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- The process of scenario Cataloguing, the design of the Catalogue interface, and the estimation of any non-public content contained throughout the Catalogue was delivered with support from a Vivid Economics team including: Alex Kazaglis (Project Director), Aditi Sahni (Project Manager), Fabian Knoedler-Thoma (Senior Project Economist), James Bragg (Project Economist) and Will Glevey (Project Economist);
- The 2023 update of the Catalogue was delivered with support from a Vivid Economics team including: Aditi Sahni (Project Director), Suzanne Angliviel (Project Manager), Algirdas Brochard (Project Analyst), Panchimma Cheriyan (Project Economist) and Fizza Rahman (Project Analyst).

Disclaimer

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This Catalogue provides general information only, based on hypothetical future scenarios. The information used to compile this Catalogue has been collected from a number of sources, including publicly available information. We assume no responsibility for, nor give any representations with respect to, the accuracy or completeness of any such information. The information is not intended as financial advice.

Methodologies employed to estimate new variables for the Catalogue were developed by Vivid Economics. The Forum has not yet validated or reviewed in detail the expansion calculations or methodologies.
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1 Introduction

1.1 Purpose

The Climate Scenario Catalogue (the Catalogue) is designed to be used in association with and to support the Climate Scenario Reference Approach (the Approach) developed by the Energy Forum to enhance climate risk analysis and disclosure. The Approach was developed by the Energy Forum with the WBCSD Project Team to advance the project objectives and intended outcomes, including increasing the quantity and quality of strategic assessment and disclosure based on climate scenario analysis. It provides a yardstick for businesses to enhance transparency, consistency, and comparability of scenario analysis in response to the Task Force on Climate-Related Financial Disclosures’ (TCFD) recommendations.¹

The Catalogue helps companies address key challenges when conducting scenario analysis. The Catalogue supports scenario choices – how to choose, interpret and navigate climate scenarios. It also helps with the scenario process – how to apply scenarios under which conditions, and how to manage sensitivity analysis, data availability and reliability.

The Approach and the Catalogue follow six guiding principles developed by the Energy Forum:

- **Simplicity**: forum members agreed that they did not want to add to complexity by adding new scenarios to the existing “scenario universe.” Instead, the Project focuses on “reference scenario families”, certain existing scenarios and variables, compiled in a “Catalogue” and their application.

- **Business relevance**: by collating information from different sources and perspectives and providing key transition metrics and variables relevant to business, the Catalogue builds a bridge from scenario conditions to business drivers.

- **Comprehensiveness**: offer an approach to scenario analysis that encourages resilience assessment across a range of possible outcomes and diverse pathways as decarbonisation plans are progressed.

- **Neutrality**: considers a range of possible future industry and market developments, options and solutions drawn from public scenarios.

- **Support a common starting point and transparent approach** to scenario analysis.

- **Ease of interpretation**: the reference scenario approach is intended to provide a structured, transparent perspective to scenario analysis for a wide range of stakeholders, the process and results of which can be more easily interpreted and compared by investors.

1.2 Catalogue overview and features

The Catalogue is a live online repository within which certain public climate scenarios are referred to as “catalogued scenarios”. New scenarios and additional variables will be added to the

Catalogue based on user requests. Additionally, existing catalogued scenarios will be updated as new information is released to ensure that users have access to the most accurate representation of each climate scenario.

Publicly available scenarios from leading institutions were filtered, categorised and augmented for use in the Catalogue. The project uses publicly available scenarios as a starting point, selecting only scenarios that have passed plausibility constraints defined by leading institutions. It categorises them into scenario families (described below). Finally, the project increases variable availability to close the gap between granularity of existing public scenarios and the requirements for business relevance set out by Forum members.

As of March 2022, the Catalogue is almost exclusively composed of scenarios taken from leading public institutions on climate transition modelling with small additions for alternative economic growth.

- The Catalogue includes scenarios from the following leading public institutions:
  - the International Energy Agency (IEA);
  - the Network for Greening the Financial System (NGFS);
  - the Inevitable Policy Response (IPR);
  - the International Renewable Energy Agency (IRENA);
  - Bloomberg New Energy Finance (BNEF).

- The catalogue includes two scenarios which explore the possible impacts of economic growth sensitivities. Both scenarios are aligned with 1.5C temperature increase, but they follow different Socioeconomic Pathways (SSPs). The “high growth” scenario follows SSP5, and the “low growth” scenario follows SSP3 - other scenarios included in the database follow the “middle of the road” SSP2 pathway. The former is characterized by fossil-fuel led economic growth. It assumes that a push for economic and social development is coupled with the exploitation of abundant fossil fuel resources, leading to rapid growth of the global economy. The latter is characterized by regional rivalry. The scenario builds on the narrative that nationalism, concerns about competitiveness and security, leads to low international priority for addressing environmental concerns causing environmental degradation low economic growth. Both scenarios illustrate how decarbonization pathways could be affected if the world diverges from assumed socioeconomic pathways. The scenarios were analysed in Riahi et al (2017), “The Shared SocioEconomics Pathways and their energy, land use, and greenhouse gas emissions implications: An overview”, *Global Environmental Change*, 42:153-168.

- In one part of the Catalogue – the Scenario Explorer – additional scenarios from the AR6 Scenario Explorer and Database, hosted by IIASA, provide more context to the comparison of scenarios, but they are not available for deeper analysis and download.
The Catalogue is a live tool designed to be updated as new and improved climate scenarios are released over time.

The catalogued scenarios have been grouped into climate reference scenario families (families). The families have been identified and agreed with Forum members to ensure that users compare scenarios of similar climate ambition when conducting their analyses. These are:

- **Paris Ambitious 1.5°C**: Scenarios with outcomes designed to keep temperature rise within 1.5°C above pre-industrial levels with limited/no overshoot²

- **Paris Aligned Well-Below 2°C**: Scenarios with outcomes designed to keep temperature rise within 2°C above pre-industrial levels with limited/no overshoot

- **Current Policies/Business as Usual (BAU)**: Scenarios that reflect the range of current climate policies and Nationally Determined Contributions (NDCs) or other national pledges, resulting in a temperature rise between 2.5 and 3.5°C by 2100.

The scenarios included in the Catalogue are listed by provider in Figure 1 to Figure 5.

---

² Overshoot means that temperatures rise above a certain global warming target before falling below it.
### Figure 1  Catalogued IEA scenarios and characteristics

<table>
<thead>
<tr>
<th>Scenario family</th>
<th>Net Zero Energy 2050</th>
<th>Stated Policies Scenario</th>
<th>Announced Pledges Scenario</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paris Ambitious 1.5°C</td>
<td></td>
<td>Current Policies/BAU</td>
<td>Current Policies/BAU</td>
</tr>
<tr>
<td>Temperature target in 2100</td>
<td>1.5°C</td>
<td>Not target-based, achieves ~2.65°C</td>
<td>Not target-based, achieves ~ 2.1°C</td>
</tr>
<tr>
<td>Scenario type</td>
<td></td>
<td>Orderly</td>
<td></td>
</tr>
<tr>
<td>Geography</td>
<td>World</td>
<td>World</td>
<td>World</td>
</tr>
<tr>
<td>Sectors covered</td>
<td>Energy, power, transport, buildings, industry, mining</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Time steps</td>
<td>2020 – 2050; 5-year intervals</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Note:** The characteristics correspond to the information from IEA that is included in the Catalogue – some regional data is available directly from the IEA.

**Source:** Vivid Economics
### Figure 2   Catalogued NGFS scenarios and characteristics

<table>
<thead>
<tr>
<th>Net Zero 2050</th>
<th>Divergent Net Zero</th>
<th>Below 2°C</th>
<th>Delayed Transition</th>
<th>NDCs</th>
<th>Current Policies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model</td>
<td>RM</td>
<td>GCAM</td>
<td>RM</td>
<td>GCAM</td>
<td>RM</td>
</tr>
<tr>
<td>Scenario family</td>
<td>Paris Ambitious 1.5°C</td>
<td>Paris Aligned Well-Below 2°C</td>
<td>Current Policies/BAU</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Temperature target in 2100</td>
<td>1.5°C</td>
<td>1.5°C</td>
<td>1.7°C</td>
<td>1.8°C</td>
<td>2.5°C</td>
</tr>
<tr>
<td>Scenario type</td>
<td>Orderly</td>
<td>Disorderly</td>
<td>Orderly</td>
<td>Disorderly</td>
<td>Current Policies/BAU</td>
</tr>
<tr>
<td>Geography</td>
<td>Canada, Australia and New Zealand (CAZ), China (CHA), European Union and United Kingdom (EU27 + UK), India (IND), Japan (JPN), Latin America (LAM), Middle East, North Africa and Central Asia (MEA), Non-EU Europe (NEU), Other Asian States (OAS), Reforming Economies (REF), Sub-Saharan Africa (SSA), United States (USA), World</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sectors covered</td>
<td>Energy, power, transport, buildings, industry, mining and AFOLU</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Time steps</td>
<td>2020 – 2050; 5-year intervals</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Download</td>
<td>Derived data available for download in the Catalogue.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Source details</td>
<td>NGFS</td>
<td>Latest release: v3.4 October 2022 ; Release schedule: next update Q2-Q32023</td>
<td>Available from: IXMP Scenario Explorer developed by IIASA</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: The characteristics correspond to the information from NGFS that is included in the Catalogue. RM = REMIND-MAgPIE model. Regional data is available from: IXMP Scenario Explorer developed by IIASA. Country-level results can also be downloaded for select variables from the IIASA website.

