Technical Supplement

The Use of Scenario Analysis in Disclosure of Climate-Related Risks and Opportunities

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TCFD | TASK FORCE ON CLIMATE-RELATED FINANCIAL DISCLOSURES

Contents

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A Introduction

Scenario analysis is a well-established method for developing strategic plans that are more flexible or robust to a range of future states. The use of scenario analysis for assessing climate-related risks and opportunities and their potential implications, however, is relatively recent. Given the importance of forward-looking assessments of climate-related risk, the Task Force believes that scenario analysis is an important and useful tool for an organization to use, both for understanding strategic implications of climate-related risks and opportunities and for informing stakeholders about how the organization is positioning itself in light of these risks and opportunities. It also can provide useful forward-looking information to investors, lenders, and insurance underwriters.

To assist organizations in undertaking and using climate-related scenario analysis, this technical supplement sets out and discusses:

- Using scenario analysis
- Considerations for applying scenario analysis
- Analytical choices involved in scenario analysis
- Types of climate-related scenarios
- Publicly-available climate-related scenarios from the International Energy Agency (IEA), the Intergovernmental Panel on Climate Change (IPCC), and others [1]

The technical supplement is organized as follows. Section B discusses why scenario analysis is useful and what a scenario is. Section C discusses the application of scenario analysis; key parameters, assumptions, and analytical choices organizations should consider when they undertake scenario analysis; and some of the key application challenges. Section D discusses the two main categories of scenarios—transition and physical—and the publicly-available climate scenarios in each category. The supplement concludes with a glossary of key terms and suggested further reading.

Given both the limited use of scenario analysis for climate-related risks and opportunities currently and the challenges involved in implementing a rigorous climate-related scenario analysis process, it is important that organizations begin to use scenario analysis and develop supporting capabilities, with the expectation that their capabilities will improve over time.

[1] For more information on the IEA, see www.iea.org; and for more information on the IPCC, see www.ipcc.ch.

B Scenario Analysis

1. Why is Scenario Analysis Useful?

The purpose of scenario analysis is to consider and better understand how a business might perform under different future states (i.e., its robustness).[2] In the case of climate change, climate-related scenarios allow an organization to explore and develop an understanding of how the physical and transition risks and opportunities of climate change might impact the business over time. Scenario analysis, therefore, evaluates a range of potential outcomes by considering a variety of alternative plausible future states (scenarios) under a given set of assumptions and constraints.

A critical aspect of scenario analysis is the selection of a set of scenarios that cover a reasonable variety of future outcomes, both favorable and unfavorable. While there is an almost infinite number of possible scenarios, organizations can use a limited number of scenarios to provide the desired variety. In this regard, the Task Force is recommending that organizations use, at a minimum, a 2° Celsius (2°C) scenario and consider using other scenarios most relevant to the organization's circumstances, such as scenarios related to Nationally Determined Contributions (NDCs), business-as-usual (greater than 2°C) scenarios, or other challenging scenarios.[3,4]

2. What Is a Scenario?

A scenario describes a path of development leading to a particular outcome. Scenarios are not intended to represent a full description of the future, but rather to highlight central elements of a possible future and to draw attention to the key factors that will drive future developments. It is important to remember that scenarios are hypothetical constructs; they are not forecasts or predictions nor are they sensitivity analyses.[5]

A key feature of scenarios is that they should challenge conventional wisdom about the future. In a world of uncertainty, scenarios are intended to explore alternatives that may significantly alter the basis for "business-as-usual" assumptions.

[2] In this context, robustness refers to the resilience or ability of an organization's business strategy to tolerate disruptions or adapt to changes or uncertainties in the business environment that might affect the organization's performance and to remain effective under all or most situations and conditions.

[3] A 2°C scenario lays out a pathway and an emissions trajectory consistent with limiting the average global temperature increase to 2°C in accordance with the stated goal of the UNFCCC Paris Agreement in 2015 that entered into force on November 4, 2016.

[4] NDC is a term used under the United Nations Framework Convention on Climate Change (UNFCCC) for reductions in greenhouse gas emissions that all countries that ratified the Paris Agreement have committed to achieve. Prior to ratification, NDCs were referred to as INDCs (Intended National Determined Contributions); following ratification, the "Intended" has been dropped. See section D.1.c for a discussion of NDC scenarios.

[5] Scenario analysis differs from techniques such as sensitivity analysis, forecasting or value at risk (VaR). Sensitivity analysis is the process of recalculating outcomes under alternative assumptions to determine the impact of a particular variable. Forecasting is based on past and present data and analysis of trends. Often it takes the form of predicting a single, most probable trend for and into the future. Value at risk measures the size of financial loss a given portfolio might experience within a given time horizon and for a particular probability. Climate VaR has a long time horizon (many years) compared with the shorter time horizon of standard financial VaR.

Scenarios should have the following characteristics: [6]

1. Plausible. The events in the scenario should be possible and the narrative credible (i.e., the descriptions of what happened, and why and how it happened, should be believable).

2. Distinctive. Each scenario should focus on a different combination of the key factors. Scenarios should be clearly differentiated in structure and in message, not variations on a single theme. Multiple scenarios should be used to explore how different permutations and/or temporal developments of the same key factors can yield very different outcomes.

3. Consistent. Each scenario should have strong internal logic. The goal of scenario analysis is to explore the way that factors interact, and each action should have a reaction. Neither actors nor external factors should completely overturn the evidence of current trends and positions unless logical explanations for those changes are a central part of the scenario.

4. Relevant. Each scenario, and the set of scenarios taken as a whole, should contribute specific insights into the future that relate to strategic and/or financial implications of climate-related risks and opportunities.

5. Challenging. Scenarios should challenge conventional wisdom and simplistic assumptions about the future. When thinking about the major sources of uncertainty, scenarios should try to explore alternatives that will significantly alter the basis for business-as-usual assumptions.

The Task Force believes that organizations should use a range of scenarios that illuminate future exposure to both transition and physical climate-related risks and opportunities, such as business-as-usual, NDC, and 2°C scenarios. In identifying scenarios that might work best, organizations may make use of existing publicly-available scenarios and models or organizations may wish to internally develop their own scenarios.[7] The approach taken will depend on an organization's needs, resources, and capabilities. Among the range of scenarios used, the Task Force believes it is important that organizations include a 2°C scenario given the agreed international climate change commitments.

[6] J. Maack, Scenario Analysis: A Tool for Task Managers. http://siteresources.worldbank.org/INTPSIA/Resources/490023-1121114603600/13053_scenarioanalysis.pdf.
[7] The different publicly-available scenarios are discussed in Section D.

C Applying Scenario Analysis

Applying scenario analysis, although potentially complex, has a number of significant benefits for organizations faced with the uncertainties of climate change. For organizations just beginning to use scenario analysis, a qualitative approach may be appropriate.

As organizations gain experience with scenario analysis, and for organizations already conducting scenario analysis, greater rigor and sophistication in the use of data sets and quantitative models and analysis may be warranted. Quantitative approaches may be achieved by using existing external scenarios and models (e.g., those provided by third-party providers) or by organizations developing their own, in-house modeling capabilities. The choice of approach will depend on an organization's needs, resources, and capabilities. Organizations that are likely to be significantly impacted by climate-related transition and/or physical risks should consider some level of quantitative scenario analysis.

Organizations should apply scenario analysis as part of their strategic planning and/or enterprise risk management processes by:

- identifying and defining a range of scenarios, including a 2°C scenario, that reasonably cover the range of future potential exposure to climate-related transition and physical risks (and opportunities);
- evaluating the potential effects on their strategic and financial position under each of the defined scenarios; and
- using the results to identify options for managing the identified risks and opportunities through adjustments to strategic and financial plans.

Over time, organizations can improve disclosure through documenting:

- the process and transparently disclosing key inputs, assumptions, and analytical methods and outputs (including potential business impacts and management responses to them) and
- the sensitivity of the results to key assumptions.

1. Considerations for Building Climate Change into Scenario Analysis

Recognizing the benefits of scenario analysis and the need to minimize implementation costs, organizations undertaking scenario analysis for the first time may want to consider starting with a simple, yet robust, process for incorporating climate-related considerations into their scenarios.

First, an organization needs to understand the nature of the climate-related risks and opportunities it may face. Each individual organization faces a different blend of climate-related risks and opportunities. The business impacts related to climate change may vary significantly depending on the industry and economic sector(s)/sub-sector(s) in which an organization operates. Business impacts may also vary significantly depending on:

- the geographic location of the organization's value chain (both upstream and downstream);
- the organization's assets and nature of operations;
- the structure and dynamics of the organization's supply and demand markets;
- the organization's customers; and
- the organization's other key stakeholders.

Many organizations already disclose their views on climate-related risks and opportunities at a high, qualitative level. The Task Force's Phase I report identified several frameworks for reporting climate-related information, many of which include disclosures around risks and opportunities.[8] Such information provides a starting point for scenario analysis and for further disclosure.

Figure 1 provides a summary of the typical categories of climate-related risks and opportunities an organization should consider when applying scenario analysis. Figure 2 (p. 6) presents an indicative process for applying climate-related scenario analysis, reflecting the climate-related risks and opportunities outlined in Figure 1.

Figure 1

Typical Categories of Climate-Related Risks and Opportunities

Markets and Technology Shifts

Policies and investments to deliver a low carbon emissions economy.

- Reduced market demand for higher carbon products/commodities
- Increased demand for energy-efficient, lower-carbon products and services
- New technologies disrupt markets

Reputation

Growing expectations for responsible conduct from stakeholders, including investors, lenders, and consumers.

- Opportunity to enhance reputation and brand value
- Loss of trust and confidence in management

Policy and Legal

An evolving patchwork of requirements at international, national, and state level.

