Scenario Processing Methodology

THEIA Finance Labs

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Introduction: Climate Scenarios in the 1in1000 Transition Risk Stress Test

Climate scenarios are hypothetical future trajectories of the Earth's climate, based on various assumptions about factors like greenhouse gas emissions, socioeconomic development, and policy choices. These scenarios are essential tools for researchers, policymakers, and stakeholders to explore and understand the range of possible outcomes for our planet's climate. They help us assess the potential impacts of different choices and decisions regarding emissions reductions, energy transitions, and adaptation strategies.

We represent the set of transition scenarios by a set of climate-adjusted economic parameters with geographical differentiation to account for institutional and regulatory heterogeneity across economic systems. This allows to capture the different capabilities and responsibilities of individual countries in climate change mitigation.

In the 1in1000 Stress Test, we use climate scenarios primarily to extend the company specific production pathways, which we have available until 2027, until a desired time horizon (mostly 2050) for a business-as-usual scenario, in which no new climate policies are engaged, and a target scenario, in which more ambitious policies lead to a limitation of global temperature rise below 2°C.

The total collection of climate-adjusted economic parameters we use includes factors like mentioned decarbonization paths, projected unit costs and technology prices, and carbon tax pathways. These parameters again represent different scenarios related to climate policies, shifts in demand, and technological changes in energy and industry systems. These scenario parameters are external and capture various socio-economic and climatological assumptions from different climate-economic models. Our approach for the 1in1000 TRISK Model is scenario-agnostic and can be applied across a range of scenarios, which we are mentioning in Section 3. The level of granularity that can be adopted in a our model will largely depend on the granularity of the scenario data on which the stress scenario can be calibrated. In Section 4 we cover the newest addition in 1in1000 Model Suite, the Steel sector, and its underlying scenario processing methodology.

Scenario Data and Main Integration Process

As mentioned previously, the scenarios in our model provide several key inputs. These key inputs are:

- The trajectory of certain technologies for a specific scenario
- The capacity factors for technologies in the power sector
- The unit cost projection for technologies in the power sector
- The prices of fossil fuel

In the following section, we want to highlight the importance of these inputs and how they play a role, as well as how we procure these values.

Technology Trajectories

Technology trajectories covers the development of key technologies in the Power, Oil and Gas, Coal or Automotive sector. With technologies, we refer to the main types of technology used for different parts of the sector. Our technologies per sector are defined as follows:

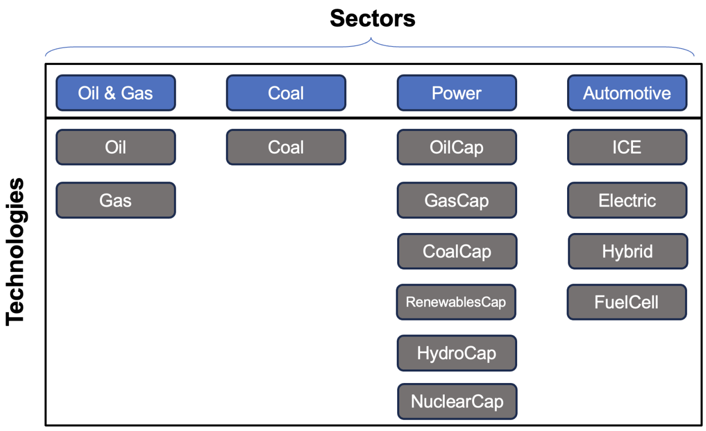

Figure 1 Overview of Sectors and Technologies

The technologies with "Cap" refer to capacity related technologies in the power sector. CoalCap for example refers to the electrical capacity that is generated by coal. In contrast the technology Coal refers to the extraction of coal. The pathways provided for these technologies by the scenarios are the expected/calculated development of the relevant resource for different scenarios. As an example, we can refer to the following graph:

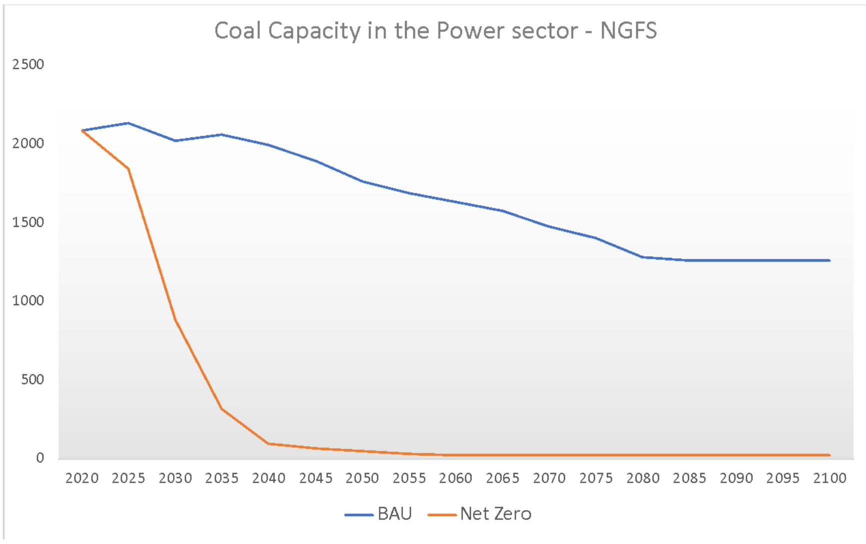

Figure 2 CoalCap Development under two scenarios

The graph shows the development of CoalCap in a Business-as-usual scenario and a Net Zero scenario. In the Net zero scenario, Electricity generated from coal has to be drastically phased out in order to remain in a specific carbon budget to reach a global mean temperature rise of below 2°C. Note that these pathways can signficantly differ, based on the scenario provider, the scenario ambition and the region. These pathways are then processed by our model and used to create company specific target and baseline pathways.

Technology Trajectories: From raw to processed

For each scenario, we load the relevant raw data and wrangle it. This includes for interpolating the data between available frequencies and created RenewablesCap, which is the aggregate of sustainable low carbon technologies, except Hydro and Nuclear.

Scenario Pathways

Additionally, we then obtain the market share $\eta_{iyha}{}^{t}$ of asset *a* of firm *i* in sector *y* and technology *h* in region *g* at time *t*, which is given by its asset production $P_{iyhga}{}^{t}$ relative to the total production $P_{yh}{}^{t}$ in sector *y* and and technology *h* in region *g* at time *t*; i.e.,

$$\eta^{t}_{iyha} = \frac{P^{t}_{iyha}}{P^{t}_{yh}} . \qquad (1)$$

The market share η^t_{iyha} of asset *a* of firm *i* is typically defined based on current data, but could in principle be defined based on the market share at a future time *t* projected under a given scenario *s*. Therefore, the market share $\eta_{iyha}{}^{s,t}$ could be given a superscript *s*.

Obtaining the firm *i*'s asset market share η^t_{iyha} allows us to derive the firms responsibility in implementing the requisite change in the absolute production levels in scenario *s* to achieve a certain decarbonisation climate target. For instance, according to a Parisaligned scenario, electricity generated from coal will slowly be phased out according to government commitments and the cost-disadvantage due to the replacement of renewable power generation. We then assume that a firm that owns a coal-fired power plant will contribute to such a decarbonisation by decreasing its production according to its market share. An asset with higher capacities and production will therefore be required to reduce production levels to a greater absolute extent. A firm that has both, production assets in oil extraction and power plants that produce electricity from solar, will need to adjust its respective production levels in oil extraction (downwards) and solar power (upwards) depending on the location of the plants and applicability of regional targets that are consistent with climate objectives. More formally, the requisite production level change $\Delta P^{s,t}_{iyha}$ by asset *a* of firm *i* is given by its asset-specific market share η^t_{iyha} times the change in production levels $P^{s,t}_{yh}$ specificed in scenario *s*, i.e.

$$\Delta P^{s,t}_{iyha} = \eta^t_{iyha} \Delta P^{s,t}_{yh}, \tag{2}$$

where the change in production in region *g* in technology *h* under scenario *s* is defined as $\Delta P_{yh}{}^{s,t} = P_{yh}{}^{s,t} - P_{yh}{}^{s,t-1}$.[1] Firms *i*'s overall market share across technologies and sectors at a given time *t* is ultimately a composition of its market shares $\eta_{iyha}{}^t$ of asset *a* at time *t*. Importantly, it can be seen from equation 2 that a firm with a smaller market share across its assets in sustainable technologies today will be at greater transition risk tomorrow if its high-carbon technologies are subject to a phase-out according to the requisite scenarios production levels $P_{yh}{}^{s,t}$. Further, from equation 1, it is clear that $\eta_{iyha}{}^t$ is time-varying and could be made dependent on the firms' own production plans as observed in the data.

[1] Henceforth, the Δ of a variable is always defined as the difference between a variable at time *t* and *t*− 1.

To translate the trajectories and make them available for firm specific use, we calculate two market share ratios, the Technology Market Share Ratio (TMSR) and the Sector Market Share Ratio (SMSR). The formula to calculate these ratios are as follows:

$$(1) \quad TMSR_{i,x,g}^{t} = \frac{(S_{i,x,g}^{t} - S_{i.x,g}^{t0})}{S_{i,x,g}^{t0}}$$

$$(2) \quad SMSR_{i,x,g}^{t} = \frac{(S_{i,x,g}^{t} - S_{i,x,g}^{t0})}{Sector_{x,g}^{t0}}$$

With S being the scenario production value at time t, for technology i, scenario x and region g. t0 refers here to the starting point of the scenario production/capacity data. $Sector_{x,g}^{t0}$ refers to the starting point value of the entire Sector production for a specific scenario. This means for the Power sector, it's the aggregate of Oilcap, Coalcap, Gascap, Hydrocap, Nuclearcap and Renewablescap for the start year for a specific region.

Technology Market Share Ratio

The TMSR ratio is used only for high carbon technologies or the "declining technologies", which often are Oil, Gas, Coal, Oilcap, Gascap, Coalcap. As we can see from the formula (3), it is the growth rate of the Technology in question. This growth rate is then directly applied to the company specific production level to calculate the target production level:

$$(3) \quad p_{i,j}^{tmsr}(t) = p_{i,j}(t0) * (1 + TMSR(t))$$

with $p_i(t0)$ being the starting level production of a specific company j for technology i, which is received from Asset Impact. TMSR is as calculated in formula (1). $p_i^{tmsr}(t)$ is then the company specific target production for the technology i at time t. It shows the amount of production that the company i would produce for technology i at time t, if it would be following the target trajectory for technology i which is provided by the scenario. The target is always in relation to the actual production of the company based on AI.

