Technical Guide:

Climate Scenario Tool for Food, Agriculture and Forest Products

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1 Overview

1.1 Purpose

This Technical Guide provides detailed documentation related to the following aspects of the Climate Scenario Tool ("Tool") available at https://climatescenariocatalogue.org/explore-the-data/:

1. **Scenarios: The scenarios and underlying drivers used to generate the Tool's outputs as well as the design and syndication process used to develop the scenarios.**
2. **Analytical Methods: The models, methods, and limitations associated with the economic and land use modeling employed by Vivid Economics to generate the Tool's outputs.** The guide describes the steps taken to create the scenarios, the modeling process, and the Tool's outputs. For additional information on the application of scenario analysis, refer to the Scenarios Analysis and Application Guide.

The Tool's scenarios are the first of their kind, designed specifically to provide the level of granularity relevant to the Food, Agriculture, and Forest Products (FAF) sector. These scenarios are aligned with the scenario analysis recommendations of the Task Force on Climate-Related Financial Disclosures (TCFD)[1] and are also designed to complement non-FAF sector scenarios available in the public domain.

TCFD-aligned scenario analysis and strategic insights allow companies to position themselves as climate and business leaders through strategic planning, identification of new business opportunities, public reporting and disclosures, and communications with stakeholders. Additionally, investors can use TCFD disclosures to better understand how resilient an organization is to climate risks and opportunities.

The TCFD categorizes climate risk as either "physical" or "transition" risks. Physical risks/opportunities include chronic (e.g., heat stress) and acute (e.g., flooding) climactic changes that have both direct and indirect impacts on businesses and economies. Transition risks and opportunities are created by societal actions to decarbonize such as policy, technology development, or consumer shifts.

The Tool only models transition scenarios and related impacts. As described in Section 3, the model considers select underlying chronic physical impacts pre-specified in the economic and land use models deployed, but users should only use the tool to evaluate transition impacts.

These transition scenarios are not predictions nor forecasts, but rather a set of plausible futures. When using these scenarios to develop or test strategy, companies should use multiple scenarios to achieve a true range of potential futures. Furthermore, the scenario outputs are designed to complement a company's existing forecasts.

For example, assuming a company's internal forecasts do not currently consider future transitions, a company can take the percentage difference between the 'Historic Trends' scenario and the 'Innovation' scenario, and apply that percentage change to their forecasts. Alternatively, if a company's existing forecasts appear to align with the scenario drivers of a specific scenario, the company could use a percentage change between the 2020 value and a future date's value to derive the relevant impact in

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[1] TCFD is a framework for companies and financial institutions to understand the material relevance of climate driven risks and opportunities. Scenario analysis (of both physical and transition risks) underpins the TCFD framework, providing insight into plausible future pathways and climate change impacts on a business or portfolio.

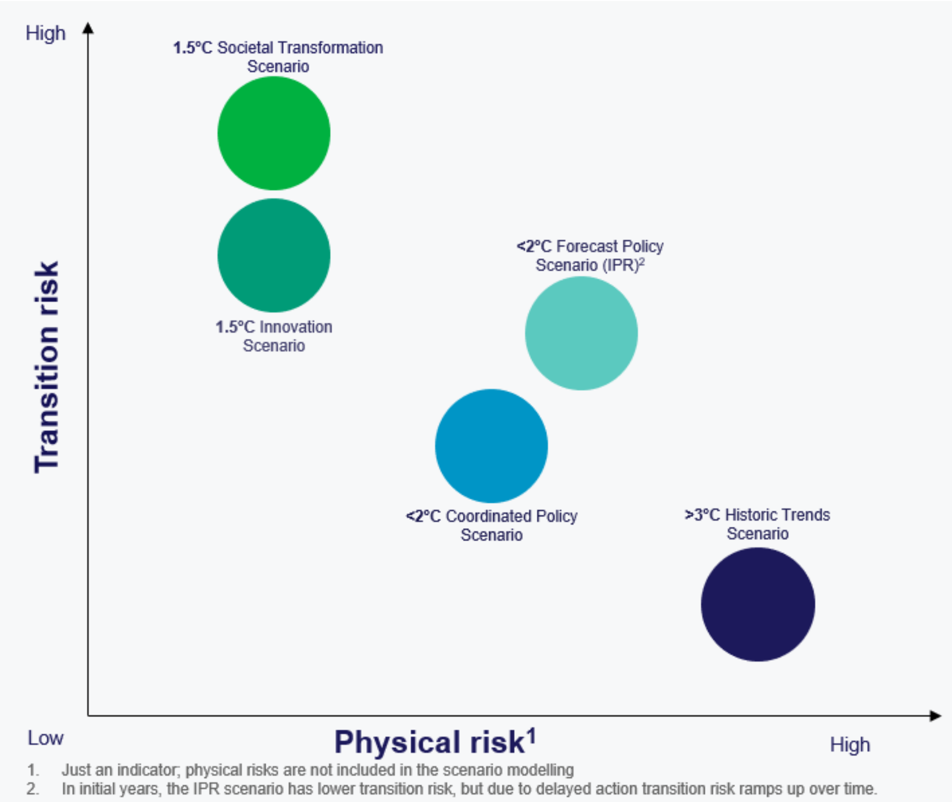
that period. For more specific guidance on applying the scenarios, refer to the Scenarios Analysis and Application Guide.

Although these climate scenarios provide a broad range of future climate pathways, WBCSD would like to reaffirm that a 1.5°C pathway for society is the only option to create a net-zero, nature-positive, and more equitable future.

Each scenario models transition risk associated with a specific set of actions society could take to limit global warming to a specific temperature increase. The Climate Scenario Tool includes outputs derived from five different scenarios that together provide a wide range of possible futures. These scenarios are:

- **>3°C Historic Trends Scenario.** Climate action remains stable at current levels creating limited transition risks, but the world fails to limit global warming to manageable levels, resulting in substantial future physical risks. This scenario has low levels of transition risk.
- **<2°C Forecast Policy Scenario (the Inevitable Policy Response, or IPR).** Climate action starts abruptly and late, around 2030, resulting in limited transition risk in early years. After 2030, transition risks ramp up significantly due to the sudden implementation of greenhouse gas (GHG) prices, area protection regulation, and a scale-up of bioenergy with carbon capture and storage (BECCS) capacity. This scenario has varying levels of transition risk over time.
- **<2°C Coordinated Policy Scenario.** Timely policy and regulation work to curb emissions in an orderly fashion, decreasing the physical risk of climate change but increasing the transition risk. This scenario has moderate levels of transition risk.
- **1.5°C Societal Transformation Scenario.** Strong, coordinated, and prompt global policy action, as well as market responses (e.g., diet shifts and lower food waste), result in widespread carbon pricing and land protection to enable decarbonization and limit the physical impacts of climate change. This scenario has high levels of transition risk.
- **1.5°C Innovation Scenario.** Large demand from the energy system for BECCS, coupled with greater-than-historical yield growth in agriculture and government support for R&D, enables early decarbonization and limited physical impacts of climate change. This scenario has high levels of transition risk.

Figure 1: Scenario Overview



Source: WBCSD with supporting analysis from Vivid Economics

1.2 The Team

To develop robust scenarios and underlying drivers, the transition scenarios were developed, iterated and pressure-tested with three groups:

1. **Corporate Forum.** The Corporate Forum met as a group four times over the course of the design of the scenarios and Climate Scenario Tool. Additionally, the modeling team met individually with most Corporate Forum members to solicit feedback. Throughout the scenario design and modeling process, the Forum provided feedback on the scenarios to ensure that they are useful and applicable to FAF businesses. The Forum consisted of the following members:

   Bayer: Nicolas Schweigert
   Cargill: Dana Boyer
   CMPC: Andrés Yaksic Beckdorf, Felipe Naranjo De Lucca, Nicolas Gordon Adam
   Corteva: Rory Nussbaumer, Anjali Marok
   Danone: Marie-Pierre Bousquet
   International Paper: Sophie Beckham, Matt Inbusch
   Mondi Group: Anthony Campbell, Gladys Naylor, Gregory Salmon
   Olam Food Ingredients: Ria Bakshi, Adam Dixon-Warren, Andrew Van Haght
   Rabobank: Luke Disney
   Royal DSM: Salla Sulasuo, Lucie van de Steeg

Tyson Foods: Justin Ransom, Katherine Pickus
Viterra: Bart de Rijk
Weyerhaeuser: Vaughan Andrews

2. **Technical Advisory Panel.** The Technical Advisory Panel consisted of academic and institutional experts with extensive land use and/or economic modeling and sustainability expertise. The modeling team met individually with the members of this panel, and the panel provided feedback on the data used for the scenarios and the scenarios' narratives, assumptions, and outputs. This panel was comprised of the following individuals:

   Cornell College of Agriculture and Life Sciences: Daniel Mason-D'Croz
   EAT-Lancet Commission and Food Systems Economics Commission: Franziska Gaupp
   PBL Netherlands Environmental Assessment Agency: Jonathan Doelman
   Potsdam Institute for Climate Impact Research: Jan Dietrich, Alexander Popp

