduction (-47%)	Moderate reduction (-47%)
NGFS-NZORD	Very High Increase (+93%)	Low Reduction (-29%)	High reduction (-75%)	Very Low Reduction (-9%)	Low reduction (-24%)
NGFS-NZDIS	Very High Increase (+101%)	Moderate Reduction (-34%)	High reduction (-78%)	Low Reduction (-15%)	Low reduction (-29%)

Source: State Street Global Advisors, IEA, NGFS, IPCC as of December 2023.
Scale: Very Low: <10%; Low: 10–30%; Moderate: 30-70%; High 70–90%; Very High >90%. Primary energy from fossil fuels includes coal, oil and gas used with CCS and without CCS technology (in other words, both abated and unabated use).
* Secondary Energy from Green sources include renewables (such as solar, wind, hydro, geothermal), biomass, nuclear as well as fossil fuels used with CCS technology.
** Secondary Energy from Brown sources include coal, oil and gas without CCS technology.
*** Due to data availability, IEA-NZE Green and Brown Energy Use data utilises final energy data instead of secondary energy data.

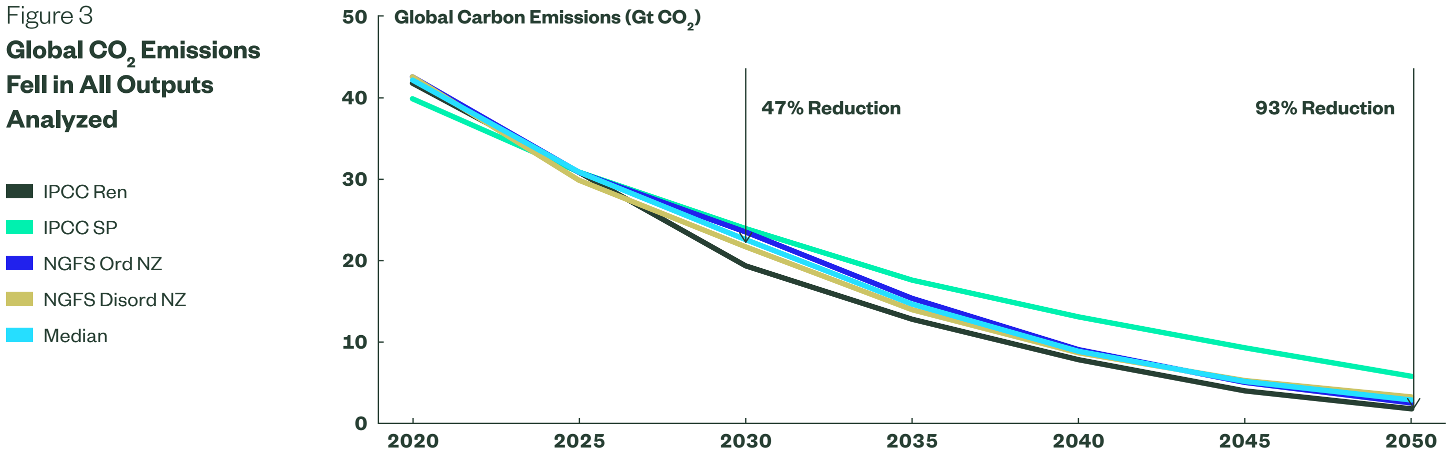
Primary vs Secondary vs Final Energy[10]
Energy in its simplest definition means the amount of work or heat delivered. Here, to keep it simple, we look at how energy becomes useful to humans, its flows and conversions from one point to another.
Primary energy (or the energy source) is the energy embodied within natural sources (oil, gas, etc.) that hasn't gone through any conversion. This is a very commonly used statistic and widely available (e.g. barrels of oil, tonnes of uranium).
The raw energy is then transformed into a more useable form, termed as secondary energy, by various methods, including conversion into electricity and heat. This conversion can be highly inefficient,[11] particularly in the case of fossil fuels, nuclear energy and biomass.
Lastly, when this secondary energy is delivered to its end use facilities, wherein it can be used by humans (such as for powering our electronic appliances), it is called final energy.
From an investor point of view, it is important to understand which metrics to use in different use cases, with the understanding that there is no perfect proxy. Since certain companies derive revenues from the final energy supplied to their customers, investors may prefer to look at final energy for green/brown revenue metrics. However, due to data limitations (except with the IEA), it is possible only to use secondary energy to determine the green/brown contributions. In our view, this is not a large challenge, as final energy differs from secondary energy mainly through transmission losses and hence, the takeaways are likely to be similar. On the other hand, for companies that own and extract fossil fuel reserves, the primary energy is likely to correlate more closely compared to secondary/final energy. As a result, in this paper, we present primary energy data for fossil fuel sources, and secondary energy data to differentiate green and brown sources in aggregate.

A Deep Dive Using the REMIND-MAgPIE[12, 13] IAM

We now limit our attention to the four scenarios run using the REMIND-MAgPIE IAM. Climate scenarios are typically run across various IAMs, and each IAM differs in its assumptions and building blocks. It is challenging to interpret data coming from different models. Therefore, we make deeper comparisons of scenarios using the REMIND-MAgPIE model only, to avoid model-related effects and to maintain comparability. Specifically, we compare outputs for IPCC-Ren, IPCC-SP, NGFS-NZORD and NGFS-NZDIS.