Source: Vivid Economics
<table>
<thead>
<tr>
<th>Scenario family</th>
<th>Required Policy Scenario</th>
<th>Forecasted Policy Scenario</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature target in 2100</td>
<td>1.5°C</td>
<td>1.8°C</td>
</tr>
<tr>
<td>Scenario type</td>
<td>Disorderly</td>
<td>Disorderly</td>
</tr>
<tr>
<td>Geography</td>
<td>CAZ, CHA, EU27 + UK, IND, JPN, LAM, MEA, NEU, OAS, REF, SSA, USA, World</td>
<td></td>
</tr>
<tr>
<td>Sectors covered</td>
<td>Energy, power, transport, buildings, industry, mining</td>
<td></td>
</tr>
<tr>
<td>Time steps</td>
<td>2020 – 2050; 5-year intervals</td>
<td></td>
</tr>
<tr>
<td>Download</td>
<td>Available for download in the Catalogue.</td>
<td></td>
</tr>
</tbody>
</table>

Source details:
- Required Policy Scenario: UN PRI. The Inevitable Policy Response Available from: [UNPRI website](#)
- Forecasted Policy Scenario: UN PRI. The Inevitable Policy Response Available from: [UNPRI website](#)

Note: Available from: [UNPRI website](#)
Source: Vivid Economics
### Figure 4  Catalogued IRENA scenarios and characteristics

<table>
<thead>
<tr>
<th></th>
<th>1.5°C Scenario</th>
<th>Transforming Energy Scenario</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Scenario family</strong></td>
<td>Paris Ambitious 1.5°C</td>
<td>Paris Aligned Well-Below 2°C</td>
</tr>
<tr>
<td><strong>Temperature target in 2100</strong></td>
<td>1.5°C</td>
<td>Unknown</td>
</tr>
<tr>
<td><strong>Scenario type</strong></td>
<td>Unknown</td>
<td>Unknown</td>
</tr>
<tr>
<td><strong>Geography</strong></td>
<td>World</td>
<td></td>
</tr>
<tr>
<td><strong>Sectors covered</strong></td>
<td>Energy, power, transport, buildings</td>
<td></td>
</tr>
<tr>
<td><strong>Time steps</strong></td>
<td>2050; no time series available.</td>
<td></td>
</tr>
<tr>
<td><strong>Download</strong></td>
<td>Available for download in the Catalogue</td>
<td></td>
</tr>
<tr>
<td><strong>Source details</strong></td>
<td>IRENA Global Renewables Outlook: Energy transformation 2050. Latest release: 2020; Available from: [IRENA website](<a href="http://IRENA">http://IRENA</a> website)</td>
<td>IRENA World Energy Transitions Outlook Latest release: 2021 Available from: [IRENA website](<a href="http://IRENA">http://IRENA</a> website)</td>
</tr>
</tbody>
</table>

**Note:** The characteristics correspond to the information from IRENA that is included in the Catalogue.  
**Source:** Vivid Economics
The Catalogue includes 6,335, unique variables for climate risk testing and disclosure, which are either extracted directly from the selected scenarios, or, disaggregated and/or expanded with support and analysis by Vivid Economics. Disaggregated variables are a more granular version of existing variables which has been extracted directly from the scenario provider. Expanded variables are new variables which use extracted outputs from the scenario provider as inputs for calculation. Section 3 Catalogue contents of this document details the methodology for the additional variables. The final list of Catalogue variables has been agreed with Forum members as being necessary for business-relevant climate scenario analysis.

The Catalogue classifies the variables based on their place in the energy system:

- **Primary energy** refers to naturally occurring energy forms that have not been subjected to any human engineered conversion process, encompassing both fuels such as oil and gas as well as renewable energy such as wind and geothermal energy.

- **Secondary energy** describes the fuels converted into electricity, hydrogen, or other secondary fuels.
Final energy includes primary and secondary energy used in end-use sectors of the economy including industry, transport, and buildings.

In addition to energy variables, the Catalogue includes other classes of variables that have been named by Forum members as having business-relevancy. This includes:

- **Emissions** which corresponds to Scope 1 CO₂ energy emissions from fuel combustion and/or industrial process i.e. the direct CO₂ at the point of combustion or process. Other major GHG are also reported for the macroeconomy.

- **Carbon capture and sequestration** which refers explicitly to either the capture and permanent storage of carbon from any technology (including direct air carbon capture and storage i.e. DACCS) or sequestration from natural sources such as afforestation.

- **Demand and Production** refers to the quantity of a material or commodity, such as steel, cement, or lithium, at the point of consumption or production.

- **Investment** includes total capital expenditures, typically including low-carbon and non-low-carbon in nature, for different activities within various sectors of the economy.

- **Cost and price** refer to the total cost of producing some good or the price faced by consumers at a particular stage in the value change, respectively. Costs are levelized when appropriate, such as for power-sector generation or storage technologies.

- **Macroeconomic indicators and policy** variables includes variables with macro-economy relevancy such as GDP and productivity, in addition to carbon prices (explicit levies or shadow prices) and economy-wide climate damages and mitigation costs.

The Appendix provides a detailed list of the variables included in the catalogue.

The Catalogue has three main features:

1. **Scenario Explorer**: shows how selected scenarios compare across key variables in 2050 to present the distribution of scenarios within their family to illustrate the range of uncertainty across those scenarios.

2. **Variable Explorer**: presents all variables in the Catalogue in their full sectoral and regional disaggregation.

3. **Data Download**: offers extraction of variables from the Catalogue for further analysis and disclosure.

The Energy Forum’s report and accompanying user guidance provides a more detailed overview of the Catalogue, its features and utility for companies conducting scenario analysis. This Technical Document focuses on the design and development of the Catalogue and its content, how it is structured, and how variables have been expanded and developed:

- **Section 2 Approach to catalogue creation** summarises the approach for creating the Catalogue.
Section 3 Catalogue contents details the Catalogue variables, methods for estimation where applicable, and also describes the models and scenarios included in the Catalogue.

2 Approach to catalogue creation
This section covers the general approach taken to categorise and estimate variables within the Catalogue (Section 2.1 General approach) including processes to ensure scenario consistency and quality assurance (Section 2.2 Scenario alignment and quality assurance).

2.1 General approach
The Catalogue consists of:

- Public scenarios listed in Section 1.2 Catalogue overview and features, including extracted outputs and variables from those scenarios. The public scenarios and associated variables are modelled using a wide range of models and methods. Except as otherwise stated, the Catalogue does not disturb or alter the public scenario outputs and variables.

- New and bespoke variables developed with support and analysis by Vivid Economics, which were estimated in response to Forum member advice on variables of most business-relevance for scenario analysis at the sector or sub-sector level.

Variables in the Catalogue are assigned a typology which is visible to users while exploring the data. The typology is designed to clearly signify which variables are extracted outputs from a scenario provider, and which variables are derived data i.e., new variables estimated at the request of Forum members. The typology is also used to communicate the number of intermediate steps that were required for estimation and the degree of alignment with the characteristics of a scenario.

Each variable in the Catalogue is either extracted, disaggregated or (partially) expanded. Assigning a variable to a typology is conducted through the application of a standardised decision tree which is outlined in Figure 6.
The definitions for each type of variable are provided below.

1. **Extracted** – variables in this category are taken directly from the public scenarios from which they originate and are unaltered. In some cases, the variables are expressed to increase accessibility for users. For example, primary energy demand for natural gas can be transformed from Exajoules per year (EJ/year) into British thermal units (Btu/year) per year using a simple energy conversion factor. The variable itself remains unaltered.

2. **Disaggregated** – refers to the process of disaggregating extracted outputs into more detailed parts. Scenario providers often provide a detailed but incomplete picture of the energy system. The most common omissions are full subsector and fuel granularity. A disaggregated variable breaks down a value into constituent parts without changing the overall aggregated value. For example, the final energy mix for road transport, aviation, shipping and rail are disaggregated using the final energy mix for passenger transport. The margin for error is therefore small on aggregate: the sum of the disaggregated components will always reconcile with the higher-level value of the aggregated scenario output. Some variables, specifically for IEA scenarios, are listed as “Disaggregated – 2021”, which means the source of the variable remains a 2021 IEA publication, because the same data was not available from 2022 sources.

3. **Expanded** – refers to the process of creating entirely new variables. Variables created through expansion will use extracted and disaggregated variables as inputs to calculations. External literature and additional energy system modelling are also typically required. For
example, vehicle sales are estimated using disaggregated final energy mix, extracted energy service demand for passenger transport, and additional energy system modelling using the Vivid Energy System Model. In contrast to disaggregated variables, the alignment of an expanded variable with a climate scenario is typically indirect. The level of consistency therefore depends on the number of indirect channels for alignment. The margin for error is therefore larger relative to disaggregated variables as differences in model assumptions and inputs are likely. However, the defining characteristics of the scenario – including the observed energy mix, emissions, and, most notably, the carbon budget – are preserved. A step-by-step example of an expanded variable is provided in Box 1. Figure 7 also provides a visual representation of subsector disaggregation for the transport sector, which is then used to create several new expanded variables such as vehicle sales and the mineral requirements of vehicle sales.