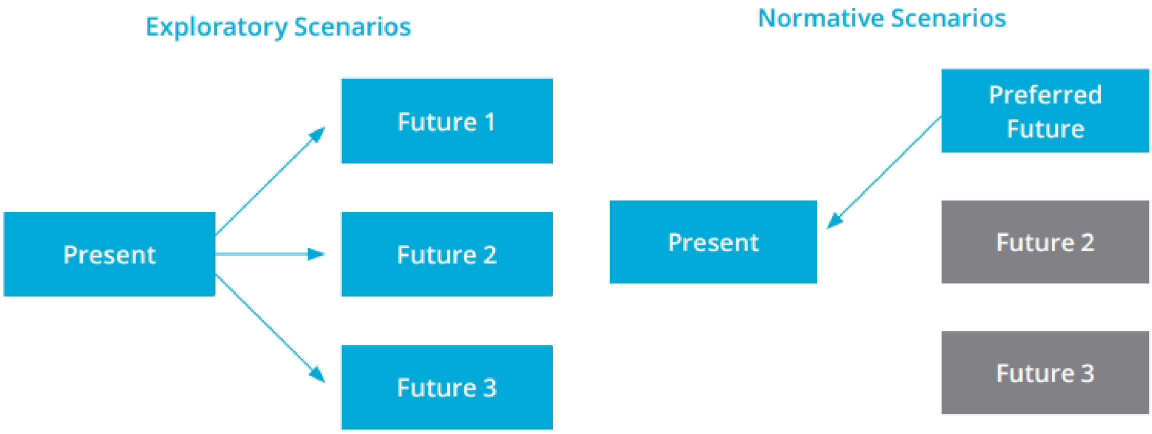
3. **Stakeholder Advisory Panel.** The Stakeholder Advisory Panel provided feedback on the scenarios and how to ensure their relevance to sustainable and industry-relevant pathways for the FAF sector. Panel members included:

   BSR: Maria Troya
   Climate Bonds Initiative: Michael Bullen, Chris Moore, Ewan Thomson, Oluwatoyin Oyekenu, Rachel Hemingway
   Orbitas: Niamh McCarthy
   Tropical Forest Alliance: Petra Tanos
   United Nations Environment Programme Finance Initiative: Sarah Kemmitt
   World Wildlife Fund: Emily Moberg

1.3 Scenario Overview

The five scenarios that underlie the Tool represent a broad range of potential futures. TCFD recommends a wide spectrum of futures in order to pressure-test a business or portfolio against a variety of risks and opportunities**.** Scenarios fall into two main categories: normative and exploratory. Normative scenarios are a range of plausible pathways back-casting from one preferred or desired future. In contrast, exploratory scenarios span a number of plausible futures. The TCFD recommends using exploratory scenarios to conduct climate scenario analysis because these scenarios provide a much wider range of potential futures than normative scenarios; this allows companies to more thoroughly test their strategy.

Figure 2: Exploratory and Normative Scenarios



Source: 2020 TCFD Scenario Analysis Guidelines

The Climate Scenario Tool provides five diverse, exploratory scenarios. Below are detailed explanations of each scenario narrative:

- **>3°C Historic Trends Scenario**
  - **Overview.** This represents a business as usual scenario in which today's level of climate ambition remains stable and reminiscent of historical trends. As a result, the world fails to adequately avoid catastrophic physical impacts. The global average carbon price stabilizes at around $4/ton[2] through 2050 while governments fail to protect any additional land area. Significant expansion of cropland causes a decrease in total forest land of approximately 30 million hectare acres (Mha) and other land of nearly 300 Mha through 2050. Lack of investment in agricultural innovation limits the deployment of technologies aimed at increasing input efficiency and causes productivity for low crop yield to grow at <1% per annum (p.a.) through 2050. Lack of regulation or public investment in alternative proteins hinders a significant shift away from animal proteins.
  - **Results summary.** While transition risks are low, the lack of climate action exacerbates the effects of extreme events on the FAF sector, making it costlier in the longer run for producers to maintain a stable supply. To accommodate additional production needs, forest land is converted to agricultural land, destroying valuable ecosystems, with significant negative impacts on the planet and lives.
  - **Comparable scenarios.** Intergovernmental Panel on Climate Change (IPCC) Scenario C6-C8, Network for Greening the Financial System (NGFS) Current Policies Scenario
- **<2°C Forecast Policy Scenario (IPR)**
  - **Overview.** The forecast policy scenario reflects society's current ambitions, with climate action starting late and abruptly, resulting in high transition risks in later years as society attempts to limit global warming to under 2 degrees. The need to curb emissions fast to

[2] In 2020 US dollars

meet this target leads to a disorderly increase in GHG costs, with prices in emerging economies remaining below $90/ton and prices in high income regions reaching $145/ton. Between 2025 and 2030, the ramp-up in policy ambition forces the FAF sector to abruptly shift away from unsustainable practices. Limited demand and supply-side action exacerbate the effect of climate policies on land use competition, that is, the competition for available land to be used for growing either a given crop, for pasture of one of the different animal products, or for growing forests.

  - **Results summary.** The FAF sector transitions fast and without a clear plan. High carbon prices result in high production costs for emission-intensive products (e.g., inorganic fertilizers, livestock products). Area protection increases regulatory risks for companies. Agricultural producers invest in available technology to increase yields.
  - **Comparable scenarios.** IPCC AR6 SSP2-2.6

- **<2°C Coordinated Policy Scenario**
  - **Overview.** Timely policy and regulation work to curb emissions, limiting both physical and transition risks over time. The partial participation of the FAF sector in carbon markets supports regulation in halting deforestation and incentivizing ecosystems' restoration and conservation. Carbon prices stabilize at $100/ton by 2050 and biodiversity hotspots are protected by 2030. Nevertheless, the lack of both public and private sector investment in innovation limits global yields' growth to <1% p.a. through 2050, making agricultural land expansion onto other land necessary to meet food demand; this causes a decrease of approximately 100 Mha in other land by 2050.
  - **Results summary.** Climate policy incentivizes early action, allowing the FAF sector to transition smoothly. Carbon pricing pushes the agricultural sector to use available technology to mitigate CH_4 and N_2O emissions. Deforestation declines steadily as more areas are protected and carbon pricing makes land clearing progressively more costly.
  - **Comparable scenarios.** NGFS Below 2°C, International Energy Agency (IEA) Sustainable Development Scenario (SDS)

- **1.5°C Societal Transformation Scenario**
  - **Overview.** Strong, coordinated global policy action results in widespread adoption of carbon pricing at $153/ton by 2050 and the achievement of the "50x50"[3] land protection target. This collaboration enables early decarbonization and limits the physical impacts of climate change.
  - **Results summary.** Timely action allows for a smoother transition. However, high carbon costs and ambitious area protection increase production costs and prices for emission-intensive commodities: companies operating close to protected areas are subject to legal and reputational risks. Public sector investment in alternative proteins further incentivizes a shift away from animal products, emphasizing the need for animal

[3] The goal of protecting 50% of global land and sea areas by 2050.

producers and their supply chains to reduce emissions and diversify into new segments to maintain growth rates.

  - **Comparable scenarios.** IPR Required Policy Scenario (RPS), NGFS Net Zero 2050, IEA Net Zero Emissions by 2050 (NZE), IPCC AR6 SSP2-1.9

- **1.5°C Innovation Scenario**
  - **Overview.** Strong demand from the energy system for bioenergy (with carbon capture and storage) of >100 EJ/year by 2050, coupled with greater-than-historical yield growth in agriculture, enables early decarbonization and limits the physical impacts of climate change. Government technology policy is supportive of R&D and commercialization, leading to an increase in the market share of alternative proteins to 23% by 2050, a reduction in food waste, and an increase in input efficiency.
  - **Results summary.** Productivity increases as a result of investment in innovation. Broader use of existing technology increases productivity in developing countries while developed economies invest in new technologies to push the boundaries of productivity and maximize input efficiency. As a result, deforestation stops and previously deforested land naturally regrows without increasing the amount of competition across land uses.
  - **Comparable scenarios.** 1.5°C IPR Required Policy Scenario (RPS), NGFS Net Zero 2050, IEA Net Zero Emissions by 2050 (NZE), FOLU's Better Futures Scenario, IPCC AR6 SSP2-1.9

Despite their varied narratives, these scenarios are not mutually exclusive. For example, it is possible that society embarks on what is thought to be a 1.5°C pathway but falls short, resulting in 2°C of warming. This would mean that the world and the FAF sector would eventually experience the physical risks associated with a 2°C pathway but the transition risk of a 1.5°C pathway.

1.4 Scenario Drivers

Ten drivers shape these scenarios; eight of these drivers vary by scenario, while two (GDP and population; trade) remain constant across all scenarios. These drivers represent the scenario narratives and create variation in scenario outputs. In addition to these ten drivers, we also constructed three timber demand pathways based on literature and expert consultation. These pathways were overlaid and aligned with the five outlined scenarios. See section 4.1, "Modeling Process".

Figure 3 provides an overview of how the ten drivers differ across five scenarios. These inputs are global values, so they do not reflect the variation between regions included in the model itself. For example, the <2°C Forecast Policy Scenario (IPR) and <2°C Coordinated Policy Scenario often have similar global averages to each other in Figure 3, but in the Forecast Policy Scenario there is much larger regional variation. For the 1.5°C pathways, all of the climate transition drivers specified in the figure must meet or overshoot the trajectories described below; this scenario is not possible without concerted, unified, global action to decrease GHG emissions. More detail on each of these drivers can be found in Section 3.3 Qualitative Impact of Driver Forces.