Notice that using this logic the starting value for the AI production data and the company specific target pathway will be the same. We can illustrate the target pathway using an example company in the GasCap sector:

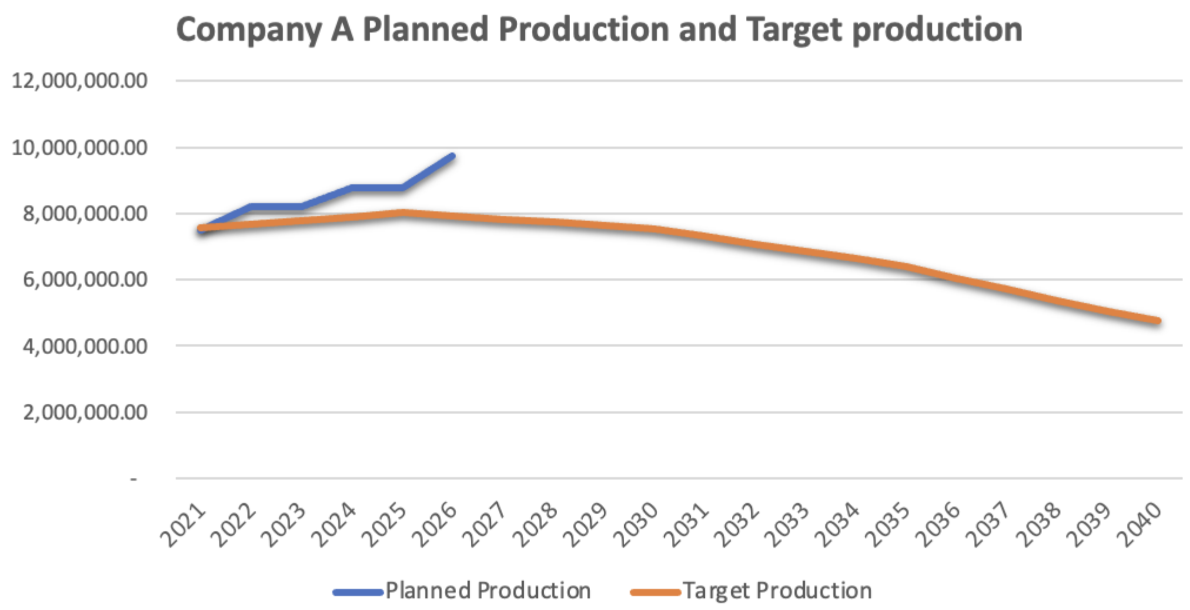

Figure 3 Planned and Target Production

In Figure 3, the target production shows how the future production of Company A would evolve, if it would be perfectly aligned with the trajectory of the Target Scenario.

Sector Market Share Ratio

SMSR is generally used for low carbon technologies, which can be expected to increase in the future, like Renewable energy or Hydro energy.

As we can see from formula (2) the calculation for SMSR is different from TSMR. This is because company specific low carbon technology production for "increasing" technologies could have a starting point of 0, although future production may be planned for a specific Company based on AI data. For TMSR, this is not a problem, since a company that has no fossil fuel production in year 0 is also not forced to increase/decrease it further in the target scenario. A company without renewables capacity in the start year however might have planned production in some point in the next 5 years. This planned production is then expected to be further expanded according to a target scenario, in order to phase out the high carbon technologies.

Company specific target production for increasing technologies is calculated as follows:

$$(4) \quad p_{i,j}^{smsr}(t) = p_{i,j}(t0) + P_j(t0) * SMSR(t)$$

With P(t0) being the company specific production across all technologies within the sector, which in our model covers mostly the Power sector. The idea is to calculate the ratio of target i.e. Renewable production change to total sector production. This same ratio is then applied on company specific level to simulate how much the company "should have" in Renewables based on its total Power production in year t0. It can be interpreted in the way that we assume the company should have the same ratios than the entire global/regional industry, when it comes to the phase in of renewables.

Baseline (Business as Usual) pathways

In contrast to a firm specific target pathway, we also calculate a Business-as-usual scenario or Baseline scenario. This pathway relies on BaU scenarios by the provider, and implies no drastic climate policy ambitions.

Firm specific baseline production pathways don't use TMSR and SMSR. Instead, they rely on the forecasted production and the technology specific baseline growth rate that is implied from the scenario data.
To calculate the firm specific Baseline production, we first create a separate variable called *"SCENARIO_BAU"* (in our code the variable name is based on baseline scenario choice).

This variable is calculated by taking the first-year production from AR and increase it with the scenario and technology specific growth rate.

$$(5)\ \ SCENARIO\_BAU_{i,j}(t) = p_{i,j}(t0) * (1 + growth\,rate_{x,i,g})$$

As a second step, we create a different variable which equals *WEO_2021_STEPS* called *scen_to_follow*.

$$(6)\ \ scen\_to\_follow_{i,j}(t) = SCENARIO\_BAU_{i,j}(t)$$

Following this, we calculate *scenario_change*, which is the difference between *scen_to_follow* and the lag of it.

$$(7)\ \ scenario\_change_{i,j}(t) = scen\_to\_follow_{i,j}(t) - scen\_to\_follow_{i,j}(t-1)$$

Finally, we calculate the final firm specific production pathway. This pathway follows the AR production forecasts and after that is calculated as an aggregation of *scenario_change* and the last years value of the baseline pathway.

$$(8)\ \ baseline_{i,j}(t) = baseline_{i,j}(t-1) + scenario\_change_{i,j}(t)$$

Using this procedure, we calculate the baseline trajectory only after the we don't have any more forecasts for the planned production data from AI.

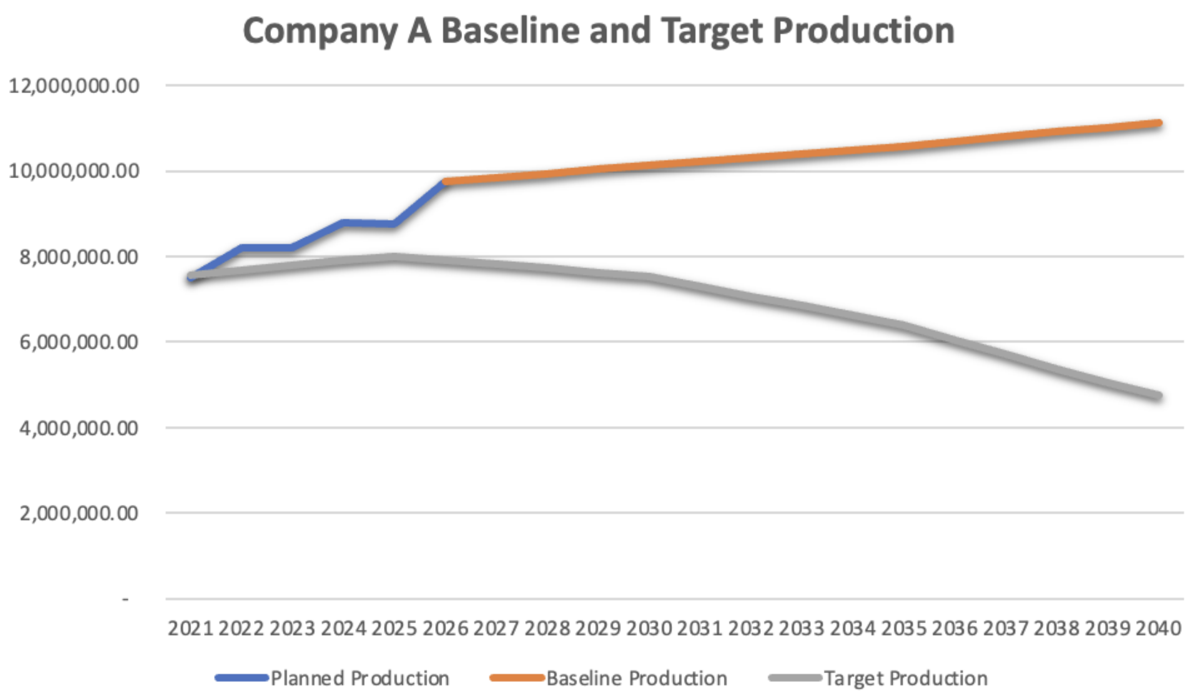

Figure 4 Baseline and Target Production

Figure 4: In the case of company A, we can see that according to the planned production, the company is already producing more than the scenario is "allowing" the company to produce. By extending the planned production with the firm specific baseline trajectory, we can see that for this company, this trend is projected to become more extinguished, with a further decoupling of what the company is expected to produce in the BaU scenario and allowed to produce in the Target Scenario.

Capacity Factors

The capacity factor is a measure used in the context of energy production to assess the actual output of a power plant or system in comparison to its maximum potential output. It is expressed as a percentage and is calculated by dividing the actual output of the plant over a specific period by its maximum possible output under ideal conditions.

Mathematically, the capacity factor (CF) is calculated using the formula:

$$CF = \frac{Net\ Electricity\ Generation}{Capacity} * 100\%$$

For example, if a coal power plant has a maximum capacity of 100 megawatts (MW) and generates 30 megawatt-hours (MWh) of electricity in a day, its capacity factor for that day would be:

$$CF = \frac{30\ MWh}{100\ MW * 24h} * 100\% = 12.5\%$$

A higher capacity factor indicates that the plant is operating closer to its maximum capacity, while a lower capacity factor suggests that the plant is not operating at full capacity for various reasons such as maintenance, downtime, fluctuations in resource availability (e.g., sunlight or wind for solar and wind power plants), or the efficiency development of a certain technology. In our model, we use capacity factors to translate the capacity data we receive from AI into net electricity generation units. The actual produced units are then in a next step included in the revenue calculation of each firm.

Scenarios either publish the capacity factors by themselves, or publish them indirectly, by publishing raw data for capacity and the corresponding net electricity generation. Typically, scenarios provide capacity data in GW, while net electricity is given in TWh. We transform TWh into GW by multiplying by 1000 and dividing by the total amount of hours in a year. The degree of capacity factors by scenario can alter the result of the stress test, by making companies produce more on a given total capacity level. For example, the plot below shows the capacity factor for the BAU scenario from three different scenario sources.

