Global scenarios for CCDR analyses

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Overview

Climate change is both an immediate and long-term challenge that involves significant uncertainty. There is uncertainty about how the physical climate will evolve in response to accumulating atmospheric greenhouse gases (GHGs). This uncertainty affects evaluations of climate resilience. There is also uncertainty about how countries and economies may act to reduce climate change in the future and how these actions could impact technology costs, demands for commodities and other goods, trades, investment flows, and other economic trends. There are a multitude of relevant factors that should be considered by climate policymaking and are represented by the different models and tools being used for the CCDR analyses. The evolution of most of these factors are independent of individual developing-country's actions, with the exception for bigger countries like China, Brazil, and India. These uncertainties affect analyses of economic performance, welfare, and country development and decarbonization policies. To manage this uncertainty in CCDRs, it is recommended that teams use a set of scenarios.

CCDR Global Scenarios

To take these factors into account and ensure some consistency and comparability across CCDRs, we recommend that CCDR teams consider three broad narrative scenarios that describe how socioeconomic and technology conditions might evolve along with physical climate changes that could result from the associated GHG emissions (Table S1):

Table S1: Global Narrative scenarios for socioeconomic and technology conditions and associated physical climate conditions[1]

Socioeconomic and technology conditions		Physical climate conditions
Recent Policies: Continuation of policies around 2020, without adoption of new policies to meet existing or more ambitious commitments and targets.	➡	**Bad climate outcomes:** High GHG concentrations, possibly combined with higher climate sensitivity, result in strong warming (~4°C warming).
Recent commitments and targets: Implementation of policies needed to meet NDCs and additional publicly stated targets.	➡	**Intermediate climate outcomes:** Continuation of GHG emissions lead to warming around 2.5°C.
Successful decarbonization: Implementation of policies needed to be consistent with Paris Agreement, recognizing individual country context.	➡	**Limited warming:** Elimination of net GHG emissions stabilizes the climate below a 2°C warming.

By combining these factors, we constitute three CCDR Global Scenarios (Table S2), which collectively represent a wide range of policy action on climate change and a wide range of physical climate changes to consider for CCDR analyses. These scenarios are quantified based on modeling of global socio-economic activity, resulting GHG emissions, and physical climate conditions conducted for the Intergovernmental Panel on Climate Change (IPCC) climate change assessments and subsequently

[1] Note that the current trends and policies do not necessarily lead to warming by 4°C, but it could, depending on the sensitivity of the climate.

adapted for other policy evaluations by the Central Banks and Supervisors Network for Greening the Financial System (NGFS).

Table S2: Recommended CCDR Global Scenarios and characteristics for adaptation and development planning

CCDR Global Scenario	Socioeconomic and technology conditions					Physical climate changes		
	NGFS Scenario	Policy reaction	Technology change	Carbon dioxide removal	Regional policy variation	IPCC Scenarios (CMIP5 or CMIP6)	Radiative Forcing by 2100	Average Warming by 2100
Recent policies & bad climate outcomes (pessimistic case)	Current Policies	None – current policies continued	Slow change	Low use	Low variation	RCP8.5 or SSP3-7.0	7.0 – 8.5 W/m²	+4ºC
Recent commitments & targets with intermediate climate outcomes	National Determined Contributions (NDCs)	Implementation of NDCs	Slow change	Low use	Low variation	RCP4.5 or SSP2-4.5	4.5 W/m²	+2.5º
Successful decarbonization and limited warming (optimistic case)	Net Zero 2050	Immediate and smooth	Fast change	Medium use	Medium variation	RCP2.6 or SSP1-1.9	1.9 – 2.6 W/m²	+1.5º

To represent the socio-economic aspects of the CCDR Global Scenarios, we recommend the use of mitigation focused climate scenarios developed by the Central Banks and Supervisors Network for Greening the Financial System (NGFS). For physical climate risks needed to assess adaptation needs, we recommend the use of the global climate scenarios (CMIPs) used by the Intergovernmental Panel on Climate Change's (IPCC) Fifth and Sixth Assessment Reports. Two data platforms – the (open) Climate Change Knowledge Portal (CCKP)[2] for the climate scenarios and the (internal) "global scenario dashboard"[3] are available to access the required variables for the various scenarios.

The use of a small set of standardized scenarios should facilitate understanding of the new CCDRs and provide some consistency useful for comparing results across countries. However, these scenarios only partially cover the possible future. For instance, it is likely that rapid decarbonization and rapid progress on green technology are correlated (one is more likely if the other occurs). But it is possible to see rapid decarbonization even with slower progress on green technology. CCDRs should be sure to account for this limitation in the interpretation of results. Country teams may choose to develop additional scenarios based on their understanding of the local context and the direction of policy change. For example, teams may want to consider a fuller set of plausible futures using a Robust Decision Making (RDM) or Decision Making Under Deep Uncertainty (DMDU) approach.

CCDRs should seek to identify climate solutions that are robust and make recommendations to a country that deliver development gains in most plausible futures. This can help avoid brittle recommendations (i.e., options that perform very well in a few scenarios, but may collapse catastrophically if the right technology is not available or in the absence of the right trade policies). This note provides additional information on how CCDR teams can quantify these scenarios.

[2] The CCKP is available here: https://climateknowledgeportal.worldbank.org/.

[3] The CCDR Global Scenarios Dashboard is available within the World Bank, here: https://tab.worldbank.org/t/WBG/views/CCDRScenariosExplorerWB581659/INTRO?:showAppBanner=false&:display_count=n&:showVizHome=n&:origin=viz_share_link.

Country-specific development pathways and link with global scenarios

Country-level scenarios used in CCDR are developed by the CCDR teams. We recommend that CCDRs develop at least two different country development pathways—one reference pathway, reflective of recent policies or implementation of a countries' NDC, and another one consistent with the Paris Agreement, both in terms of emissions (e.g., decarbonization) and adaptation.