Figure 3: Global Overview (values vary by region within the model)

Level of action (low to high)

Types of drivers: Policy action, Tech-driven action, Demand-side action

Input assumptions	>3°C Historic Trends	<2°C Forecast Policy (IPR)[2]	<2°C Coordinated Policy	1.5°C Societal Transformation	1.5°C Innovation
GDP & Pop/Trade	**Medium:** IPCC Shared Socioeconomic Pathway 2 (SSP2), a 'middle of the road' scenario: Population grows from 7bn at 0.6% p.a. before slowing, 2070 peak at 9.5 bn. GDP doubles by 2050 **Current patterns:** Maintains current trade policy regime, without systematic liberalisation or de-liberalisation				
GHG Prices $/ton of CO_2e	**Current prices** $4/ton CO_2e by 2050	**Disorderly** ~$115/ton CO_2e by 2050[3]	**Medium** $100/ton CO_2e by 2050	**High** $153/ton CO_2e by 2050	
Bioenergy pathway Exajoules (EJ)	**Current levels** 8.8 EJ/year in 2050 (no 2nd generation bioenergy crops)	**Disorderly** Demand reaches moderate levels only after 2040 (72 EJ/yr 2nd generation)	**Moderate** 90 EJ/year by 2050 (72 EJ/yr 2nd generation)	**Ambitious** 100 EJ/year by 2050 (82 EJ/yr 2nd generation bioenergy crops)	**High** 130 EJ/year by 2050 (112 EJ/yr 2nd generation bioenergy crops)
Diet shifts Caloric Shift between 2020 and 2050	**No diet shift** +18% demand for livestock products between 2020 and 2050	**Medium diet shift** -2% demand for livestock products between 2020 and 2050		**High diet shift** -12% demand for livestock products between 2020 and 2050	**Medium diet shift** -2% demand for livestock products between 2020 and 2050
Protected areas[1]	**WDPA** current protection 13% of terrestrial land surface	**WDPA + Biodiversity hotspots** (After 2025, limited to a subset of countries)	**WDPA + Biodiversity hotspots**	**Meets 50x50 targets** 50% terrestrial area by 2030	**WDPA + Biodiversity hotspots**
Input efficiency Nitrogen Uptake Efficiency (NUE), %	**No change** Global average <60% by 2050	**Medium** Global average ~65% by 2050			**High** NUE global average 70% by 2050
Yield-enhancing tech Per annum growth crop yields	**Low** Crop yields grow < 1%p.a.	**Medium** Crop yields grow at ~1% p.a.			**High** Yields grow >1% p.a.
Food waste reductions % of food wasted	**No reduction** 33% food is wasted by 2050	**Medium reduction** 20% by 2050 (faster reduction from 2030 to 2050)	**Medium reduction** 20% by 2050 (smooth reduction)	**High reduction** 16.5% by 2050 (UN Sustainable Develop Goal 12.3)	**Medium reduction** 20% by 2050
Other climate policies	**Nationally determined policies on reforestation/ avoided deforestation**	**Adjusted land-use Nationally Determined Contributions (NDCs)** Lower forest NDC for China			
Timber demand pathways	**Low demand**. Demand for timber in construction remains low (~0.5%)	**Medium demand.** Demand for timber in construction of new builds grows to 10%.			**High demand.** Demand for timber in construction of new builds grows to 50%.

1. "Protected areas" refers to Cat I, VI World Database for Protected Areas.
2. Action starts between 2025 and 2030.
3. Starting 2025, high-income regions begin to experience higher GHG prices than emerging and developing regions.

Source: WBCSD with supporting analysis by Vivid Economics

1.5 Scenario Output Overview

Our Climate Scenario Tool provides output for 23 commodities and 18 regions (including six large individual countries) between 2020 and 2050 in five-year intervals.

The 23 commodities included as output variables are:

- **Crop commodities:**
    - Cotton Seed
    - Fruits Vegetables Nuts
    - Groundnuts
    - Maize
    - Oil Palms
    - Other Oil Crops, including Rapeseed
    - Potatoes
    - Pulses
    - Rice
    - Soybean
    - Sugar Beet
    - Sugar Cane
    - Sunflower
    - Temperate Cereals
    - Tropical Cereals
    - Tropical Roots
- **Animal Products:**
    - Beef, Sheep and Goat
    - Dairy
    - Eggs
    - Pork
    - Poultry
- **Forest products**
    - Timber
    - Pulpwood

The 18 regions included in the output variables are:

- Australia & New Zealand (ANZ)
- Brazil (BRA)
- Canada (CAN)
- European Union & United Kingdom (EUR)
- Former Soviet Union, excluding Russia (REF)
- Greater China (CHA)
- India (IND)
- Japan & Korea (DEA)
- Latin America’s Southern Cone (SCO)
- Middle East & Northern Africa (MEA)
- Other Europe, excluding EU & UK (NEU)
- Russia (RUS)
- South Asia (SAS)
- South East Asia (SEA)
- Southern Africa (SAF)
- Tropical Africa (TAF)
- Tropical Latin America (TLA)
- United States (USA)

The tool includes business variables, land use, and environmental variables for each of these commodities in each of the 18 regions, as shown in Figure 4 below.

Figure 4: Overview of Output Variables

Available for the 18 Regions, 23 Commodities
Available for the 18 Regions Only

Business Variables[1]

- Production (Mt DM/yr)
- Prices (% change since 2020)
- Market Size (% change since 2020)
- Yield Growth (% change since 2020)
- Production Share (% global production)

1. If a region’s production share is below 5% of global production, we focus only on reporting production because our model cannot provide robust estimates for very small markets.

Mt = Mega tonnes
t DM = Tonnes of dry matter
Mha = Million hectares

Land Use

- Land use change by:
  - Cropland (Mha)
  - Forest (Mha)
  - Pastures and rangeland (Mha)
  - Urban area (Mha)
  - Other land (Mha)

Environmental Variables

- CO_2 (Mt CO_2e/yr)
- CH_4 (Mt CO_2e/yr)
- N_2O (Mt CO_2e/yr)
- All GHG (Mt CO_2e/yr)
- Avoided Deforestation (Mt CO_2e/yr since 2020)
- Forest Restoration (Mt CO_2e/yr since 2020)
- Total forest-based CO_2 mitigation potential (Mt CO_2e/yr since 2020)

Source: WBCSD with supporting analysis from Vivid Economics

An overview of which drivers impact each output variable can be found in Section 4.2 MAgPIE Variables Interactions.

Business Variables:

Production. Total production of a commodity within a specific region

Prices. Percent change in price relative to 2020

Market Size. Percent change in market size relative to 2020

Yield Growth. Total growth of output per area (i.e., yield) of a commodity within a specific region

Production Share. Share of global production in a specific region based on the overall global production amount in the scenario

Land Use Variables:

Land Cover: Cropland. Total amount of cropland within a specific region. Cropland includes all land that is suitable to grow crops after the model conducts cost-optimization of relevant land. Cropland cannot also be forestland or pastures and rangeland – the three variables are mutually exclusive

Land Cover: Forest. Total amount of forestland within a specific region. Forestland includes all primary (old-growth) forest, secondary (regrown) forest, and forest plantations. Forest land cannot also be cropland or pastures and rangeland – the three variables are mutually exclusive

Land Cover: Pastures and Rangeland. Total amount of land where livestock are grazed or raised within a specific region after the model conducts cost optimization of relevant land. Pastures and rangeland cannot also be cropland or forestland – the three variables are mutually exclusive

Land Cover: Urban Area. Total amount of land used for urban settlement areas within a specific region

Land Cover: Other Land. All land that is not forest, cropland, pastures and rangeland, or urban land within a specific region. Some areas in this category include highly biodiverse environments, such as the savannah, which are important to preserve natural capital, maintain functioning ecosystem services, and reach biodiversity targets

Environmental Variables:

Agriculture, Food and Land use (AFOLU) Emissions: Sum of total AFOLU emissions from the following sources:

- Gross land use change
- Regrowth
- Animal waste management
- Inorganic fertilizers
- Manure applied to croplands
- Decay of crop residues

- Soil organic matter loss
- Pasture soils
- Rice cultivation
- Enteric fermentation

This can also be disaggregated to CO_2, N_2O, or CH_4 output variables in the Climate Scenario Tool:

CO_2 (Carbon Dioxide). Sum of the total CO_2 emissions from the following AFOLU sources within a specific region:

- Gross land use change
- Regrowth

N_2O (Nitrous Oxide). Sum of the total N_2O emissions from the following AFOLU sources within a specific region:

- Animal waste management
- Inorganic fertilizers
- Manure applied to croplands
- Decay of crop residues
- Soil organic matter loss
- Pasture soils

CH_4 (Methane). Sum of the total CH_4 emissions from the following AFOLU sources within a specific region:

- Rice cultivation
- Animal waste management
- Enteric fermentation

Forest-Based Mitigation: Avoided Deforestation. Annual amount of avoided CO_2 emissions from forest area that is lost in the >3°C Historic Trends scenario but is protected in the selected scenario. Includes primary and secondary forest protection. Avoided emissions are estimated assuming that deforestation would result in a complete loss of aboveground & belowground vegetation biomass, with annual emissions estimated as an average over the typical creditable lifetime of such a project

Forest-Based Mitigation: Forest Restoration. Annual CO_2 sequestration on forest land that has been established since 2020. Includes natural regrowth of secondary forests, NDC-driven re/afforestation, and incentivized re/afforestation (i.e., forest establishment driven by an economic reward through a carbon price). Excludes timber plantations

Forest-Based Mitigation: Total forest-based CO_2 mitigation potential. The gross amount of CO_2 abatement in the forest sector from forest restoration since 2020 and avoided deforestation relative to the >3°C Historic Trends scenario. Forests include all primary (old-growth) forest, secondary (regrown) forest, and managed forest (excluding those used for timber production)

It should be noted that emissions abatement related to forest NDCs are not considered “additional”, as such reforestation is prescribed by policy and is therefore expected to occur in the absence of a GHG price. However, a fraction of non-NDC forest-related mitigation is additional as it is at least partially motivated by the increase in GHG prices. The remaining forest-driven abatement is partly related to other drivers of land dynamics, such as diet shifts

1.6 Methodology Overview

The scenario design and modeling team used a four-step process, detailed briefly below, to develop the five scenarios. The complete methodology is described in step-by-step detail in the following sections.