4. **Partially expanded** – refers to variables which have been altered or transformed without additional modelling. A partial expansion involves substantive change to a variable but does not require complex calculations or additional modelling. Partially expanded variables are typically variables which have been transformed into a new unit or normalised for better comparisons across scenarios. Despite the simplicity in approach, a partially expanded variable is distinguished from an extracted variable to avoid misrepresenting outputs from the various scenario providers. However, the level of uncertainty for these variables is typically low relative to fully expanded variables. A prime example of a partially expanded variable is oil demand, which is converted from units of energy (EJ/year) into a unit of volume (Million barrels/year). This only requires an energy-to-volume conversion factor based on the average energy content per barrel of oil; however, the conversion factor introduces some uncertainty as the underlying average energy content assumed by the scenario or model is unknown. As such, the variable is no longer extracted directly from source.
Figure 7  Example approach for variable disaggregation (transport subsector final energy consumption) and variable expansion (vehicle sales and mineral requirements)

Illustrative Example
- **NGFS provided**
- **Disaggregated variable**
- **Expanded variable**

Source: Vivid Economics
Box 1  Illustrative example of variable expansion: mineral demand

Mineral demand is an example of an expanded variable. The methodology highlights the techniques and approaches used to create a new variable. For visual aid, the process of expansion, which includes data extraction and disaggregation using the NGFS as an example, is shown in Figure 7 for electric vehicles. The high-level steps taken to expand this variable are:

1. **Disaggregate the fuel mix in all end-consumption sectors.** Consumption of every fuel at the sector-level is broken down to the subsector-level. To ensure a realistic allocation of fuels between subsectors, several IAMs are used.

2. **Estimate technology stock associated with the disaggregated subsector fuel mix.** The disaggregated fuel mix in end-consumption is used to estimate the technology mix in every sector of the economy.

3. **Calculate technology additions.** The technology stock is converted into sales using a stock-flow optimization model and technology lifetimes.

4. **Apply mineral intensities.** A mineral intensity database allows us to calculate the total mineral requirements of each technology each year. Intensities originate from external literature and are calibrated to remain consistent with material production provided by unaltered scenario outputs. Additional factors such as circular economy, material efficiency changes and the market composition for batteries are also considered.

### 2.2 Scenario alignment and quality assurance

When a variable is requested to be included in the Catalogue, the first step taken is to check all available data or reports that have been published directly from the scenario provider. In many cases the variable request can be fulfilled without any additional analysis. The data is then processed into a standardised format so that the user can easily view and compare it across scenario providers. In general, disaggregation and expansion are never undertaken if the variable can be extracted directly from source. Disaggregation and expansion are only undertaken for variables where extracted scenario outputs do not sufficiently fulfil the request of a Forum member for a particular variable.
3 Catalogue contents

This section presents details of the Catalogue content and is structured as follows:

- a high-level summary of the variables included in the Catalogue (Section 3.1 Variable summary)
- a description of approach for every variable, by sector (Sections 3.2 Variables by sector)
- 3.2.1 Energy variables to 3.2.7 Macro-economy variables)
- descriptions of scenarios included in the Catalogue (Section 3.3 Scenario descriptions)
- descriptions of models included in the Catalogue (Section 3.4 Model descriptions)

3.1 Variable summary

The Catalogue contains 6,754 distinct variables. Table 1 summarizes the classification of the Catalogue variables according to whether they have been extracted directly from source or otherwise developed with the support of Vivid Economics. Most variables are extracted directly from source, though significant time has been invested to process and make these variables more accessible for business. The remaining 51.48% of unique variables in the Catalogue are either disaggregated or expanded (see Section 2.1 General approach for definitions) with support and additional analysis from Vivid Economics and are therefore not directly available from selected public climate scenarios. The Forum has not validated or reviewed in detail the expansion calculations or methodologies. As shown in Table 2, there are variables available for businesses operating in many sectors of the economy. A visualisation of the Catalogue variables, distinguished by sector, is also shown in Figure 8.

Table 1 Catalogue variables by classification

<table>
<thead>
<tr>
<th>Variable type</th>
<th>Number of variables (percentage)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Expanded</td>
<td>2,706 (40.1%)</td>
</tr>
<tr>
<td>Disaggregated</td>
<td>658 (9.7%)</td>
</tr>
<tr>
<td>Extracted variables</td>
<td>3,390 (50.2%)</td>
</tr>
</tbody>
</table>

Source: Vivid Economics

Table 2 Catalogue variables by sector

<table>
<thead>
<tr>
<th>Sector</th>
<th>Number of variables (percentage)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Buildings</td>
<td>990 (14.6%)</td>
</tr>
<tr>
<td>Energy (cross-sectoral)</td>
<td>896 (13.3%)</td>
</tr>
</tbody>
</table>

3Defined as any unique combination of model, scenario and data point – not including regions. Summary statistics as of February 2023 and may change with subsequent scenario and variable additions to the Catalogue.

4Energy refers to all sectors within the energy system and therefore can include power, transport, buildings and industry.
### Sector

<table>
<thead>
<tr>
<th>Sector</th>
<th>Number of variables (percentage)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Industry</td>
<td>2,381 (35.2%)</td>
</tr>
<tr>
<td>Macroeconomy/other</td>
<td>127 (1.88%)</td>
</tr>
<tr>
<td>Mining</td>
<td>130 (1.9%)</td>
</tr>
<tr>
<td>Power</td>
<td>1,366 (20.2%)</td>
</tr>
<tr>
<td>Transport</td>
<td>862 (12.8%)</td>
</tr>
</tbody>
</table>

Source: Vivid Economics
Figure 8 Catalogue variable tree and interactions

Notes: ASHP = Air to surface heat pump for heating.
Source: Vivid Economics
3.2 Variables by sector

3.2.1 Energy variables

3.2.1.1 Overview of sector

Energy variables are applicable across all sectors of the energy system (including power, transport, buildings and industry) and are represented in the Catalogue by the following:

1. **Primary energy demand**: total energy consumption of unconverted fuels.

2. **Primary energy prices**: the price before transport, taxation or processing.

3. **Primary energy emissions**: direct CO₂ emissions from the combustion of unconverted fuels. It does not include process emissions or emissions from other greenhouse gases.

4. **Primary energy investment**: total capital expenditure for the extraction and conversion of primary fuels, including coal, oil, gas and bioenergy.

5. **Final energy**: total final consumption of energy in transport, buildings, industry, mining and all other end-use sectors.

6. **Low-carbon energy shares**: the share of electricity, hydrogen or bioenergy in total final consumption across all end-use sectors.

7. **Hydrogen costs**: the average cost of producing hydrogen from all sources. It includes the additional costs from carbon pricing.

8. **Total CCS**: carbon captured and stored from CO₂ combustion in all sectors of the energy system including industrial processes.

9. **CCS investment**: all investment in equipment and infrastructure for the capture, transportation and storage of CO₂.

10. **Electrolyser capacity**: total productive capacity for green hydrogen in Gigawatts including merchant production and production for own-use in industry or refining.

The granularity of energy variables available in the Catalogue is provided in Figure 9.
<table>
<thead>
<tr>
<th>Variable</th>
<th>Regions</th>
<th>Sector</th>
<th>Subsectors</th>
<th>Technologies and fuels</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary energy demand</td>
<td>NGFS &amp; UN PRI (IPR): 12 regions</td>
<td>Energy</td>
<td>Not applicable</td>
<td>All fuels and technologies, Coal, oil, gas, biomass, nuclear, non-biomass renewables</td>
</tr>
<tr>
<td></td>
<td>IEA &amp; BNEF: World</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Primary energy prices</td>
<td>NGFS &amp; UN PRI (IPR): 12 regions</td>
<td>Energy</td>
<td>Not applicable</td>
<td>Oil, gas, biomass, coal</td>
</tr>
<tr>
<td></td>
<td>IEA: World</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Primary energy emissions</td>
<td>NGFS &amp; UN PRI (IPR): 12 regions</td>
<td>Energy</td>
<td>Not applicable</td>
<td>NGFS, IEA &amp; BNEF: All fuels and technologies Coal, oil, gas</td>
</tr>
<tr>
<td></td>
<td>IEA &amp; BNEF: World</td>
<td></td>
<td></td>
<td>UN PRI (IPR): All fuels and technologies</td>
</tr>
<tr>
<td>Primary energy investment</td>
<td>NGFS: 12 regions</td>
<td>Energy</td>
<td>Extraction</td>
<td>Coal, oil, gas, bioenergy, total fossil</td>
</tr>
<tr>
<td>Final energy</td>
<td>NGFS &amp; UN PRI (IPR): 12 regions</td>
<td>Energy</td>
<td>Not applicable</td>
<td>Electricity, hydrogen, gases (biogas, natural gas, gas from coal), liquids</td>
</tr>
<tr>
<td></td>
<td>IEA, BNEF &amp; IRENA: World</td>
<td></td>
<td></td>
<td>(oil, biofuels, liquids from coal and natural gas, ammonia, synth fuels) and solids</td>
</tr>
<tr>
<td>Low-carbon energy shares</td>
<td>NGFS &amp; UN PRI (IPR): 12 regions</td>
<td>Energy</td>
<td>Not applicable</td>
<td>Bioenergy, electricity, hydrogen</td>
</tr>
<tr>
<td></td>
<td>IEA, BNEF &amp; IRENA: World</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hydrogen costs</td>
<td>NGFS: 12 regions</td>
<td>Energy</td>
<td>Not applicable</td>
<td>Not applicable</td>
</tr>
<tr>
<td></td>
<td>IEA: World</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>NGFS &amp; UN PRI (IPR): 12 regions</td>
<td>Energy</td>
<td>Not applicable</td>
<td>All fuels and technologies w CCS, Bioenergy with CCS (BECCS)</td>
</tr>
<tr>
<td>---------</td>
<td>-------------------------------</td>
<td>--------</td>
<td>----------------</td>
<td>---------------------------------------------------------------</td>
</tr>
<tr>
<td>CCS</td>
<td>NGFS: 12 regions</td>
<td>Energy</td>
<td>Not applicable</td>
<td>Total CCS investment</td>
</tr>
<tr>
<td>Capacity</td>
<td>NGFS: 12 regions</td>
<td>Energy</td>
<td>Not applicable</td>
<td>Electrolyser</td>
</tr>
</tbody>
</table>

Source: Vivid Economics

3.2.1.3 Approach to variable disaggregation and expansion

Primary energy demand

*Variable type: partial expansion*

**Primary energy demand** is extracted directly from source and translated into native or volumetric units where appropriate. Primary energy demand is typically expressed in units of energy such as EJ/year. Some fossil fuels are converted into native\(^5\) or volumetric units using either direct conversion factors or by estimating average energy content per volume from output tables. For example, oil is expressed in barrels and gas in British thermal units. Unit conversion is done purely for accessibility.