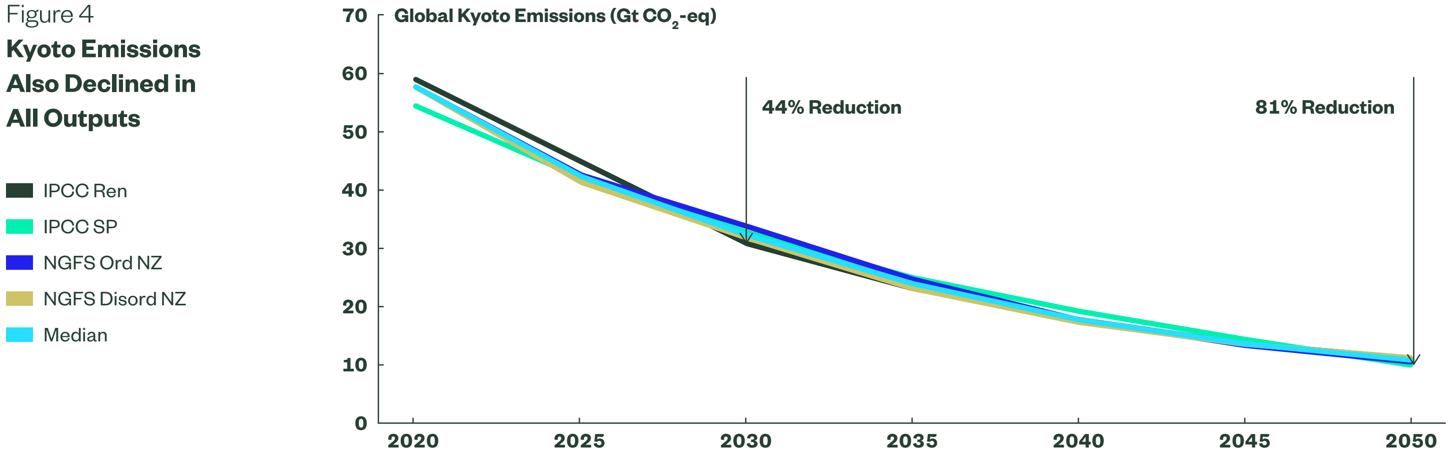
Figure 3 shows that globally, CO_2 emissions decline significantly in all scenarios, with a median decrease of 47% by 2030, and 93% by 2050, relative to 2020 levels. Kyoto emissions (which include five other greenhouse gases in addition to CO_2) follow a similar trajectory, with a median decrease of 44% by 2030, and 81% by 2050, relative to 2020 levels (Figure 4).

Figure 3
Global CO_2 Emissions Fell in All Outputs Analyzed



Source: State Street Global Advisors, NGFS, IPCC as of December 2023.

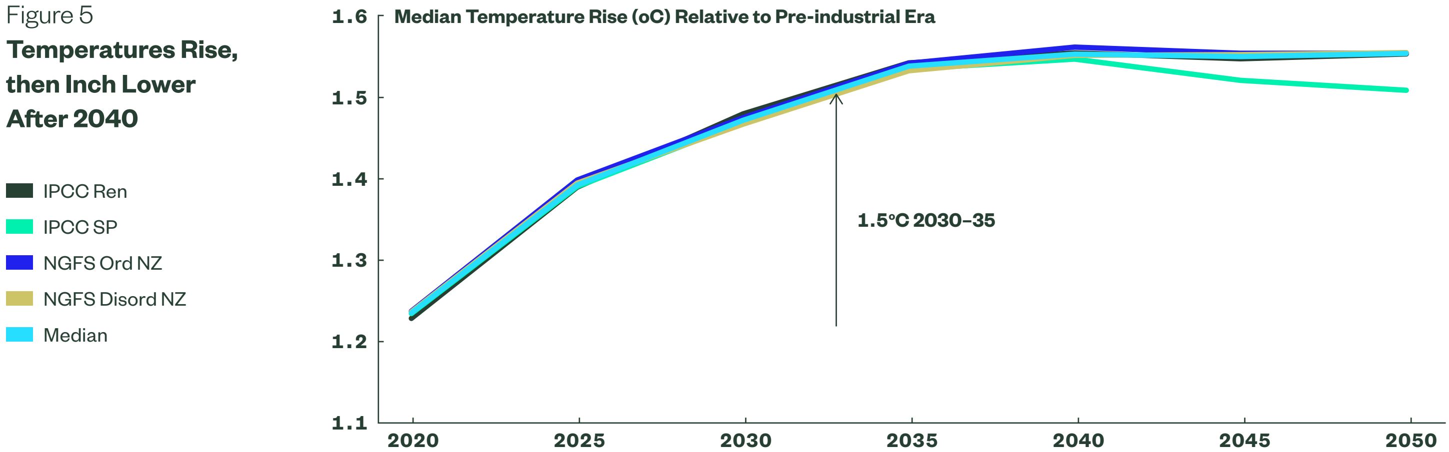
Figure 4
Kyoto Emissions Also Declined in All Outputs



Source: State Street Global Advisors, NGFS, IPCC as of December 2023.