- Increased input/operating costs for high carbon activities
- Threats to securing license to operate for high carbon activities
- Emerging concern about liabilities

Physical Risks

Chronic changes and more frequent and severe extremes of climate.

- Increased business interruption and damage across operations and supply chains with consequences for input costs, revenues, asset values, and insurance claims

Sources:
CDP, "Climate Change Questionnaire." 2016. https://www.cdp.net/Documents/Guidance/2016/CDP-2016-Climate-Change-Reporting-Guidance.pdf. Task Force on Climate-related Financial Disclosures, Recommendations of the Task Force on Climate-related Financial Disclosures. December 2016. https://www.fsb-tcfd.org/publication/recommendations-report/.

[8] Task Force on Climate-related Financial Disclosures, "Phase I Report of the Task Force on Climate-related Financial Disclosures." March 31, 2016. https://www.fsb-tcfd.org/wp-content/uploads/2016/03/Phase_I_Report_v15.pdf.

Figure 2

A Process for Applying Scenario Analysis to Climate-Related Risks and Opportunities

1 Ensure governance

Integrate scenario analysis into strategic planning and/or enterprise risk management frameworks. Assign oversight to relevant board committees/sub-committees. Identify which internal (and external) stakeholders to involve, and how.

2 Assess materiality of climate-related risks

- **Market and Technology Shifts**
- **Reputation**
- **Policy and Legal**
- **Physical Risks**

What are the current and anticipated organizational exposures to climate-related risks and opportunities? Do these have the potential to be material in the future? Are organizational stakeholders concerned?

3 Identify and define range of scenarios

- **Transition Risk Scenarios**
- **Physical Risk Scenarios**

What scenarios (and narratives) are appropriate, given the exposures? Consider input parameters, assumptions, and analytical choices. What reference scenario(s) should be used?

4 Evaluate business impacts

Impact on:

- Input costs
- Operating costs
- Revenues
- Supply chain
- Business interruption
- Timing

Evaluate the potential effects on the organization's strategic and financial position under each of the defined scenarios. Identify key sensitivities.

5 Identify potential responses

Responses might include:

- Changes to business model
- Portfolio mix
- Investments in capabilities and technologies

Use the results to identify applicable, realistic decisions to manage the identified risks and opportunities. What adjustments to strategic/financial plans would be needed?

6 Document and disclose

Document the process; communicate to relevant parties; be prepared to disclose key inputs, assumptions, analytical methods, outputs, and potential management responses.

2. Analytical Choices in Scenario Analysis

In constructing scenarios and conducting scenario analysis, organizations face a number of choices and considerations. These will affect whether scenarios are applied consistently, analyses and disclosures are comparable, and the process is efficiently applied.

Three major categories of considerations are:

- **Parameters** (e.g., discount rate, GDP, other macro-economic variables, demographic variables)
- **Assumptions** (e.g., assumptions related to future policy implementation, technology development, energy mix, price of key commodities or inputs, geographical tailoring of transitional and physical impacts, and timing of implications)
- **Analytical Choices** (e.g., choice of scenarios, time horizons, supporting data, and models)

All scenarios, including climate-related scenarios, contain a series of critical parameters and assumptions that are key drivers of the modeling results and outcomes. Organizations should first endeavor to identify and understand the key drivers of their business performance and look to build these into their scenarios. Figure 3 (p. 8) outlines some climate change parameters that may have a material impact on organizations' business performance. Figure 3 (p. 8) may also serve as a roadmap for investors and other stakeholders in analyzing organizations' disclosures around scenario analysis.

Organizations should carefully consider the key parameters, assumptions, and other analytical choices made during scenario analysis as well as the potential impacts or effects that are identified and how those results are considered by management. Organizations should consider disclosing this information where appropriate. In particular, organizations are encouraged to disclose the approach used for selecting scenarios used as well as the underlying assumptions for each scenario regarding how a particular pathway might develop (e.g., emergence and deployment of key technologies, policy developments and timing, geopolitical environment around climate policies). This information will be important for an organization to disclose and discuss, including the sensitivity of various assumptions to changes in key parameters such as carbon prices, input prices, customer preferences, etc., so that investors and other stakeholders have a clear understanding of the scenario process—not only the outcomes each scenario describes, but the pathway envisioned by an organization that leads to that outcome (i.e., the how and why of those outcomes).

Transparency around key parameters, assumptions, and analytical choices will help to support comparability of results between different scenarios used by an organization and across organizations. In turn, this will support the evaluation, by analysts and investors, of the potential magnitude and timing of impacts on individual organizations and sectors and the robustness of organizations' strategies across the range of plausible impacts, thereby supporting better risk and capital allocation decisions.

Given the number of variables and analytical approaches to scenario analysis, there will be a wide range of scenarios used that describe various outcomes. Given this, direct comparability across organizations is likely to be a very real challenge. This underpins the importance of transparency across the three categories of considerations. Keeping in mind that improved disclosure and transparency are important for comparability, organizations should consider disclosing as many of these considerations as possible and endeavor to increase their levels of disclosure over time.

Figure 3

Key Considerations: Parameters, Assumptions, Analytical Choices, and Impacts

Parameters/Assumptions

Discount rate — what discount rate does the organization apply to discount future value?

Carbon price — what assumptions are made about how carbon price(s) would develop over time (within tax and/or emissions trading frameworks), geographic scope of implementation, whether the carbon price would apply only at the margin or as a base cost, whether it is applied to specific economic sectors or across the whole economy and in what regions? Is a common carbon price used (at multiple points in time?) or differentiated prices? Assumptions about scope and modality of implementation of a CO_2 price via tax or trading scheme?

Energy demand and mix — what would be the resulting total energy demand and energy mix across different sources of primary energy e.g., coal/oil/gas/nuclear/ renewables (sub-categories)? How does this develop over time assuming supply/ end-use efficiency improvements? What factors are used for **energy conversion efficiencies** of each source category and for end-use efficiency in each demand category over time?

Price of key commodities/products — what conclusions does the organization draw, based on the input parameters/ assumptions, about the development over time of market prices for key inputs, energy commodities (e.g., coal, oil, gas, and electricity)?

Macro-economic variables — what GDP rate, employ-ment rate, and other economic variables are used?

Demographic variables — what assumptions are made about population growth, and/or migration?

Efficiency — to what extent are positive aspects of efficiency gains/clean energy transition/physical changes incorporated into scenarios and business planning?

Geographical tailoring of transition impacts — what assumptions does the organization make about potential differences in input parameters across regions/ countries / asset locations / markets?

Technology — does the organization make assumptions about the development of performance/cost and resulting levels of deployment over time of various key supply and demand-side technologies (e.g., solar PV/ CSP, wind, energy storage, biofuels, CCS/CCUS, nuclear, unconventional gas, transport sector technologies such as electric vehicles, and efficiency technologies in other key sectors including industrial and infrastructure)?

Policy — what are assumptions about strength of different policy signals and their development over time (e.g., national headline carbon emissions targets; energy efficiency or technology standards and policies in key sectors; subsidies for fossil fuels; subsidies or support for renewable energy sources and for CCS/CCUS)

Climate sensitivity assumptions — what assumptions of temperature increase relative to CO_2 increase have been made?

Analytical Choices

Scenarios — what scenarios does the organization use for transition impact analysis and which sources are used to assess physical impact (e.g., CMIP5) – both for central/base case and for sensitivity analyses?

Quantitative vs. qualitative or "directional" — is the scenario exercise fully quantitative, or a mix of quantitative and qualitative?

Timing — how does the organization consider timing of implications under scenarios e.g., is this considered at a decadal level for potential futures to 2020; 2030; 2040; 2050

Scope of application — is the analysis applied to the whole organization value chain (inputs, operations and markets), or just direct effects on specific business units / operations?

Climate models/data sets — which climate models and data sets support the assessment of physical impacts?

Physical risks — when assessing physical risks, which specific risks have been included and their severity (e.g., temperature, precipitation, flooding, storm surge, sea level rise, hurricanes, water availability/ drought, landslides, wildfires or others)? To what extent has the organization assessed the physical impact to its portfolio (e.g., largest assets, most vulnerable assets) and to what extent have physical risks been incorporated in investment screening and future business strategy?

To what extent has the impact on prices and availability in the **whole value chain** been considered, including knock on effects from suppliers, shippers, infrastructure and access to customers?

Business Impacts/Effects

Earnings — what conclusions does the organization draw about impact on earnings and how does it express that impact (e.g., as EBITDA, EBITDA margins, EBITDA contribution, dividends)?

Costs — what conclusions does the organization draw about the implications for its operating/ production costs and their development over time?

Revenues — what conclusions does the organization draw about the implications for the revenues from its key commodities/ products/ services, and their development over time?

Assets — what are the implications for asset values of various scenarios?

Capital allocation/investments — what are the implications for capex and other investments?

Timing — what detail does the organization provide about development of costs, revenues and earnings across time (e.g., 5/10/20 year averages)?

Responses — what detail does the organization provide in relation to impacts (e.g., intended changes to capital expenditure plans, changes to portfolio through acquisitions and divestments, retirement of assets, entry into new markets, development of new capabilities etc.)?

Business interruption due to physical impacts — what is the estimate of business interruption/productivity loss due to physical impacts both direct effects on the organization's own assets and indirect effects of supply chain/product delivery disruptions?

3. Challenges

Conducting climate-related scenario analysis is not without challenges. First, the majority of publicly-available climate-related scenarios (both transition and physical risk scenarios) were not designed for individual company risk assessment or financial analysis. Consequently, they do not always provide the ideal level of transparency, range of data outputs, and functionality of tools that would facilitate their use in organizational scenario analysis or third-party analysis by investors or analysts. For example:

- A majority of transition risk scenarios provide outputs such as the energy mix under given circumstances in the future, but not sector- or activity-specific results in most instances.
- The outputs of climate modeling of physical scenarios, undertaken within the framework of the IPCC, are currently not easily accessible to the wide majority of organizations.