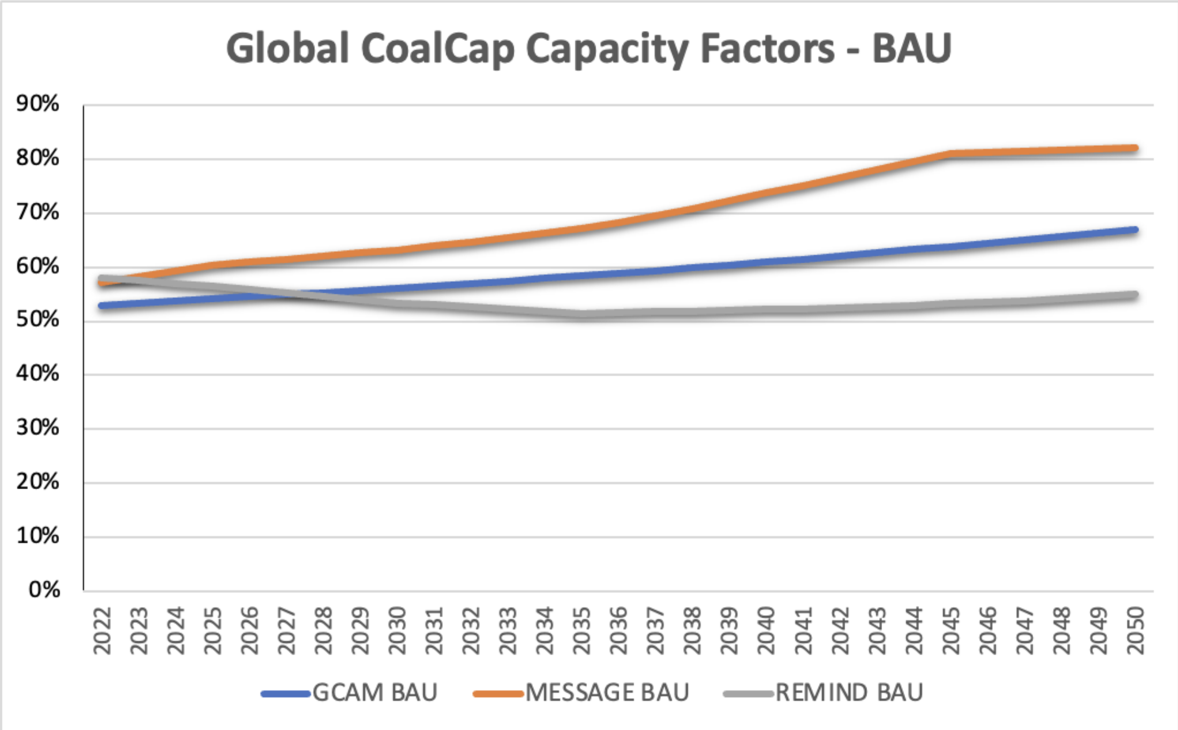

Figure 5: CoalCap Capacity Factors. Note that capacity factors can signficantly vary between scenario providers and scenarios, as we can see when comparing the previous plot with the NZ scenarios from the same providers and technology.

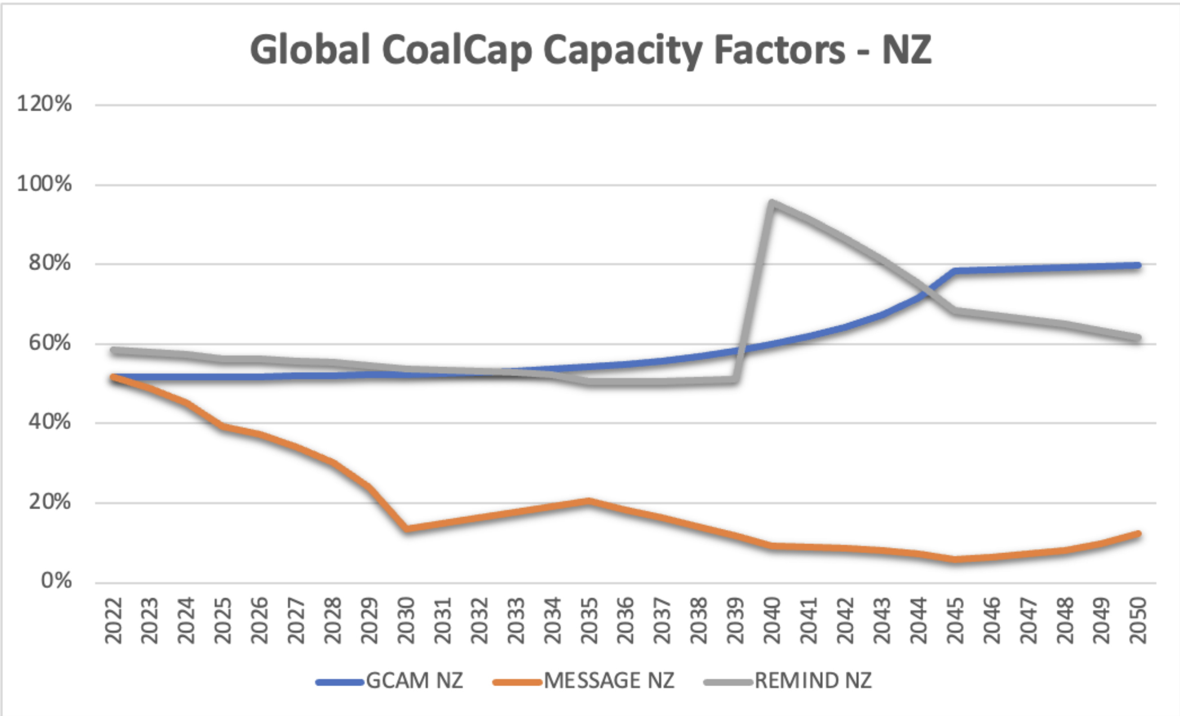

Figure 6: Global Coal Capacity Power generation capacity factors under the three NGFS IAMs for the Net Zero Scenairo narrative

Prices and costs

The projected path of decarbonisation of the economy, is driven by assumptions and models of technological cost advancements. This is reflected through $c_{yhg}^{s,t}$, which is the unit cost of production in sector *y*, across technologies *h*, in region *g*, in scenario *s* at time *t*. Most often, cost pathways are modelled in integrated assessment models (IAMs) or by academics such as as Way, Ives, Mealy, and Farmer (2021)[2] who use historical trends in production costs to forecast future trends. For instance, the costs of many sustainable technologies, such as producing solar power, have fallen exponentially over the last decades in line with Moore's and Wright's law. The costs of extracting oil from the ground has not experienced exponential decay, but rather stayed relatively constant ((Way et al., 2021)). Future trends of production costs is an integral part of the transition scenario, as it reflects the likely diffusion and comparative advantage across a range of high-carbon and sustainable technologies. Unit cost developments may be significantly different under various climate mitigation and policy scenarios. Information on time-variant, regional different and scenario-specific unit costs is a critical information in the set of scenario parameters that underlie our climate stress testing approach. This will impact the comparative advantage and unit cost structure of firms in our model.

In the TRISK model the unit cost projections are represented on the basis of the scenario price and cost data. We use technology prices to match them with forecasted production and thus create projected cash flows. For prices, we separate between Fossil Fuel prices and Power prices.

Fossil Fuel prices can often be directly sources from the scenarios. For example, the IEA gives the price projections for different future scenarios for crude oil, natural gas, and coal. As with capacity factors, the price development can vary significantly even among similar scenario ambitions.

[2] Way, R., Ives, M. C., Mealy, P., & Farmer, J. D. (2021). Empirically grounded technology forecasts and the energy transition. , 23.

Figure 7: The trajectories of coal price under IPR, Oxford and IEA scenario narratives

Generation of power prices is more complicated than the generation of fossil fuel prices, mainly because we receive no raw data on power prices by scenario providers. Instead, we use the Levelized cost of electricity (LCOE) for the power sector. The LCOE captures the overall cost of generating electricity. We use LCOE to proxy the prices for the power sector using the following procedure.

LCOE to prices

An an intital step the raw LCOE data undergoes interpolation, and a "renewables cap" is established. The "Renewablescap" is determined as the mean of the LCOE values for Solar, Wind onshore, and Wind offshore (if available also Biomass and geothermal). We are grouping certain technologies on a renewablescap technology, as in previous model we had further data restrictions that made more granularity difficult. Note that this procedure is currently outdated and slated for future updates. Following this, a global LCOE is created, representing the mean of LCOE values for the available regions. Additionally, there are no LCOE values available for Oilcap and Hydrocap. For simplification, we assume Oilcap equals Gascap and Hydrocap equals Renewablescap.

In the following step, the focus shifts to converting LCOE into prices. The underlying assumption is that combining LCOE with the Net Profit Margin (NPM) can yield price data. We follow hereby the following intuition.

$$(1)\quad NPM = \frac{Profit}{Revenue}$$

$$(2)\quad NPM = \frac{Production\ (price - LCOE)}{Production * price}$$

$$(3)\quad NPM = \frac{(price - LCOE)}{price}$$

$$(4)\quad LCOE = (1 - NPM) * price$$

$$(5)\quad implied\ price = \frac{LCOE}{(1 - NPM)}$$

By breaking down the basic NPM formula, we assume that it is a function of the relation of price and cost, which in this case is captured through the LCOE. Hence, by rearranging the formula, we can imply the power price using the available LCOE and the Net Profit Margins. The NPM of firms are available through Bloomberg or Refinitiv. We calculate an average NPM of firms of the power sector, which amount to 11.5%. As a next step, we calculate a “cost factor”. The cost factor is calculated as follows:

$$(6)\quad cost\ factor_t = \frac{LCOE_{t0=2020}}{LCOE_t}$$

The cost factor is calculated every year and is aimed to be applied to the implied price of (5). It is designed to capture the inverse trend of growth or decline in the LCOE data. The intuition behind this is that if a technology would have rising costs (LCOE), the implied price with formula (5) will keep a constant NPM. This in turn would indicate that power companies could just push rising costs of electricity generation on to consumers indefinitely, which is not realistic. In contrast, we want to cover that rising costs will ultimately eat away the NPMs of companies, as they are unable to just pass on the cost increases. We use the following formula to derive the final price:

$$(7)\quad final\ price_t = implied\ price * \ cost\ factor_t$$

Note that the implied price has no subscript, as it is independent on the year. We calculate the implied price only once in 2020, and then keep it constant over time. Using this logic, it is important to highlight that the LCOE are only used as a construct to derive the implied prices and are not entering the ST on another occasion. This is crucial, as we often see in the calculations that the final price can be smaller than the LCOE that were used to derive it.