Primary energy prices

*Variable type: partial expansion*

**Primary energy prices** are extracted directly from NGFS and, as for primary energy demand, translated into native or volumetric units where appropriate. Prices for the IEA scenarios are extracted directly from source.

Primary energy emissions

*Variable type: disaggregation*

The following steps are taken to estimate NGFS and IRENA\(^6\) primary energy emissions:

\(^5\) Refers to conventional units used for trading in energy commodity markets. For oil, demand and price is reported in barrels (bbl) of crude.

\(^6\)IRENA data availability limited to the year 2050.
1. **Extract primary energy demand for fossil fuels.** Scenarios provide primary energy demand for fossils both with and without CCS.

2. **Convert energy to emissions while accounting for CCS.** Fuel-specific emissions factors and CO₂ capture rates are used to convert EJ/year to MtCO₂/year.

3. **Calibrate emissions to reconcile with extracted NGFS outputs.** Emissions by fuel source are constructed so that the sum of emissions from all fossil fuels is exactly equal to total primary energy emissions in each scenario.

Emissions for the IEA and BNEF scenarios are taken directly from the source.

**Primary energy investment**

*Variable type: extraction*

**Primary energy investment is taken directly from source for all scenarios.** It measures all capital expenditures on the extraction and conversion of primary fuels.

**Final energy**

*Variable type: extraction*

**Final energy is taken directly from source for all scenarios.** It covers all fuels and consumption in every end-use sectors (excluding power sector inputs for electricity generation).

**Hydrogen costs**

*Variable type: expansion*

**The average production cost of hydrogen is either partially expanded by unit conversion (NGFS).** The cost per GJ of energy from hydrogen is provided by the NGFS. This is converted to $ per kilogram by estimating average energy content per volume from output tables. Hydrogen costs for BNEF scenarios were taken directly from source.

**CCS**

*Variable type: extraction*

**CCS is taken directly from source for all scenarios.** This variable strictly measures carbon captured that is permanently stored. Carbon captured for re-utilisation is not included. It includes CCS in every sector of the energy system, including power, industry, fuel processing and production, and atmospheric removals from innovative technologies such as direct air carbon capture and storage (DACCs).

**CCS investment**

*Variable type: extraction*

**CCS investment is taken directly from source for all scenarios.** CCS investment segmented into the capture unit (CCS) and CO₂ transport and storage capacity (CO₂ transport and storage). Estimates
for the IEA scenarios do not distinguish between carbon capture and utilised and carbon captured and stored.

Electrolyser capacity

*Variable type: expansion/extraction*

*For NGFS, electrolyser capacity is estimated as the required productive capacity for the volumetric production of green hydrogen in each scenario.* The energy content of hydrogen from electricity is extracted directly from the NGFS and is assumed to come from dedicated renewables due to cost considerations. The energy content of hydrogen is converted into an annual volume and a required capacity factor per Mt is applied. Electrolyser capacity for IEA scenarios is extracted directly from source material.

3.2.2 Power variables

3.2.2.1 Overview of sector

The **power sector** is represented in the Catalogue by the following variables:

1. **Electricity generation and capacity**: energy output and maximum capable energy output of installed electricity generation sources. Annual capacity additions are also reported separately.

2. **The LCOE and LCOS**: the discounted cost of building and operating a generation or generation storage asset expressed per unit of electricity outputted or stored over the lifetime of the asset.

3. **Electricity generation emissions**: direct CO₂ emissions from the combustion of fuels for electricity generation.

4. **Carbon intensity of electricity**: the average carbon content of all electricity generation output.

5. **Electricity generation CCS**: the capture of CO₂ in electricity generation for reutilisation and/or storage in geological deposits.

6. **Grid investment**: all investment in electricity transmission, distribution and storage.

7. **Electricity price indices**: tracks changes in the price electricity from 2020 (where 2020 = 1.00) for large-scale consumers. The index will include carbon price.

8. **Renewables share of generation**: the percentage share of electricity generation from renewables, including biomass. Nuclear is not included.

The granularity of power sector variables available in the Catalogue is provided in Figure 10.
<table>
<thead>
<tr>
<th>Variable</th>
<th>Regions</th>
<th>Sector</th>
<th>Subsectors</th>
<th>Technologies and fuels</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electricity generation &amp; capacity</td>
<td>NGFS &amp; UN PRI (IPR): 12 regions</td>
<td>Power</td>
<td>Not applicable</td>
<td>All generation sources</td>
</tr>
<tr>
<td></td>
<td>IEA &amp; BNEF: World</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>NGFS: 12 regions</td>
<td>Power</td>
<td>Not applicable</td>
<td>Gas, solar PV, offshore wind, onshore wind, battery storage, All fuels and technologies (weighted average)</td>
</tr>
<tr>
<td></td>
<td>IEA: CHA, EU, IND, USA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LCOE/LCOS</td>
<td>NGFS: 12 regions</td>
<td>Power</td>
<td>Not applicable</td>
<td>NGFS, IEA &amp; BNEF: All fuels and technologies, coal, oil, gas</td>
</tr>
<tr>
<td></td>
<td>IEA &amp; BNEF: World</td>
<td></td>
<td></td>
<td>UN PRI (IPR): Total</td>
</tr>
<tr>
<td>Electricity generation emissions</td>
<td>NGFS &amp; UN PRI (IPR): 12 regions</td>
<td>Power</td>
<td>Not applicable</td>
<td>Not applicable</td>
</tr>
<tr>
<td></td>
<td>IEA &amp; BNEF: World</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Carbon intensity of electricity</td>
<td>NGFS: 12 regions</td>
<td>Power</td>
<td>Not applicable</td>
<td>Not applicable</td>
</tr>
<tr>
<td></td>
<td>BNEF: World</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Electricity generation CCS</td>
<td>NGFS &amp; UN PRI (IPR): 12 regions</td>
<td>Power</td>
<td>Not applicable</td>
<td>Coal, gas, oil, biomass</td>
</tr>
<tr>
<td></td>
<td>IEA: World</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grid investment</td>
<td>NGFS: 12 regions</td>
<td>Power</td>
<td>Not applicable</td>
<td>Electricity storage, electricity transmission and distribution</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Electricity prices</td>
<td>NGFS: 12 regions</td>
<td>Power</td>
<td>Not applicable</td>
<td>Not applicable</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Renewable share of generation</td>
<td>NGFS &amp; UN PRI: 12 regions</td>
<td>Power</td>
<td>Not applicable</td>
<td>All renewables</td>
</tr>
<tr>
<td></td>
<td>IEA, BNEF &amp; IRENA: World</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
3.2.2.3 Approach to variable disaggregation and expansion

Electricity generation and capacity

*Variable type: extraction*

Electricity generation and capacity is taken directly from source for all scenarios apart from some disaggregation for some fuel types, e.g. summing together offshore and onshore wind to compute total wind.

Electricity generation emissions

*Variable type: disaggregation*

The following steps are taken to estimate NGFS and IRENA\(^7\) electricity generation emissions:

1. **Extract secondary energy demand for all fossil fuel generation sources.**
2. **Convert generation to emissions while accounting for CCS.**
3. **Calibrate emissions to reconcile with extracted NGFS outputs.** The sum of emissions by generation source reconciles with total electricity emissions in each scenario, accounting for negative emissions from bioenergy with CCS (BECCS).

Power sector emissions from all other scenarios are extracted from source materials.

LCOE/LCOS

*Variable type: expansion*

The levelised costs of electricity and storage are estimates using cumulative deployment by generation or storage asset and technology-specific learning rates. Technology-specific learning rates are used to calculate costs as a function of experience. Experience for LCOE and LCOS are measured using the cumulative deployment of different technologies in each scenario. Current costs are taken from the IEA\(^6,9\) and Lazard.\(^10\) Where relevant, the LCOE also accounts for carbon costs, fossil fuel prices and CCS deployment which vary by scenario and region. For the sector-average, the

\(^7\)IRENA data availability limited to the year 2050.


average technology-specific levelized cost weighted by its share of the total generation mix is used. LCOE for IEA scenarios are extracted directly from source.

Carbon intensity of electricity

*Variable type: partial expansion*

The carbon intensity of electricity is estimated as aggregate electricity generation emissions over annual electricity output. The measure includes all generation sources including negative emissions technologies such as BECCS. Both total generation emissions and total electricity output are extracted from source.

Electricity generation CCS

*Variable type: disaggregation*

Electricity generation CCS is estimated using technology-specific emissions factors and CO₂ capture rates. Emissions factors and capture rates are the same as those used to estimate electricity generation emissions. CCS by generation source are constructed so that the sum of CCS from all sources reconciles with total CCS in the supply of electricity for each scenario.