However, in the spirit of the UNFCCC and its concept of common but differentiated responsibility, not every country will follow a similar trajectory. Furthermore, it is possible that a country's own ambition may be different from the average global ambition. Therefore, to understand the success of a smaller, developing country in achieving its development and decarbonization goals, a CCDR could evaluate the two country development pathways against the optimistic and pessimistic climate and policy scenario, with a priority on the three indicated in Table S3. A CCDR analysis that is focused on adaptation issues, for example, might compare a case in which the country develops in a resilient manner yet faces bad climate outcomes (case B) to a global reference case in which the country does not develop resiliently and faces bad climate outcomes (case A). A CCDR analysis that is focused on low-carbon development, in contrast might compare a case in which it does not develop in a low carbon way, while the rest of the world does (case C) with the case in which the country also decarbonizes with the rest of the world (case D).

Table S3: Evaluation of Country Pathways Under Global Scenarios

CCDR Global Scenarios	**Country Pathways (mitigation and adaptation)**	
	Reference (Recent policies or current commitments)	***Paris alignment (emissions and resilience)***
Recent policies & bad climate outcomes (pessimistic case)	(A) Reference case	(B) Focus on physical risks, or leakage risks
Successful decarbonization and limited warming (optimistic case)	(C) Focus on transition risks or cost of delayed action	(D) Global decarbonization scenario

Useful (internal) resources:

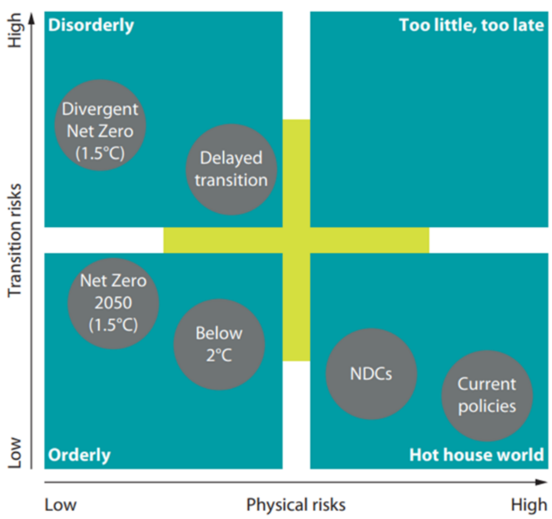
- The Global Scenario Dashboard where CCDR teams can compare scenario assumptions across models, review guidance for model selection, and download timeseries from the NGSF scenarios and other sources. It also provides historical emissions pathways and scenarios for all countries, with NGFS scenarios and short-term projections from EFI, with sectoral breakdown and NDC targets. (To be used carefully, since the NGFS scenarios are from global models that may have missed some country specificities, but provides an idea of the country pathways compatible with the global 2050 net zero target.)
- The Climate Change Knowledge Portal (FRUL: CCKP/) provides collections of the current global climate model compilations (CMIP5 and CMIP6) across multiple scenarios and time periods.
- An externally-available data portal—climate-impact-explorer.climateanalytics.org/—provides climate impact projections for select indicators based on a range of global climate scenarios from the Inter-Sectoral Impact Model Intercomparison Project (ISIMIP).

Global socio-economic scenarios

CCDR analyses of country low-carbon development will need to account for the wide range of plausible ways in which climate policies, technology developments, and lifestyle changes may play out over the coming decades. Some factors are global in nature, for example, oil prices, costs for technology, policy reactions to climate threats. Others are local or regional, for example, natural gas prices and beef demand.

To support evaluations of climate risk to the world's economies and financial systems, the Central Banks and Supervisors Network for Greening the Financial System (NGFS) constructed a set of six global scenarios based on two-dimensions—transition risks and physical risks (Figure 1). Scenarios in the lower-right quadrant describe futures in which global efforts are insufficient to halt significant global warming. Scenarios on the left side lead to lower climate risks, but different levels of transition risks to the economy, depending on how orderly or disorderly the global policy response is. In the lower-left, policies are introduced early and gradually increase, leading to an orderly transition. In the upper-left, policies are delayed or not well coordinated, leading to higher transition risks.

Figure 1: NGFS Scenario Framework



Source: NGFS (2021)

These scenarios were created by developing different assumptions about a wide range of parameters grouped in the following categories:

- **Policy ambition**: aggregate global GHG emissions reductions leading to different levels of warming by 2100,
- **Policy reaction**: the way in which decarbonization policies are implemented in the coming decades,
- **Technology change**: the pace of technological change and evolution of costs,
- **Carbon dioxide removal**: the extent and cost of the use of carbon capture and storage approaches, and
- **Regional policy variation**: the extent to which climate policy is coordinated.

The NGFS scenarios were quantified by three different integrated assessment models (IAMs)[4]:

- Global Change Analysis Model (**GCAM**), version 5.3 (Joint Global Change Research Institute)[5];
- **MESSAGEix-GLOBIOM**, version 1.1 (International Institute for Applied Systems Analysis) [6]; and
- **REMIND-MAgPIE** versions 2.1-4.2 (Potsdam Institute for Climate Change Impact Research)[7].

The modeling of these scenarios created a large database of global and regional assumptions that can be used as a starting point for CCDRs analyses.

Recommended socio-economic scenarios

For the CCDR analyses, we recommend the use of the assumptions associated with three of the NGFS scenarios (Table 1). Two scenarios describe futures in which climate ambition is low, leading to high climate changes but lower transition risks, and one other scenario represents a future with high achievement of decarbonization goals that proceeds in a mostly orderly manner:

- **Current Policies**: Represents current policies as of mid-2021 leading to a worst-case adaptation conditions consistent with global warming of greater than 3°C.
- **Nationally Determined Contributions (NDCs)**: Assumes the full adoption of the NDC targets, as of mid-2021, leading to more constrained but still significant warming of around 2.5°C.
- **Net Zero 2050**: Assumes smoother and consistently increasing policies, coupled with fast technology changes and greater use of CO2 removal approaches, which limits warming to 1.5°C.