1. **Scenario and narrative design**

The modeling team designed the five scenarios to span a wide range of plausible futures as defined by a set of key drivers listed in Figure 3. The team first defined a list of driving assumptions for the scenarios, which included themes recurring across other reviewed climate scenarios, as shown in Figure 3. For each driving assumption, the team researched the range of plausible values through 2050. This spread of values can be seen in Figure 5 on the following page. Next, the team defined narratives for how society could achieve the selected temperature thresholds. The team characterized each scenario using the projected driving assumptions to obtain a wide range of different futures, spanning a variety of temperature targets. Additionally, in the near future the team will develop signposts to allow scenario users to gauge how the world is progressing along these scenario pathways over time. Throughout the scenario and narrative design process, the team solicited feedback from the Corporate Forum, Advisory Panel, and internal experts.

Figure 5: Literature Review of Plausible Driver Values

We reviewed key data sources to identify what the existing range of value is for each input assumption. Note that not all 2050 boundaries are plausible, as some represent extreme outcomes (e.g. 50x50 targets).

Types of drivers

Policy action · Tech-driven action · Demand-side action

Input assumptions	Metrics	Boundaries 2020	Boundaries 2050	Data sources	Confidence in data sources	
Population	Million people	7,516 -7,795 million people	8,416 – 10,588 million people	IPCC AR6, UN, SSP Database	High confidence	Technical and corporate experts encouraged use of IPCC AR6
GDP	Billion US$	97-103 Billion US$05	198-360 Billion US$05	IPCC AR6, OECD, SSP Database	High confidence	Technical and corporate experts encouraged use of IPCC AR6
Protected areas[1] (Policy action)	Mha protected area	352 – 2,250 Mha	352 Mha – 6,156 Mha (50% of land, 50x50 target)	Molotoks et al. (2018), CAT, Dasgupta, Dinerstein et al. (2019)	High confidence	Experts highlighted that it's unlikely that the world will meet 50x50 targets
GHG Prices $/ton of CO_2e (Policy action)	$ per ton of CO_2eq	$4-6/ton	$4-1,959/ton	NGFS, IEA, CAT, IMF	Tested with experts	
Bioenergy pathway (Tech-driven action)	EJ per year	2.2- 10.3 EJ	1 – 300 EJ	NGFS, IPCC Special Report on Renewables	Tested with experts	Experts highlight changing views around usage of dedicated crops for BECCS
Diet shifts Share of different proteins (Demand-side action)	Market share for plant-based meat (% total protein market)	2% market share	16-60% market share	Vivid, BCG, Kearney	High confidence	
Food waste reductions Amount of food wasted (Demand-side action)	% of food produced that is wasted	33% of all food is wasted	+31%, - 50%	WRI, EAT Lancet, BCG, FAO, World Bank	High confidence	
Input efficiency Nitrogen Uptake Efficiency (Tech-driven action)	Nitrogen Uptake Efficiency	25% - 65%	60% - 75%	Anas et al. (2020), Yara	High confidence	
Yield-enhancing tech Per annum growth crop yields (Tech-driven action)	Increase in productivity relative to 2020		0.7% - 1.2% p.a.	Zeist et al. (2020)	Tested with experts	Updated as range was too wide (15% - 160% between 2020 and 2050, NGFS)
Trade					Assumption-driven	

High confidence
Data comes from reputable sources and is consistently used in scenario analysis.

Tested with experts
Sources are reputable, but ranges vary substantially.
Test ranges with experts

Assumption-driven
The driver will be defined based on a set of assumptions. For trade, we will keep current trade patterns unvaried.
Test assumptions with experts.

1. Protected areas refer to areas which are under "strict protection" (WDPA Cat I, II), i.e. human activity is limited and controlled.

Source: WBCSD with supporting analysis from Vivid Economics

2. **Scenario development**

The modeling team developed the five scenarios using the Model of Agricultural Production and its Impact on the Environment (MAgPIE). This model was developed and made open source by the Potsdam Institute for Climate Impact Research (PIK). To characterize each scenario, the team downscaled the driving assumptions to the regional level and used them as input for the model. The team also conducted additional off-model analysis to estimate timber & pulpwood production and nature-based solutions (NBS).

3. **Refinement of raw output**

3a. Calibration: The modeling team collected historical data from a variety of academic and other publicly available sources to compare to the model output. A selection of these sources is shown in Figure 5 above, and a detailed list can be found in Section 3.3 Qualitative Impact of Driving Forces. The team calibrated the model outputs to sources where the team saw an unreasonable discrepancy.

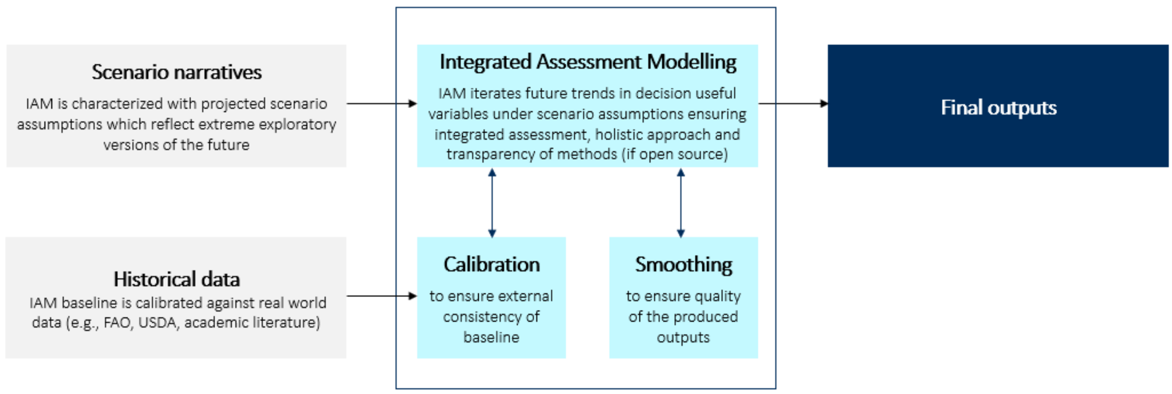
3b. Smoothing: The modeling team smoothed the calibrated output to ensure that there were no unreasonable jumps in the output data.

4. **Final output**

The team then finalized the output after iterations and discussions with the Corporate Forum and the Advisory Panel.

An illustration of these steps can be seen below:

Figure 6: Modeling Methodology Overview



The following sections will go through each of these steps in detail.

2 Scenario Narratives

2.1 Existing Scenario Review

The modeling team began with a review of publicly available scenarios in order to analyze their themes and key assumptions. This review included 34 publicly available scenarios from the following organizations:

- IPR
- NGFS
- Science Based Targets initiative (SBTi)
- Food, Agriculture, Biodiversity, Land-Use and Energy (FABLE) Consortium
- IPCC
- IEA
- EAT-Lancet Commission
- McKinsey 1.5°C Agricultural Decarbonization Pathway
- The Organization for Economic Co-operation and Development (OECD) and Food and Agriculture Organization (FAO)
- The Dasgupta Review
- Climate Action Tracker (CAT)
- The World Economic Forum (WEF)

These public scenarios were both quantitative and qualitative and spanned a wide range of climate pathways from business as usual to 1.5°C of warming.

The modeling team also reviewed more than 50 FAF companies' climate disclosures to identify current trends in FAF scenario analysis. These companies spanned the agriculture, food, and forestry value chains. Based on the scenario and literature reviews, the team identified six significant gaps in the public reference scenarios for the FAF sector as compared to TCFD scenario design recommendations:

1. **Entire company and its value chain coverage.** None of the reviewed scenarios provide data for all output variables that are relevant to the FAF sector. For example, even the best-practice NGFS scenarios lack price data for forestry commodities.
2. **Appropriate commodity/product resolution.** None of the reviewed scenarios covered all relevant commodities. Missing commodities tended to include alternative proteins, forest commodities, and key secondary products. For example, although it covers a large number of commodities, the OECD-FAO scenario does not include any forestry commodities or alternative proteins.
3. **Sufficient number and diversity of scenarios.** Providers with multiple scenarios tended to distinguish them primarily by temperature outcome and rarely disclosed all key assumptions. Best-practice providers created scenarios by varying driving forces to create a comprehensive array of

futures. For example, the IPCC and CAT scenarios created more holistic scenario narratives, while WEF scenarios focused narrowly on two scenario drivers.