Grid investment

*Variable type: extraction*

Grid investment is taken directly from source for all scenarios. Investment figures for IEA scenarios are reported as an annual average over a multi-decade period due to data limitations.

Electricity price indices

*Variable type: extraction*

Electricity price indices are extracted directly from source. Price indices are only available for the NGFS scenarios. Please note that electricity prices are often set according to unique country- or regional-level policies and regulations. The index should be used as a general gauge for the underlying technology costs of electricity generation as well as a proxy for the effects of carbon pricing. Use of the index may benefit from additional consideration of regulatory conditions and additional non-market factors within a specific geography.

Renewables share of generation

*Variable type: expansion*

The share of electricity generation from renewable sources is calculated using the full generation mix extracted from source. The sum of electricity generated from wind, solar, biomass, hydro, marine and geothermal sources is divided by total electricity generation in that region.

3.2.3 Transport variables
The transport sector is represented in the Catalogue by the following variables:

1. Transport final energy demand: end-use consumption of energy for transport.
2. **Transport emissions**: direct CO₂ emissions from energy use in transport.

3. **Car sales**: annual sales of electric personal passenger vehicles (EV) and internal combustion engine (ICE) personal passenger vehicles.

4. **Transport infrastructure investment**: investment in all public and private transport infrastructure, including low carbon and non-low carbon investment.

The granularity of transport sector variables available in the Catalogue is provided in Figure 11.

**Figure 11  Transport sector variable granularity**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Regions</th>
<th>Sector</th>
<th>Subsectors</th>
<th>Technologies and fuels</th>
</tr>
</thead>
<tbody>
<tr>
<td>Final energy demand</td>
<td>NGFS &amp; UN PRI (IPR): 12 regions</td>
<td>Transport</td>
<td>NGFS &amp; IEA: Road, Aviation, Shipping</td>
<td>All fuels and technologies, Electricity, hydrogen, gases (biogas, natural gas, gas from coal, ammonia), liquids (oil, biofuels, liquids from coal and natural gas, synth fuels) and solids (coal, biomass)</td>
</tr>
<tr>
<td></td>
<td>IEA &amp; BNEF: World</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Emissions</td>
<td>NGFS &amp; UN PRI (IPR): 12 regions</td>
<td>Transport</td>
<td>NGFS &amp; IEA: Road, Aviation, Shipping</td>
<td>Not applicable</td>
</tr>
<tr>
<td></td>
<td>IEA &amp; BNEF: World</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Car sales</td>
<td>NGFS &amp; UN PRI (IPR): 12 regions</td>
<td>Transport</td>
<td>Road</td>
<td>NFGS: EV, FCEV and ICE</td>
</tr>
<tr>
<td></td>
<td>IEA &amp; BNEF: World</td>
<td></td>
<td></td>
<td>IEA and UN PRI: EV and ICE</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>BNEF: EV</td>
</tr>
<tr>
<td>Infrastructure investment</td>
<td>NGFS: 12 regions</td>
<td>Transport</td>
<td>Not applicable</td>
<td>Not applicable</td>
</tr>
</tbody>
</table>

Source: Vivid Economics

3.2.3.3 Approach to variable disaggregation and expansion

Transport final energy demand

*Variable type: disaggregation*
Total transport final energy demand and total final energy demand by subsector (road, shipping and aviation) by fuel is taken directly from source for all scenarios. The breakdown of each subsector into fuels is performed using freely available data from IEA WEO 2022, IEA Net Zero by 2050 (2021) and IEA Energy Technology Perspectives 2020 on the fuel mix by subsector. This fuel mix data is reconciled with the subsector and fuel totals provided by NGFS and IEA scenarios.

Final energy demand for IRENA, UN PRI, and BNEF scenarios are extracted from source.

Transport emissions

Variable type: disaggregation

Transport emissions are disaggregated using the full final energy mix and emissions factors in datasets where direct extracts are not available. Emissions factors are applied to the final consumption of fossil fuels within each subsector. Estimates are constructed to ensure that the sum of CO₂ emissions across all transport subsectors is equal to total transport sector emissions for that scenario. Emissions in the Catalogue cover scope 1 CO₂ emissions.

Energy Service Demand

Variable type: extraction

The Energy Service demand by transport mode is taken directly from source for NGFS scenarios. Different categories are available for the GCAM and REMIND-MAgPIE models, which are provided raw with no modifications.

Car sales

Variable type: expansion

The following steps are taken to expand car sales of all powertrains.

1. Convert fuel consumption and energy service demand into vehicle stock. NGFS scenarios now provide energy service demand by transport mode. The trend of energy service demand is used to project forward the current stock of cars. The stock is then split into vehicle types (Electric, Hydrogen Fuel Cells and ICE) using the passenger road transport final energy mix computed previously.

2. Convert vehicle stock into annual sales using a stock-flow optimization model. The model estimates the ‘optimal’ or ‘best fit’ sales profile for a given stock projection. The lifetime distribution of each vehicle type and technology, often referred to as a ‘scrappage rate’, is applied to ensure a realistic distribution of vehicle retirements over time.

Car sales for the IEA scenarios by fuel type are extracted from IEA reports and BNEF and UN PRI scenarios are extracted directly from source material.

Transport infrastructure investment

Variable type: expansion

Infrastructure investment refers to both public and private investments and covers the following:
1. **Non-low carbon infrastructure.** Infrastructure requirements are split by transport subsector and projected forward using the estimated evolution of vehicle, locomotive, aircraft, and shipping vessel stocks.

2. **EV charging stations.** The total charging infrastructure is estimated using electricity consumption in road transport and the charging capacity required to support EV vehicle stocks. Costs are differentiated between assumed splits in private and public chargers, as well as fast and slow chargers.

3. **Hydrogen refuelling infrastructure.** Hydrogen refuelling infrastructure is calculated using a projected capital requirement per vehicle from the McKinsey Centre for Future Mobility.\(^\text{11}\)

Infrastructure requirements for non-NGFS scenarios are not included in this version of the Catalogue.\(^\text{12}\)

### 3.2.4 Buildings variables

#### 3.2.4.1 Overview of sector

The **buildings sector** is represented in the Catalogue by the following variables:

1. **Buildings final energy demand:** end-use consumption of energy in residential and commercial buildings.

2. **Buildings emissions:** direct CO\(_2\) emissions from energy use in residential and commercial buildings.

3. **Heat pump sales:** annual installations of heat pumps in residential and commercial buildings.

4. **Floor space:** total floor space and annual floor space additions.

5. **Low carbon floor space:** total low carbon floor space split by new builds and retrofits of existing buildings. Annual low carbon additions are also reported separately.

6. **Buildings infrastructure investment:** total low-carbon and non-low-carbon investment in public or private buildings, including new builds, retrofits, and heating.

The granularity of buildings sector variables available in the Catalogue is provided in Figure 12.

---

\(^{11}\)https://www.mckinsey.com/features/mckinsey-center-for-future-mobility/overview

\(^{12}\) As of March 2022.
<table>
<thead>
<tr>
<th>Variable</th>
<th>Regions</th>
<th>Sector</th>
<th>Subsectors</th>
<th>Technologies and fuels</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>IEA &amp; BNEF: World</td>
<td></td>
<td>Commercial</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Residential</td>
<td></td>
</tr>
<tr>
<td>Emissions</td>
<td>NGFS &amp; UN PRI (IPR): 12 regions</td>
<td>Buildings</td>
<td>NGFS &amp; IEA:</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td>IEA &amp; BNEF: World</td>
<td></td>
<td>Commercial</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Residential</td>
<td></td>
</tr>
<tr>
<td>Heat pump sales</td>
<td>NGFS &amp; UN PRI (IPR): 12 regions</td>
<td>Buildings</td>
<td>NGFS &amp; IEA:</td>
<td>Heat pumps</td>
</tr>
<tr>
<td></td>
<td>IEA &amp; BNEF: World</td>
<td></td>
<td>Commercial</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Residential</td>
<td></td>
</tr>
<tr>
<td>Floor space</td>
<td>NGFS: 12 regions</td>
<td>Buildings</td>
<td>Commercial</td>
<td>Floor space, Floor space - annual additions</td>
</tr>
<tr>
<td></td>
<td>IEA &amp; BNEF: World</td>
<td></td>
<td>Residential</td>
<td></td>
</tr>
<tr>
<td>Low carbon floor space</td>
<td>NGFS: 12 regions</td>
<td>Buildings</td>
<td>Commercial</td>
<td>Floor space - low carbon, Floor space - annual low carbon, Floor space - annual low carbon retrofits, Floor space - low carbon retrofits, Floor space - annual low carbon new builds, Floor space - low carbon new builds</td>
</tr>
<tr>
<td></td>
<td>IEA &amp; BNEF: World</td>
<td></td>
<td>Residential</td>
<td></td>
</tr>
<tr>
<td>Investment</td>
<td>NGFS: 12 regions</td>
<td>Buildings</td>
<td>Not applicable</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
3.2.4.3 Approach to variable disaggregation and expansion

Buildings final energy demand

**Variable type: Extraction/disaggregation**

**For NGFS, buildings final energy is extracted for GCAM and disaggregated to the commercial and residential subsectors for REMIND.** Additional modelling is conducted to disaggregate models or scenarios which do not provide the fuel mix for residential and commercial subsectors. Fuel aggregates are further disaggregated using linking equations. The allocation of fuels between residential and commercial buildings is constructed to reconcile with extracted scenario outputs.

**For IEA, building final energy by fuel and commercial and residential total final energy are extracted directly from source.** Data from 2021 publications is used to split up commercial and residential final energy into relevant fuel types.