Table 1: NGFS global scenarios associated with CCDR global scenarios

NGFS Scenario	**Transition risks**				**Climate outcomes** (globally averaged warming)
	Policy reaction	**Technology change**	**Carbon dioxide removal**	**Regional policy variation***	
Current Policies	None—current policies	Slow change	Low use	Low variation	+3°C
Nationally Determined Contributions (NDCs)	Implementation of NDCs	Slow change	Low use	Low variation	+2.5°C
Net Zero 2050	Immediate and smooth	Fast change	Medium use	Medium variation	+1.5°C

Source: Derived from NGFS (2021). Range of carbon capture and storage by 2060 for scenarios is: 10-15 Mt CO2e/yr (Net Zero 2050); 2-13 Mt CO2e/yr (Nationally Determined Contributions); and 0-3 Mt CO2e/yr (Current Policies).

These scenarios include a modest range of assumptions about regional policy variation, or the extent of policy collaboration across countries. When and where it is useful and relevant, CCDR teams may wish to consider a wider range of policy variation along these lines:

- **Collaborative global architecture (low variation)**
    - Large ODA flows (0.4% of global GDP in 2030)

[4] See https://www.iamcdocumentation.eu/index.php/IAMC_wiki for descriptions of common IAMs.
[5] See http://www.globalchange.umd.edu/gcam/.
[6] See https://docs.messageix.org/projects/global/en/latest/overview/index.html.
[7] See https://www.pik-potsdam.de/en/institute/departments/transformation-pathways/models/remind.

    - Climate finance reaching USD 200 billion per year in 2030
    - International carbon markets
    - Technological and IP transfers
    - Low interest rate environment
    - Increase in global trade
- **Adversarial global architecture (high variation)**
    - Constant ODA (0.2% of GDP in 2030 – same as 2020)
    - Limited climate finance (USD 80 billion per year)
    - Trade penalties for non-cooperative countries and Carbon Border Adjustment Mechanisms in all high-income countries (with carbon price at border at USD 100/tCO2 in 2030)
    - Higher interest rate environment
    - Slowly declining global trade

Other scenario archives may contain useful parameters. For example, scenarios from the IEA can be roughly mapped to the NGFS scenarios. The IEA Hot House World scenario roughly corresponds to the NGFS Current Policies scenario. The IEA Stated Policies scenario corresponds to the NGFS NDC scenario. The Sustainable Development Scenario is roughly in line with the NGFS Orderly Below 2 °C scenario, and the IEA NZE scenario (May 2021) corresponds to the NGFS Net Zero 2050 scenario (see https://www.ngfs.net/ngfs-scenarios-portal/faq/).

Obtaining socio-economic scenario data

For each of these scenarios, NGFS provides the values for a wide range of variables used by the three global integrated assessment models (IAMs).[8] As the IAMs are developed independently by different research teams, the assumptions used to model each NGFS scenario are not harmonized. We therefore reviewed the trajectories of key variables used by each modeling group and propose one or several models upon which to base CCDR analyses.

The Climate Change Group (CCG) has developed a "global scenario dashboard" where CCDR teams can compare scenario assumptions across models, review guidance for model selection, and download timeseries from the NGSF scenarios and other sources.[9] Table 2 presents the currently available NGFS variables in the dashboard. Each of these variables are provided at a global level in the dashboard, but regional data will be added as needed.

Table 2: Currently available NFGS variables for socio-economic scenarios

Geographic Aggregation	Variable Type	Variable
Global	Agricultural	• Livestock demand and production • Livestock price index
	Carbon Sequestration	• Carbon capture and storage (CCS) • Sequestration by land use

[8] Data can be obtained directly from the NGFS Scenario Explorer, hosted by IIASA (https://data.ene.iiasa.ac.at/ngfs/#/workspaces).
[9] CCDR Scenario Dashboard is available here: https://tab.worldbank.org/t/WBG/views/CCDRScenariosExplorerWB581659/INTRO?:showAppBanner=false&:display_count=n&:showVizHome=n&:origin=viz_share_link.

	Carbon Price	• Carbon price
	Electricity CAPEX	• Coal (with and without CCS) • Gas (with and without CCS) • Solar • Wind
	Energy prices	• Coal • Gas (global average) • Oil
	Socioeconomics	• GDP (PPP and per capita) • Population

For each of these variables, the dashboard enables users to compare the NGFS scenario assumptions and select which models to use as the basis for CCDR analyses. Using this dashboard, the CCG has developed recommendations for which models to use for the variables shown above (Table 3). Other NGFS variables are available and can be included at the request of the CCDR teams.[10]

[10] See CCDR Global Scenarios Dashboard here for full list of potentially available variables: https://tab.worldbank.org/t/WBG/views/CCDRScenariosExplorerWB581659/NGFSGlobalVariablesfullset?:showAppBanner=false&:display_count=n&:showVizHome=n&:origin=viz_share_link.