As for temperature rise, all scenarios exhibit a very similar trajectory, with the median temperature rise overshooting 1.5°C by a small margin in the 2030s and 2040s, before falling back below 1.5°C over the rest of the 21st century (Figure 5).

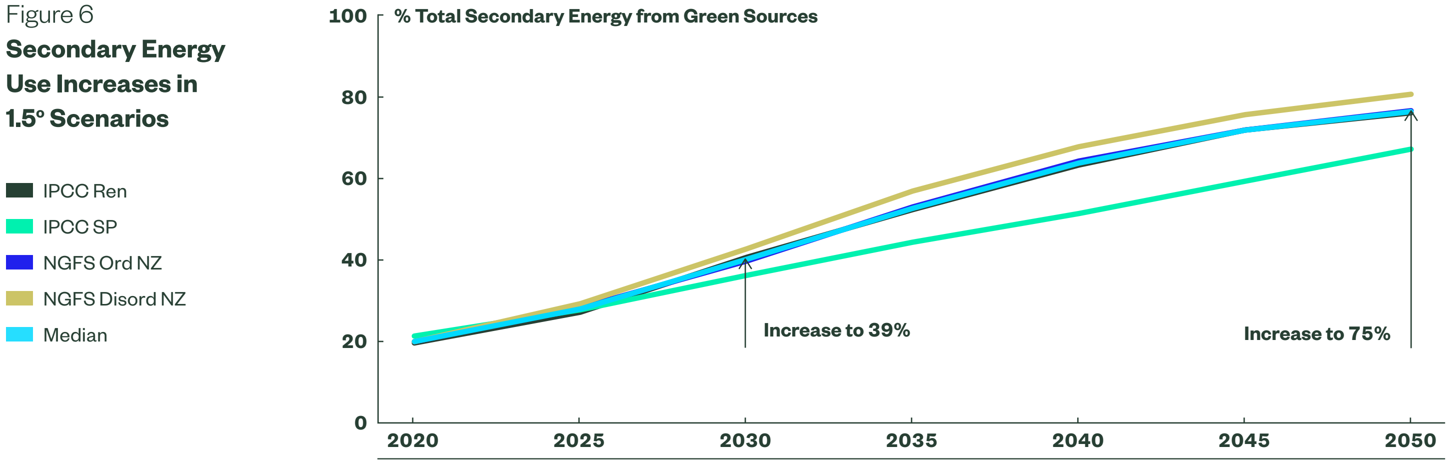
Figure 5
Temperatures Rise, then Inch Lower After 2040



Source: State Street Global Advisors, NGFS, IPCC as of December 2023.

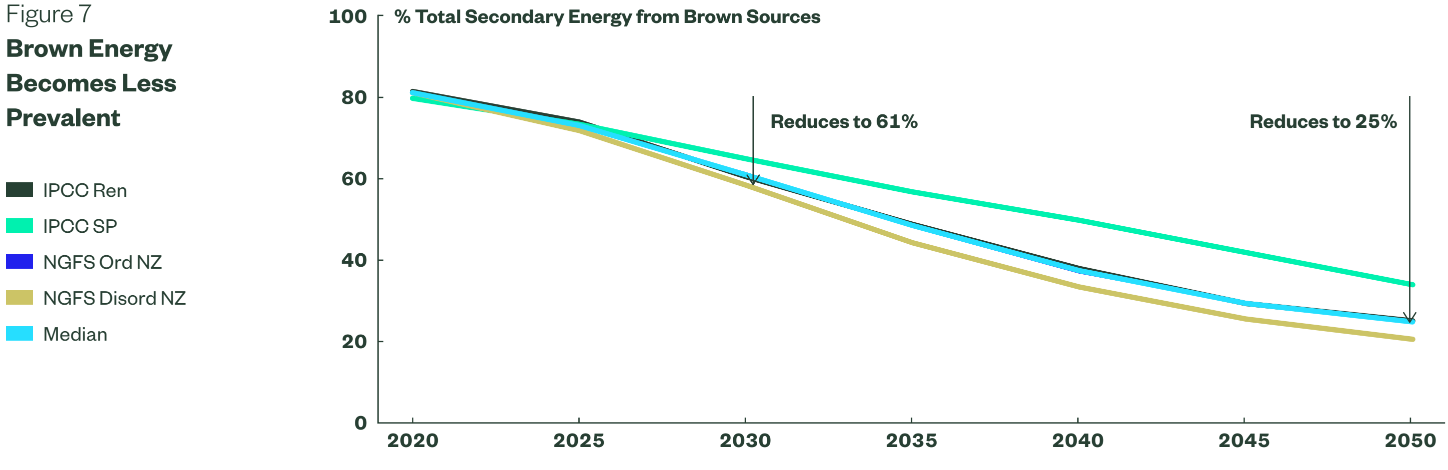
Broadly, the scenarios' outputs have a reduction in carbon-related energy sources, which are supplanted by renewable sources. Figures 6 and 7 show that the percent of secondary energy from green sources increases from a median of 19% in 2020 to 39% by 2030 and 75%, by 2050, while the percent from brown sources decreases from a median of 81% in 2020 to 61% by 2030, and 25% by 2050.