Organizations across many different sectors will inevitably need to learn by doing. Many are likely to seek guidance appropriate for their sector from industry associations, consultants, and other experts on how to apply scenarios to make forward-looking analyses of climate-related risks and opportunities.

Second, scenario-based climate assessments are still in their infancy. Although a handful of the world's largest companies and investors are applying climate-related scenario analysis as part of their strategic planning and risk management processes, it is not a tool widely used in many sectors that are exposed to transition and physical risks. Sharing experiences and approaches to scenario analysis across organizations, therefore, is critical to advancing both the use and the capability of scenario analysis. Industry associations, for example, may be able to play an important role in this regard by facilitating information and experience exchanges among organizations; developing tools, data sets, and methodologies; and working to set standards.

Third, for those organizations that use scenario analysis, whether for transition and/or physical risk, in their strategic planning and risk management processes, the number that have publicly disclosed information about these analyses is limited, while even fewer disclose scenario analysis information in financial filings. Disclosure is critical to advance both the goals of transparency around an important category of risk and to the development of better measures and methodologies for assessing such risk by investors and other stakeholders.

Addressing these challenges may require further work by industry groups, NGOs, and official bodies, both individually and collectively, to:

- further develop applicable 2°C (or lower) transition risk scenarios and physical risk scenarios at the sector and geographic level and create industry-specific (financial and non-financial) guidance for preparers and users of climate-related scenarios;
- further develop, and improve access to, methodologies, data sets, and tools that allow organizations to more effectively conduct scenario-based analysis of transition and physical risk at more granular industry, geographic, and temporal levels;
- develop and refine accepted good practice for scenario-based climate-related financial disclosure and facilitate uptake by organizations in sectors most greatly impacted by climate change;
- establish stronger norms for better, relevant disclosure around scenario analysis; and
- develop methodologies and tools for investors to better understand and use disclosures around scenario analysis.

D Publicly-Available Climate-Related Scenarios

While organizations may want to develop their own climate-related scenarios, there are many publicly-available scenarios that can be used by organizations as a platform on which to base their own evaluations of the impacts posed by climate change. These can be broadly assigned into two categories: (1) scenarios that articulate different pathways in the energy and economic system that would result in a certain level or trajectory of GHG emissions and resulting GHG concentrations in the atmosphere (transition risk scenarios) and (2) scenarios that articulate different pathways that account for physical changes arising from different levels of GHG concentrations (physical risk scenarios) (see Figure 4).

Figure 4

Overview of Publicly-Available Climate-Related Scenarios

Publicly-Available Scenarios

Transition	Physical
3.6°C IEA New Policies Scenarios	**6°C** IPCC RCP 8.5
2°C IEA 2DS/450 Scenarios, DDPP, IRENA, Greenpeace	**4°C** IPCC RCP 6.0
1.5°C Forthcoming IEA 1.5DS scenario	**2.6°C** IPCC RCP 4.5
	2°C IPCC RCP 2.6

Pathways to deliver a given limit to warming are commonly referred to as "**transition risk scenarios**." Transition risk scenarios typically present plausible assumptions about the development of climate policies and the deployment of "climate-friendly" technologies to limit GHG emissions. Transition risk scenarios draw conclusions, often based on modeling, about how policy and technology regarding energy supply and GHG emissions interact with economic activity, energy consumption and GDP among other key factors. Such scenarios may have material consequences for organizations in certain sectors of the economy in the short and medium term as well as longer term. These scenarios can reflect a faster or slower transition depending on different rates of change of key parameters (e.g., the rate of technology development and deployment; changes and timing of key policies). The IEA and others produce a number of transition risk scenarios.

Patterns of physical impacts attributable to climate change can be termed "**physical risk scenarios**." Physical risk scenarios typically present the results of global climate models (referred to as "general circulation models") that show the response of the Earth's climate to changes in atmospheric GHG concentrations. IPCC scenarios based on "Representative Concentration Pathways" (RCPs) are examples of physical climate change scenarios adopted by the IPCC in its 5th Assessment Report (AR5).[9] Model results are frequently "downscaled" to derive potential local-level changes in climate, which are then used to generate scenarios of impacts from climate change (first order impacts such as flooding or drought, second order impacts such as loss of crop production, and third order impacts such as famine).[10] Physical risk scenarios assist organizations in exploring questions such as:

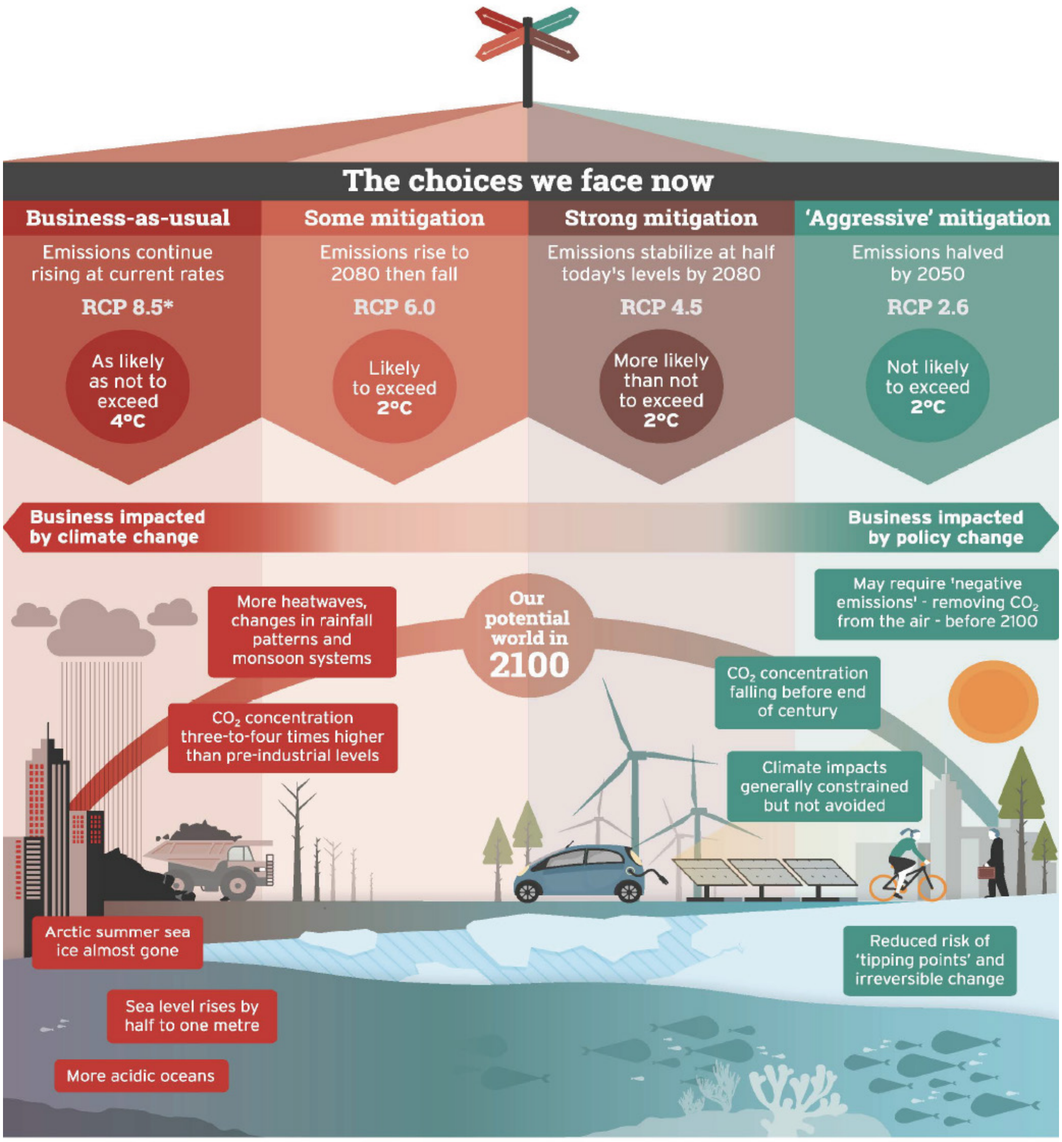
- What type of physical impacts might there be?
- What if the physical consequences of climate change become more severe?
- When, where, to whom, and to what degree might they be felt?

In scenarios, both transition and physical considerations are complementary when assessing climate-related financial impacts and both are required to understand the full implications of climate change and the resilience of organizations to those implications. For example, delays in addressing the transition to a low-carbon economy through policies, technology, and markets will likely exacerbate physical risks. Delays may also result in sharper, more dramatic policy shifts and market shifts. Finally, the transition and physical impacts will fall differently on different organizations. Some organizations will likely be more affected by transition risk (e.g., fossil fuel and energy-intensive manufacturers), while others will be more affected by physical climate risk (e.g., those reliant upon agriculture or infrastructure). This is why the two sets of risks should be evaluated together (Figure 5, p. 12). Using both types of scenarios allows organizations to consider a range of potential effects on their performance, strategy, and financial plan and how these effects compare to various publicly-available scenarios and national goals.

[9] Representative Concentration Pathways (RCPs) are referred to as pathways to emphasize that their primary purpose is to provide time-dependent projections of atmospheric greenhouse gas (GHG) concentrations, both a specific long-term concentration outcome and the trajectory that is taken over time to reach that outcome. They are representative of several different scenarios that have similar radiative forcing and emissions characteristics and are intended to expedite the preparation of integrated scenarios. The IPCC's current RCPs describe four possible climate futures, all of which are considered possible depending on the volume of greenhouse gases are emitted in the future—RCP 2.6 assumes that global annual GHG emissions (measured in CO_2-equivalents) peak between 2010-2020, with emissions declining substantially thereafter; RCP 4.5 assumes that emissions peak around 2040, then decline; in RCP 6, emissions peak around 2080, then decline; while RCP 8.5, assumes that emissions continue to rise throughout the 21st century (Intergovernmental Panel on Climate Change (IPCC). "Towards new Scenarios for Analysis of Emissions, Climate Change, Impacts, and Response Strategies," September, 2007. IPCC Expert Meeting Report. http://www.aimes.ucar.edu/docs/IPCC.meetingreport.final.pdf).