Scenario Types

Most scenarios are linked to a specific climate ambition or policy narrative. The main Narratives for climate scenarios are as follows:

Business-as-Usual (BAU) Scenario: The Business-as-Usual (BAU) Scenario assumes that current practices and policies remain unchanged, representing a reference point for projecting future greenhouse gas emissions and climate impacts if no new climate measures are implemented. It often reflects a trajectory where emissions continue to increase, potentially leading to significant and adverse consequences for the environment and society. The BAU Scenario underscores the importance of adopting proactive climate policies and interventions to deviate from this default path and work towards a more sustainable future.

Nationally Determined Contributions (NDC) Scenario: The Nationally Determined Contributions (NDC) Scenario is based on the commitments made by individual countries under the Paris Agreement. These contributions outline each nation's efforts to reduce emissions and adapt to climate change. In contrast to the Business as Usual scenario, this scenario included pledged that countries have made to combat climate change, which have not yet have effectively implemented in real policies.

Net Zero Scenario: The Net Zero Scenario is an ambitious pathway that aims to achieve a balance between greenhouse gas emissions and removal, typically by around 2050. This scenario highlights the commitment to mitigating the most severe impacts of climate change by rapidly transitioning to renewable energy sources, enhancing energy efficiency, and implementing carbon capture and sequestration technologies to a certain degree. It represents a future where emissions are significantly reduced and kept at a level where they can be offset by actions like afforestation and carbon removal technologies. This scenario is often linked to a 1.5°C of global warming

2°C Scenario: The 2°C Scenario, or below 2°C scenario, outlines similarly to the Net Zero Scenario a strategic approach to limit global warming to 2 degrees (1.7°C) Celsius above pre-industrial levels, in alignment with the goals set forth by the Paris Agreement. Achieving this scenario necessitates substantial emissions reductions, transition to clean energy sources, and the widespread adoption of energy-efficient practices. It recognizes the urgency of curbing emissions to prevent more severe climate impacts and strives to strike a balance between sustainability and the need for immediate action to mitigate climate change.

Delayed Action Scenario: The Delayed Action Scenario explores the consequences of postponing significant emissions reduction efforts. It serves as a stark reminder of the potential risks of inaction or slow response to climate change. In this scenario, greenhouse gas emissions continue to rise until a certain point, when the narrative shifts and strong policies are enacted to limit temperature rise to below 2°C. Compared to the Net Zero and Below 2° C Scenarios, the policies are much stronger and abrupt, resulting in critical disruptions in the economy and the transition. It underscores the necessity of taking timely and substantial measures to address climate change and avoid increasingly challenging and costly interventions in the future.

Scenario Providers Overview

There are several different internationally located institutions who provide climate scenarios. In our current framework, we are using scenarios from 5 different providers.

The International Energy Agency (IEA) is an autonomous agency within the framework of the Organization for Economic Co-operation and Development (OECD). It is dedicated to promoting energy security, economic growth, and environmental sustainability by providing energy-related data, analysis, and policy recommendations to its member countries and the broader international community.

The Network for Greening the Financial System (NGFS) is a global network of central banks and financial supervisors committed to addressing climate and environmental risks in the financial sector. The NGFS aims to enhance the financial industry's understanding of these risks and promote sustainable finance practices to help transition toward a greener and more resilient global economy.

The Inevitable Policy Response (IPR) is a climate transition forecasting initiative commissioned by the United Nations Principles of Responsible Investing (UN PRI), with the goal of equipping institutional investors to navigate portfolio risks and opportunities arising from the anticipated acceleration of policy responses to climate change.

The Joint Research Centre (JRC) is the European Commission's in-house science and knowledge service. It conducts research and provides scientific support across a wide range of policy areas, including agriculture, energy, environment, and more, to aid in the development and implementation of EU policies and initiatives, ensuring they are based on sound scientific evidence.

INET Oxford, part of the Oxford Martin School, is a cross-disciplinary research institute committed to utilizing cutting-edge ideas and approaches from both the social and physical sciences to address global economic issues.

Scenario Providers Deep Dive

IEA

The International Energy Agency (IEA) is an intergovernmental organization that was established in 1974 in response to the oil crisis. It operates within the framework of the Organization for Economic Co-operation and Development (OECD), but it is an autonomous agency. The IEA's primary mission is to promote energy security, economic growth, and environmental sustainability around the world. It achieves this by providing reliable and comprehensive energy-related data, conducting in-depth analysis, and offering policy recommendations to its member countries and the broader international community.

One of the key publications produced by the IEA is the World Energy Outlook (WEO) report. The WEO is an annual publication that provides a comprehensive analysis of global energy trends and projections for the future. The report examines various scenarios based on different assumptions about future developments in the energy sector, helping policymakers, industry leaders, and the public to understand potential challenges and opportunities.

IEA Scenarios

The IEA publishes multiple scenarios which each new vintage of WEO data.

IEA Net Zero Emissions by 2050 (NZE) Scenario: This scenario outlines a prescribed pathway for the energy sector to contribute to limiting the global temperature increase to 1.5 °C above preindustrial levels by 2100, with at least a 50% probability and limited overshoot. The NZE Scenario, as highlighted in the recently released Net Zero Roadmap: A Global Pathway to Keep the 1.5 °C Goal in Reach[3], has been thoroughly updated. Additionally, this scenario aligns with key energy-related UN Sustainable Development Goals (SDGs), ensuring universal access to reliable modern energy services by 2030 and significant improvements in air quality. Despite the challenges posed by years of high emissions and limited SDG progress, recent

[3] https://www.iea.org/reports/net-zero-roadmap-a-global-pathway-to-keep-the-15-0c-goal-in-reach

advancements in clean energy transitions indicate that the NZE Scenario goals are still achievable.

IEA Announced Pledges Scenario (APS): In this scenario, it is assumed that governments will fulfill all climate-related commitments, including announced net-zero emissions targets and pledges within Nationally Determined Contributions (NDCs), on time and in full. Business and stakeholder pledges are considered, particularly if they contribute to the ambition outlined by governments. Acknowledging that many governments lack the policies necessary to fully meet their commitments and pledges, the APS scenario provides them with a favorable assessment. Substantial progress would be required for this scenario to be realized. Countries without ambitious long-term pledges benefit from accelerated cost reductions in various clean energy technologies. The APS is associated with a 1.7 °C temperature increase in 2100 with a 50% probability.

IEA Stated Policies Scenario (STEPS): This scenario offers insight into the prevailing direction of energy system progression based on a detailed examination of the current policy landscape. Unlike the APS, which reflects governments' stated intentions, the STEPS scrutinizes the actual policies and measures in place or announced to achieve energy-related targets and objectives. Aspirational energy or climate targets are not automatically assumed to be met in the STEPS. Currently, the STEPS is associated with a 2.4 °C temperature increase in 2100 with a 50% probability.

Sustainable Development Scenario: In older vintages of the WEO report, the IEA also referred to a Sustainable Development Scenario (SDS). Aligned with the "well below 2 °C" objective, the SDS serves as a pathway leading to the goals outlined in the Paris Agreement. Similar to the NZE Scenario, the SDS relies on a substantial increase in clean energy policies and investments, steering the energy system towards key Sustainable Development Goals (SDGs). In this scenario, all existing net-zero pledges are fully realized, accompanied by extensive efforts to achieve near-term emissions reductions. Advanced economies achieve net-zero emissions by 2050, China by around 2060, and all other countries by 2070 at the latest. This scenario maintains consistency with limiting the global temperature rise to 1.65 °C (with a 50% probability), without assuming any net negative emissions. Incorporating some degree of net negative emissions after 2070 could further reduce the temperature rise to 1.5 °C by 2100. Since the WEO2022 report the SDS has been phased out.

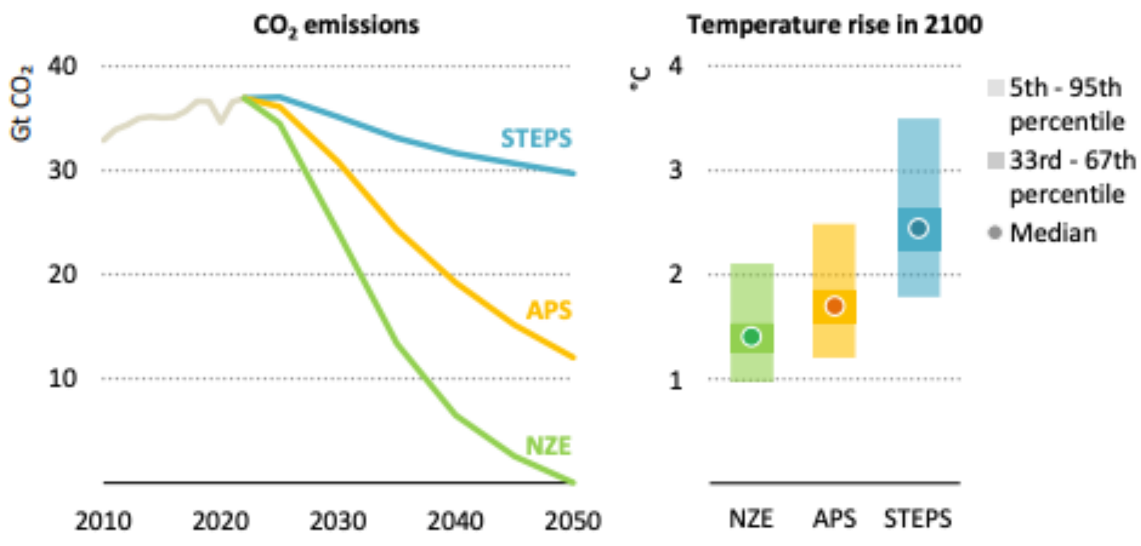

Figure 8 Emission and Temperature Rise comparison between three IEA scenarios (WEO2023)

The following table shows a short overview of the narrative and temperature goals for the IEA scenarios:

Scenario	Acronym	Global Warming	Overshoot	Probability	Narrative
Net Zero Emissions by 2050	NZE	1.5°C	no	50%	Narrow but achievable pathway to reach net zero CO2 emissions by 2050. Advance Economies Net Zero earlier.
Sustainable Development Scenario	SDS	1.65°C	-	50%	All current NZ pledges are met with and additional increased effort to realise further emission reductions. Reaches Net Zero emissions by 2070.
Announced Pledges Scenario	APS	-	-	-	assumes all climate commitments by governments, including NDCs and net zero targets, are met in full and on time
Stated Policy Scenario	STEPS	-	-	-	reflects current policy settings for each sector based on government policies that are already in place or under development

Table 1 IEA Scenario Overview

IEA Calculation and Methods

For the WEO2023 vintage, the forecasts of the scenarios are generated using the Global Energy and Climate (GEC) Model, this model aligns energy demand and supply dynamics across numerous countries and regions, considering an extensive array of fuels and energy technologies. It encompasses not only currently prevalent options but also those anticipated to be on the verge of commercialization. The GEC Model is a simulation model designed to mirror the intricate interactions between policies, costs, and investment decisions in the real world. It offers insights into the potential ripple effects, demonstrating how alterations in one aspect may impact others. The GEC Model synergizes the modeling features found in both the World Energy Model (WEM) and Energy Technology Perspectives (ETP) models, which were used for past WEO vintages. This synthesis yields a comprehensive bottom-up partial-optimization modeling framework, offering a unique suite of analytical capabilities. These capabilities span energy markets, technology trends, policy strategies, and investments across the energy sector, playing a crucial role in attaining climate objectives. The model takes into account various inputs, encompassing historical data on technology stock, costs, and performance, along with energy statistics, balance data, policies, regulations, and socio-economic drivers. On the flip side, the model. generates a range of outputs, forecasting future technology stock, cost, and performance. It also provides insights into energy flows by fuel, investment requirements and costs, demand for materials and critical minerals, as well as emissions of carbon dioxide (CO2), methane (CH4), and nitrous oxide (N2O).[4,5]

NGFS

The Network for Greening the Financial System (NGFS) is a collaborative alliance of central banks and financial supervisors from around the world, dedicated to collectively tackling the challenges posed by climate change and environmental risks within the financial sector. Beyond its commitment to enhancing awareness of these risks, the NGFS actively engages in the development of guidelines and recommendations for integrating climate-related considerations into financial supervision and risk management practices. The network facilitates information exchange and collaboration between its members, fostering a shared commitment to advancing sustainable finance initiatives. Furthermore, the NGFS collaborates with other international organizations, policymakers, and stakeholders to amplify the impact of its efforts and contribute to the broader global transition toward a more environmentally sustainable and resilient economy. The NGFS uses three Integrated Assessment Models (IAMs) to create 6 different scenarios (7 different scenarios depending on the vintage).

[4] https://www.iea.org/reports/global-energy-and-climate-model/about-the-global-energy-and-climate-model
[5] WEO 2023

NGFS Scenarios

In the newest NGFS phase 4 vintage from November 2023, the NGFS publishes 7 scenarios.

NGFS Delayed Transition Scenario: This scenario envisions that annual emissions persist without reduction until 2030. Stringent policies become imperative to restrict global warming to below 2 °C, with limited reliance on negative emissions.

NGFS Net Zero 2050 Scenario: In this scenario, global warming is effectively limited to 1.5 °C through the implementation of rigorous climate policies and innovative approaches. The goal is to achieve global net zero CO2 emissions by approximately 2050.

NGFS Below 2 °C Scenario: Gradually intensifying climate policies stringencies characterize this scenario, providing a 67% likelihood of constraining global warming to below 2 °C.

NGFS Low Demand Scenario: In this scenario, significant behavioral changes, specifically a reduction in energy demand, are anticipated. This, coupled with the influence of (shadow) carbon pricing and efforts driven by technology, would alleviate the strain on the economic system in achieving global net-zero CO2 emissions by approximately 2050.

NGFS Fragmented World Scenario: This scenario envisions a delayed and divergent global response to climate policy, resulting in elevated physical and transition risks. Countries with net-zero targets achieve them only partially (80% of the target), while others adhere to existing policies.

NGFS Nationally Determined Contributions (NDCs) Scenario: This scenario incorporates all pledged targets, even if not yet supported by effective implemented policies.

NGFS Current Policies Scenario: Assuming the preservation of only presently implemented policies, this scenario carries high physical risks.

NGFS Divergent Net Zero Scenario: This scenario reaches a net-zero status around 2050 but with elevated costs due to divergent policies introduced across sectors, resulting in a faster phase-out of oil use. This scenario has been removed from the fourth vintage given the reduced likelihood of a successful uncoordinated transition.

The NGFS assigns each of these scenarios to a certain category, depending on the degree of transition and physical risk they inherit.

Orderly Scenarios: These scenarios envision the early introduction of climate policies, gradually increasing in stringency. Both physical and transition risks remain comparatively subdued.

Disorderly Scenarios: Exploring scenarios marked by higher transition risks, attributed to delayed or divergent policies across countries and sectors. For instance, (shadow) carbon prices are typically elevated for a given temperature outcome in these scenarios.

Hot House World Scenarios: These scenarios assume partial implementation of climate policies in certain jurisdictions, yet global efforts fall short of curbing significant global warming. The outcomes of these scenarios include severe physical risks, such as irreversible impacts like sea-level rise.

Too-Little-Too-Late Scenarios: Envisaging scenarios where a belated and uncoordinated transition fails to effectively limit physical risks.

You can see the categorization of each scenario in the following figure.

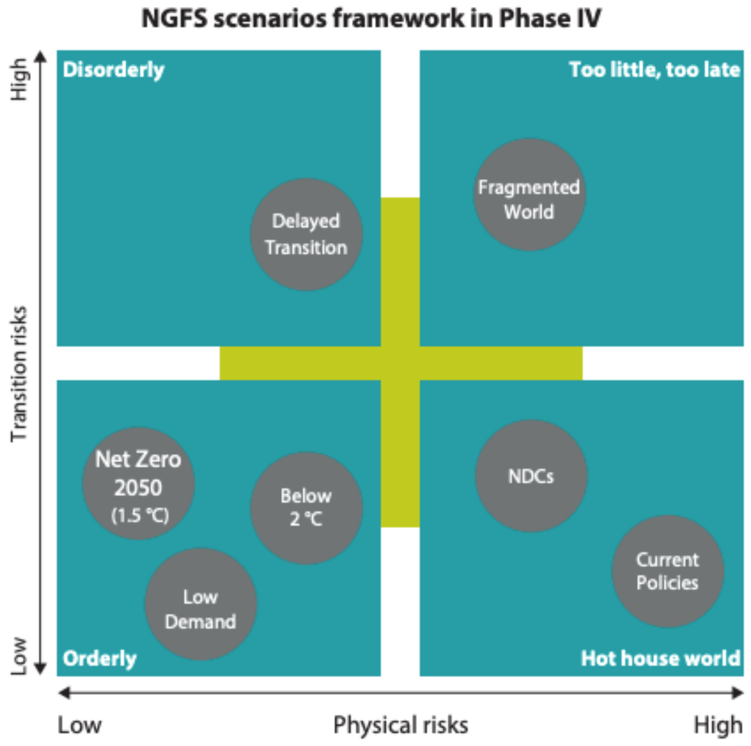

Figure 9 NGFS scenario framework - NGFS Scenarios for central banks (11/2023)

Moreover, the following tables capture the different narrative and policy assumptions of each NGFS scenario.

IAMs	Scenario	Acronym	Global Warming	Overshoot	Probability	Narrative
•GCAM •REMIND •MESSAGEix	Net Zero 2050	NZ2050	1.4°C	No/limited	50%	1.5°C limit, ambitious climate policies, net zero CO2 around 2050
•GCAM •REMIND •MESSAGEix	Below 2°C	B2DS	1.6°C	No	67%	Immediate gradual emissions reductions. Net Zero in 2060-2070
•GCAM •REMIND •MESSAGEix	Divergent Net Zero	DNZ	1.4°C	No/limited	50%	Net Zero in 2050 but with higher associated costs due to uncoordinated policy stringency
•GCAM •REMIND •MESSAGEix	Delayed Transition	DT	1.6°C	Yes	67%	No emissions decrease until 2030, strong policies needed afterwards with limited CDR.
•GCAM •REMIND •MESSAGEix	Nationally Determined Contributions	NDC	2.6°C	-	-	Includes pledged targets, moderate policy ambitions, emissions decline but not very strongly
•GCAM •REMIND •MESSAGEix	Current Policies	CP	3°C+	-	-	Continuation of status quo, emissions increase with high implicated physical risk.

Table 2 NGFS Scenario Overview – Part 1

IAMs	Scenario	Policy reaction	Technology change	CDR	Regional Policy Variation
•GCAM •REMIND •MESSAGEix	Net Zero 2050	Immediate and smooth	Fast	Medium-high	Medium
•GCAM •REMIND •MESSAGEix	Below 2°C	Immediate and smooth	Moderate	Medium-high	Low
•GCAM •REMIND •MESSAGEix	Divergent Net Zero	Immediate but divergent	Fast	Low-medium	Medium
•GCAM •REMIND •MESSAGEix	Delayed Transition	Delayed	First slow then fast	Low-medium	High
•GCAM •REMIND •MESSAGEix	Nationally Determined Contributions	NDC	Slow	Low-medium	Medium
•GCAM •REMIND •MESSAGEix	Current Policies	-	Slow	Low	Low

Table 3 NGFS Scenario Overview - Part 2

NGFS Model Calculations

The main engine behind the calculation of these scenarios are the three IAMs that NGFS uses. The IAMs are GCAM, MESSAGEix-GLOBIUM and REMIND-MAgPIE. The NGFS publishes the scenarios mentioned above for each of the three IAMs.

All of the three IAMs are used for key energy, lad, water and carbon tax series, and while they share some common characteristics, their outputs can vastly differ even when comparing the results for the same scenario.

REMIND-MAgPIE

The REMIND-MAgPIE model, developed at the Potsdam Institute for Climate Impact Research, integrates two sophisticated models, REMIND and MAgPIE. These models, created over a decade ago and continuously refined, offer current scientific insights into global climate impact dynamics. REMIND, the Regional Model of Investment and Development, is a numerical model that projects future global economic trajectories, with a specific emphasis on the development of the energy sector and its implications for the world climate. The primary goal of REMIND is to ascertain the optimal investment mix within each of its 12 model regions, considering factors such as population dynamics, technological advancements, policy frameworks, and climate constraints. It also incorporates regional trade characteristics related to goods, energy fuels, and emissions allowances, while representing the most relevant greenhouse gas emissions stemming from human activities.