Table 3: Recommended NGFS models to average for each CCDR Global Scenario

Variable Type	Variable	NGFS IAM Model to include in average for CCDR Global Scenarios			Rationale
		GCAM	MESSAGEix-GLOBIOM	REMIND-MAgPIE	
Agricultural	Livestock demand	✓	✓		Included models show similar patterns of declining demand for Net Zero 2050 scenario. REMIND-MAgPIE shows less realistic rapid near-term decline.
	Livestock price index		✓	✓	Included models show similar patterns of increasing livestock prices for Net Zero 2050 scenario. GCAM includes extreme values of more than 10 times 2020's index value by 2055.
Carbon Sequestration	Carbon capture and storage (CCS)	✓	✓	✓	All three models show similar patterns of increasing CCS for NDCs and Net Zero 2050 scenarios.
	Sequestration by land use	✓	✓	✓	All three models show similar patterns of increasing sequestration across all scenarios, with greater increases for NDCs and Net Zero 2050 scenarios.
Carbon Price	Carbon price (US$2010/t CO2)	✓	✓	✓	All three models show similar patterns of increasing carbon price for scenarios, with greater increases for NDCs and Net Zero 2050 scenarios (reaching about $600 by 2050).
Electricity CAPEX	Coal (with and without CCS)		✓		MESSAGEix-GLOBIOM only model with significant variations across the scenarios for w/o CCS.
	Gas (with and without CCS)			✓	REMIND-MAgPIE shows lower costs for Gas with and without CCS in Net Zero 2050 scenario reflecting increased investment. Other models do not exhibit variation across models for w/ CCS variable. MESSAGEix-GLOBIOM exhibits higher natural gas costs in Net Zero 2050 scenario.
	Solar (CSP and PV)			✓	MESSAGEix-GOBIOM shows declining Solar CSP and PV costs for Net Zero 2050. Other models show no variation for Solar PV. MESSAGEix-GLOBIOM shows opposite pattern for Solar CSP, so exclude.
	Wind (offshore and onshore)	✓ (onshore)		✓ (offshore)	Onshore: GCAM closest to EPM projection; no variable across scenarios for all models; Offshore: MAgPIE only model with variation.
Energy prices	Coal	✓		✓	MESSAGEix-GOBIOM shows price swings for Net Zero 2050, so excluded.
	Gas (global average)	✓	✓	✓	All three models show similar patterns of modestly higher gas prices for Net Zero 2050 scenario.
	Oil			✓	GCAM shows opposite trend of rising oil prices for Net Zero 2050. Largest range across scenarios with only REMIND-MAgPIE.
Socioeconomics	GDP (PPP)	✓	✓	✓	All three models use roughly the same projections
	Population	✓	✓	✓	All three models use exactly the same projections

Figures 4 and 5 shows two examples of global scenario parameter values—one for oil price and one for amounts of annual carbon sequestration.[11]

Figure 4: Recommended scenarios for Oil Price based on the REMIND-MAgPIE model

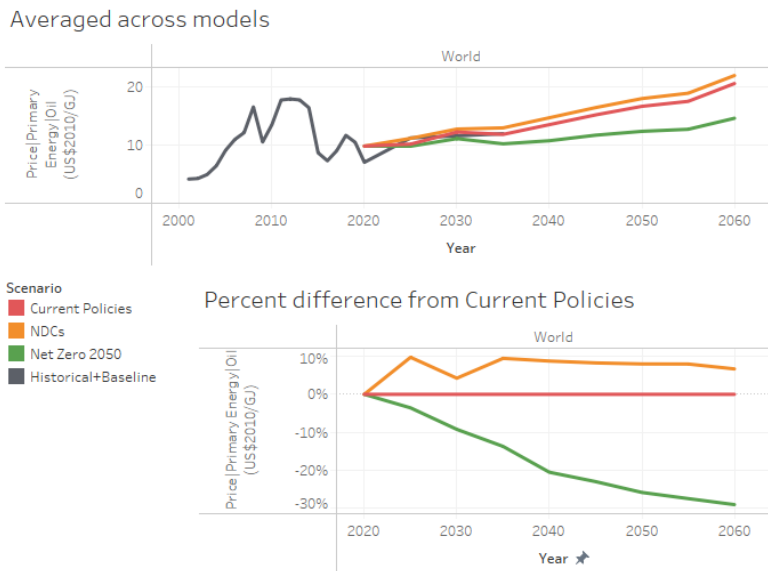
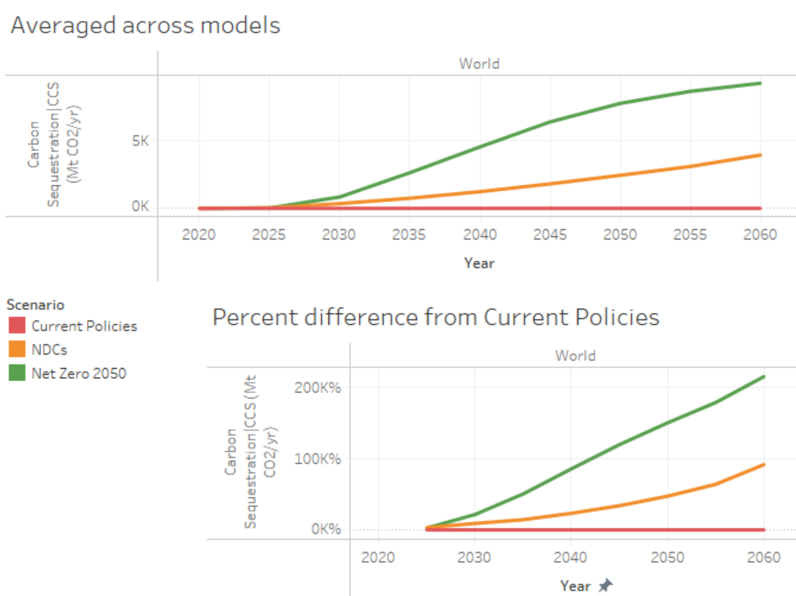


Figure 5: Recommended scenarios for Annual Carbon Sequestration based on an average of three models



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[11] These visualizations are available in the CCDR Global Scenarios Dashboard here: https://tab.worldbank.org/t/WBG/views/CCDRScenariosExplorerWB581659/CCDRScenarioVariableTrajectories?:showAppBanner=false&:display_count=n&:showVizHome=n&:origin=viz_share_link.