[10] For example, see Wilby, R.G., et al (2004). "Guidelines for Use of Climate Scenarios Developed from Statistical Downscaling Methods." (August, 2004.) Supporting Material of the IPCC, Task Group on Data and Scenario Support for Impacts and Climate Analysis (TGICA). http://www.ipcc-data.org/guidelines/dgm_no2_v1_09_2004.pdf.

Figure 5
Interplay between Transition and Physical Scenarios



*The four RCP (Representative Concentration Pathway) scenarios each project a certain amount of carbon to be emitted by 2100 and, as a result, lead to a different amount of human-driven climate change. Climate change will continue after 2100 and elevated temperatures will remain for many centuries after human CO_2 emissions cease.

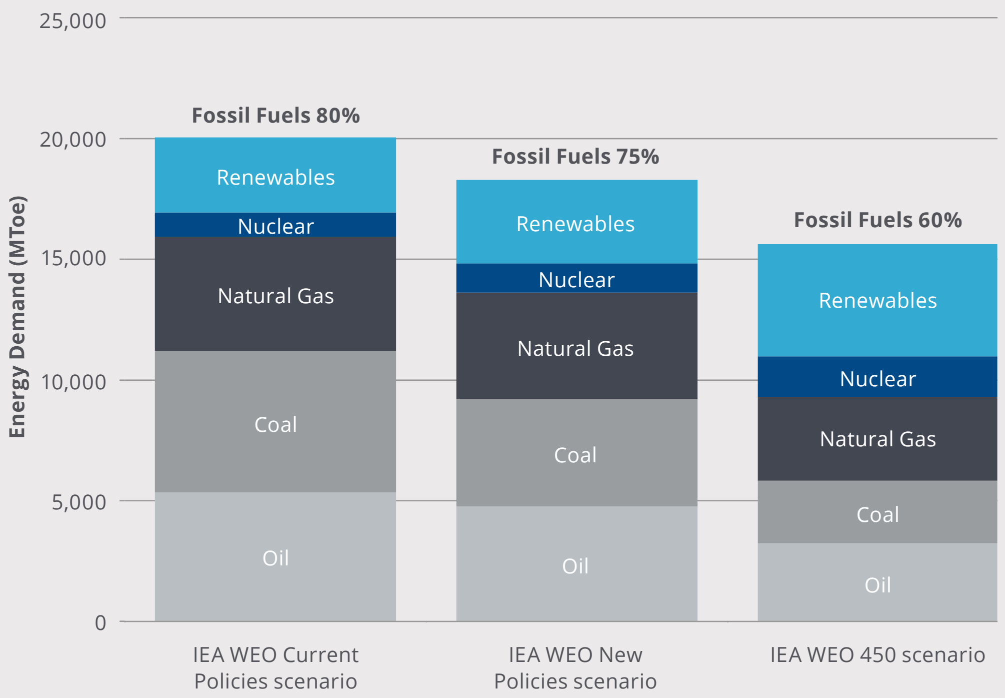
Source: Intergovernmental Panel on Climate Change, Fifth Assessment Report (AR5), Climate Change: Action, Trends, and Implications for Business, Cambridge University Press, 2013. http://www.cisl.cam.ac.uk/business-action/low-carbon-transformation/ipcc-climate-science-business-briefings/climate-science.

1. Transition Risk Scenarios

In constructing scenarios about the potential impact of the transition to a low-carbon economy on an organization, the organization may use one or more publicly-available climate-related scenarios as well as their own scenarios. A number of published scenarios are available that lay out various plausible pathways to particular target outcomes (e.g., specific temperature increases) and that have varying assumptions about the likely timing of policy changes, technology adoption, changes in energy mix and other factors to achieve a climate-friendly economy. For example, Figure 6 shows the potential impacts on energy mix and share of fossil fuels produced in three of the IEA scenarios.

Figure 6

IEA World Energy Outlook (WEO) Scenarios to 2040



Source: IEA. World Energy Outlook, 2015. http://www.worldenergyoutlook.org/weo2015/

Boxes 1 and 2 (pp. 15-16) summarize various published transition risk scenarios and associated target pathways. They include:

- six different IEA scenarios around various assumed pathways and temperature increases and
- a number of alternative, publicly available 2°C scenarios and tools, such as International Renewable Energy Agency (IRENA) REmap, Greenpeace Advanced Energy [R]evolution, and Deep Decarbonization Pathways Project (DDPP).

Organizations, therefore, have a variety of choices available to them on plausible future development pathways when carrying out scenario analysis.

a. Publicly-Available IEA Transition Risk Scenarios

The most well-known, widely used and reviewed scenarios for the transition to a low carbon economy are those prepared by the IEA. A majority of analyses conducted by academic and industry analysts are built upon or compared with the IEA scenarios. The IEA data and scenarios capture the entire energy chain, but not "non-energy" sectors such as land use/land use change/forestry (LULUCF) and process emissions from industry that do not involve fuel combustion. These scenarios, however, are not suited to producing precise estimates, but they can be used to qualitatively assess risks associated with different pathways.[11] The IEA scenarios are summarized in Box 1 (p. 15).

b. 2°C Transition Risk Scenarios

One type of transition scenario is a so-called 2°C scenario, which lays out a pathway and an emissions trajectory consistent with limiting the average global temperature increase to 2°C.[12] Effectively, a 2°C scenario asks the question "if the world limits warming at or below 2°C, what are the pathways for achieving that goal?" It is useful for comparison against alternative scenarios. A variety of 2°C scenarios are available or an organization can develop its own 2°C scenario.

It is important to note that, of the IEA scenarios, only the IEA 450ppm and 2DS scenarios model a 2°C future, although the INDC and Bridge scenarios also acknowledge 2°C as a policy objective.[13] A number of other alternative 2°C scenarios and tools are available in addition to the IEA 450 and 2DS scenarios; these alternatives are potentially helpful to organizations seeking to understand possible future transition pathways.

In designing a 2°C scenario, organizations should consider publicly-available scenarios that are (1) used, referenced, and issued by an independent body; (2) wherever possible, supported by publicly available data sets; (3) updated on a regular basis; and (4) linked to functional tools (e.g., visualizers, calculators, and mapping tools) that can be applied by organizations. Examples of 2°C scenarios that presently meet most of these criteria include: IEA 2DS, IEA 450, DDPP, and IRENA (see Boxes 1 and 2 on pp. 15-16 for a description of these scenarios). These publicly-available scenarios can help inform development of an organization's own scenarios or they can be used directly. However, it is important to note that these scenarios do not consider impacts on all sectors and individual organizations.

[11] This is borne out by the recognition that, in recent years, the IEA scenarios have significantly under-forecast the deployment of renewables (Paltsev, Sergey. "Energy Scenarios: The Value and Limits of Scenario Analysis." MIT CEEPR WP 2016-007, 2016. http://ceepr.mit.edu/files/papers/2016-007.pdf).

[12] Limiting the temperature increase to below 2°C (relative to pre-industrial levels) is a stated goal of the 2015 UNFCCC Paris Agreement that entered into force on November 4, 2016.

[13] The IEA 450 scenario is premised on a 50% likelihood of keeping below 2°C.

Box 1

IEA Scenarios

IEA WEO Current Policies Scenario (projected to generate warming of 6°C)

The Current Policies Scenario considers only those policies that have been formally adopted by governments. According to the UNEP, it sets out "a business-as-usual future in which governments fail to follow through on policy proposals that have yet to be backed-up by legislation or other bases for implementation and do not introduce any other policies that affect the energy sector."[14] This 'No New Measures' Scenario provides a comparison point against which new policies can be assessed.

IEA WEO New Policies Scenario (projected to generate warming of 4°C)

The New Policies Scenario is the central scenario of WEO. It takes into account the policies and implementing measures affecting energy markets that have been adopted, together with relevant policy proposals, even though specific measures necessary to put them into effect may need to be fully developed. The WEO report makes a case-by-case judgment (often cautious) of the extent to which policy proposals will be implemented. This is done in view of the many institutional, political, and economic obstacles that exist, as well as, in some cases, a lack of detail in announced intentions about how they will be implemented. [15]

IEA INDC Paris Agreement Scenario (projected to limit warming to 2.6°C)

The INDC Scenario assesses implications of the INDCs submitted before COP21 as the basis for the Paris Agreement. "The share of fossil fuels in the world energy mix declines, but is still around 75% in 2030. The rate of growth in coal and oil demand slows but demand does not decline, while gas use marches higher. Renewables become the leading source of electricity by 2030, but sub-critical coal-fired capacity declines only slightly. The carbon intensity of the power sector improves by 30%."[16] Carbon capture and storage (CCS) achieves no more than marginal penetration by 2030. Increased efficiency measures across sectors reduce the energy used to provide energy services, without reducing the services themselves.

IEA Bridge Scenario (keeps world on path to 2°C limit to 2025, but more needed after 2025)

The IEA sought to contribute to practical discussions about near-term GHG mitigation options amongst policymakers and business planners by developing the Bridge Scenario. The purpose of the Bridge Scenario is to facilitate adoption of methods through which the movement towards a peak in global energy-related GHG emissions can be achieved by each country or region individually. This Bridge Scenario is not, in itself, a pathway to the 2°C target – additional technology developments and policy requirements for such a pathway are set out in the WEO 450 Scenario.