Figure 6
Secondary Energy Use Increases in 1.5° Scenarios



Source: State Street Global Advisors, NGFS, IPCC as of December 2023.

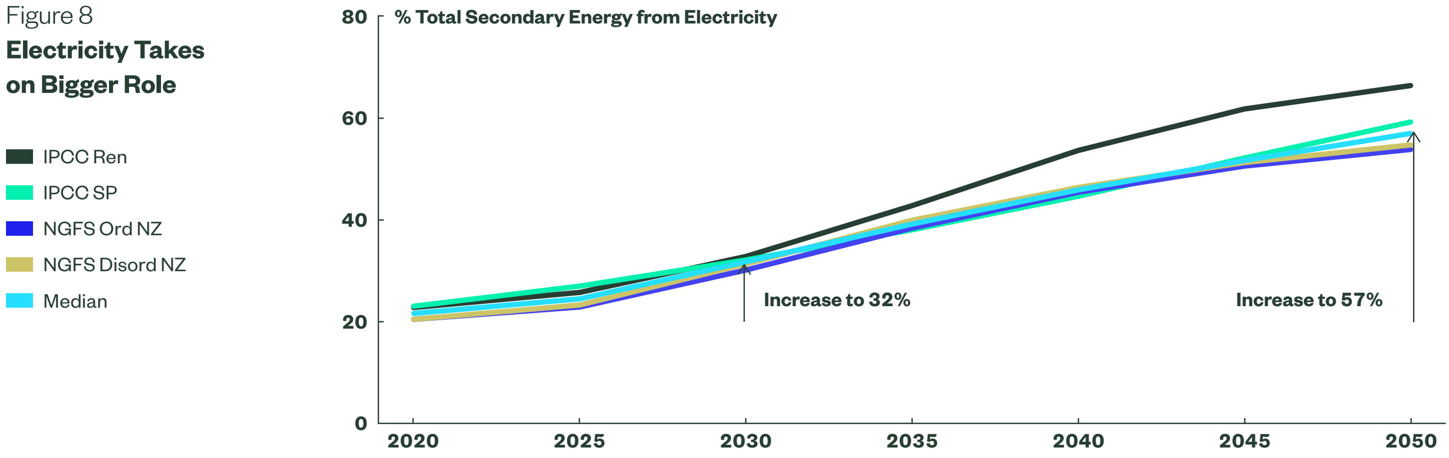
Figure 7
Brown Energy Becomes Less Prevalent



Source: State Street Global Advisors, NGFS, IPCC as of December 2023.

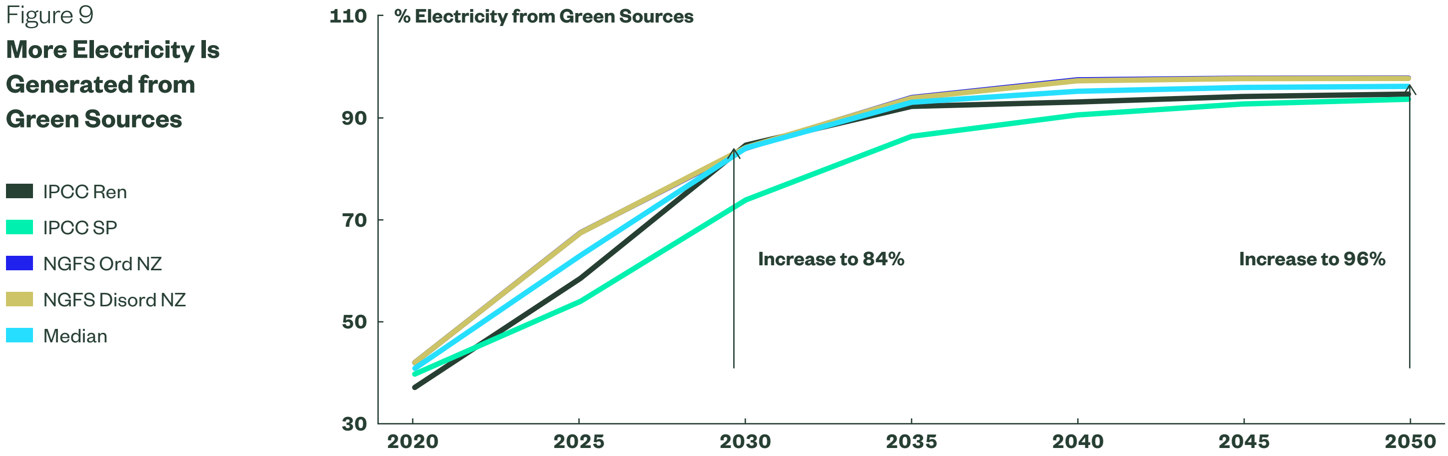
Furthermore, the contribution of electricity to secondary energy increases from a median of 22% in 2020 to 32% by 2030 and 57% by 2050. Within electricity generation, the contribution of green sources increases from a median of 41% in 2020 to 84% by 2030 and 96% by 2050. The contribution of brown sources decreases from a median of 59% in 2020 to 16% by 2030 and 4% by 2050 (Figures 8–10).