Global climate scenarios for physical risks

The nature and magnitude of physical risks depend on how climate conditions will change in the future, which in the longer-term are likely to be influenced by changing policy, investment, and technology environments. For climate resilience and adaptation evaluations, **climate scenarios** can be used to characterize how physical risks might evolve over time due to climate change. A minimum of three scenarios should be considered, corresponding to conditions that we can summarize as: *Current Commitments and 2030 Targets, Successful Decarbonization,* and *Bad Climate Surprises*.

Available climate scenarios

We recommend using the projected climate scenarios used in the IPCC's fifth or sixth assessment reports, as presented in the CMIP5 or CMIP6 collections. The climate characteristics over time of these scenarios are quantified by a large set of global and regional, coupled atmosphere-ocean general circulation and Earth system models driven by scenarios of cumulative GHG emissions and global concentrations, derived to provide insight into the carbon feedback cycle and the climate's sensitivity to a designated radiative forcing (RF) by 2100. While many of the same modeling groups participate in CMIP5 and CMIP6, the individual models within each collection are different and result in different outputs in climate sensitivity and atmospheric response. Analysis should not 'mix' data derived from CMIP5 or CMIP6 collections.

Scenarios in the CMIP5 ensemble are based on four Representative Concentration Pathways (RCPs), named for the specified 2100 GHG radiative forcing (RF, W/m^2):

- RCP2.6: represents reductions in GHG emissions in line with the Paris Agreement and average warming of less than 2 deg C by 2100.
- RCP4.5: an intermediate case
- RCP6.0: an intermediate case
- RCP8.5: represents a high-emissions scenario in which unabated GHG emissions continue, leading to an average warming of almost 5 deg C by 2100. It should be noted that RCP8.5 models have been found to align most closely with recent historical emission trends (2005 – present)

Scenarios in the CMIP6 ensemble are based on five Shared Socioeconomic Pathways (SSPs) combined with assumption on policies to achieve certain levels of RF. Five SSPs are configured to describe eight different 2100 RF outcomes, a subset which are consistent with the RPCs. These all have been modeled by a collection of Integrated Assessment Models (IAMs) and coupled atmosphere-ocean general circulation and Earth system models.

For instance, SSP1-2.6 represents a world with socioeconomic trends consistent with SSP1 (which is an environmentally friendly world) combined with a set of policies that ensure that RF does not exceed 2.6 W/m^2 and global temperature increases do not exceed 2 degrees. (Note, however, that there are many other ways to achieve the same climate target, so SSP1-2.6 is only one way of achieving the 2 deg C warming target, but not necessarily the only way or even the most efficient one.)

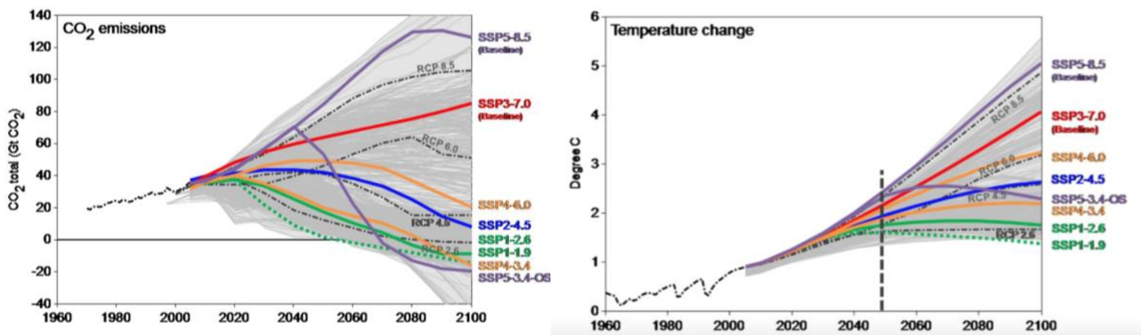
The CMIP6 scenarios are the following:

- SSP1-1.9: represents reductions in GHG emissions in line with 1.5 deg C warming by 2100.
- SSP1-2.6: represents reductions in GHG emissions in line with the Paris Agreement and average warming of less than 2 deg C by 2100.

- SSP2-4.5: represents global mitigation consistent with current climate commitments and 2030 targets (as of November 2021).
- SSP3-7.0: represents a scenario in which warming reaches 4 deg C by 2100, due for example to more lax climate policies in the future or to a reduction of the ability of ecosystems and oceans to capture carbon.
- SSP5-8.5: represents an extreme worst case in which unabated GHG emissions continue, leading to an average warming of almost 5 deg C by 2100.

Figure 6 shows a figurative assumption of the range of CO_2 emissions and resulting global average temperature changes corresponding to the CMIP6 SSP-RF scenarios.

Figure 6: CO2 emissions and global average temperature changes from CMIP6 scenario ensemble



Source: O'Neill et al. (2016)

It is important to note that in the near-term—before 2040s and 2050s (in many areas)—there is not much difference in global average temperature change across the scenarios. This is reflective of the relatively long lag in the climate response, which is driven by cumulative emissions and concentrations. As such, we recommend that near-term CCDR adaptation analyses include the pessimistic case that is most consistent with most recent global emissions tracks and reflective of the climate system response to cumulative emissions.

Recommended climate scenarios

Table 4 summarizes the recommended scenarios for CCDRs to use for near- or mid-term and longer-term climate risk assessments, depending on whether analyses are using CMIP5 or CMIP6 data. Note that for the pessimistic case, we recommend using SSP3-7.0 over SSP5-8.5, as while still possible, the scientific literature suggests that SSP5-8.5 outputs reflect an overly sensitive climate response by the end of the century (Hausfather and Peters, 2020). There is no corresponding 7.0 RF scenario for CMIP5, so studies using CMIP5 data should use RCP8.5 for their pessimistic case.