4. **Developed signposts.** Reviewed scenarios focus on narratives and data without discussing ways to determine whether a scenario remains plausible over time. WEF provides an assessment of the current plausibility of each scenario but does not provide signposts to enable future assessments.
5. **Transparency of methods.** Reviewed scenarios rarely list all of their assumptions explicitly, which makes them difficult to replicate independently. Additionally, the scenarios often used non-open-source models.
6. **Easy to apply.** Many public scenarios are not user-friendly, and no scenario provides examples of how it can be applied in a TCFD context.

This gap analysis does not imply that the reviewed scenarios are inaccurate or not applicable to the FAF sector; they are simply do not meet all of the TCFD's recommendations for scenario analysis for the FAF sector. The reviewed scenarios were designed with different purposes in mind.

2.2 Scenario Narrative Creation

After completing the existing scenario review process, the modeling team defined what five temperature pathways would provide a comprehensive range for the scenarios. The team selected a business-as-usual scenario to serve as a baseline and designed the >3°C Historic Trends Scenario based on feedback from the Corporate Forum, Technical Advisory Group, and internal experts.

Next, the modeling team selected two scenarios to represent medium action toward climate change: the <2°C Forecast Policy Scenario (IPR) and the <2°C Coordinated Policy Scenario. The differentiation between the two <2°C scenarios in the Climate Scenario Tool is based on how coordinated society's response to climate change is. Ultimately, both pathways reach the same temperature outcome, but in the <2°C Coordinated Policy Scenario, coordinated policy action begins today and slowly increases to reach the levels needed to limit warming to 2°C. In contrast, in the <2°C Forecast Policy Scenario (IPR), little policy action occurs from 2025 to 2030, when society abruptly ramps up policy actions through 2050 to reach about 2°C of global warming. Due to this sudden increase in policy action, the <2°C Forecast Policy Scenario (IPR) has higher, but delayed, transition risks than the <2°C Coordinated Policy Scenario.

Finally, the modeling team selected two 1.5°C scenarios to provide a range of high transition risk scenario outcomes: the 1.5°C Societal Transformation Scenario and the 1.5°C Innovation Scenario. These two scenarios vary in how society reaches the 1.5°C pathway; while they share key assumptions around climate policy ambition, they differ somewhat in the ambition of some drivers:

- In the 1.5°C Societal Transformation Scenario, society reaches the 1.5°C pathway mainly through climate-positive policy and consumer behavior shifts
- In the 1.5°C Innovation Scenario, society reaches its climate goal mainly through highly innovative technologies that make the world more efficient, thereby decreasing emissions.

Scenario alignment to TCFD:

The scenarios in this tool were designed to follow TCFD recommendations for scenario analysis.[5] These recommendations can be organized into four categories on what scenarios should include:

Scope (output). Scenario should cover an entire company and its value chain, cover commodities/products relevant for a company, provide sufficient geographical granularity, and cover a time horizon aligned with climate policies.

Design (assumptions). Users should include four to five scenarios that explore extreme outcomes and the intersection of the most important driving forces. Scenarios should have logical narratives that link historical trends to plausible futures, and include "disorderly" assumptions that account for realistic inefficiency in climate policy. Scenarios should also inlcude signposts that link scenario variables to real-world indicators.

Modeling. Scenarios should be based on integrated assessment modeling and follow an external consistency approach to align model input with historical data. Scenarios should be built on sense-checked models and transparent methods allowing for repeatability.

Application. Scenarios should be easy to apply and clearly documented.

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[4] https://assets.bbhub.io/company/sites/60/2020/09/2020-TCFD_Guidance-Scenario-Analysis-Guidance.pdf

Both scenarios have relatively high transition risk but lower physical risk. This is due to the rapid action needed by society to minimize the physical impacts of climate change.

Throughout the scenario narrative creation process, the modeling team solicited feedback from the project's Corporate Forum and the Advisory Panels to ensure that these narratives covered a sufficient range of hypothetical, plausible futures that are relevant to FAF businesses.

2.3 Qualitative Impact of Driving Forces

After selecting the scenario narratives, the modeling team identified ten drivers (as shown in Figure 3)—eight of which vary across the five scenarios while the other two do not. The differentiation between these drivers is what causes the differences across scenarios. A detailed description of each driver is below.

1. Population and GDP

Overview. All scenarios assume a medium growth trajectory aligned with the SSP2 middle-of-the-road scenario. The population grows from 7.0 billion at 0.6% p.a. before slowing to a peak of 9.5 billion in 2070. Global GDP doubles by 2050.

Importance for FAF scenario design. Population and GDP drive caloric intake and determine food, feed, and material demand pathways.

2. Trade

Overview. All scenarios assume that society maintains the current trade policy regime without systematic liberalization or de-liberalization.

Importance for FAF scenario design. Trade is considered a key mechanism through which each region can meet domestic demand. Free trade implies lower costs for the FAF system.

3. Protected areas

Overview. Protected areas vary between scenarios from the protection of 13% of terrestrial land surface to 50% of terrestrial land surface by 2050. Protected areas are any land formally under legal protection for conservation.

A decrease and eventual reversal of deforestation is an important part of society's transition toward a sustainable future; continued deforestation poses a severe risk to society. Variety in this driver is an aspect of the climate scenario analysis tool to create a wide array of future potential climate futures. However, WBCSD remains adamant that the 1.5°C pathway is the only option for society and must include an end to deforestation across supply chains.

Importance for FAF scenario design. An increase in protected areas decreases the amount of land available for forestry and agricultural activities, creating land use competition and intensifying the need for higher agriculture and forestry land use productivity.

4. GHG prices

Overview. GHG prices range from $4/ton of CO_2e to $153/ton of CO_2e in the scenarios. This price is the shadow price of emissions in the FAF sector from both carbon price policies and implicit pricing.

Importance for FAF scenario design. GHG price implementation increases the cost of emitting GHG for a company and society broadly, which raises costs along the entire FAF value chain and incentivizes a decrease in GHG emissions. GHG price increases will incentivize the creation of emission mitigation opportunities that are considered “additional” (i.e., tied to carbon offsets).

5. Bioenergy pathways

Overview. Bioenergy values in the scenarios range from 8.8 EJ/year to 130.0 EJ/year by 2050. Growth in bioenergy demand is mostly driven by increased demand for BECCS but also standard biofuels. The bulk of the demand is met using second-generation bioenergy crops and residues to reduce competition with food supply.

Importance for FAF scenario design. An increase in bioenergy production decreases the amount of land available for forestry and agricultural activities, creating land use competition and intensifying the need for higher agriculture and forestry land use productivity.

6. Diet shifts

Overview. Diet shifts in the scenarios range from no change to a decline of 12% demand for animal products in 2050 relative to the baseline. This is related to the role of alternative proteins; scenarios with declining livestock calories represent a diet shift toward alternative proteins. The model considers alternative proteins to be plant-based sources of protein or cultivated meat.

Importance for FAF scenario design. An increase in the market share of alternative proteins decreases agricultural emissions. This emissions decline is primarily due to a decrease in ruminant meat production. Diet shifts also decrease the amount of land needed to grow animal feed, reducing land competition overall.

7. Food waste reductions

Overview. Food waste ranges in the scenarios from 33% to 16.5% of global food lost or wasted in 2020. The definition of food waste for the scenarios includes food losses, meaning the model considers food waste along the whole value chain from field to the consumer.

Importance for FAF scenario design. A decline in the share of food waste decreases the amount of food that needs to be produced in order to meet demand. This leads to a decrease in agricultural emissions and lower land use competition.

8. Input efficiency

Overview. The model includes NUE as a proxy for input efficiency in the FAF sector as a whole. Input efficiency across the scenarios ranges from a global average of <60% to up to 70% NUE by 2050. Importantly, the model does not assume that the use of inorganic fertilizer decreases to zero. While the model assumes that inorganic fertilizer use will be partially displaced by organic fertilizer, the modeling team did not find evidence for a full displacement of inorganic fertilizer in the literature reviewed for the scenario development. Instead, using inorganic fertilizer will become less economical compared to organic fertilizer as the former gets included in GHG pricing. In addition, some scenarios assume the adoption of more precise agricultural practices that require less fertilizer use, modeled through a higher NUE, which further reduces the need for inorganic fertilizer.

Importance for FAF scenario design. Fertilizer efficiency leads to more efficient use of input and reduces GHG emissions from agriculture.

9. Yield-enhancing technology

Overview. Crop yield growth ranges from <1% p.a. to >1% p.a. through 2050 across the scenarios. This yield growth is caused by investments in yield-increasing technological change that are incentivized through higher land competition.

Importance for FAF scenario design. Innovation in crop yield technologies boosts productivity, helping to reduce the need for expansion of agricultural land and increasing the land available for restoration.

10. Other climate policies

Overview. Other climate policies focus on national and international commitments on forest restoration and avoided deforestation – e.g., NDCs from parties to the Paris Agreement. This driver has two options: either each country follows its own nationally implemented forest policies, or all countries work together to achieve NDCs. NDCs targets for China are reduced to stabilize land competition in the region.

Importance for FAF scenario design. Forest NDCs affect how much area is available for land use, potentially increasing land use pressures.