IEA WEO 450ppm Scenario (projected to limit warming to 2°C)

The WEO 450 Scenario takes a different approach. "It adopts a specified outcome: achievement of the necessary action in the energy sector to limit the rise in long-term average global temperature (with a likelihood of 50%) to 2°C and offers steps by which that goal might be achieved." [17] Many separate efforts are required to reduce energy-related CO_2 emissions from 2015 to 2040, including stronger deployment of technologies that are familiar and available at commercial scale today, which will deliver close to 60% of the emissions reductions; the building of significant additional nuclear capacity; and rapid CCS expansion after 2025 matching the pace of expansion of gas-fired capacity between 1990 and 2010.

IEA ETP 2DS Scenario (projected to limit warming to 2°C)

The IEA has a separate annual publication called "Energy Technology Perspectives" (ETP) which provides scenario analysis of lower carbon technology development and deployment in various sectors. ETP 2016 lays out an energy system development pathway and an emissions trajectory consistent with at least a 50% chance of limiting the average global temperature rise to 2°C. The 2DS sets the target of cutting CO_2 emissions by almost 60% by 2050 (compared with 2013), followed by continued decline after 2050 until carbon neutrality is reached. The 2DS identifies changes that help ensure a secure and affordable energy system in the long run, while emphasizing that transforming the energy sector is vital, but not enough on its own.

[14] UNEP, *Best Practices and Case Studies for Industrial Energy Efficiency Improvement*. February, 2016. http://www.unepdtu.org/-/media/Sites/energyefficiencycentre/Publications/C2E2%20Publications/Best-Practises-for-Industrial-EE_web.ashx?la=da.

[15] IEA, World Energy Model Documentation 2015 Version. 2015.

[16] IEA, "Energy and Climate Change," 2015. http://www.worldenergyoutlook.org/media/weowebsite/2015/WEM_Documentation_WEO2015.pdf.

[17] Ibid.

Box 2

Other 2°C Scenarios

International Renewable Energy Agency (IRENA) REmap (2016) This scenario outlines a plan to double the share of renewables in the world's energy mix by 2030. A renewable generation share of 36% is required by 2030, up from 18% currently and a quadrupling of "modern" renewables due to the phase out of traditional uses of biomass (e.g., fuel wood) energy. "REmap determines the realistic potential for countries, regions and the world to scale up renewables, starting with separate country analyses done in collaboration with country experts, and then aggregating these results to arrive at a global picture. The analysis encompasses 40 countries representing 80% of global energy use. The road map focuses not just on renewable power technologies, but also technology options in heating, cooling and transport. In determining the potential to scale up renewables, REmap focuses on possible technology pathways."[18]

Greenpeace Advanced Energy [R]evolution (5th Edition)
This scenario sets out an ambitious pathway toward a fully decarbonized energy system by 2050. The scenario adds significant additional efforts to the basic Energy [R]evolution scenario (which is also covered in the latest edition of Greenpeace's Advanced Energy [R]evolution). It is based on the basic scenario, which includes significant efforts to exploit opportunities for energy efficiency, along with large-scale integration of renewables, biofuels, and hydrogen into the energy mix. The advanced scenario requires much stronger efforts to move energy systems towards a 100% renewable energy supply. Consumption pathways remain similar, but faster introduction of these technologies leads to complete decarbonization. The IEA's World Energy Outlook 2014 Current Policies Scenario serves as the reference case.

Deep Decarbonization Pathways Project (DDPP)
The DDPP fills a gap in the climate policy dialogue by providing, in the form of deep decarbonization pathways (DDPs), a clear and tangible understanding of what will be required for countries to reduce emissions, consistent with the 2°C limit. "The DDPP framework has been developed and utilized by a consortium led by The Institute for Sustainable Development and International Relations (IDDRI) and the Sustainable Development Solutions Network (SDSN). The DDPP is a global collaboration of scientific research teams from leading research institutions in 16 of the world's largest greenhouse gas-emitting countries: Australia, Brazil, Canada, China, France, Germany, India, Indonesia, Italy, Japan, Mexico, Russia, South Africa, South Korea, UK and USA." [19] The research teams developed these blueprints for change, sector by sector and over time, for each physical infrastructure of the 16 countries, to inform decision makers of the technological and cost requirements of different options for meeting their country's emissions reduction goal. DDPs begin with an emissions target in 2050 and determine the steps required to get there. This tool therefore allows the user to create any number of 2°C pathways.

In common with, and sometimes going beyond the IEA scenarios, these 2°C scenarios are:

- publicly available, peer reviewed, and generally used/referenced,
- supported by publicly available data sets providing data at global, regional and national level, and
- in some cases, linked to functional tools (e.g., visualizers, calculators, and/or mapping tools) that can be employed by "user" organizations.

c. Nationally Determined Contributions and the Importance of 2°C Scenarios

When considering resilience to transition risks, an organization's management, shareholders, and analysts should, as a starting point, take into account the stated measures and outcomes of governments' NDC plans. In some instances, NDCs are built on domestic policy considerations around what constitutes a practical, sound pathway to a low-carbon economy in light of energy security requirements.

[18] International Renewable Energy Agency (IRENA), Remap. 2016. http://irena.org/remap/.
[19] Deep Decarbonization Pathways Project (DDPP), DDPP, 2016. http://deepdecarbonization.org/about/.

While taking into account NDC goals in scenario analysis is a substantive first step, the following should be noted:

- The current NDCs are not sufficient to deliver the objective, stated in Article 2 of the Paris Agreement and agreed to by 195 signatory countries, of "holding the increase in the global average temperature to well below 2°C above pre-industrial levels and to pursue efforts to limit the temperature increase to 1.5°C above pre-industrial levels."[20]
- The current NDCs end at 2030 (some earlier than 2030) and only achieve an expected 2.7°C warming limit.
- Article 4 of the Paris Agreement introduces the "ratcheting" requirement for countries to communicate enhanced NDCs every five years (i.e., to go further than they have currently committed to in order to achieve the Agreement's objectives of below 2°C above pre-industrial levels).

It is important, therefore, that organizations take into account a 2°C scenario in their analyses. A 2°C scenario provides a common reference point that is aligned with the objectives of the Paris Agreement and will support the evaluation, by analysts and investors, of the potential magnitude and timing of transition-related implications for individual organizations, across different organizations within a sector, and across different sectors.

In this context, it is useful to highlight several points from the Grantham Institute submission to the Task Force:[21]

- *...it is becoming increasingly risky for companies to pin all business strategies on the assumption that extensive decarbonization will not happen, for example, on the basis because of (mostly backward-looking) lack of political will.*
- *It is likely that all businesses will need to have an answer to the key question "what strategy is in place to transition business models to ones that remain valuable once ambitious climate policies are in place?" Similar questions relating to exposure to physical risks and future-proofing business models will have to be formulated, these varying according to different sectors' exposure.*
- *Resilience requires the presence of forward risk management and hedging strategies. In addition to answering the question "what is your most likely scenario?" investors will seek to ask "what will you do in alternative scenarios such as a net zero emissions world?" The answer to this puts market players in a better position to assess market capitalization.*

d. Comparison of Relevant Parameters and Signposts

A comparison of the IEA and other scenarios, their related models and tools, and their underlying assumptions is presented in Table 1 (p. 18). It should be noted that this figure does not include the IEA WEO Current Policies and New Policies scenarios since these do not explicitly model the transition to a lower-carbon economy. Instead, they model alternative versions of "business-as-usual."

Analyzing the range of 2°C and other transition risk scenarios from the IEA, DDPP, IRENA, and Greenpeace, a number of key drivers or signposts appear relevant for organizations to consider when constructing, using, and assessing various scenarios (Table 2, p. 19). These drivers and signposts can also serve as key indicators that organizations may wish to monitor in order to gauge the emergence or change of different transition pathways and the implications for their organization relative to these indicators. For instance, information from such monitoring is likely to be an important input into an organization's strategic planning process as well as contributing to the ongoing adjustment of scenarios to emerging trends and conditions.

[20] United Nations Framework Convention on Climate Change, "The Paris Agreement," December 2015, http://unfccc.int/files/essential_background/convention/application/pdf/english_paris_agreement.pdf.

[21] Dimitri Zenghelis and Nicholas Stern, The importance of looking forward to manage risks: submission to the Task Force on Climate-Related Financial Disclosures, Policy Paper, June 2016, http://www.lse.ac.uk/GranthamInstitute/wp-content/uploads/2016/06/Zenghelis-and-Stern-policy-paper-June-2016.pdf.