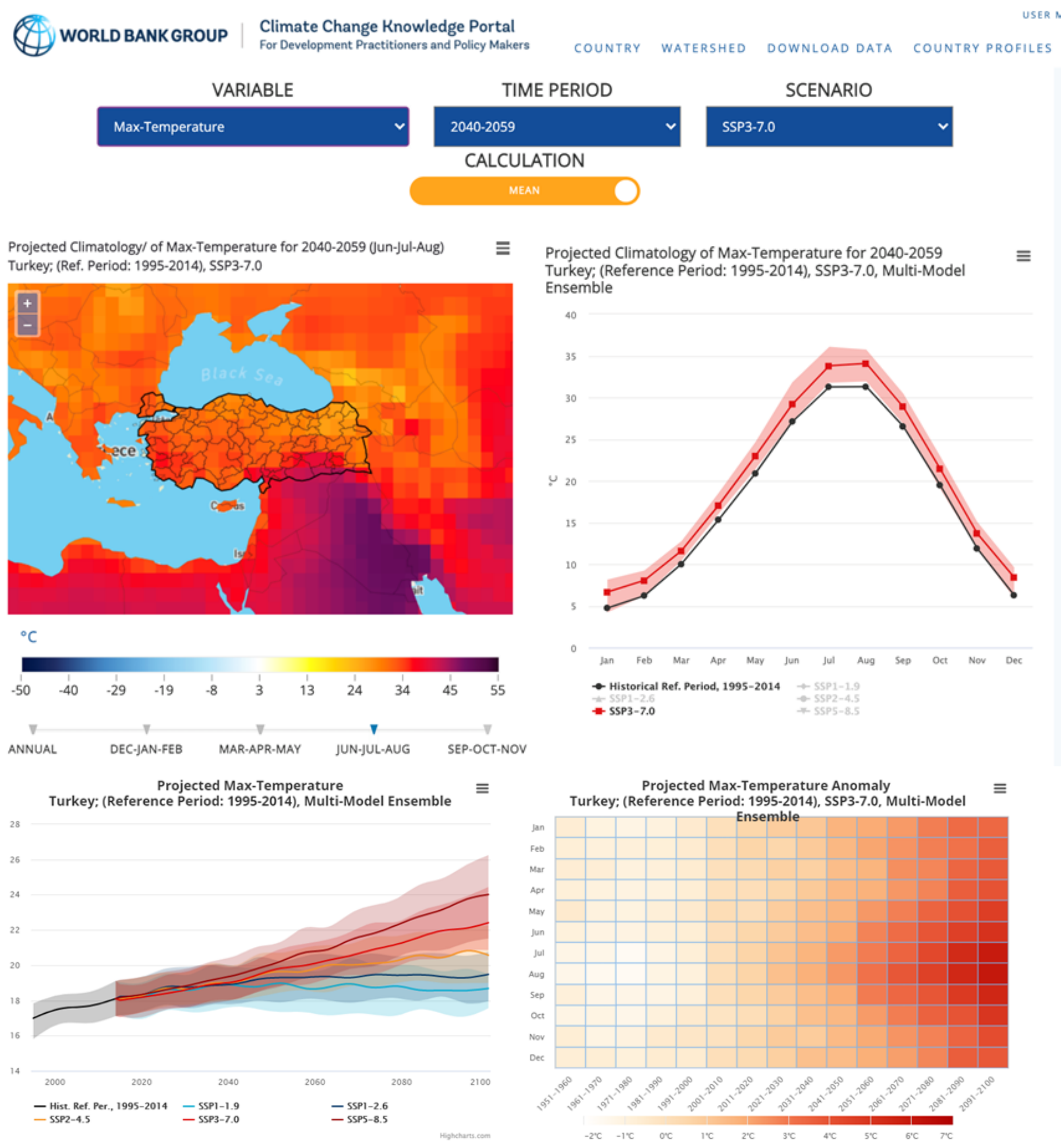
Table 4: Global climate scenarios for resilience evaluations

CMIP5/6 Scenario and Key Assumptions	***Bad Climate Surprises (pessimistic case)***	***Intermediate Climate Outcomes***	***Limited Warming (optimistic case)***
Scenarios	CMIP5: **RCP8.5** CMIP6: **SSP3-7.0**	CMIP5: **RCP4.5** CMIP6: **SSP2-4.5**	CMIP5: **RCP2.6** CMIP6: **SSP1-1.9**
Climate policies	Low achievement of current climate commitments	Achievement of current climate commitments and 2030 targets	High global ambition and achievement in decarbonization and sequestration
Climate response	High climate sensitivity; Possible amplification through reduction in natural carbon sinks	Medium climate sensitivity	Low climate sensitivity
Level of global warming	Average global temperature rise around 4 deg C by 2100	Average global temperature rise between 2 and 3 deg C in 2100	Average global temperature rise below 2 deg C in 2100
Other factors	• Sea level rise exceeds 100 cm in 2100 • Net increase in intensity of major storms • CO2 fertilization is limited by other factors and crop yield losses are in the higher range • Tipping points in major ecosystems (e.g., Amazon)	• Average global sea level rise in 2100 is 50 cm • CO2 fertilization translates into limited crop yield losses (and benefits in some regions) • Some resilience of major ecosystems (e.g., Amazon)	• Average global sea level rise in 2100 is 30 cm • CO2 fertilization translates into limited crop yield losses (and benefits in some regions) • Good resilience of major ecosystems (e.g., Amazon)

Obtaining climate scenario data

The Climate Change Knowledge Portal (FRUL: CCKP/) provides collections of the current global climate model compilations (CMIP5 and CMIP6) across multiple scenarios and time periods. CCKP data products are aggregated at national, sub-national and watershed scales to help users understand projected climate futures and potential for risk for area of interest. The CCKP, updated in November 2021, includes an easy-to-use portal for visualizing and downloading data corresponding to more than 40 climate variables. Figure 7 shows a portion of the full CCKP webpage displaying Max-Temperature results for Turkey by region, over the annual cycle, across scenarios, and over months and years.