In parallel, MAgPIE, the Model of Agricultural Production and its Impacts on the Environment, operates as a global land use allocation model. Linked to the dynamic vegetation model LPJmL, MAgPIE simulates intricate interactions between the land surface and the atmosphere, focusing on the impact of human activities on the environment. As a partial equilibrium model, MAgPIE aims to fulfill global agricultural demand at minimum costs, considering a range of biophysical and socioeconomic constraints. Its results are then consolidated into the 12 REMIND regions through spatial aggregation, a process that involves grouping or merging individual regions into larger, more manageable units for analysis and modeling. The specific method of consolidation varies based on the modeling framework's requirements and research objectives, commonly considering geographical proximity, economic similarities, administrative boundaries, and model-specific criteria.

The overarching purpose of REMIND-MAgPIE is to offer valuable insights to policymakers and decision-makers, by increasing the knowledge of the roles, synergies and tradeoffs between various factors.[6]

MESSAGE-GLOBIUM

The MESSAGE-GLOBIOM model, developed by the International Institute for Applied Systems Analysis (IIASA), is an Integrated Assessment Model (IAM) that assesses the long-term implications of energy and climate policies by combining energy systems, environmental impacts, and economic analysis. Despite its name highlighting only two components, the model comprises five specialized modules: the energy model MESSAGEix38, land-use model GLOBIOM, air pollution and greenhouse gas model GAINS, aggregated macro-economic model MACRO, and simplified climate model MAGICC. Together, these modules form the IIASA IAM framework, also known as MESSAGEix-GLOBIOM. The core of the model, MESSAGEix-GLOBIOM, is an energy-engineering optimization model that integrates technology details for energy planning. It interacts with macro-economic, land-use, and climate models, incorporating feedback and limitations beyond the energy system during scenario development cycles.[7]

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[6]https://www.ngfs.net/sites/default/files/media/2023/11/07/ngfs_scenarios_technical_documentation_phase_iv.pdf
[7]https://www.ngfs.net/sites/default/files/media/2023/11/07/ngfs_scenarios_technical_documentation_phase_iv.pdf

GCAM

The Global Change Analysis Model (GCAM), an Integrated Assessment Model (IAM), combines economic, energy, land use, and climate systems to analyze how human activities influence global environmental changes. Applied to NGFS phase IV scenarios, GCAM assesses the impacts of policy scenarios and technology options on energy use, land use change, greenhouse gas emissions, and climate change. Its inputs include macroeconomic factors, earth system variables, land use details, water-related coefficients, emission data by sector, and marketplace dynamics covering supply and demand for various commodities.

GCAM's outputs for each scenario and horizon year encompass emissions (CO2 and non-CO2), land use data, prices for energy, agriculture, forestry, water, and fish, as well as quantities related to energy production and consumption. This comprehensive model provides valuable insights into the intricate interactions between human activities and environmental changes, offering a robust analytical tool for policymakers and decision-makers.

IPR

The UN IPR was tasked by the Principles for Responsible Investment (PRI) and is backed by esteemed research partners, philanthropic organizations, financial institutions, and non-governmental organizations to predict the pace and magnitude of the shift toward achieving net-zero emissions. IPR distinguishes itself through a thorough examination of foreseeable policy trajectories in both the short and long term, providing clear insights into major policy areas across global countries and regions. They use expert judgment and realistic expectation about the future development of climate change related factors.

This is in contrast to 'hypothetical' scenarios that rely on temperature constraints or assumptions about meeting stated commitments. IPR maintains transparency in its policy expectations, enabling financial institutions to comprehend the specific perspectives guiding the scenarios. Furthermore, IPR considers crucial technology and market dynamics that not only facilitate policy changes but are also accelerated by such shifts.

IPR publishes one scenario, but in earlier vintages two scenarios were available.

IPR Scenarios

IPR Forecasted Policy Scenario (FPS): A comprehensive climate scenario that models the anticipated policies' influence on the actual economy until 2050, meticulously tracing the specific effects on all sectors contributing to emissions. The FPS encompasses forecasted policies based on current expert judgement, which are then incorporated in the calculation of the scenario.

IPR 1.5°C Required Policy Response (RPS): This scenario expands upon the IEA NZE by conducting a more in-depth analysis of policy, land use, emerging economies, NETs, and value drivers. This scenario is valuable for those seeking alignment with the 1.5°C target. The RPS scenario is the IPRs assessment of future policy developments required to accelerate emissions reductions and restrict global temperature increase to 1.5°C

The latest vintage of IPR data included new data for the Forecasts Policy Scenario, including data on Energy, Bioenergy and Land & Nature.

JRC Global Energy and Climate Outlook

The Joint Research Centre (JRC) is the European Commission's science and knowledge service. It acts as the Commission's in-house research and scientific support center. The JRC employs scientists and researchers to carry out independent research to support EU policies. Its main goal is to provide evidence-based scientific and technical support to the European Commission, helping it to formulate policies and implement legislation across a wide range of areas.

The Global Energy and Climate Outlook (GECO 2021) is a report that evaluates recent updates in nationally determined contributions (NDCs) and long-term net-zero emission targets (LTS) leading up to and during COP 26. GECO focuses mostly on the transition of G20 countries, but delivers data also on a global level.

Notably, at the 1in1000 Trisk models current state, we use GECO only for stress testing the automotive sector. Nevertheless, Geco also provides, data for the energy sector, which we intend to integrate in later vintages.

JRC Scenarios

GECO Current Policies CurPol: The CurPol scenario represents a world where existing policies on greenhouse gas emissions, renewables, and energy efficiency are maintained without additional measures beyond those legislated by 2019. It uses macroeconomic projections, energy prices, and technological development specific to the POLES model to calculate energy system and CO_2 emission projections. This scenario doesn't aim for the structural decarbonization needed for a 1.5°C trajectory and doesn't consider unstated policies or objectives without concrete action plans.

GECO NDC-LTS: In this scenario, the focus is on the policies outlined in Nationally Determined Contributions (NDCs) for the medium term and Long-Term Strategies (LTSs) for the longer term. The scenario assumes the fulfillment of NDC objectives, including conditional ones, by the years 2025-2030. To achieve this, new measures such as carbon values and regulatory instruments are implemented in addition to the existing legislated measures of the CurPol scenario. Post-2030, the scenario continues by actively pursuing the objectives stated in countries' LTS, where applicable. In cases where a country has not declared an LTS, the assumption is that no further efforts are made, and carbon values remain constant at their 2030 levels.

GECO 1.5°C-Uniform: The 1.5°C Uniform scenario aims to achieve a global greenhouse gas trajectory consistent with the Paris Agreement's goal of limiting temperature rise to well below 2°C by the end of the century. These scenarios are designed with a global carbon budget of around 500 $GtCO_2$ cumulative net emissions from 2018 to 2100, providing a 50% probability of not exceeding 1.5°C of warming. The scenario involves implementing a single global carbon price applicable to all regions, starting in 2021 and increasing significantly. Unlike the NDC-LTS scenario, it doesn't include bottom-up policy drivers and relies solely on the global carbon price as the model's policy driver. This approach creates a stylized representation of an economically efficient pathway to the 1.5°C climate target, ensuring emissions are reduced where abatement costs are lowest.

JRC Model Calculations:

The GECO2021 report uses two types of model. The POLES-JRC and the JRC-GEM-E3. POLES-JRC is a world energy-economy simulation model that comprehensively simulates the energy sector from production to final user demand. It employs a recursive year-by-year modeling approach, incorporating endogenous international energy prices and lagged adjustments in supply and demand across world regions, allowing for the description of development pathways up to 2050. The model provides detailed energy and emission balances for 66 countries or regions, including explicit representation for OECD and G20 countries, as well as 14 fuel supply branches and 15 final demand sectors. The version used in this exercise is POLES-JRC 2019. In contrast, the JRC-GEM-E3 model is a global, multi-region, multi-sector, dynamic-recursive computable general equilibrium (CGE) model designed to analyze energy, climate, and environmental policies. It involves households, firms, and governments as agents and considers international trade connections among different regions. The agents in the model engage in various economic activities, including consumption, savings, production, and government actions such as taxation, subsidies, and consumption.

Oxford INET

The Institute for New Economic Thinking at the Oxford Martin School (INET Oxford) is a multidisciplinary research center focused on addressing global economic challenges. It applies cutting-edge insights from a wide range of disciplines, including economics, mathematics, computer science, physics, biology, ecology, geography, psychology, sociology, anthropology, philosophy, history, political science, public policy, business, and law. With over 75 affiliated scholars, INET Oxford operates within the University of Oxford's Martin School, collaborating with a community of over 300 scholars dedicated to tackling the major challenges of the 21st century. Additionally, it has partnerships with nine academic departments and colleges.

Oxford Scenarios

Oxford INET produces two main scenarios.

Oxford Base: A scenario type highlighting a business as usual continuation of current policies.

Oxford Fast: A scenario highlight a fast adaption of technologies in relevant sectors to still meet ambitious climate policies set out by the scenario.

Specific Scenario Process Considerations

Regarding the overall process steps highlighted in the first section of this report, it is critical to mention also some of the specific methodology adjustment we take when processing scenarios from the different scenario providers mentioned in the previous section.

Scenario Interlinks

In our scenario processing, our aim is to keep the scenario unique and separated as best as possible. However, given the unique data set up by some scenarios and resulting data limitations, this is not always possible. In these cases, we use scenario interlinkages to fill data gaps.

Scenario interlinks	**NGFS**	**IPR**	**IEA**	**Oxford**
Production	NGFS	IPR	IEA	Oxford
LCOE	Oxford	IEA	IEA	Oxford
Fossil Fuel Prices	NGFS	IPR	IEA	Oxford
Capacity Factors	NGFS	IPR	IEA	IEA
Baseline Scenario	NGFS	IEA / IPR FPS	IEA	Oxford
Target Scenario	NGFS	IPR	IEA	Oxford

Figure 10 Scenario interlinks

Figure 1 shows the source of the different Parameters for each Scenario Source. The following section will address each instance where scenarios are interlinked (marked in red).