Table 1

Summary of Transition Risk Scenarios and their Underlying Assumptions

	Scenario Description		Model Details				
Scenario	**Temp Impact Range and % Likelihood**	**Source and Data Visualization**	**Model**	**Underlying Assumption: Population**	**Underlying Assumption: Economics**	**Details: Non-Energy emissions sources[22]**	**Details: Timeframe**
IEA WEO 450 Scenario	2°C, with a likelihood of around 50%	IEA Special Report: Energy and Climate Change and WEO 2014	IEA World Energy Model (WEM)	World population to grow by 0.9% per year, from 7 billion in mid-2012 to 9 billion in 2040 (WEO 2014, pp. 42-44)	World GDP assumed to grow at a rate of 3.4% over 2012- 2040 (WEO 2014, pp. 39-42)	No (p. 35)	2012-2040
ETP 2DS Scenario	2°C, with a likelihood of around 50% (p. 29)	ETP (Energy Technology Perspectives) 2016 http://www.iea.org/etp/explore	ETP Model	Population to grow from 7.1 billion in 2013, to 9.4 billion in 2050 (p. 385)	Average World GDP growth for 2013-2050 is 3.2% (p. 385)	Yes (p. 29)	2013-2050
Deep decarbonizati on Pathways Project (DDPP)	Consistent with… warming to less than 2°C with a "better than even" chance	DDPP 2015 Report http://deepdecarbonization.org/countries/visualization-of-country-scenarios/		Expanded population growth of 17% from 2010-2050 across the 16 countries (p. 6)	Global average GDP growth rate of 3.1% per year (pp. 4-5)	"Some of the individual country analyses consider sources of carbon emissions other than energy" (p. 4)	2010-2050
IRENA REmap	2°C, if the lower end of CO_2 emissions reductions are achieved (p. 42)	IRENA: Roadmap for a Renewable Energy Future (Remap): 2016 edition & IRENA Working Paper: Synergies between Renewable Energy and Energy Efficiency http://resourceirena.irena.org/gateway/dashboard/		Population growth between 2010-2030 for 8 significant countries is in table 3 of the IRENA 'Synergies' paper	GDP change between 2010-2030 for 8 significant countries is in Table 3 of the IRENA 'Synergies' paper	"The energy use of agriculture, forestry, and fishing, as well as nonenergy use is excluded" p. 27, 2016 REmap Paper	2010-2030
Greenpeace Advanced Energy [R]evolution	Aim to hold temperature increase to under 2°C (p. 59)	Greenpeace Energy [R]evolution (5th Ed)		Population expected to grow by 0.8% per year on average over the period of 2015-2050 from 7.3 Bn in 2009 to nearly 9.5 Bn in 2050	Average annual GDP growth rate of 3.1% between 2012-2050	Yes - Final energy demand includes nonenergy use (p. 317)	2012-2050
IEA WEO Bridge Scenario	Aim to "keep the door to the 2°C goal open" through the energy transition. Note: this is NOT a 2°C scenario in itself.	IEA Special Report: Energy and Climate Change	IEA World Energy Model (WEM)	Population expected to grow by 0.9% per year, from an estimated 7 Bn in mid-2012 to 9 Bn in 2040 (WEO 2014, pp. 42-44)	World GDP assumed to grow at a rate of 3.4% over 2012-2040 (WEO 2014, pp. 39-42)	No (p. 35)	2012-2030
IEA WEO INDC Scenario	By 2040, all remaining carbon budget for a 50% change of 2°C will be used. If no stronger action after 2030, warming of 2.6°C by 2100, and 3.5°C after 2200 (p. 12)	IEA Special Report: Energy and Climate Change and Data/Tables available at http://www.worldenergyoutlook.org/indc/	IEA World Energy Model (WEM)	Population expected to grow by 0.9% per year, from an estimated 7 Bn in mid-2012 to 9 Bn in 2040 (WEO 2014, pp. 42-44)	World GDP assumed to grow at a rate of 3.4% over 2012-2040 (WEO 2014, pp. 39-42)	No (p. 35)	2012-2030

[22] Note: One key non-energy source of emissions is the contribution to GHG emissions expected from land-use, land-use change and forestry, which, for some countries, can be very significant (IEA, "Energy and Climate Change: Special Briefing for COP21." 2015. http://www.worldenergyoutlook.org/media/news/WEO2015_COP21Briefing.pdf).

Table 2

Comparison of Relevant Parameters and Signposts within Transition Risk Scenarios

Key Drivers / Signposts			Scenario: IEA WEO 450 scenario	ETP 2DS scenario	Deep Decarbonization Pathways Project (DDPP)	IRENA REmap	Greenpeace Advanced Energy[R] evolution
Key Drivers / Signposts	Policy & Demand	Energy Efficiency	– Strong efficiency related policy action	– Around 5100 GW of new capacity is avoided between 2016 and 2050. – A decrease in energy intensity is of almost two thirds is assumed from 2013 to 2050. (p. 31)	– Average energy intensity of GDP for the 16 DDPP countries as a whole falls 64% from ~8.2 MJ/$ in2010 to 3 MJ/$ in 2050. (p. 9) – Average Carbon Intensity of electricity falls from~530 gCO_2/kWh in 2010, to ~40gCO_2/kWh in 2050. (p. 9)	– Building sector has the greatest energy savings. (p. 22, Synergies paper) – Efficiency gains from the deployment of REmap would keep the global Total Primary Energy Supply 5% below 2010 level. (p. 27,Synergies paper)	– Efficiency measures in the industry, residential and service sectors avoid the generation of about 16,700 TWh/a (by 2050] (p. 13)
		CO_2 Price	– After 2020, a CO_2 price is adopted in OECD countries. – Fossil fuel subsidies removed in all regions except the Middle East by 2035. CO_2 prices in most OECD markets reach $140/ton in 2040, up from ~$20/ton in 2020 (p. 45, WEO 2014)	– Assumptions are that in the US Carbon taxes begin in2020 at $35/ tCO_2, and increase linearly to$210/ tCO_2 by 2050. – Where the current level of taxation is greater than this, taxes are maintained until this schedule catches up with them.	– Note: "The choice of policy instruments depends on societal preferences;" therefore in the DDPPs, the importance of carbon pricing does vary, although it is of importance in all. (pp.39-41)	– A range of USD 17-80/t CO_2 is assumed for carbon prices (p. 26- 27, 2016 REmap paper)	– In contrast to the 2012 edition, the 2015 Energy [R]evolution analysis, CO_2 pricing is set aside. (p. 67)
		Energy Demand	– Global energy demand grows on average by only 0.6% per year; in 2040 demand is up 17% on 2012.	– Final energy demand to grow to 455EJ by 2050, up from 390 EJ in 2014. (p.32)	– Medium emissions/moderate income countries: Energy consumption peaks 2030-40. Fossil fuel consumption in 2050 = 2010 levels. (p.15) – High emissions/ high-income countries: Final energy demand falls 10% below 2010 levels by 2050.(p. 17)	– Global energy demand grows 30% in 2030 compared to levels today. (p. 14, Remap 2016 Paper)	– Primary energy consumption 433,000 PJ/a in 2050 (excluding non- energy consumption), down from 534,870 PJ/a today. (p.92) – Peak final energy demand reached in 2020 with a total of 355,000 PJ/a. (pp.12-13)
	Emerging Technologies	Solar PV Deployment		– In 2050, urban rooftop solar PV is assumed to account for around 47% of global electricity generated by solar PV, and 9% of the electricity consumed in cities. (p. 284)	– Cumulative production of decarbonized energy(GW) from Solar PV, in all DDPP countries, grows as follows: 2010: 1GW, 2020: 275GW, 2030:823GW, 2040: 1752GW, 2050: 3254GW (p. 29)	– Solar PV power generation capacity is 1760 GW by 2030, up from 180GW in 2014 and 780 GW in the reference case (p. 67, 2016 REmap paper) – Solar PV power capacity increases at a rate of 99 GW/year in 2012- 2030.	– Solar PV provides 14% of total electricity generation by 2030, employing 10.3 million people. – Total generation rises from 1,090 TWh in 2020, to 2,659 TWh in 2025, and 5,067 TWh in 2030. (p. 202)
		EV Deployment	– Sale of EVs exceed 40% of total passenger car sales worldwide in 2040. (p. 109, WEO Special Report) - – Advanced biofuels and EVs reduce oil consumption by 13.8 mboe per day in 2040 (p. 123, WEO Special Report)	– 100 million EVs by 2030, up from 1 Million in 2016. (p. 253) – Annual sales growth of EVs assumed to be sustained, from 53% in 2014, to 66% through 2020 and to 39% through 2025. (p. 104)	– Production of EVs (per million): 2010: 0, 2020:32, 2030:134, 2040:333, 2050: 650 (p. 29)	– The number of electric vehicles reaches 160 million units in 2030 under the Remap scenario, up from 60 million in the reference case and 0.8 million in 2013/2014. (p. 102, 2016 REmap paper)	

Table 2

Comparison of Relevant Parameters and Signposts within Transition Risk Scenarios *(continued)*