Figure 8
Electricity Takes on Bigger Role



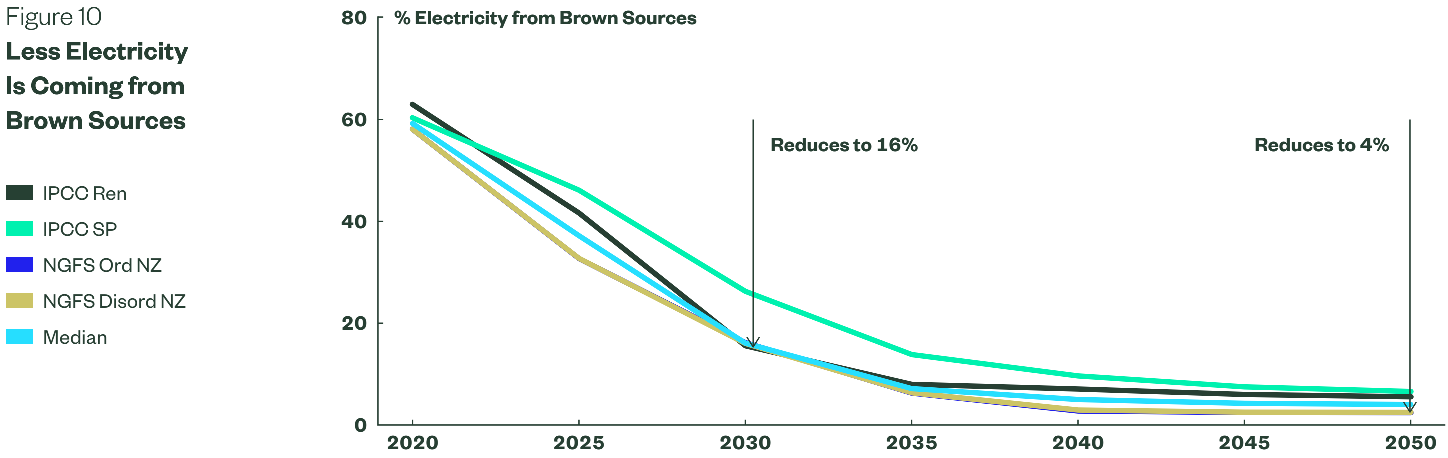
Source: State Street Global Advisors, NGFS, IPCC as of December 2023.

Figure 9
More Electricity Is Generated from Green Sources



Source: State Street Global Advisors, NGFS, IPCC as of December 2023.

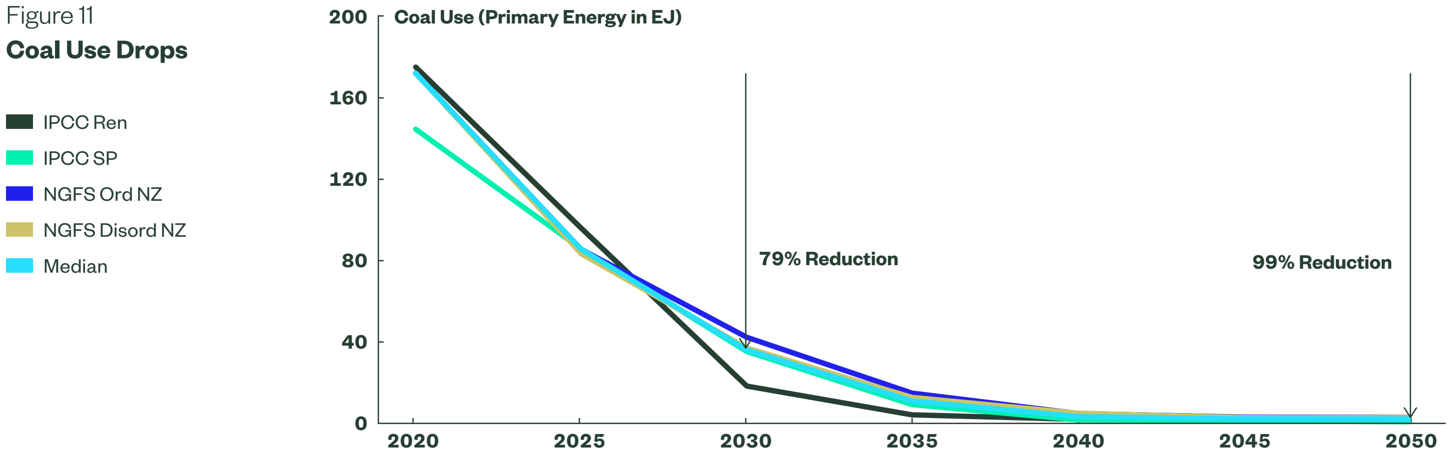
Figure 10
Less Electricity Is Coming from Brown Sources



Source: State Street Global Advisors, NGFS, IPCC as of December 2023.