After developing these scenario drivers, the modelling team aligned with FAF experts to make sure the drivers were insightful. This prompted a few rounds of iteration for the drivers before their finalization. Additionally, the technical advisory panel provided feedback throughout the scenario process on the types of drivers and their magnitude.

Key academic sources for the narrative creation included:

Protected areas. The Dasgupta Review; CAT; FABLE Consortium; Science Advances Journal; Dinerstein et al., 2019 “A global deal for nature: Guiding principles, milestones, and targets,” The Nature Conservancy; Molotoks et al., 2018 “Global projections of future cropland expansion to 2050 and direct impacts on biodiversity and carbon storage”

GHG prices: International Monetary Fund; Dietz et al., 2018 “The economics of 1.5°C climate change”; Wood Mackenzie; IEA; CAT; NGFS

Bioenergy pathways. IEA; IPR Required Policy Response; CAT; IPCC; Hasegawa et al., 2020 “Food security under high bioenergy demand toward long-term climate goals”; NGFS; Humpenoder et al., 2018 “Large-scale bioenergy production: how to resolve sustainability trade-offs?”; Wu et al., 2019 “Global advanced bioenergy potential under environmental protection policies and societal transformation measures”

Diet shifts. The Dasgupta Review; SBTi; CAT; McKinsey, “Cultivated meat: Out of the lab and into the frying pan”; World Resources Institute (WRI); IHS Markit; EAT-Lancet

Food waste reductions. World Bank; OECD-FAO; EAT-Lancet; WRI; SBTi; UN Sustainable Development Goal 12.3

Input efficiency and yield-enhancing technology. Anas et al., 2020 “Fate of nitrogen in agriculture and environment: Agronomic, eco-physiological and molecular approaches to improve nitrogen use efficiency”; Yara; Zeist et al., “Are scenario projections overly optimistic about future yield progress?”

An overview of the scenario narratives design and build process can be seen in Figure 7 below.

Figure 7: Overview of Scenario Design and Build Process

2.4 Connection to Existing Scenarios

NGFS. The scenarios use the same population and GDP projections as the NGFS scenarios and a middle-of-the-road SSP2 IPCC scenario. The scenarios also use similar drivers to NGFS, such as GHG price and bioenergy usage. However, these scenarios focus on these drivers for the FAF sector specifically, which the NGFS does not include in its current scenarios. Additionally, both NGFS and these scenarios use MAgPIE to model scenario outputs.

Science Based Targets initiative. The models underlying the scenarios are not the same as those behind the SBTi Forest, Land and Agriculture (FLAG) Guidance, but they have shared aspects. For instance, the timespan covered by the scenarios is also within the scope of FLAG. Outputs in FLAG include global cropland area and production totals for vegetal and animal-source products, and the outputs are disaggregated by region and crop. This is the case as well for all outputs included in the scenarios. Notable differences between FLAG and the scenarios include the modeling of yields, which are fixed per crop under FLAG but increase over time in the scenarios. Another difference is greenhouse gas emissions, which in FLAG are available for vegetal and animal-source products, whereas the scenarios just feature total AFOLU emissions by gas.

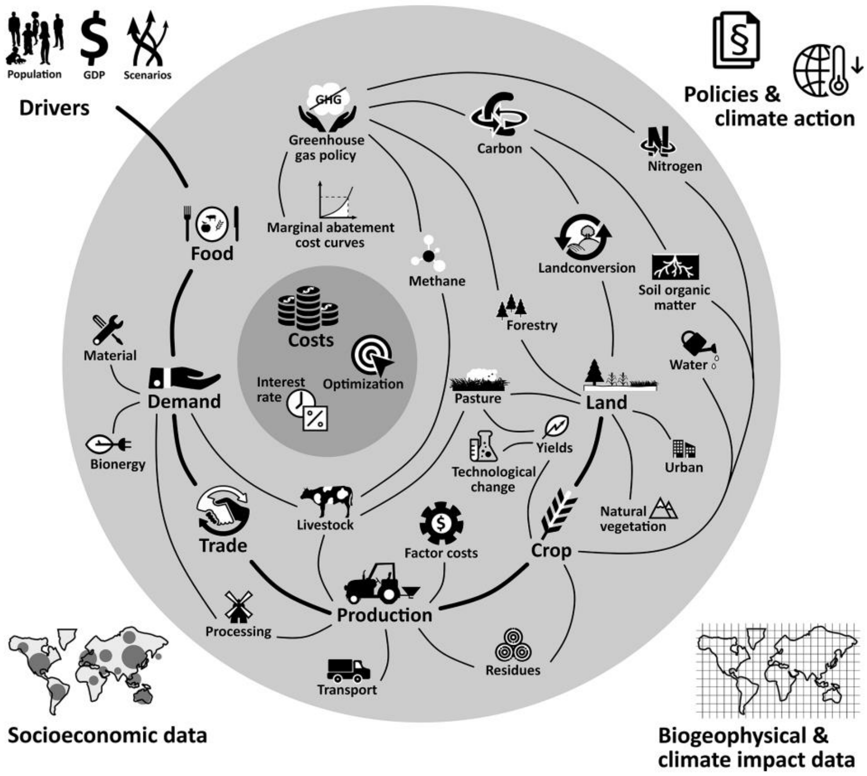
3 MAgPIE

For the modeling itself, the modeling team selected the "Model of Agricultural Production and its Impact on the Environment" (MAgPIE), an open-source model. The model simulates the interactions between human decision making and natural earth systems in relation to the AFOLU sector. Other publicly available scenarios built with MAgPIE include FABLE, NGFS, IPCC, IPR, CAT, and the Dasgupta Review.

MAgPIE was developed and made open source by PIK. Dietrich et al. (2019) gives an overview of the development of MAgPIE, a more than 14-year project. MAgPIE is an established modeling framework that has been regularly utilized by the international community to inform global understanding of the impacts associated with climate change and policies, including in IPCC reports. MAgPIE is now on version 4.5. In this release, model developers at PIK began calling MAgPIE a modeling framework to reflect its modular design and flexibility.

MAgPIE is a global land use allocation model. Taking population and GDP projections, caloric requirements, and demand elasticities as input, the model determines the lowest cost way to meet global food demand while accounting for spatially disaggregated biophysical constraints, including those on land and water and potential crop yields. Specifically, the objective function is to minimize the total cost of production for a given level of food and bioenergy demand. Food demand is defined exogenously given population, income, and regional diets with future trends derived from regression analysis as documented in Bodirsky et al. (2020).

Figure 8: Model Dynamics in MAgPIE



Source: Potsdam Institute for Climate Impact Research

For example, relative to business as usual, scenarios that price emissions from the FAF sector show higher levels of forest land and lower levels of agricultural land. Introducing a carbon price increases the costs associated with deforestation, making forest land clearing an expensive option to produce agricultural commodities. Additionally, this land competition incentivizes technological development, leading to an increase in productivity and reducing the amount of land needed to feed the world.

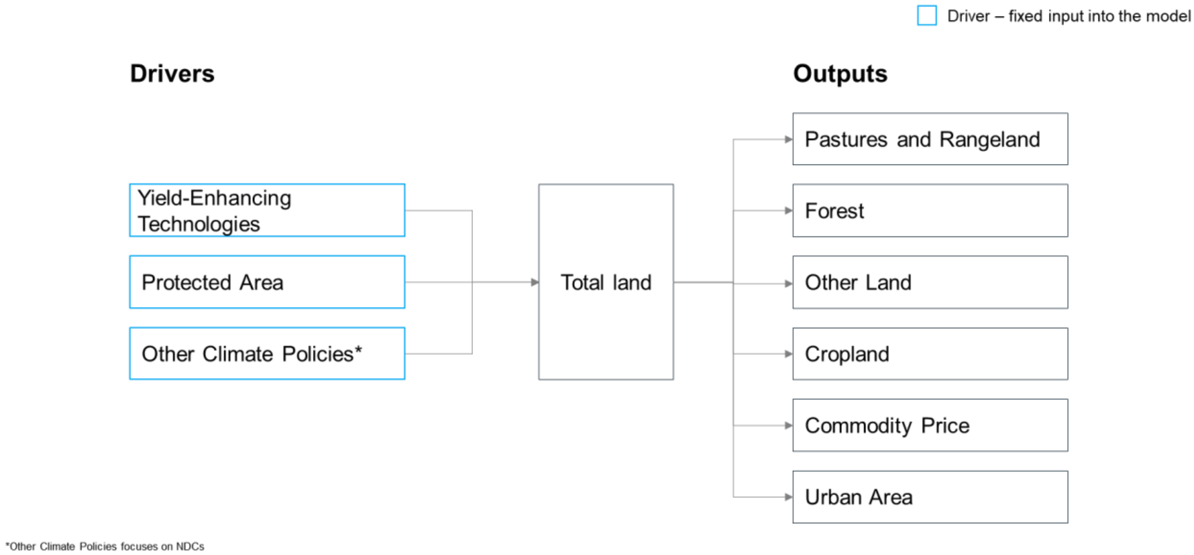
3.1 MAgPIE Variables Interactions

3.1.1 Drivers

All of these drivers are regionally specific.