Figure 7: Climate Change Knowledge Portal visualization for Turkey



Note: Available directly at https://climateknowledgeportal.worldbank.org/country/turkey/climate-data-projections

For some analyses, model ensembles are insufficient or misleading as the median value of an ensemble present a 'smoothed' or averaged output. For instance, in agricultural assessments changes in precipitation patterns are important (and often averaged out in ensembles). Teams may wish to use data from individual model runs in these cases. The CCKP includes an "Expert Mode" which provides data at the model level.

The selection of individual models should be done to ensure the analysis captures the range of possible futures to the extent that it is relevant for the analysis. For instance, an agricultural risk assessment that depends on changes in rainfall patterns in an area where models disagree will be more robust if the team evaluates results from models that are more optimistic (e.g., a model with increased water availability) and more pessimistic (e.g., a model with increased water scarcity). If the analysis is focused on extreme temperatures, then the best approach would be to select models that offer different projections in terms of temperature change. The performance of individual GCMs also varies across the world, and this can be another criterion for selection. CCDR teams should seek guidance to ensure sufficient understanding of the underlying assumptions, biases, and responses of selected models, prior to their use. Reach out to the CCKP team for additional guidance on the models to choose.

Another externally-available data portal—climate-impact-explorer.climateanalytics.org/—provides climate impact projections for select indicators based on a range of global climate scenarios from the Inter-Sectoral Impact Model Intercomparison Project (ISIMIP). This collection includes scenarios consistent with RCPs, the Network for Greening the Financial System (NGFS) scenarios (see above), and one from the Climate Action Tracker (CAT).

The dataset includes the following scenarios (those recommended for use are indicated in bold):

- **RCP2.6**, **RCP4.5**, RCP6.0, **RCP8.5**
- NGFS current policies, delayed 2degC, net-zero 2050
- CAT current policies

For each scenario, the dataset includes sub-country level impacts for the following indicators:

- Agricultural yields for Maize, Rice, Soy, and Wheat
- Soil moisture
- Economic damages from tropical cyclones, river flooding, and heatwaves
- Extreme event impacts on population and land
    - Crop failures
    - Heatwaves
    - Wildfires
    - River floods
- River flood depths and discharge levels

Note that the available impacts assume changing climate hazards, as characterized by the global climate scenarios, but constant (as of 2005) population distributions, building stocks, and agricultural practices. As such, CCDRs should use this information in conjunction with estimates for socioeconomic changes over time to characterize potential future climate risks.

Country-level Development Pathways

CCDRs also need to explore various development and emissions pathways, which are largely independent from global conditions. For instance, one country may decarbonize while the rest of the world continues emitting, or it could continue, business-as-usual, while the rest of the world decarbonizes. Countries may also not build in resilience in their development plans, risking large impacts if the global warming continues unabated.

Country-level scenarios used in CCDR are developed by the CCDR teams. In a simplified setting, the emissions associated with development pathways can be represented by two numbers that are widely used in country commitments and strategies: **the peaking year** (i.e., the year when economywide emissions start to decline) and **the year when zero net emission is achieved**. In between the peaking and the net zero years, a linear decline is often assumed. When pathways cannot be expressed in terms of peaking date and target for net zero emissions, absolute milestones, such as the level of emissions in

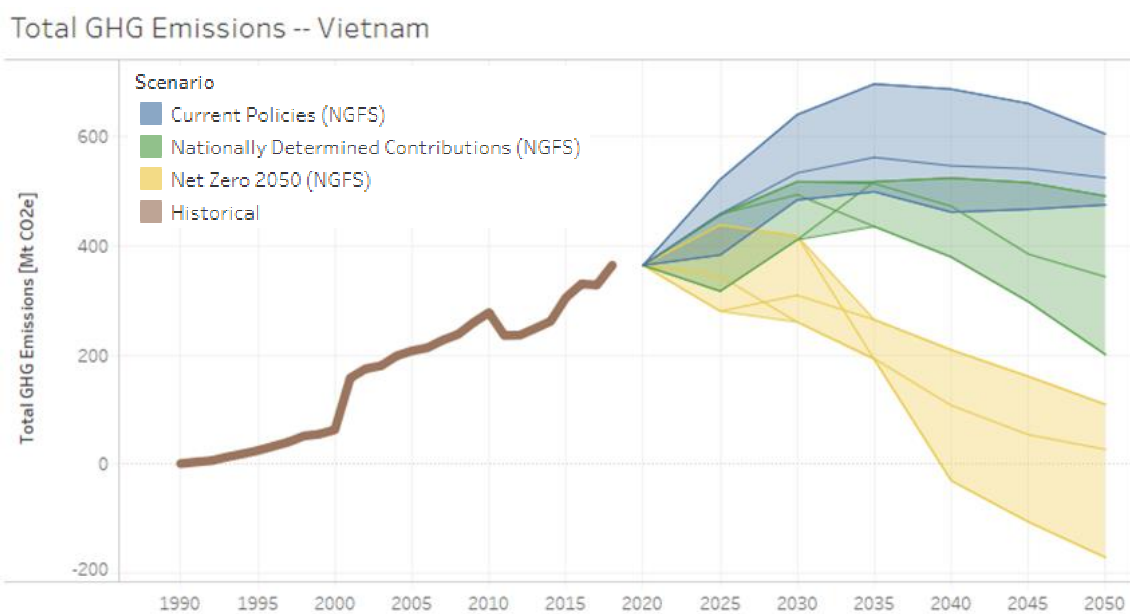
MtCO2 in 2030, are preferred to relative milestones, especially when expressed relative to an uncertain baseline. Adaptation, however, is more complicated and can vary significantly across sectors and geographically within a country. Descriptions of resilient development for the Paris Aligned pathway will vary across sectors and countries.