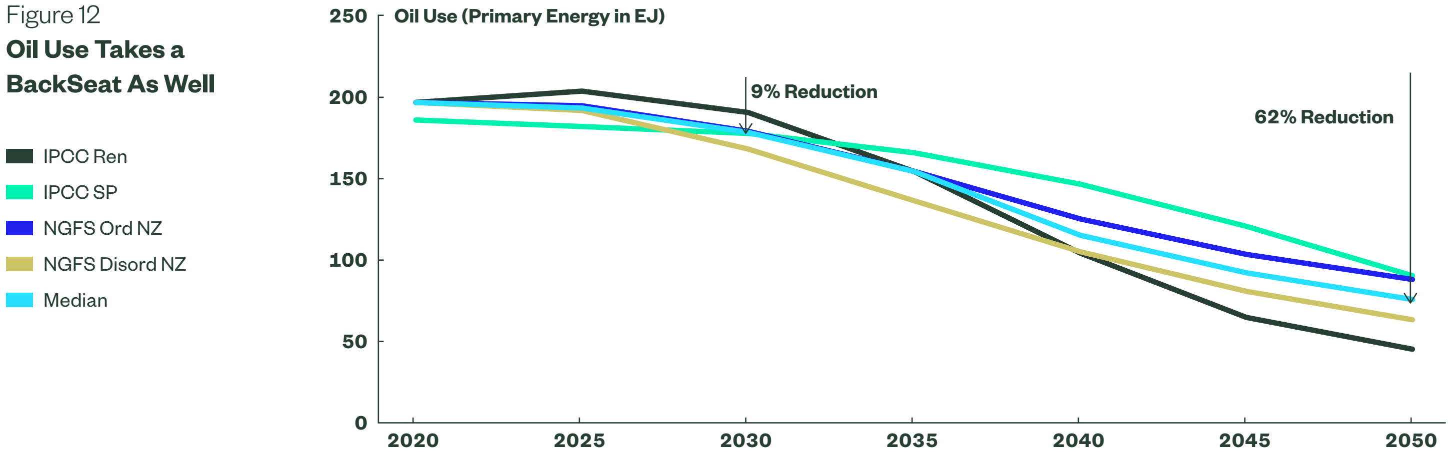
Looking deeper at the fossil fuel-related sources of energy (based on primary energy data), the scenarios imply that median coal use decreases by 77% by 2030, and 99% by 2050, relative to 2020 levels. Median oil use decreases by 9% by 2030, and 62% by 2050, relative to 2020 levels, and median gas use decreases by 28% by 2030, and 83% by 2050, relative to 2020 levels (Figures 11–13).

Figure 11
Coal Use Drops



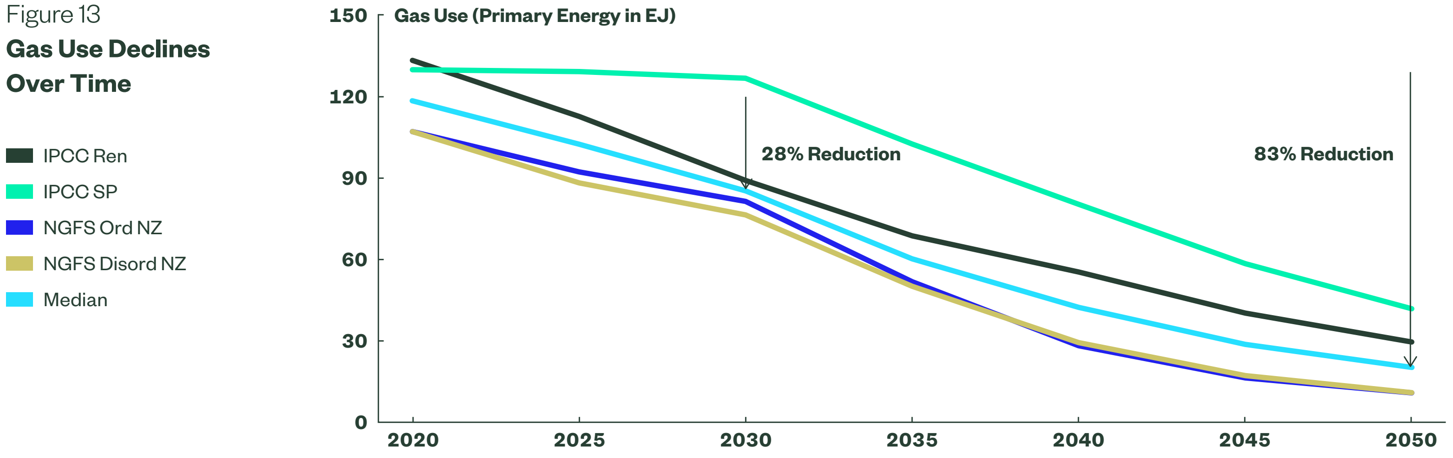
Source: State Street Global Advisors, NGFS, IPCC as of December 2023.