Buildings emissions

**Variable type: disaggregation**

**Buildings emissions are disaggregated using the full final energy mix and emissions factors.** Emissions factors are applied to the final consumption of fossil fuels within commercial and residential buildings. Estimates are constructed to ensure that the sum of CO₂ emissions across commercial and residential buildings is equal to total buildings sector emissions for that scenario. Emissions in the Catalogue cover scope 1 CO₂ emissions.

Heat pump sales

**Variable type: expansion**

**Heat pump sales for NGFS are estimated in 3 steps, specifically:**

1. Estimate the amount of electricity consumed for the heating of residential and commercial buildings.
2. Use the electricity consumption trend to project forward the stock of heat.
3. Convert stock into annual sales using an average technology lifetime and historical sales data.

IEA heat pump sales are extracted.

Floor space - NGFS

**Variable type: extraction/disaggregation**

**For NGFS scenarios, floor space is taken directly from source and used to calculate annual floor space additions.**
For IEA, floor space is estimated based on 2021 values, projected forward using 2022 final energy pathways.

Low carbon floor space

**Variable type: expansion**

Low carbon floor space is estimated using zero-carbon standards for new buildings and annual retrofit rates. The percentage of new buildings that meet zero-carbon or near zero-carbon building standards is applied to annual floor space additions to measure total floor space from new, low carbon buildings. Total floor space with low carbon retrofits – including insulation, sealing, window replacements and systems for energy management\(^{13}\) – are calculated using annual retrofit rates and the existing buildings stock, including new buildings added that do not meet zero-carbon or near-zero-carbon building standards. Low carbon floor space from new buildings and retrofits are both only available for IEA scenarios.

Heat pump investment

**Variable type: expansion**

Heat pump investment are estimated based on costs, taken from recent literature, adjusted by location/building type and assuming learning over time.

Infrastructure requirements for non-NGFS scenarios are not included in this version of the Catalogue.\(^{14}\)

### 3.2.5 Industry variables

3.2.5.1 Overview of sector

The **industry sector** is represented in the Catalogue by the following variables:

1. **Industry final energy demand**: end-use consumption of energy for industry.
2. **Industry emissions**: emissions from both energy use and industrial processes in industry.
3. **Industrial CCS**: carbon captured and stored from CO\(_2\) combustion and industrial processes.
4. **Volume of demand**: total demand for key industrial goods in total volume (mega tonnes).

The granularity of industry sector variables available in the Catalogue is provided in Figure 13.

---


\(^{14}\) As of March 2022.
<table>
<thead>
<tr>
<th>Variable</th>
<th>Regions</th>
<th>Sector</th>
<th>Subsectors</th>
<th>Technologies and fuels</th>
</tr>
</thead>
<tbody>
<tr>
<td>Final energy demand</td>
<td>NGFS &amp; UN PRI (IPR): 12 regions</td>
<td>Industry</td>
<td>Cement, Steel, Aluminium, Paper, pulp and printing, Other industry, Chemicals (Chemicals HVCs, Chemicals Methanol, Chemicals Plastics)</td>
<td>All fuels w CCS, All fuels and technologies, Electricity, Gases, Heat, Hydrogen, Liquids, Solids biomass, Solids coal, Gases biomethane, Gases natural gas w CCS, Gases natural gas w o CCS, Liquids oil, Other renewables, Solids, Solids coal w CCS, Solids coal w o CCS, Gases coal, Gases natural gas, Liquids biofuels, Liquids coal, Liquids natural gas, Gases synthetic methane, Bioenergy, Coal w CCS, Gas w CCS, Coal, Gas, Solids bioenergy</td>
</tr>
<tr>
<td>Emissions</td>
<td>NGFS &amp; UN PRI (IPR): 12 regions</td>
<td>Industry</td>
<td>Cement, Steel, Chemicals, Aluminium, Paper, pulp and printing, Other industry</td>
<td>IEA and NGFS: Total energy and industrial process emissions, Energy Demand Emissions, Industrial Process Emissions UN PRI (IPR): Total energy and industrial process emissions BNEF: Total energy emissions</td>
</tr>
<tr>
<td>CCS</td>
<td>NGFS &amp; UN PRI (IPR): 12 regions</td>
<td>Industry</td>
<td>Cement, Steel Chemicals</td>
<td>NGFS and IEA: All fuels with CCS</td>
</tr>
<tr>
<td></td>
<td>IEA: World</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
3.2.5.3 Approach to variable disaggregation and expansion

**Industry final energy demand**

*Variable type: disaggregation or expansion*

*Industry final energy is disaggregated to industrial subsectors using current and projected energy balances and secondary energy production.* Fuel use in 2022 is allocated to subsectors using the IEA’s World Energy Balances. Additional modelling is done to project low-carbon fuel shares for all scenarios. Fuel aggregates are further disaggregated using linking equations. The allocation of fuels between industrial subsectors is constructed to reconcile with extracted scenario outputs.

**Industry emissions**

*Variable type: disaggregation or expansion*

*Industrial emissions are disaggregated using the final energy pathways of the subsectors under different scenarios.* Emissions estimates are then disaggregated into emissions from energy demand and emissions from industrial processes, while ensuring that the sum of CO₂ for all industrial subsectors reconciles with total industrial emissions extracted from source for that
particular scenario. Emissions in the Catalogue cover scope 1 CO₂ emissions. For BNEF, industrial emissions do not include process emissions.

Industry CCS

*Variable type: disaggregation or extraction*

**Industrial CCS is disaggregated using subsector-specific CCS potential.** Additional modelling is undertaken to estimate future CCS potential in each subsector using the same approach taken to final energy. Estimates are constructed to ensure that the sum of energy and process CCS in all industrial subsectors reconciles with total industrial CCS for that scenario.

**Volume of commodity demand**

*Variable type: expansion*

**Industrial commodity demand is estimated using final energy demand and projected material and energy efficiency improvements.** For subsectors that cannot be directly extracted from extracted outputs, commodity demand grows with energy and material efficiency-adjusted final energy demand. Production estimates are normalised to ensure consistency with actuals. Volume of demand for plastics measures industrial production from non-recycled content. Plastics production is estimated using changes in demand for primary chemicals, notably of high-value chemicals like ethylene that are used in plastic production. Aluminium volumes also do not include production from recycled content.

**End-use of Materials**

*Variable type: expansion*

**Industrial material demand is split into end-use sectors, while accounting for the sector demand increase and the material efficiency gains across scenarios.** Current and 2050 end-use splits are extracted from the IEA’s Energy Technology Perspective 2020, and applied to the overall demand pathway for steel and cement. The pathways thus reflect demand changes driven by variations in sector size by scenario, as well as changes in material efficiency across end-use sectors.

### 3.2.6 Mining variables

#### 3.2.6.1 Overview of sector

The **mining sector** is represented in the Catalogue by the following variables:

1. **Volume of material demand:** total transition and non-transition related mineral demand from mined and recycled sources.
2. **Material prices:** market prices for minerals.

The granularity of mining sector variables available in the Catalogue is provided in Figure 14.
3.2.6.3 Approach to variable disaggregation and expansion

Material demand

*Variable type: expansion*

The following steps are taken to estimate mineral demand.

1. **Estimate all transition-related drivers across all sectors.** Annual additions for every transition-related technology in energy production, power, transport, buildings and industry are estimated.

2. **Convert annual technology additions into mineral demand.** Technology-specific mineral intensities and market share projections for key technologies are combined to estimate minerals required to fulfil demand for each transition technology.

3. **Estimate non-transition related demand and combine with demand from transition-related sectors estimated in Step 2.**

Mineral prices

*Variable type: expansion*

Material prices for IEA are estimated using sector revenue and demand for IEA scenarios. Prices are consistent with the IEA’s reporting on mineral prices which assume
“...cost increases (around a 10% - 20% increase from current levels to 2050)”. The same assumption is used for all scenarios.

Material prices for NGFS and IPR use the mineral demand estimates and empirical price elasticities in the mineral sector. An in-house model combines price elasticities from the academic literature on mineral transition and combines them with the estimates on mineral demand. The approach captures deviations from long-run mineral prices caused by steep increases in demand due to the climate transition. The prices are indexed, with 2020 the base value.

3.2.7 Macro-economy variables
3.2.7.1 Overview of sector

Variables covering the macro-economy in the Catalogue include:

1. **Gross domestic product (GDP):** the total value of goods and services produced in an economy.

2. **Population:** total persons.

3. **Inflation:** the annual inflation rate of the economy.

4. **Unemployment:** the annual percentage of the workforce that is unemployed.

5. **Productivity:** average output per hour of labour.

6. **Climate damages and climate policy costs:** the combined impact of physical damages from climate change and all climate policy on GDP. Damages are expressed in annual and cumulative terms in current dollars.

7. **Carbon prices:** carbon prices for the IEA and NGFS scenarios are defined and reported separately. Carbon prices in IEA scenarios represent an explicit price levied on each tonne of CO₂. Carbon prices in NGFS scenarios represent the shadow price of carbon, which is the price per tonne of CO₂ from all implicit or explicit mitigation policies, required to mitigate the last tonne of CO₂ in that year. The two measures are not comparable.

8. **House prices:** the level of housing prices in an economy

9. **Energy intensity:** energy requirements per unit of GDP, measured in terms of primary energy supply per US$2021 and final energy consumption per US$2021.

10. **Non-CO₂ emissions:** emissions from three largest sources of non-CO₂ greenhouse gases including methane (CH₄), nitrous oxide (NOₓ), and fugitive gases (F-Gases).

The granularity of macro-economy variables available in the Catalogue is provided in Figure 15.