For CCDRs, it is recommended that two country development pathways be developed:

- **Reference pathway**: the country continues current policies and trends (including the level of resilience incorporated into development), or adopts policies to be consistent with its NDC commitments; and
- **Paris Alignment pathway**: the country reinforces and/or strengthens its decarbonization commitments to ensure emissions peaking in the near future and net zero emissions by approximately mid-century, in alignment with the Paris Agreement, and ensures that new development is resilient to a range of potential climate change severity.

For the Paris Alignment pathway, the date in which a country aims to achieve net zero GHG emissions should be based on the country situation, income level, and endowment. It should also be roughly consistent with a global net zero pathway. Teams may want to look at global scenarios like the ones from NGFS to inform what is both realistic and consistent with Paris Agreement (see Figure 8 for an example for Vietnam, with the Net Zero 2050 scenarios showing different peaking and net zero dates, depending on the model that is used and the pathway that is considered). In all countries this would require achieving net zero before 2100, and around 2050-2060 for high- and middle-income countries. **[But these scenarios are for guidance only: country-level scenarios are designed by the CCDR team.]**

Figure 8: Emissions pathways from NGFS scenarios for Vietnam exhibiting different peaking years and timelines for net zero emissions



Note: The CCDR Global Scenarios Dashboard includes a dashboard with NGFS emissions pathways for all countries here: https://tab.worldbank.org/t/WBG/views/CCDRScenariosExplorerWB581659/CountryGHGEmissionsNGFS/wb581659@wb.ad.worldbank.org/844a6b69-1afe-45ef-bdb5-a3b2e2469fdc?:display_count=n&:showVizHome=n&:origin=viz_share_link.

Evaluating Country Development Pathways Under Global Scenarios

In general, the three global climate and policy scenarios described above imply that most countries, and particularly those with the largest economies, act in similar ways—e.g., continuing current policies, meeting their current commitments, or decarbonizing per the Paris Agreement. However, in the spirit of the UNFCCC and its concept of common but differentiated responsibility, not every country will follow a similar trajectory. Furthermore, it is possible that a country's own ambition may be different from the average global ambition.

To understand the success of a smaller, developing country in achieving its development and decarbonization goals, a CCDR could evaluate the two country development pathways against the optimistic and pessimistic climate and policy scenario, with a priority on the three indicated in Table 5. A CCDR analysis that is focused on adaptation issues, for example, might compare a case in which the country develops in a resilient manner yet faces bad climate outcomes (case B) to a global reference case in which the country does not develop resiliently and faces bad climate outcomes (case A). A CCDR analysis that is focused on low-carbon development, in contrast might compare a case in which it does not develop in a low carbon way, while the rest of the world does (case C) with the case in which the country also decarbonizes with the rest of the world (case D).

Table 5: Evaluation of Country Pathways Under Global Scenarios

	Country Pathways (mitigation and adaptation)	
CCDR Global Scenarios	***Reference (Recent policies or current commitments)***	***Paris alignment (emissions and resilience)***
Recent policies & bad climate outcomes (pessimistic case)	(A) Reference case	(B) Focus on physical risks, or leakage risks
Successful decarbonization and limited warming (optimistic case)	(C) Focus on transition risks or cost of delayed action	(D) Global decarbonization scenario

Suggested reporting for the scenarios

CCDR teams should explain clearly the assumptions underlying the country level scenarios they are explored (and possibly modeling). Qualitative descriptions can be as important than quantified pathways, and the connection with existing country commitments should be emphasized. If possible, CCDRs should report for each pathway and scenario:

- the year in which peak net emissions,
- the year net zero emissions are reached, and
- emissions by sector and decade.

Depending on the models used for quantifying the pathways, additional standardized information should be presented. For example, when using a CGE or equivalent macroeconomic model, the following parameters should be reported at a ten-yearly interval:

- GDP (growth)
- HH Consumption (growth)
- Income per capita (growth)

- Emissions (growth)
    - Energy share in emissions
    - Carbon Price (inclusive of subsidies)
- Damages (% of GDP)
    - Agriculture
    - Labor Productivity
    - Extreme weather (capital destruction)
        - Median
        - Downside
    - Pollution
    - Tourism
- Poverty rate
- Income per capita (level real USD)
- Fiscal revenue (% of GDP)
- Fiscal expenditure (% of GDP)
    - Without interest payments
- Deficit
- Debt
- Current account balance
- Investment
    - Private
    - Public
- Foreign capital inflows

When using microsimulations to explore distributional and poverty implications, the team can report:

- Poverty rate at three lines:
    - US$ 1.9 a day (2011 PPP)
    - US$ 3.2 a day (2011 PPP)
    - US$ 5.5 a day (2011 PPP)
- Inequality
    - Gini coefficient
- Change in per capita household consumption/income by quintile (10-yr annualized growth in average per capita consumption, %)
    - Total
    - Quintile 1
    - Quintile 2
    - Quintile 3
    - Quintile 4
    - Quintile 5
- Poverty rate by gender (%)
    - Male
    - Female
- Poverty rate by region (%)
    - (regional disaggregation to be determined for each country)
- Poverty rate by ethnicity (%)
    - (ethnic disaggregation to be determined for each country)
- Share of adult population employed
    - Total
    - Male
    - Female
- Share of labor force engaged in each sector: (additional disaggregation can be added if available)
    - Agriculture

  - Industry
  - Services
- Poverty rate by sector (%)
  - Agriculture
  - Industry
  - Services

For power sector modeling, the following variables should be reported:

- Electricity demand (GWh/year)
- System NPV ($)
- Discounted Investment needs ($)
- LCOE ($/kWh)
- Tariffs (if available)
- Carbon price ($/tCO2e)
- Cumulative emissions (tCO2e)

References

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