Protected Areas, Yield-Enhancing Technologies, and Other Climate Policies

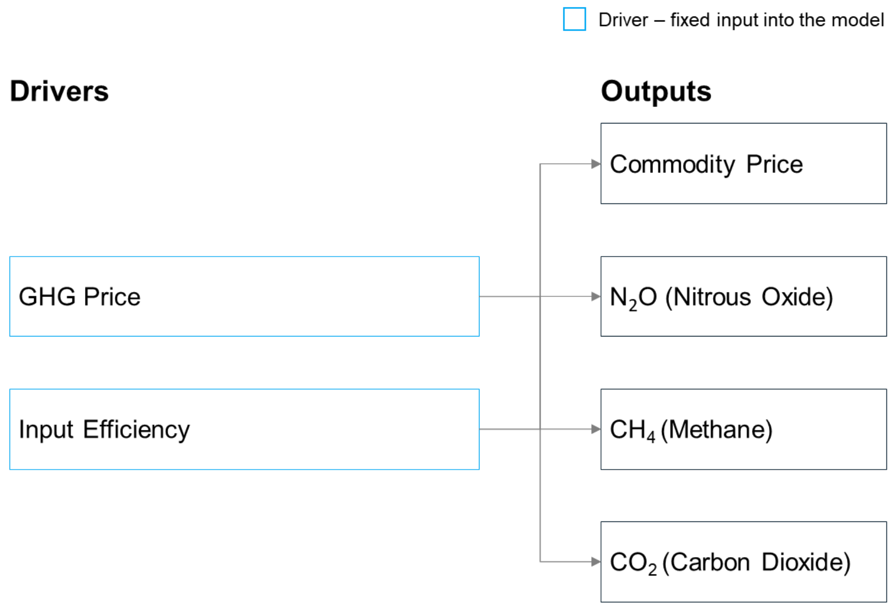
Figure 9



Source: MAgPIE Technical Documentation

GHG Price and Input Efficiency

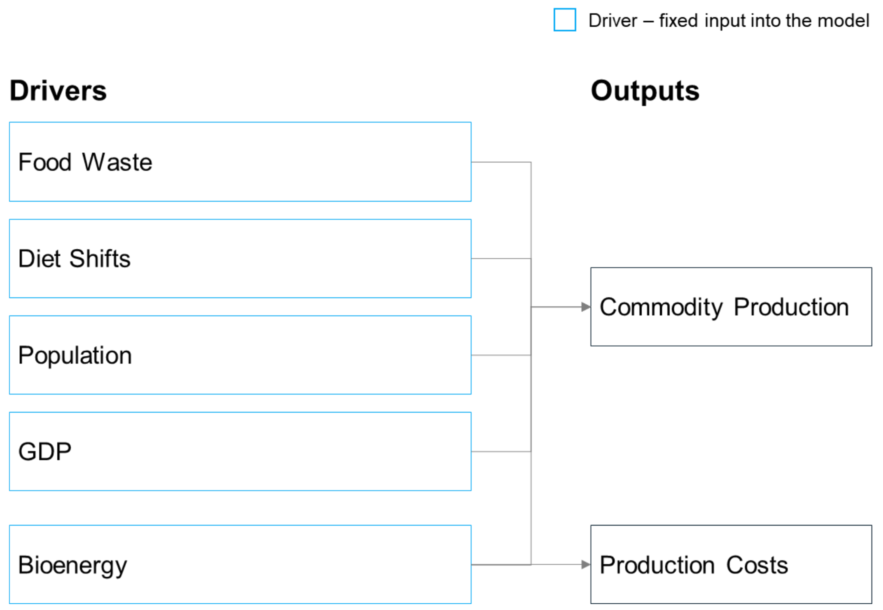
Figure 10



Source: MAgPIE Technical Documentation

Food Waste, Diet Shifts, Population, GDP, and Bioenergy

Figure 11



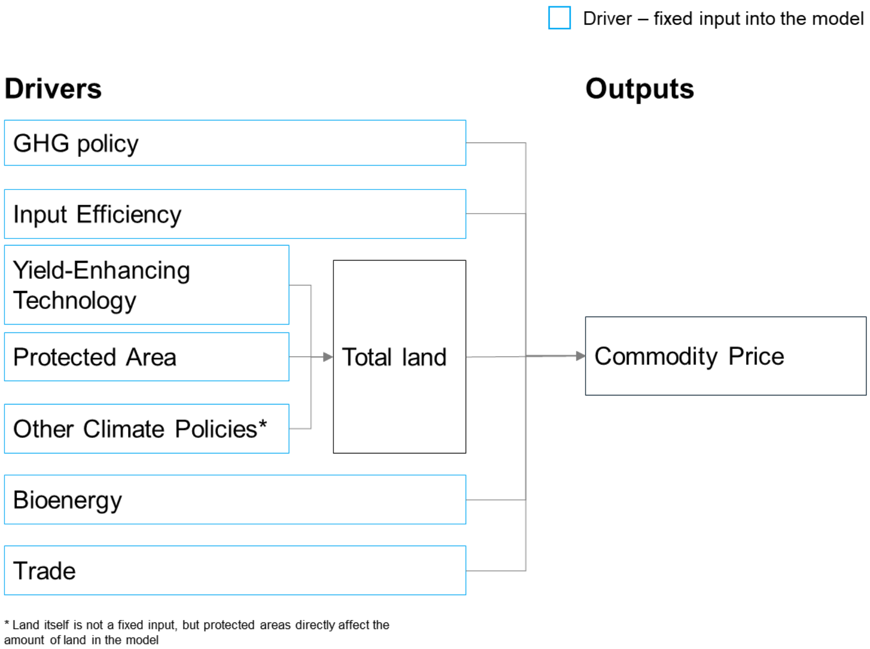
Source: MAgPIE Technical Documentation

3.1.2 Outputs

All of these outputs are regionally specific.