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## Figure 14 Macro-economic variable granularity

<table>
<thead>
<tr>
<th>Variable</th>
<th>Regions</th>
<th>Sector</th>
<th>Subsectors</th>
<th>Technologies and fuels</th>
</tr>
</thead>
<tbody>
<tr>
<td>GDP</td>
<td>NGFS: 12 regions</td>
<td>Not applicable</td>
<td>Not applicable</td>
<td>Not applicable</td>
</tr>
<tr>
<td></td>
<td>NiGEM: 6 regions</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>IEA &amp; BNEF: World</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Population</td>
<td>NGFS: 12 regions</td>
<td>Not applicable</td>
<td>Not applicable</td>
<td>Not applicable</td>
</tr>
<tr>
<td>Inflation</td>
<td>NiGEM: 5 regions and 47 countries</td>
<td>Not applicable</td>
<td>Not applicable</td>
<td>Not applicable</td>
</tr>
<tr>
<td>Unemployment</td>
<td>NiGEM: 5 regions and 47 countries</td>
<td>Not applicable</td>
<td>Not applicable</td>
<td>Not applicable</td>
</tr>
<tr>
<td>Productivity</td>
<td>NiGEM: 5 regions and 47 countries</td>
<td>Not applicable</td>
<td>Not applicable</td>
<td>Not applicable</td>
</tr>
<tr>
<td>Climate damages and policy costs</td>
<td>NiGEM: 5 regions and 47 countries</td>
<td>Not applicable</td>
<td>Not applicable</td>
<td>Not applicable</td>
</tr>
<tr>
<td>Carbon prices</td>
<td>12 regions</td>
<td>Not applicable</td>
<td>Not applicable</td>
<td>Not applicable</td>
</tr>
<tr>
<td>House Prices</td>
<td>NiGEM: 17 countries</td>
<td>Not applicable</td>
<td>Not applicable</td>
<td>Not applicable</td>
</tr>
<tr>
<td>Energy intensity</td>
<td>NGFS: 12 regions</td>
<td>Not applicable</td>
<td>Not applicable</td>
<td>Not applicable</td>
</tr>
<tr>
<td></td>
<td>IEA &amp; BNEF: World</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-CO₂ Emissions</td>
<td>NGFS: 12 regions</td>
<td>Not applicable</td>
<td>Not applicable</td>
<td>Methane (CH4), Nitrous Oxide (NOx), F-Gases</td>
</tr>
</tbody>
</table>

Source: Vivid Economics
3.2.7.3 Approach to variable disaggregation and expansion

**GDP**

*Variable type: extraction*

_GDP is taken directly from source for all scenarios and converted to US$2021 PPP for comparability._ GDP for the NiGEM model has been converted into monetary units to increase accessibility.

**Population**

*Variable type: extraction*

_Population is taken directly from source for all scenarios._

**Inflation**

*Variable type: extraction*

_Inflation is taken directly from NiGEM model outputs._ Units have been converted to express inflation as a percentage rather than a percentage point change relative to the baseline scenario.

**Unemployment**

*Variable type: extraction*

_Unemployment is taken directly from NiGEM model outputs._ Units have been converted to express unemployment as a percentage rather than a percentage point change relative to the baseline scenario.

**Productivity**

*Variable type: extraction*

**Productivity is taken directly from NiGEM model outputs.**

**Climate damages and policy costs**

*Variable type: extraction*

_Damages are taken directly from NiGEM model outputs._ Damages have been converted into monetary units to increase accessibility. Damages are presented both on an annual and cumulative basis, the latter being calculated as the cumulative sum of all physical damages and policy costs in any year post 2020.
Carbon prices

**Variable type: extraction**

*Carbon prices are taken directly from source for all scenarios.* Carbon prices by region are available directly from extracted outputs for NGFS scenarios. The carbon price for NGFS scenarios is the shadow price of carbon, which corresponds to the level of ambition of all climate-related policies to achieve the level of decarbonisation associated with the scenario. The shadow carbon price summarises the impact of all climate policies, and does not represent a price that would be faced directly by companies. For IEA scenarios, regions are classified as “advanced”, “developing” or “selected developing” and assigned a carbon price. The carbon price for IEA scenarios is an explicit carbon price, such as through a carbon tax or an emissions trading system.

House prices

**Variable type: extraction**

*House prices are taken directly from source for all NiGEM scenarios.* Prices are available for the NiGEM model in Western Europe, Australia, Canada, New Zealand, and the United States. Estimates for other regions are not available in this iteration of the catalogue.

Energy intensity

**Variable type: extraction**

*Energy intensity is either extracted directly from source or calculated using directly extracted outputs.* It can be measured in terms of a primary energy requirement per unit of GDP or final consumption requirement per unit of GDP.

Non-CO₂ emissions

**Variable type: extraction**

*Non-CO₂ emissions are extracted directly from source where available.*

### 3.3 Scenario descriptions

Descriptions of the climate scenarios included in the Catalogue are listed in Table 3.

<table>
<thead>
<tr>
<th>Institution/Author</th>
<th>Scenario</th>
<th>Scenario Family</th>
<th>Scenario description</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Below 2°C</td>
<td>Paris Aligned</td>
<td>This scenario assumes that optimal carbon prices in line with the long-term targets are implemented immediately after 2020 and keeps the 67-percentile of warming below 2°C throughout the 21st century.</td>
</tr>
<tr>
<td>Institution/Author</td>
<td>Scenario</td>
<td>Scenario Family</td>
<td>Scenario description</td>
</tr>
<tr>
<td>--------------------</td>
<td>----------</td>
<td>----------------</td>
<td>---------------------</td>
</tr>
<tr>
<td>NGFS (V3.1)</td>
<td>Current Policies</td>
<td>Current Policies/BAU</td>
<td>The Current Policies scenario assumes that only currently implemented policies are preserved and no further climate action is taken.</td>
</tr>
<tr>
<td></td>
<td>Delayed transition</td>
<td>Paris Aligned Well-Below 2°C</td>
<td>This scenario assumes that the next 10 years see a &quot;fossil recovery&quot; and thus follow the trajectory of the current policies scenario until 2030, and only thereafter countries with a clear commitment to a specific net-zero policy target at the end of 2020 are assumed to meet the target, representing regional fragmentation. Regionally fragmented CO2 prices converge to global price near 2070 to keep the 67-percentile of warming below 2°C in 2100, which also allows for temporary overshoot.</td>
</tr>
<tr>
<td>NGFS (V3.1)</td>
<td>Divergent Net Zero</td>
<td>Paris Ambitious 1.5°C</td>
<td>This scenario assumes that optimal carbon prices in line with the long-term targets are implemented immediately after 2020 to bring the median temperature below 1.5°C in 2100, after a limited temporary overshoot. Policy pressure and mitigation efforts are unevenly distributed across sectors, with stronger mitigation action taking place in the Transport and Buildings sectors relative to reflect consumer-oriented measured being preferred by policy makers.</td>
</tr>
<tr>
<td>Nationally Determined Contributions (NDCs)</td>
<td>NDCs</td>
<td>Current Policies/BAU</td>
<td>The NDCs scenarios assumes that currently pledged unconditional NDCs are implemented fully, and respective targets on energy and emissions in 2025 and 2030 are reached in all countries. The long-term policy assumption beyond current NDC target times (2025 and 2030) is that climate policy ambition remains comparable to levels implied by NDCs. This however does not clearly constrain the level of policy ambition, so long-term deviations across models are quite high.</td>
</tr>
<tr>
<td>Net Zero 2050</td>
<td>Paris Ambitious 1.5°C</td>
<td></td>
<td>This scenario foresees global CO2 emissions to be at net-zero in 2050. Furthermore, countries with a clear commitment to a specific net-zero policy target at the end of 2020 are assumed to meet this target. This scenario assumes that optimal carbon prices in line with the long-term</td>
</tr>
<tr>
<td>Institution/Author</td>
<td>Scenario Family</td>
<td>Scenario</td>
<td>Scenario description</td>
</tr>
<tr>
<td>--------------------</td>
<td>----------------</td>
<td>----------</td>
<td>----------------------</td>
</tr>
<tr>
<td></td>
<td></td>
<td>IEA Net Zero Energy 2050</td>
<td>Paris Ambitious 1.5°C</td>
</tr>
<tr>
<td></td>
<td></td>
<td>IEA Announced Pledges Scenario</td>
<td>Paris Aligned Well-Below 2°C</td>
</tr>
<tr>
<td></td>
<td></td>
<td>IEA Stated Policies Scenario</td>
<td>Current Policies/BAU</td>
</tr>
</tbody>
</table>