1. **NGFS LCOE**
   LCOEs are used to indicate prices for the power sector. This parameter, nor any other comparable parameters, is not given by the NGFS. To allow for comparable power price projections, we decided to use Oxford LCOEs here as a substitute.
2. **IPR LCOE**
   The same LCOEs are also missing for IPR, however here we decided to take the LCOEs from IEA instead. The reasoning behind this, is that IPR themselves mention that IPR scenarios are also connected to IEA scenarios.
3. **IPR Baseline Scenario**
   In the older vintage, IPR has only 2 scenarios, RPS and FPS, which are both quite ambitious in its goals. To allow for a more significant risk effect of the model, we decided to create IPR baseline as a duplicate of IEA STEPS. Again, we did this since IPR highlights the connection between IEA and IPR. However, one limitation of this are the capacity factors. Capacity factors are also used in

further model processes with TRISK. When capacity factors are significantly different in this time frame, it can create model inconsistencies. Hence, we decided to use as IPR baseline capacity Factors the ones from IPR FPS.

4. **Oxford Capacity Factors**

   Oxford Scenarios don't have capacity factors available. Members of the Oxford Sustainable Finance Group thus advised us to use the capacity factors provided by IEA.

Time Horizons

In our model, the default time horizon is set to 2050 (if available) as we consider it a reasonable limit for our Stress Test without venturing too far into the future. Furthermore, Cash Flows generated in later years are heavily discounted. However, we do have the flexibility to produce results for larger horizons.

Some of the Scenario parameters are given at different horizons than others. In order to potentially ensure longer horizon analysis, we extended the parameters until the required horizon using different methods.

Scenario Time Horizons	NGFS	Method	IPR	Method	IEA	Method	Oxford	Method
Production	2100	-	2050	-	2050	-	2100	-
LCOE	2069	linear*	2050	-	2050	-	2069	linear*
Fossil Fuel Prices	2100	-	2050	-	2050	-	2069	linear*
Capacity Factors	2100	-	2050	-	2040	-	2040	constant**
Baseline Scenario	2100	-	2050	-	2050	-	2100	-
Target Scenario	2100	-	2050	-	2050	-	2100	-
Time Horitzon	2100		2050		2040		2100	

Figure 11 Available Time Horizons per Variable

Figure 11 illustrates the time horizon available for each parameter under each scenario. The bottom row displays the maximum time horizon chosen for the scenario.

We employed the following methods for extrapolating the data:

- Cells highlighted with a "*" indicate that we used linear extrapolation based on the last 20 years of observations.
- Cells highlighted with a "**" signify that we used the last available observation and assumed it remains constant over time.

For capacity factors, we chose the "**" method because the trend observed in earlier years is unlikely to persist into the future.

1in1000 Steel Scenarios

The steel sector is the newest addition into the 1in1000 Climate Transition Stress Test. The steel sector remains one of the highest emitting sectors and with this will play a critical role in the transition to a low carbon economy. With the integration of steel, we aim to extend our sectoral coverage in the 1in1000 model suite, to cover additional six different technologies in the stress test. The data for the steel sector is much less readily made available than the data for, for example, the power and energy sector as mentioned in the previous section. For this reason, we are relying on several different data sources that we will cover in the following section.

Steel Technologies

Given the asset-based production data available from our external data provider Asset Impact, we have two new Technologies, with several new technology types to build climate transition scenarios for.

Asset Impact	
AI Technology	**AI Technology Type**
Basic Oxygen Furnace	**Integrated Blast Furnace**
Basic Oxygen Furnace	**Integrated DRI Furnace**
Electric Arc Furnace	**Integrated Blast Furnace**
Electric Arc Furnace	**Integrated DRI Furnace**
Electric Arc Furnace	**Integrated Open Hearth Furnace**
Electric Arc Furnace	**Mini-Mill**

Table 4 Asset Impact Steel Sector Coverage

As seen in Table 4, we can technically create stress tests for steel production based on Basix Oxygen Furnaces (BOF) and Electric Arc Furnaces (EAF), with subtype steel processes of Integrated Blast Furnaces (BF), Integrated Direct Reduced Iron Furnaces (DRI), Integrated Open Hearth Furnaces (OHF) and Mini-Mills (MM).

The following process wil allow us thus to extend the stress test as highlighted in the figure below.

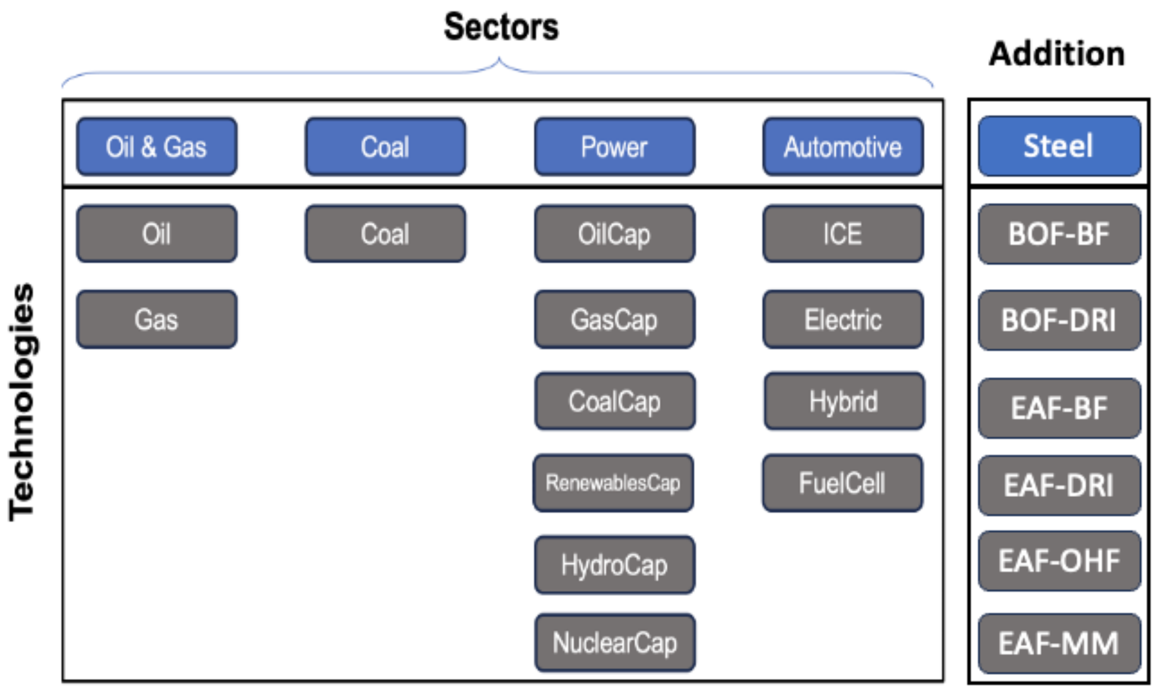

Figure 12: New Sector and Technology Coverage

Steel Scenario Data Sources

To create the stress test scenarios for the steel sector, given the production data that we have available as mentioned before, we rely on several different data sources:

1. Scenario data to create steel trajectories
2. Scenario data to create steel prices
3. Capacity Factors for steel

Steel Scenario Trajectories

For the steel trajectories, we are using data made available by the Mission Possible Partnership (MPP).

The MPP is an initiative focused on decarbonizing some of the world's highest-emitting industries to achieve net-zero emissions by 2050. Launched by a coalition of international organizations including the Energy Transitions Commission, the Rocky Mountain Institute, the We Mean Business coalition, and the World Economic Forum, MPP aims to transform industries like shipping, aviation, steel, aluminum, cement, and chemicals. The core strategy of MPP involves mobilizing industry leaders, financiers, and policymakers to work together to accelerate the transition to a low-carbon economy. They focus on creating sector-specific pathways, establishing ambitious net-zero commitments, and developing new technologies and solutions that are both scalable and economically viable. By doing this, MPP seeks to demonstrate that significant emission reductions are possible in even the most challenging sectors, through coordinated action and innovation.

The MPP publishes three different scenarios for their steel data.

The **MPP baseline scenario** shows what might happen in the steel industry without coordinated support from policy, finance, and value-chain efforts, where decarbonization technologies are adopted only if they are economically viable.

In the **MPP carbon cost scenario**, there is a push for decarbonizing the steel sector through coordinated actions towards low-CO2 steelmaking. Steel plants are advised to choose technologies that cost less over their lifetime. A carbon price is set to increase from $0 in 2023 to $200 by 2050 for all direct and indirect emissions, applied globally to promote the competitive production of near-zero emissions steel. This strategy aligns with the net-zero and 1.5°C target scenarios for the industry.

The **MPP tech moratorium scenario** will limit investments to only near-zero-emission technologies starting in 2030 to achieve net-zero emissions. It prioritizes investment in technologies that offer the lowest long-term costs and initially adopts lower-emission technologies only when they are as affordable as conventional steelmaking methods. From 2030, the strategy will ban reinvestment in high-emission technologies to ensure the industry can achieve net zero by 2050. This approach leverages the typical 20-year cycle for upgrading steel industry assets to prevent premature shutdowns and can be enforced through government regulations, financial conditions that favor environmental standards, or industry-led initiatives to phase out high-carbon investments.

An overview of the scenarios can be seen below:

	Baseline	Carbon Cost	Technology Moratorium
Demand scenario		**BAU**	
Carbon pricing	**No**	**Yes:** Starting at \$0/t CO_2 in 2023, rising linearly to \$200/t CO_2 in 2050	**No**
Market entry of novel production technologies		**(See Box 5)**	
Explicit technology constraint	**No**		**Yes:** Only near-zero emissions technologies permitted from 2030 onward
1.5°C aligned	**No**	**Yes**	**No**
Model logic		**Selects technology with lowest total cost of ownership (TCO)**	

Source: MPP analysis

Figure 13: MPP Scenario Overview

Based on our scenario type classification used in the stress test, the MPP baseline is a status quo scenario, while the MPP Carbon Cost scenario can be considered a target scenario, given its 1.5°C alignment. The Technology Moratorium scenario on the other hand is a bit harder to classifiy, given it's lack of 1.5°C alignment. For now we have decide to exclude it from our model framework.