			Scenario				
			IEA WEO 450 scenario	ETP 2DS scenario	Deep Decarbonization Pathways Project (DDPP)	IRENA REmap	Greenpeace Advanced Energy[R] evolution
	Emerging Technologies	CCS Deployment	– 80 GW of CCS equipped Oil & Gas capacity to be operating by 2025. Between 2030 and 2040, 580 GW of coal-fired power generation equipped with CCS. – By 2040, 80% of coal-fired generation capacity has CCS equipped, compared with 4% in the new policies Scenario.	– Assumed 540 MtCo2 being stored per year in 2025. (p.96) – CCS assumed to provide12% of cumulative emissions reductions, capturing around 3.5 GtCo2 worldwide in 2050. (p. 39)	– Assumed growth in CCS deployment from ~3GW in2020 to ~20 GW in 2030, rising to ~56 GW in 2040, and 76.7 GW in 2050. (p.37)	– (Credits CCS as important, but no discussion of specific impact in scenario)	– 'CCS Technologies are not implemented.' (p.60) – CCS technologies are not included in the Energy Revolution, due to the speculative nature of assumptions around costs, effectiveness and environmental effects (p.67)
	Emerging Technologies	Bio-energy	– The fuel mix is much more diversified by 2040, biofuels consisting of 17% of world transport demand (p.124, WEO Special Report)	– Assumed production of 56.8 billion liters of biofuels by 2025. (p. 108)	– Cumulative production of decarbonized energy (GW) from Biomass, in all DDPP countries, grows as follows:2010: 1 GW, 2020: 26 GW,2030: 105 GW, 2040: 221GW, 2050: 270 GW	– Demand for liquid biofuels reaches 500 billion liters per year in 2030 if all REmap options are implemented. (p. 108, 2016 Remap paper) – Bioenergy power generation capacity is 430 GW by 2030. (p. 67, 2016 REmap paper)	– Heat supplied by Biomass increases from 31,404 PJ in 2020, to 34,909 PJ in 2025, and 36,623 PJ in 2030. (p. 203)
	Energy Mix	% Renewables	– Variable renewables increase from increase from 3% of global electricity generation in 2015 to more than 20% by 2040. (p. 109, WEO Special Report)	– CO_2 intensity of electricity falling from 528 gCO_2/kWh in 2013 to less than40gCo2/kWh in 2050.Achieved through deployment of low-carbon generation.	– Annual investment in low carbon technology as a share of GDP (%) expected to grow across the DDPP countries: 0.8% in 2020, 1.2% in 2030, 1.3% in2040, 1.3% in 2050. (p.32)	– 45% of Power generation in the REmap scenario in 2030 uses renewable technology (up from 23% in 2014), compared to 30% in the Reference case. (p. 54, 2016 REmap paper)	– 45% of Power generation in the REmap scenario in 2030 uses renewable technology (up from 23% in 2014), compared to 30% in the Reference case. (p. 54, 2016 REmap paper)
	Energy Mix	Nuclear	– Global nuclear capacity more than doubles to 862 Gw in 2040, 38% higher than in the New Policies Scenario. (p. 406) – Development depends on some $81 billion/year in investment in new nuclear plants over 2014- 2040. (p. 406)	– Assumed growth in global nuclear capacity from403GW in 2016 to 553 GW by 2025. (p. 90)	– Cumulative production of decarbonized energy (GW)from Nuclear technology, in all DDPP countries, grows as follows: 2010: 2GW,2020: 53GW, 2030:259GW, 2040: 632GW,2050: 1053GW (p. 29)	– Under the REmap scenario, Nuclear power generation capacity is 600GW by 2030, up from 370GW in 2014, but less than the Reference Case in 2030, at 650GW. (p. 67, 2016 REmap paper)	– No new nuclear power plants will be built worldwide in the Energy [R]evolution Scenarios. (p. 122)
Outcomes	CO2 Emissions		– Energy-related CO_2 emissions peak at 33Gt before 2020, then fall back to 25.4 Gt in 2030 and 19.3 Gt in 2040 (almost 50% lower than New Policies Scenario).	– CO_2 emissions in the 2DSare reduced to 15 Gt in 2050, less than half the current value. (p. 28)	– Range of cumulative energy-related emissions of 805- 847GtCO_2 by 2050. (pp. 17-18)	– The lower end of this (CO_2 reduction) range is sufficient to keep the world on a 2oC pathway"(pp. 41-42, 2016 REmap paper)	– 100% Renewable energydecarbonization – of the entire energy system by 2050. – Global CO_2 emissions stabilize by 2020 and then constantly reduce. - Total cumulative CO_2 emissions between 2012 & 2050 are 667 Gt CO_2. (p. 15)

e. Outputs from Transition Risk Scenarios

The transition risk scenarios summarized above provide data and graphical outputs that present analysis and outcomes for key parameters at global and regional levels, and frequently also at national and sector levels.

In addition, many of the published transition risk scenarios are accompanied by functional tools and dashboards that can help organizations access the information of greatest relevance to them. For example, the DDPP tool (and also the Global Calculator developed by the UK government) allows users to undertake "what if" analysis by modifying certain input parameters and assumptions.[23] Further development of supporting tools and user interfaces, however, is necessary to facilitate uptake of scenario analysis by organizations, reduce organizational transaction costs, and help ensure comparability by investors.

2. Physical Risk Scenarios

The science and the results of global climate models can support organizations' assessments of the broader physical impacts of climate change (e.g., temperature, precipitation, and drought) and the associated financial consequences. As an illustration of this, recent analysis by MIT of six Integrated Assessment Models (which model interactions between anthropogenic greenhouse gas emissions in climate systems and climate change impacts on social-economic systems) found that climate outcomes such as global temperature were highly comparable across the models. The MIT work and other experience suggests that business planners, financial analysts, and others can effectively use the outputs of global climate models in scenario analysis to assess the broader consequences of physical climate-related impacts.

Downscaling these global climate models to local impacts, however, is still a work in progress. Several governments and international financial institutions are now using "downscaled" data from global climate models to assess new infrastructure projects. However, many global climate models still have difficulties in projecting accurately extreme weather events at local levels (e.g., floods, precipitation patterns, and droughts).

a. Publicly-Available Physical Risk Scenarios

The four RCPs are the latest generation of scenarios that provide input to the climate models underpinning the IPCC's AR5. These scenarios describe the climate impacts of a range of possible future GHG emissions and consequent trajectories of atmospheric GHG concentrations (Box 3, p. 22).

The RCP scenarios fix the amount of GHG concentration in the atmosphere and analyze the resulting changes in global temperatures (and other variables such as precipitation) at various future points (i.e., out to 2035, mid-century [2046-65], and end of century [2081-2100]) relative to pre-industrial levels.

[23] See http://www.globalcalculator.org/.

Box 3

IPCC Representative Concentration Pathway (RCP) Scenarios

RCP8.5 is the high-emissions scenario, consistent with a future with no policy changes to reduce emissions, and characterized by increasing GHG emissions that lead to high atmospheric GHG concentrations. It is aligned broadly with a Current Policies or Business-As-Usual Scenario.

RCP6.0 is a high-to-intermediate emissions scenario where GHG emissions peak at around 2060 and then decline through the rest of the century.

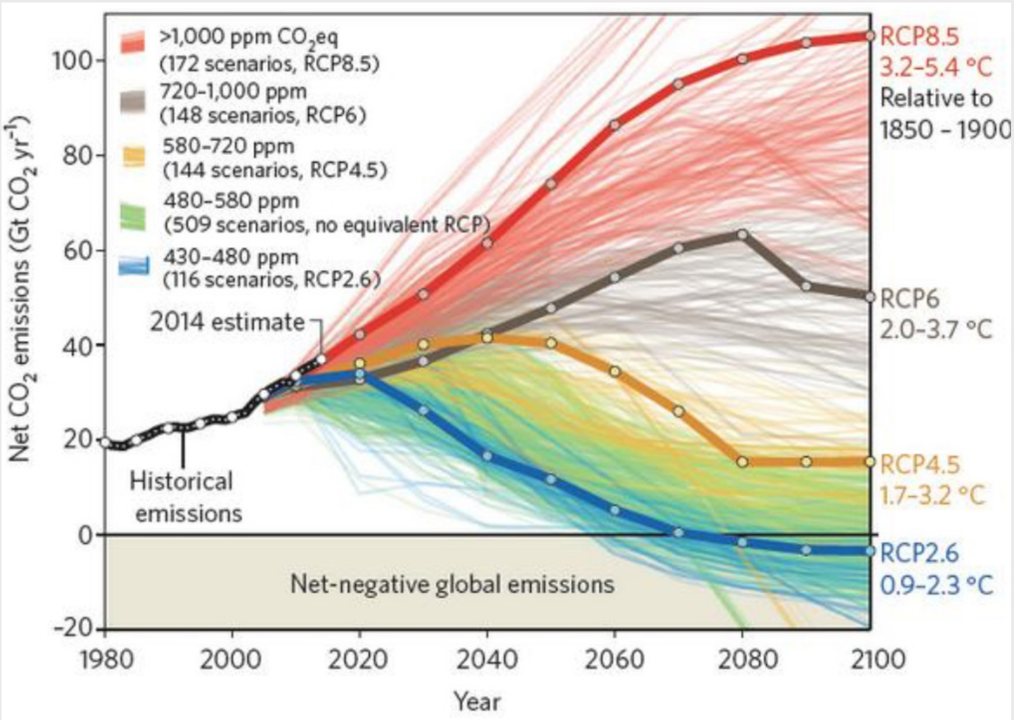
RCP4.5 is an intermediate-emissions scenario, consistent with a future with relatively ambitious emissions reductions and GHG emissions increasing slightly before starting to decline circa 2040. Despite such relatively ambitious emissions reduction actions, RCP4.5 falls short of the 2°C limit/1.5°C aim agreed on in the Paris Agreement. It is aligned broadly with the GHG emissions profile that would result from implementation of the 2015 NDCs (out to 2030), followed rapidly by peaking and then reduction of global emissions by 50% by 2080.

RCP2.6 is the only IPCC scenario in line with the Paris Agreement's stated 2°C limit/1.5°C aim. This RCP is consistent with ambitious reduction of GHG emissions, which would peak around 2020, then decline on a linear path and become net negative before 2100.

Figure 7 illustrates the range of emission pathways and temperature outcomes modeled as inputs to the IPCC's AR5 and the resulting atmospheric CO_2 concentrations and global average temperature change.

Figure 7

CO_2 Emissions Pathways and Temperature Outcomes in IPCC AR5 RCP Scenarios



Source: Fuss, Sabine; Canadell, Josep G.; Peters, Glen P.; Tavoni, Massimo; Andrew, Robbie M.; Ciais, Philippe et al., "Betting on negative emissions." Nature Climate Change 4 (10), September 2014, pp. 850–853.

The data and outcomes of this modeling are available in CMIP5, the Coupled Model Intercomparison Project Phase 5.[24] A summary of CMIP5 is provided in Box 4. This data is publicly available and is used by many organizations, academic researchers, and specialist consultants and practitioners in their evaluations of the potential first-, second- and third-order impacts of climate change.

Box 4

CMIP5 Summary

CMIP5 promotes a standard set of model simulations in order to evaluate how realistic the models are in simulating the recent past; provide projections of future climate change on two time scales, near term (out to about 2035) and long term (out to 2100 and beyond); and understand some of the factors responsible for differences in model projections, including quantifying some key feedbacks such as those involving clouds and the carbon cycle.[25]

The multi-model-mean results from the CMIP5 data sets can be used to conduct physical climate change impact assessments. Using these data, organizations can screen the outcomes for the following variables in 2030, 2050 and beyond:[26]

- temperature
- precipitation
- drought
- storm surges
- wildfires
- hurricanes/cyclones
- typhoons
- floods
- water supply and demand
- sea level rise
- landslides

For organizations wishing to understand their stressed exposure to plausible physical climate change risks in the time frame from now until mid-century, what is likely to be most helpful is to consider scenarios consistent with RCP8.5 (which most closely reflects a business-as-usual pathway consistent with failure to properly implement NDCs).

b. Comparison of Relevant Signposts

The physical scenarios or RCPs from IPCC's AR5 reflect a range of GHG emissions and concentration pathways and consequent temperature outcomes. Modeling results, such as those contained in the CMIP5 archive, provide projected climate data for the range of variables for each of the RCPs.