Commodity Price

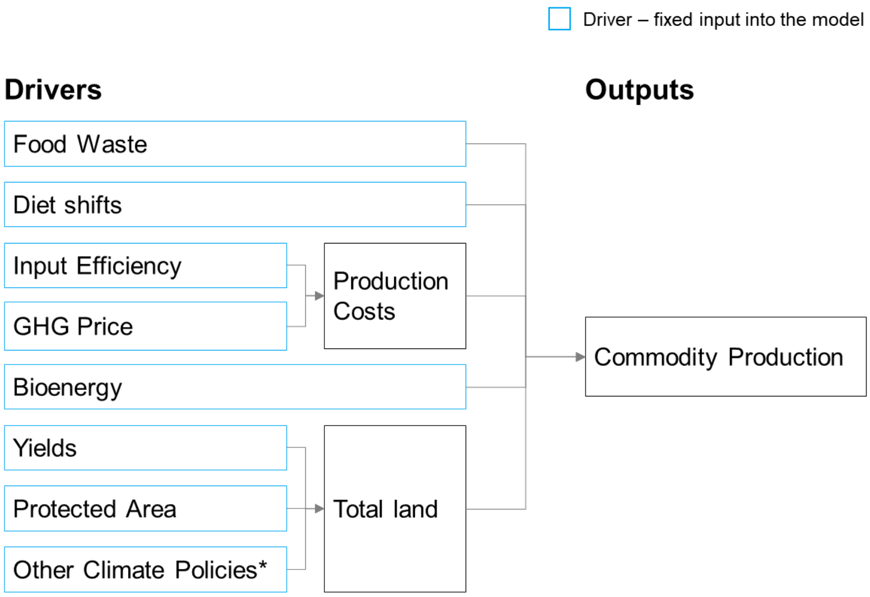
Figure 12



Source: MAgPIE Technical Documentation

Production

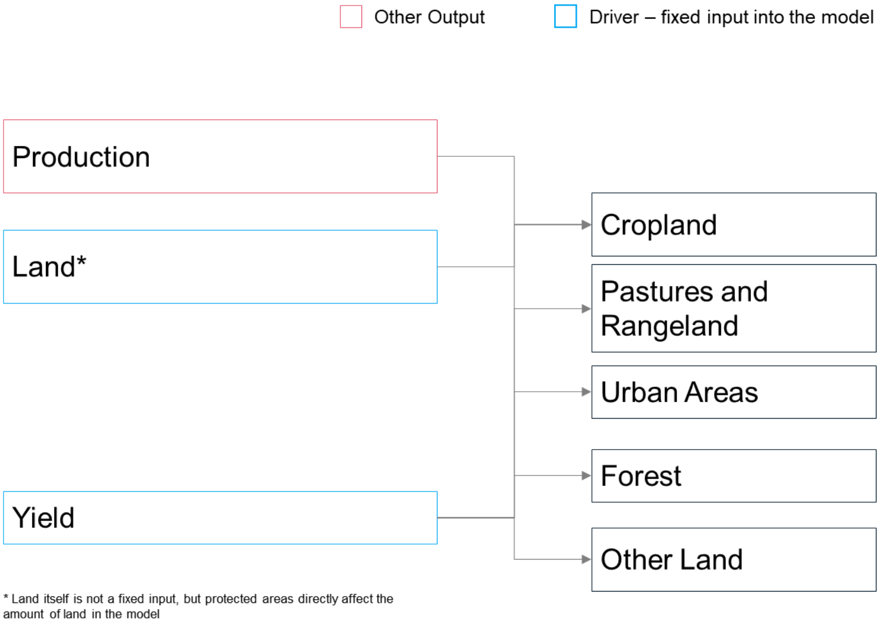
Figure 13



Source: MAgPIE Technical Documentation

Land Use

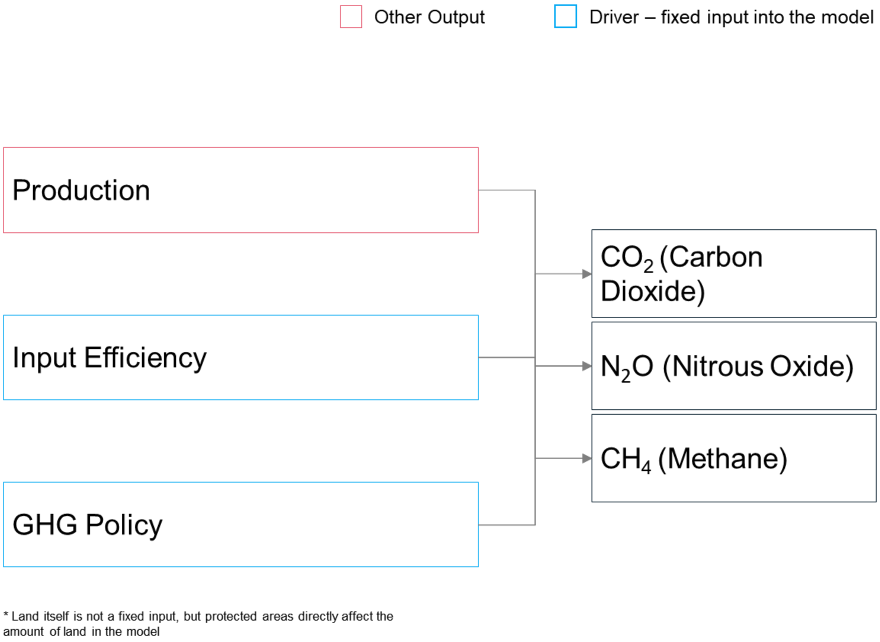
Figure 14



Source: MAgPIE Technical Documentation

Emissions

Figure 15



Source: MAgPIE Technical Documentation

4 Scenario development

4.1 Modeling Process

For the first iteration of the modeling, the team first mapped the scenarios' selected driving forces to modeling assumption variables. Next, the team inputted the driver assumptions into the MAgPIE model. After this, the team ran the model and generated output for the scenarios based on the driver assumptions. Finally, the team conducted a calibration and smoothing process as described in the sections below.

After the MAgPIE model runs, the model team conducted further modeling outside of MAgPIE to produce two additional outputs: the scenario impacts on NBS related to forests, timber and pulpwood demand and production. The team calculated the CO_2 mitigation potential of forest NBS—reforestation, afforestation, and avoided deforestation—by tracking the evolution of regional estimates of forest land use in MAgPIE simulations. For each five-year time step, we estimated the area of net forest expansion (i.e., re/afforestation) since 2020 within each policy scenario. The team estimated avoided forest conversion in each policy scenario against regional baseline deforestation rates in the reference scenario. We used time-averaged rates of enhanced sequestration or avoided emissions to convert areal estimates to mitigation potential ($GtCO_2$).

To calculate timber demand, the modeling team began with a literature review and then developed modeling relationships that varied the assumptions based on income and general consumption of the construction sector. The team designed three demand pathways:

- Low demand: where demand for timber in construction remains low with just 0.5% of new buildings are constructed with timber. This pathway is applied to the >3°C Historic Trends scenario.
- Medium demand: 10% of all new builds use timber as carbon pricing incentivizes the use of timber over more carbon-intense construction materials. This pathway is applied to three scenarios: <2°C Forecast Policy (IPR), <2°C Coordinated Policy, and 1.5°C Societal Transformation.
- High demand: 50% of all new builds use timber. Higher productivity in agriculture makes more land available for forestry, while carbon pricing simultaneously incentivizes the use of timber. This pathway is applied to the 1.5°C Innovation scenario.

The model then filled timber demand with production from plantations or natural vegetation. Next, the team econometrically estimated the relationship between timber production and pulpwood production based on historical statistics from the FAO. The team then forecast pulpwood production based on the estimated relationship with current timber production and the projected timber production in each scenario.

The modeling process included tackling two primary sources of error in MAgPIE output: inconsistencies and spikes/inflection points. MAgPIE began being modeled in 2010 to 2015, so 2020 results may diverge from observed present-day values. Additionally, some outputs are not calibrated, leading to inconsistencies with observed data. Finally, due to the fact that MAgPIE is a cost-optimization model, it can produce unintuitive results as variables approach constraints. To address these sources of error, the team used the calibration and smoothing process described in the sections below.

5 Historical Data

To begin the calibration and smoothing process, the modeling team selected historical data to compare to the scenario outputs based on the reliability of the sources and their comparability with the specific scenario outputs variables. Some of the data sets that the team selected included FAF data from FAOSTAT, USDA, World Bank, and the Good Food Institute. After selecting reliable and high-quality historical data, the team used the data as a key input for the calibration and smoothing process.

6 Calibration

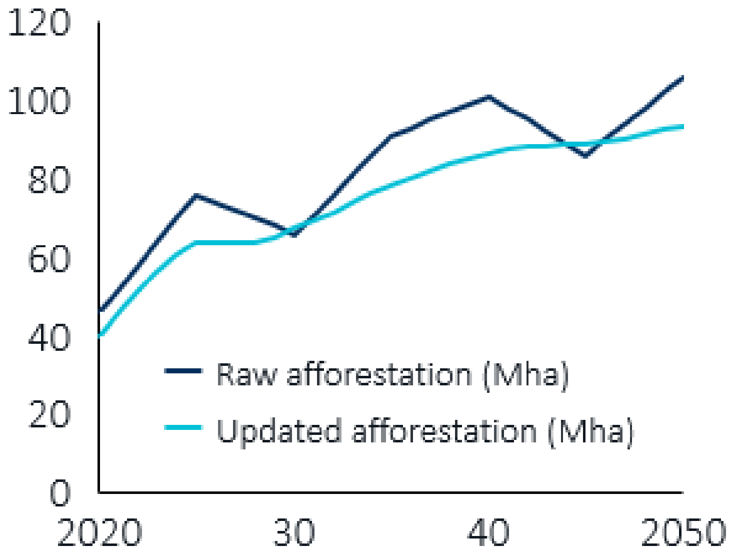
After generating initial output, the modeling team then compared all years before 2020 to the selected historical data to determine inconsistencies. The team then aligned all output through 2020 with the historical data. Additionally, while conducting the aligning process, the team sense-checked the original output by comparing it to external sources to identify inconsistencies with FAF land use modeling literature and data.

7 Smoothing

Next, the modeling team examined the data for unrealistic volatility in output. Due to the fact that significant, sometimes sudden, changes occur in the scenarios, there may be times when there are sharp changes in the scenario output for a brief period of time. This type of volatility was intentionally included in the output. However, the team smoothed for output variable volatility that came out of the optimization process itself. Whenever the team identified this volatility, they smoothed the data using a ten-year moving average.

An example of the smoothing process is shown below.

Figure 16: Example Afforestation Data Smoothing



Source: WBCSD with supporting analysis from Vivid Economics

After smoothing and calibrating, the modeling team checked the model output again to ensure that dependent variables remained consistent after adjusting erroneous output.

7.1 Scenario Alignment

Previously published scenarios typically focus on the Energy sector, in contrast to the five presented scenarios that are specifically tailored around metrics for companies in the FAF sector. That said, many scenario uses may seek to complement different scenarios to cover both Energy and FAF aspects. For those users, Table 1 offers a guide on which scenarios are generally comparable in terms of inputs and emission outcomes.

Table 1: Scenario alignment to other published scenarios

>3°C Historic Trends	IPCC Scenario C6-C8 NGFS Current Policies
<2°C Forecast Policy Scenario (IPR)	NGFS Below 2°C IEA Sustainable Development Scenario (SDS)
<2°C Coordinated Policy Scenario	NGFS Below 2°C IEA Sustainable Development Scenario (SDS)
1.5°C Societal Transformation Scenario	1.5C IPR Required Policy Scenario (RPS) NGFS Net Zero 2050 IEA Net Zero Emissions by 2050 (NZE) FOLU's Better Futures Scenario
1.5°C Innovation Scenario	IPR Required Policy Scenario (RPS) NGFS Net Zero 2050 IEA Net Zero Emissions by 2050 (NZE)

8 Limitations

Our scenarios have four main limitations:

1. The modeling does not explain the specifics of *how* the scenarios achieve the changes that are described by the drivers. For example, one of the drivers is a reduction in food waste, but we do not specify what causes this reduction; a reduction in food waste could be caused by a tax, policy shift, or technology change, among other factors. In practice, these different causes of the food waste reduction could have big impacts on society.
2. The same temperature outcome could lead to very different physical impacts. The five scenarios do not include the impact of future extreme climate events on the FAF sector. Future extreme climate events can significantly elevate all other risks. These scenarios are not statistics or forecasts but merely illustrative pathways and outcomes of potential futures.
3. While the extent of forest ecosystems is captured in this work, the scenarios do not include granular output for other critical habitats and ecosystems, such as grasslands or savannahs, which are included as part of a broader category of land use – "Other land".
4. These scenarios do not include aquatic foods, such as seafood and shellfish, which are an important part of some regional diets and thus could be a significant emissions source through the production of feed for aquaculture.

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