For the relevant scenarios, we get the estimated global trajectory of steel production for numerous different technology types. However, due to data gaps from MPP, not all technology have available both baseline and target data. Instead, some are only showing baseline trajectories, while other show only target trajectories. Moreover, the different technologies do not use the same starting point of the time series, which gives us a second scenario processing issue.

Overall, the below table shows the available technologies and data from MPP.

Technology	Baseline and Target Data available	First Year of Data	Relevant for 1in1000
Avg BF-BOF	x	2020	x
DRI-EAF	x	2020	x
DRI-Melt-BOF	x	2026	x
EAF	x	2020	x
BAT BF-BOF	x	2020	-
BAT BF-BOF_bio PCI	x	2021	-
BAT BF-BOF_H2 PCI	x	2025	-
DRI-EAF_50% bio-CH4	x	2028	-
DRI-EAF_50% green H2	x	2026	-
BAT BF-BOF+BECCUS	-	2028	-
BAT BF-BOF+CCU	-	2028	-
BAT BF-BOF+CCUS	-	2028	-
DRI-EAF_100% green H2	-	2026	-
DRI-EAF+CCUS	-	2028	-
DRI-Melt-BOF_100% zero-C H2	-	2028	-
DRI-Melt-BOF+CCUS	-	2028	-
Smelting Reduction	-	2030	-
Smelting Reduction+CCUS	-	2030	-

Table 5: MPP Technology Scenario Data

Given the production that we have available for the steel sector, we cannot use all technology trajectories in the stress strest. For our model framework, the most important technologies are highlighted with the x on the right column. Here we have baseline and target data available and also underlying production data.

There are however still some additional steel sector specific processing steps.

For DRI-MELT-BOF, the time series starts in 2026. This indicates that the values for 2020-2025 are either not available or assumed to be 0. In our opinion, 0 would be quite an exaggeration, since DRI-MELT-BOF is an established, although bit rarer technology. As a result, we fill the gaps for the missing years with the first available value of the technology given in 2026.

Another adjustment is that for the Average BF-BOF we have missing values in the last years for the carbon cost scenario. However, here it we believe its logical conclusion that the production highlighted in this 1.5°C aligned scenario just goes down to 0, which is what we also introduce in the scenario processing.

To calculate the final trajectory that we use in the stress test, we rely on the Technology Market Share Ratio, which we already mentioned previously.

$$p_{i,j}^{tmsr}(t) = p_{i,j}(t0) * (1 + TMSR(t))$$

Steel Price and Cost Data

There is no available raw price data given by MPP. Instead, MPP publishes data about the levelized cost of steel, which is what we are using to create implied steel prices.

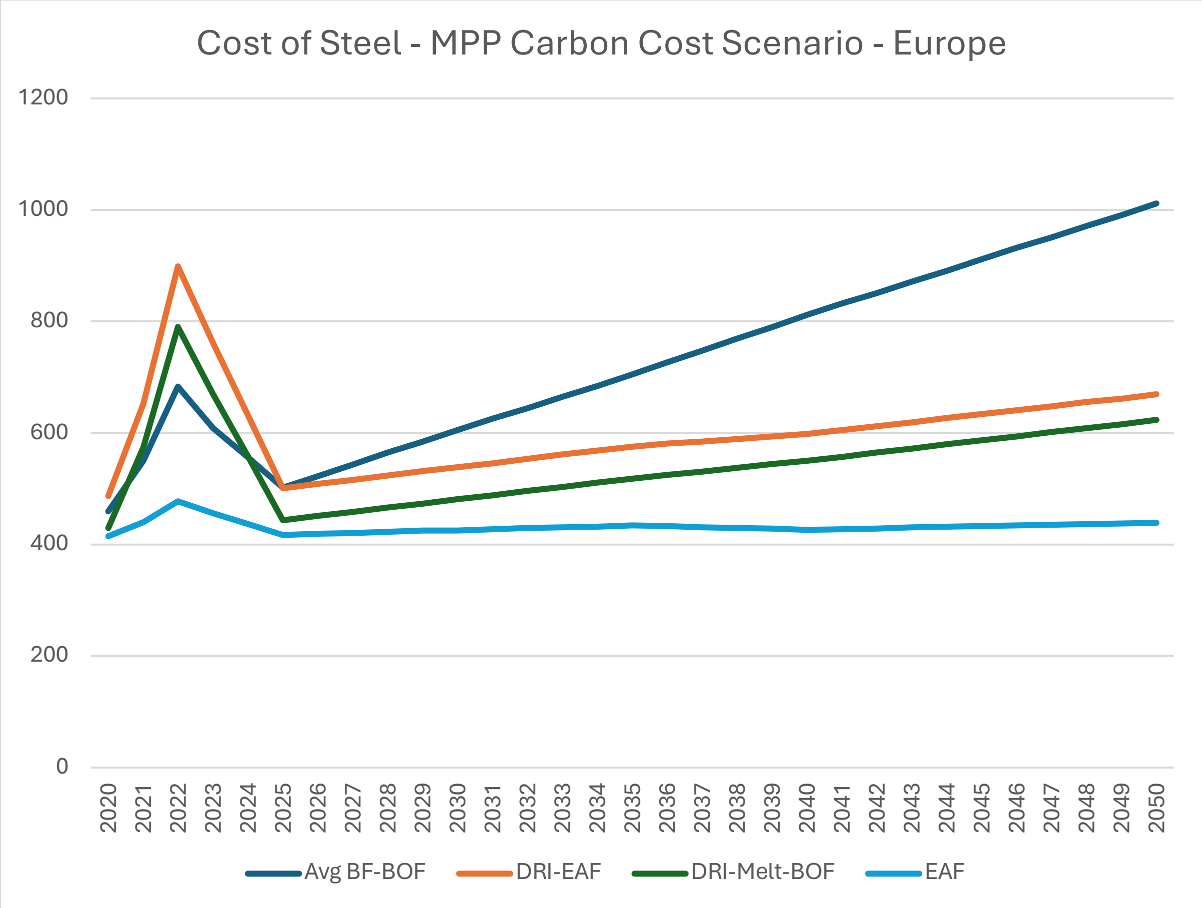

Figure 14: MPP Cost of Steel

Figure 14 shows the trajectory of different steel technologies over time for the carbon cost scenario. In order to create prices from this data, we rely on the same process that we have mentioned in section 1 "*LCOE to prices*". We leverage information about the average Net profit margin available to us for steel companies, and calculate with that, in combination with the MPP scenario steel cost data, the implied steel price for different technologies. [8]

[8] Note that this shows the current version of the steel model and might be up to adjustments with further research.

Steel Capacity Factors

Finally, the steel scenarios require a capacity or utilization factor, to tranform the raw steel capacity projections into net steel production. Unfortunately, MPP does not give this kind of information, and neither does any other scenario provider. Give the data scarcity, we rely for the capacity factors on data provided by the Global Energy Monitor.

The Global Energy Monitor (GEM) is a non-profit organization that tracks various types of energy projects and developments around the world. It focuses on providing data and analysis on projects such as coal, oil, gas, and renewable energy infrastructures. The goal of GEM is to facilitate transparency in energy projects and to promote awareness about the impacts of different energy sources on the environment and public health. GEM published datasets on the tracking of plants for different sectors, among others for the coal, oil and gas, and the steel sector.

GEM Steel is a dataset covering more than 1,000 different steel plant capacity and net production values. We process this data by matching the capacity and production data per plant and calculate an implied capacity factor.

$$CF_{i,h} = \frac{Production_{i,h}}{Capacity_{i,h}}$$

We can average the calculated implied capacity factors for each technology subtype to get an average capacity factor.

GEM Technology	Implied Capacity Factor
Crude Steel	59%
BOF Steel	62%
EAF Steel	64%
OHF Steel	93%
Iron	62%
BF	68%
DRI	46%

Table 6: Average Capacity Factors per Technology calculated from GEM

Note though that although with this we have an estimation of the capacity factor that we can use in the model, we do not have any potential scenario specific adjustments of this factor, nor any time series data. This means that we apply the capacity factors shows in Table 6 for all years and for all steel scenarios.

Harmonizing Steel Data Sources

Given the multiple different data sources used for steel and the multiple different technology types, the final step for the scenario processing of steel is data harmonization.

AI		GEM	MPP	
AI Technology	AI Technology Type	GEM Technology	MPP Technology	Harmonized Name
Basic Oxygen Furnace	Integrated Blast Furnace	BOF Steel	Avg BF-BOF	BOF-BF
Basic Oxygen Furnace	Integrated DRI Furnace	DRI	DRI-Melt-BOF	BOF-DRI
Electric Arc Furnace	Integrated Blast Furnace	EAF Steel	EAF	EAF-BF
Electric Arc Furnace	Integrated DRI Furnace	DRI	DRI-EAF	EAF-DRI
Electric Arc Furnace	Integrated Open Hearth Furnace	EAF Steel	EAF	EAF-OHF
Electric Arc Furnace	Mini-Mill	EAF Steel	EAF	EAF-MM

Table 7: Harmonized Technology Name for Steel Scenario

One challenge with the different data sources is that we have sometimes data on a more granular level in one data source, like the AI production data, while other data sources offer the data not always on the same granularity. This implies that we have to use certain matching mechanisms in order to create the final steel scenario.

As an Example, GEM only offers capacity factor data for general EAF steel production, but not on the subtype of the EAF production process.

In table 7, we can see the different relevant technologies given by the different data sources and how they are matched to the overlying production data.

In the column marked in blue, we see the harmonized name, which covers the final technology type that we can capture in the 1in1000 model framworks, as we have already mentioned in figure 12.

Afterword

This report highlights the scenario processing methodology we are using in the 1in1000 Transition Risk Stress test. As the stress test has its foundation in asset based production levels, the main data inputs needed from each scenario are technology trajectories, capacity factors and price estimates. We explain what these data points consist of in its raw format and also the additional steps taken to further transform the different parameters to be applied in the stress test.

The data we receive on climate scenarios is currently provided by five different scenario providers for the coal, oil and gas, power and automotive sector, with an additional scenario for the steel sector.. While the scenarios that these providers publish can be categorized into differet scenario narratives or types, they all still remain unique given its underlying computational mechanisms. Although different scenario providers show these difference in scenario computation and design, they remain processable with our integration procedure.

Our methodology for scenarios is ultimately designed to be as data agnostic as possible. This approach allows us to incorporate a variety of scenarios from these five providers, while maintaining flexibility to adapt to future model updates and new developments in climate scenario procurement.