Figure 12
Oil Use Takes a BackSeat As Well



Source: State Street Global Advisors, NGFS, IPCC as of December 2023.

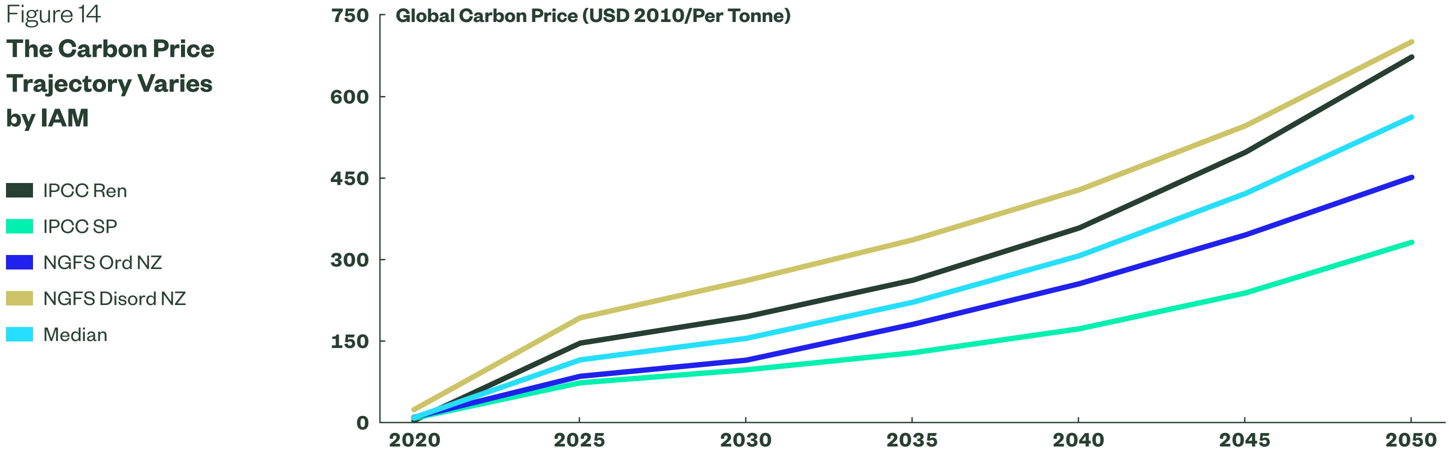
Figure 13
Gas Use Declines Over Time



Source: State Street Global Advisors, NGFS, IPCC as of December 2023.

Carbon prices increase under each of the scenarios, but there is disagreement as to the level of increase. Carbon prices are comparatively higher under IPCC-Ren and NGFS-NZDIS, while being lower under IPCC-SP and NGFS-NZORD (Figure 14).

Figure 14
The Carbon Price Trajectory Varies by IAM



Source: State Street Global Advisors, NGFS, IPCC as of December 2023.

The Bottom Line

The recent COP 28 included a global stocktake, or an evaluation of the world's progress on the goals of the Paris Agreement. One of the biggest components of the Paris Agreement is the mitigation of temperature rise, opening the door for analysis on whether, and how, a rise of 1.5°C or less can be achieved. International scenario data providers have put forth a wide range of climate scenarios with varying assumptions and inputs, including different rates of technological change, speeds of implementation, types of climate policies, and technologies available (e.g., carbon capture, solar, wind). Key socio-economic assumptions are often standardised.

Investors can benefit from reviewing the metrics that could accompany a 1.5°C scenario to gain insight into price dynamics, consumer/company behaviour, and regulatory changes that may impact industries across the globe. In addition, we believe 1.5°C scenario outputs could help inform conversations with issuers about their participation and preparedness for the global net zero transition.

Reference Links

NGFS scenarios portal NGFS Scenarios Portal

NGFS Technical Documentation technical_documentation_ngfs_scenarios_phase_3.pdf

IPCC AR6 Report Sixth Assessment Report — IPCC

IPCC AR6 Database AR6 Scenario Explorer and Database hosted by IIASA

IEA World Energy Outlook World Energy Outlook 2021 – Analysis — IEA

IEA Datasets Net Zero by 2050 Scenario — Data product — IEA

IEA Net-zero Roadmap Net-zero by 2050 — A Roadmap for the Global Energy Sector

NGFS Scenarios (Phase III Reports) https://ngfs.net/ngfs-scenarios-portal/data-resources-phase-3/

Glossary

IEA International Energy Agency

IPCC Intergovernmental Panel on Climate Change

NGFS Network for Greening the Financial System

CDR Carbon Dioxide Removal

IEA-NZE IEA Net Zero Emissions by 2050 Scenario

IPCC-SP IPCC Focus on SDGs Scenario

IPCC-Ren IPCC Focus on RenewablesScenario

IPCC-LD IPCC Low Energy Demand Scenario

NGFS-NZORD NGFS Net Zero 2050 (Orderly) Scenario

NGFS-NZDIS NGFS Divergent Net Zero 2050 (Disorderly) Scenario

Kyoto Gases Refers to the greenhouse gases regulated under the Kyoto Protocol. Thes include carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF6)