16 IEA. (2022).
<table>
<thead>
<tr>
<th>Institution/Author</th>
<th>Scenario</th>
<th>Scenario Family</th>
<th>Scenario description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>UN PRI (IPR)</strong></td>
<td>Required Policy Scenario</td>
<td>Paris Ambitious 1.5°C</td>
<td>The Required Policy Scenario (RPS) is a stringent scenario explicitly designed to assess the policy gap to limit global warming to 1.5°C. Additional policy ambition is achieved through additional performance standards and subsidies.</td>
</tr>
<tr>
<td></td>
<td>Forecast Policy Scenario</td>
<td>Paris Aligned Well-Below 2°C</td>
<td>The Forecast Policy Scenario (FPS) lays out the policies that are likely to be implemented in the 2020’s that result in global warming limited to 2°C and quantifies their impact on the real economy, energy use sectors and land use to 2050.</td>
</tr>
<tr>
<td><strong>Bloomberg New Energy Outlook (NEO 2022)</strong></td>
<td>Net Zero Scenario (NZS)</td>
<td>Paris Aligned Well-Below 2°C</td>
<td>The NEO 2022 NZS Scenario describes an economics-led evolution of the energy economy to achieve net-zero emissions in 2050. This scenario combines faster and greater deployment of renewables, nuclear and other low carbon dispatchable technologies in power with the uptake of cleaner fuels in end-use sectors, most notably hydrogen and bioenergy. Taking a sector-led approach, it describes a credible pathway to meet the goals of the Paris Agreement.</td>
</tr>
<tr>
<td></td>
<td>Economic Transition Scenario (ETS)</td>
<td>Current Policies/BAU</td>
<td>The Economic Transition Scenario is NEO 2022 baseline assessment of how the energy transition might evolve from today as a result of cost-based technology changes. In ETS, which assumes no new policy action to accelerate the clean energy transition, the rapid growth of renewable energy and electrification of transport eliminate about half of the world’s energy-related emissions in 2050, against a baseline where no such transition takes place. Despite these rapid gains for clean energy, the Economic Transition Scenario falls far short of achieving net zero by mid-century. By 2050, emissions have fallen 29%, but unabated coal, oil and gas still emit 24.6 gigatons of CO2 per year. The result is a trajectory consistent with 2.6°C of global warming, breaching the goals of the Paris Agreement.</td>
</tr>
<tr>
<td>Institution/Author</td>
<td>Scenario</td>
<td>Scenario Family</td>
<td>Scenario description</td>
</tr>
<tr>
<td>--------------------</td>
<td>----------</td>
<td>----------------</td>
<td>---------------------</td>
</tr>
<tr>
<td>IRENA</td>
<td>World Energy Transitions Outlook 1.5°C Scenario</td>
<td>Paris Ambitious 1.5°C</td>
<td>The International Renewable Energy Agency (IRENA) provides transition modelling of the energy system with a focus on renewables. The 1.5 Scenario is an orderly transition to limit global warming to 1.5°C by the end of the century with a focus on renewables. It reaches net zero energy emissions in 2050.</td>
</tr>
<tr>
<td></td>
<td>Global Renewables Outlook Transforming Energy Scenario</td>
<td>Paris Aligned Well-Below 2°C</td>
<td>The International Renewable Energy Agency (IRENA) provides transition modelling of the energy system with a focus on renewables. The Transforming Energy Scenario is an orderly transition to limit global warming to well below 2°C by the end of the century with a focus on renewables.</td>
</tr>
<tr>
<td>AR6 Scenario Explorer and Database hosted by IIASA, in collaboration with IAMC and IPCC Working Group III</td>
<td>3,131 scenarios based on 188 modelling frameworks from the IPCC AR6 scenario explorer and database – filtered to vetted scenarios only</td>
<td>All families</td>
<td>The scenario explorer presents an ensemble of quantitative climate change mitigation pathways underpinning chapter 3 of the IPCC’s 6th Assessment Report published by the Intergovernmental Panel on Climate Change (IPCC). It includes 3,131 quantitative scenarios with data on socio-economic development, emissions, energy and land use, with 188 unique modelling frameworks which are globally and nationally comprehensive.</td>
</tr>
<tr>
<td>Riahi et al (2017)</td>
<td>SSP_SSP3 (Low Growth Scenario)</td>
<td>Paris Ambitious 1.5°C</td>
<td>SSP_SSP3 (Low Growth Scenario) is characterized by regional rivalry. The scenario builds on the narrative that nationalism, concerns about competitiveness and security, leads to low international priority for addressing environmental concerns causing environmental degradation and low economic growth. It provides a scenario for climate transition with a different GDP projection than the vetted scenarios from international institutions. The 1.5 Scenario is an orderly transition to limit global warming to 1.5°C by 2100.</td>
</tr>
</tbody>
</table>

**3.4 Model descriptions**

Description of the climate models included in the Catalogue are listed in Table 4.

<table>
<thead>
<tr>
<th>Model</th>
<th>Defining characteristic</th>
<th>Model description</th>
<th>Catalogued scenarios</th>
</tr>
</thead>
<tbody>
<tr>
<td>GCAM5.3+ (NGFS)</td>
<td>Economic agents are myopic, meaning that decisions are made irrespective of the future and are only informed by past and present circumstances.</td>
<td>GCAM is a partial equilibrium model of the energy and land sector. It assumes that economic agents are self-interested and myopic. Consequently, the model solves for the least-cost (or maximum profits) outcome in a particular period without consideration of how current decisions affect costs or profits in future periods.</td>
<td>Net Zero 2050, Divergent Net Zero, Below 2°C, Delayed Transition, NDCs, Current Policies</td>
</tr>
<tr>
<td>REMIND-MagPIE 3.0-4.4 (NGFS)</td>
<td>The energy component of the model uses an intertemporal optimisation algorithm (perfect foresight).</td>
<td>REMIND-MagPIE combines a general equilibrium model on the energy sector and the macroeconomy under perfect foresight with a partial equilibrium model on the energy sector.</td>
<td>Net Zero 2050, Divergent Net Zero, Below 2°C</td>
</tr>
</tbody>
</table>

---


19 Richters et al. (2022).
<table>
<thead>
<tr>
<th>Model</th>
<th>Defining characteristic</th>
<th>Model description</th>
<th>Catalogued scenarios</th>
</tr>
</thead>
<tbody>
<tr>
<td>NiGEM (NGFS)</td>
<td>An econometric model where outputs are estimated using econometric equations of historical behaviour.</td>
<td>NiGEM is the leading global general equilibrium macroeconomic model. Countries and regions are linked together through trade and capital markets. The model reflects key dynamics and elasticities of individual countries and is updated with quarterly data such that there is a balance between the “theoretical underpinnings that guide economies towards long-run market clearing equilibria, and data-driven individual country characteristics that fit the main characteristics of real-world data outturns.”</td>
<td>Each scenario with Remind inputs &amp; GCAM inputs - Net Zero 2050 - Divergent Net Zero - Below 2°C - Delayed Transition - Nationally Determined Contributions (NDCs) - Current Policies</td>
</tr>
<tr>
<td>Global Energy and Climate Model (IEA)</td>
<td>The Global Energy and Climate Model (GEC) is a bottom-up partial-optimisation model that models energy demand, supply, transformation, and prices.</td>
<td>The GEC Model is a bottom-up partial-optimisation model covering energy demand, energy transformation and energy supply. The model uses a partial equilibrium approach, integrating prices sensitivities. It shows the transformation of primary energy along energy supply chains to meet energy service demand, the final energy consumed by the end-user. The various supply, transformation</td>
<td>- Net Zero Energy 2050 - Announced Pledges Scenario - Stated Policies Scenario</td>
</tr>
</tbody>
</table>

---


21 Richters et al. (2022).
<table>
<thead>
<tr>
<th>Model</th>
<th>Defining characteristic</th>
<th>Model description</th>
<th>Catalogued scenarios</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inevitable Policy Response (IPR)</td>
<td>IPR includes a detailed policy forecast based on ‘inevitable’ policies to limit global warming.</td>
<td>IPR creates policy forecast and then uses a suite of models to estimate the impacts of these policies on energy and land.</td>
<td>- Forecast Policy Scenario</td>
</tr>
<tr>
<td>BNEF NEO 2022</td>
<td>Built from bottom-up, sector-level economic modelling and analysis of key sectors.</td>
<td>This bottom-up, sector-by-sector modelling exercise is BloombergNEF’s long-term scenario analysis on the future of the energy economy covering electricity, industry, buildings and transport and the key drivers shaping these sectors until 2050.</td>
<td>- Net Zero Scenario</td>
</tr>
<tr>
<td>Renewable Energy Roadmap (IRENA)</td>
<td>The Renewable Energy Roadmap (REMap) approach creates normative scenarios of technology penetration.</td>
<td>The Renewable Energy Roadmap (REMap) approach involves using a parametric model with a focus on energy technologies. Like WEM, the REMap approach does not follow a solution concept. However, REMap does not model policies and rather develops a normative scenario built on penetration of renewable energy technologies across different sectors. The land use system is not integrated with the energy system and socioeconomic pathways are exogenous.</td>
<td>- 1.5°C Scenario</td>
</tr>
<tr>
<td>Various models from the AR6 Scenario Explorer and Database</td>
<td>Not applicable – the models from the IAMC 1.5°C scenario ensemble database are similar in that they are</td>
<td>Not applicable – the models originate from a plurality of different institutions and/or authors.</td>
<td>Various models from the IPCC AR6 - 1.5°C scenario ensemble data</td>
</tr>
</tbody>
</table>
## Climate Scenario Catalogue: Technical Documentation

Hosted by IIASA, in collaboration with IAMC and IPCC Working Group III, all integrated assessment models (IAMs), meaning that climatic, economic and energy (and possibly land use) systems are modelled simultaneously. However, the models originate from a plurality of different institutions and/or authors and are unlikely to share a single defining characteristic.

Source: Vivid Economics

<table>
<thead>
<tr>
<th>Model Hosted by</th>
<th>Defining characteristic</th>
<th>Model description</th>
<th>Catalogued Scenarios</th>
</tr>
</thead>
<tbody>
<tr>
<td>IIASA, in collaboration with IAMC and IPCC Working Group III</td>
<td>all integrated assessment models (IAMs), meaning that climatic, economic and energy (and possibly land use) systems are modelled simultaneously. However, the models originate from a plurality of different institutions and/or authors and are unlikely to share a single defining characteristic.</td>
<td>release hosted by IIASA</td>
<td></td>
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