IAM Integrated Assessment Model

COP Conference of Parties

SDG Sustainable Development Goals

MAGICC Model for the Assessment of Greenhouse Gas Induced Climate Change

CCS Carbon Capture and Storage

Endnotes

1 Based on MAGICC v7.5.3.

2 The Net-zero Roadmap — Net-zero by 2050 - A Roadmap for the Global Energy Sector.

3 IEA (2021), Net Zero by 2050, IEA, Paris https://iea.org/reports/net-zero-by-2050, License: CC BY 4.0.

4 Impact of declining renewable energy costs on electrification in low-emission scenarios | Nature Energy.

5 A sustainable development pathway for climate action within the UN 2030 Agenda | Nature Climate Change.

6 NGFS scenarios and data are based on Phase III outputs, released in September 2022: https://ngfs.net/ngfs-scenarios-portal/data-resources-phase-3/.

7 NGFS scenarios and data are based on Phase III outputs, released in September 2022: https://ngfs.net/ngfs-scenarios-portal/data-resources-phase-3/.

8 Green sources include renewables (such as solar, wind, hydro, geothermal), biomass, nuclear as well as fossil fuels used with CCS technology.

9 Brown sources include coal, oil and gas without CCS technology.

10 Hannah Ritchie (2022) — "Primary, secondary, final, and useful energy: Why are there different ways of measuring energy?" Published online at OurWorldInData.org. Retrieved from: 'https://ourworldindata.org/energy-definitions' [Online Resource]

11 https://eia.gov/todayinenergy/detail.php?id=44436.

12 REMIND: Regional Model of Investment and Development, Potsdam Institut für Klimafolgenforschung (PIK).

13 MAgPIE: Model of Agricultural Production and its Impacts on the Environment, Potsdam Institut für Klimafolgenforschung (PIK).

About State Street Global Advisors

Our clients are the world's governments, institutions and financial advisors. To help them achieve their financial goals we live our guiding principles each and every day:

- Start with rigor
- Build from breadth
- Invest as stewards
- Invent the future

For four decades, these principles have helped us be the quiet power in a tumultuous investing world. Helping millions of people secure their financial futures. This takes each of our employees in 29 offices around the world, and a firm-wide conviction that we can always do it better. As a result, we are the world's fourth-largest asset manager* with US $4.13 trillion† under our care.

* Pensions & Investments Research Center, as of December 31, 2022.
† This figure is presented as of December 31, 2023 and includes approximately $64.44 billion USD of assets with respect to SPDR products for which State Street Global Advisors Funds Distributors, LLC (SSGA FD) acts solely as the marketing agent. SSGA FD and State Street Global Advisors are affiliated.

ssga.com

Marketing communication.
For institutional/professional investors use only.

State Street Global Advisors Worldwide Entities

Important Risk Information

All forms of investments carry risks, including the risk of losing all of the invested amount. Such activities may not be suitable for everyone.

Past performance is not a reliable indicator of future performance.

For EMEA Investors

The information contained in this communication is not a research recommendation or 'investment research' and is classified as a 'Marketing Communication' in accordance with the Markets in Financial Instruments Directive (2014/65/EU). This means that this marketing communication (a) has not beenprepared in accordance with legal requirements designed to promote the independence of investment research (b) is not subject to any prohibition on dealing ahead of the dissemination of investment research.

This communication is directed at professional clients (this includes eligible counterparties as defined by the appropriate EU regulator), who are deemed both knowledgeable and= experienced in matters relating to investments.

The products and services to which this communication relates are only available to such persons, and persons of any other description (including retail clients) should not rely on this communication.

The returns on a portfolio of securities which exclude companies that do not meet the portfolio's specified ESG criteria may trail the returns on a portfolio of securities which include such companies. A portfolio's ESG criteria may result in the portfolio investing in industry sectors or securities which underperform the market as a whole.

The trademarks and service marks referenced herein are the property of their respective owners. Third party data providers make no warranties or representations of any kind relating to the accuracy, completeness or timeliness of the data and have no liability for damages of any kind relating to the use of such data.

All information is from State Street Global Advisors unless otherwise noted and has been obtained from sources believed to be reliable, but its accuracy is not guaranteed. There is no representation or warranty as to the current accuracy, reliability or completeness of, nor liability for, decisions based on such information, and it should not be relied on as such.

The views expressed in this material are the views of Kushal Shah and Mohit Rakyan through the period ended November 30, 2023 and are subject to change based on market and other conditions. This document contains certain statements that may be deemed forwardlooking statements. Please note that any such statements are not guarantees of any future performance and actual results or developments may differ materially from those projected.

The information provided does not constitute investment advice and it should not be relied on as such. It should not be considered a solicitation to buy or an offer to sell a security. It does not take into account any investor's particular investment objectives, strategies, tax status or investment horizon. You should consult your tax and financial advisor.

ID1954242-6230777.1.2.GBL.INST 0124
Exp. Date: 31/01/2025