Indicative outputs from the modeling of these two RCP scenarios are shown in Figure 8 (p. 24). These show some of the global mapping resources available to organizations, both from IPCC itself and from other organizations that have used IPCC modeling data to develop user-friendly mapping tools. When undertaking physical climate-related scenario analysis, organizations may find it useful to derive high-level data from such maps and to supplement this with site-, local- or region-specific data from the CMIP5 data set, and the results of relevant studies drawn from the many academic research papers that have informed the work of the IPCC. These will include research papers specific to individual regions or countries; to individual climate impacts/variables, including on the severity and frequency of extreme weather events; and to the impacts on specific industries (e.g., the impact on agricultural production within a specific country).

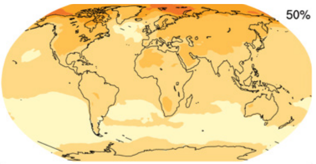
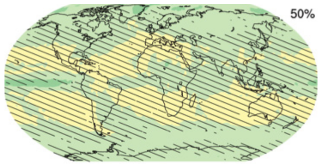
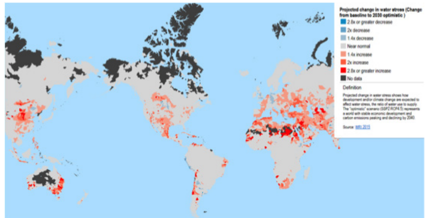
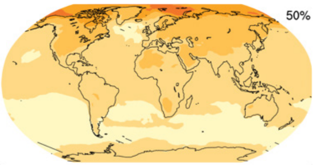
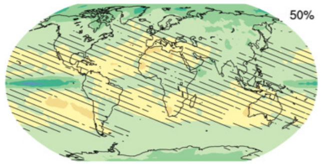
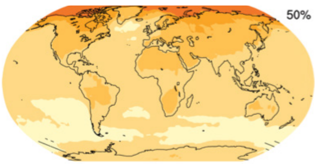
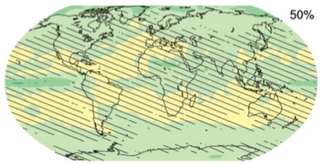
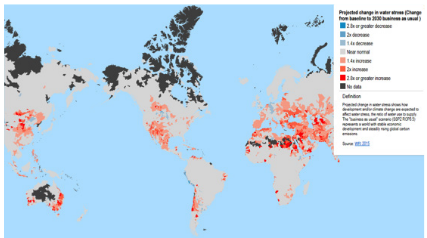
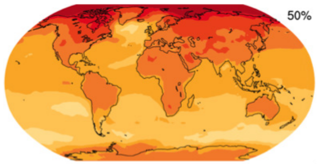
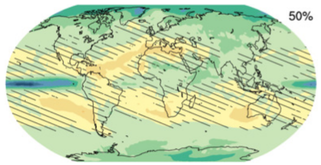
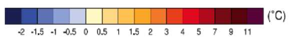
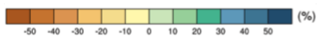
[24] CMIP was established by leading climate-modeling groups around the world in 1995 to promote a new set of coordinated climate model experiments (http://cmip-pcmdi.llnl.gov/). CMIP Phase 5 provided key results and access to data from 28 modeling centers that underpinned the IPCC 5th Assessment Report, generating projections of future climate change under each of the RCPs. The data within CMIP5 is publicly available at http://cmip-pcmdi.llnl.gov/cmip5/availability.html.

[25] Coupled Model Intercomparison Project 5 (CMIP5), CMIP5, 2016. http://cmip-pcmdi.llnl.gov/cmip5/.

[26] Note: some variables, such as wildfires, also rely upon use of separate data sets outside CMIP5.

Figure 8

Comparison of Relevant Signposts within Physical Climate Scenarios

	Key Drivers/Signpost			
	Surface Temperature Change	**Precipitation and Water Supply**		**Sea Level Change**
	Indicative change in average surface temperature (2016-2035 and 2046-2065)	Indicative precipitation maps (2016-2035 and 2046-2065)	Indicative water supply and demand map 2030	Projected ensemble mean sea level change (model projection averages) from 1986-2005 to 2081-2100
IPCC 5AR RCP 4.5	Temperature change RCP4.5 in 2016–2035: annual 	Precipitation change RCP4.5 in 2016-2035: annual 	 Taken from: WRI (2016), Aqueduct Water Risk Atlas (www.wri.org/applications/maps/aqueduct-atlas/)	Maps detail global variations in sea level rise, with darker indicating the largest increase. In RCP 4.5, sea level rise peaks at 0.3m in some regions. Increases are particularly concentrated around the 30° regions, while Antarctic region shows the smallest change.
	Temperature change RCP4.5 in 2046-2065: annual 	Precipitation change RCP4.5 in 2046-2065: annual 		
IPCC 5AR RCP 85	Temperature change RCP8.5 in 2016-2035; annual 	Precipitation change RCP8.5 in 2016-2035; annual 	 Taken from: WRI (2016), Aqueduct Water Risk Atlas (www.wri.org/applications/maps/aqueduct-atlas/)	Maps detail global variations in sea level rise, with the darkest colours indicating the largest increases. In RCP 8.5, sea level rise peaks at 0.8m in some regions. Increases are particularly concentrated in the Southern Hemisphere. There are some small areas which experience reductions in sea level.
	Temperature change RCP8.5 in 2046-2065; annual 	Precipitation change RCP8.5 in 2046-2065; annual 		
Scale				

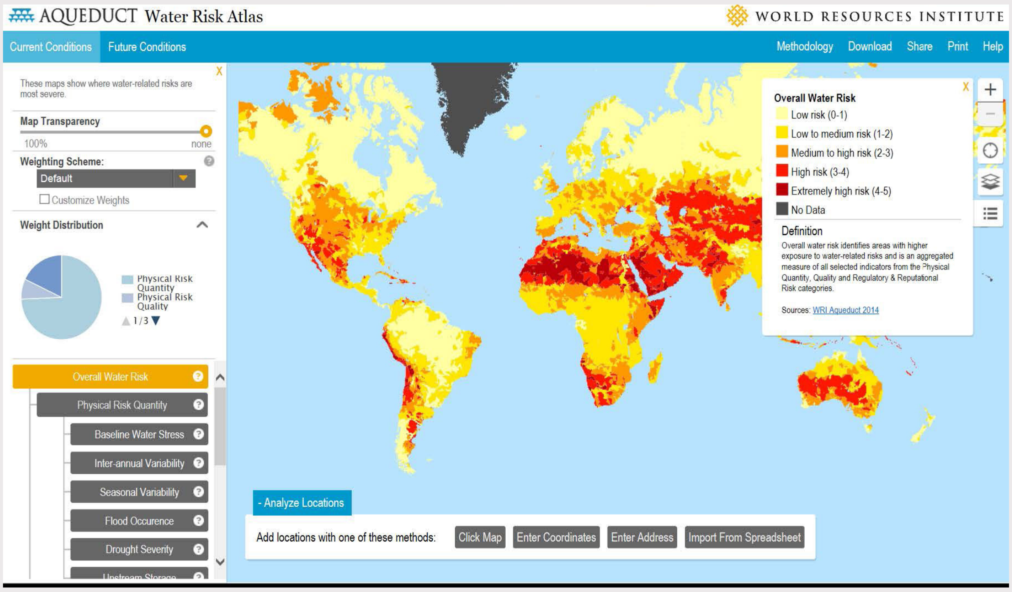
Source: IPCC, Annex I: Atlas of Global and Regional Climate Projections Supplementary Material RCP4.5 and RCP 8.5 [van Oldenborgh, G.J., M. Collins, J. Arblaster, J.H. Christensen, J. Marotzke, S.B. Power, M. Rummukainen and T. Zhou (eds.)]. 2013. In: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Available from www.climatechange2013.org and www.ipcc.ch.

c. Available Assessment Tools & Resources

In addition to the modeling results from applying the IPCC RCP scenarios shown above, drawn from the CMIP5 data set, a number of other tools are available to organizations to support their assessments of physical climate impacts and risks at global, regional, national, and local levels.

The WRI Aqueduct Atlas (Figure 9) is a risk-mapping tool that "helps companies, investors, governments, and other users understand where and how water risks and opportunities are emerging worldwide. The Atlas uses a robust, peer-reviewed methodology and the best-available data to create high-resolution, customizable global maps of water risk."

Figure 9
WRI Aqueduct Water Risk Atlas



Source: World Resources Institute (WRI). Aqueduct: Measuring and Mapping Water Risk. 2016. http://www.wri.org/our-work/project/aqueduct.

In addition to the WRI Aqueduct tool, other tools include the following:

- The WBCSD Water Tool[27] is a multifunctional resource for identifying corporate water risks and opportunities, including a workbook (for site inventories, key reporting indicators, and metrics), a mapping functionality, and Google Earth compatibility. The tool is intended to support organizations operating in multiple countries, whether they are new to water management or as part of a long-term resilience strategy. Organizations can compare sites on the basis of water availability, sanitation, population, and biodiversity.
- The UN Food and Agriculture Organization GAEZ Agri tool data portal is based on the Global Agro-Ecological Zones (GAEZ) methodology for assessing agricultural resources and potential.[28] The data portal is a collection of databases and study results, including the option for visualization. The tool was updated in 2014 to take account of the RCPs, developed for the IPCC's AR5, that enable users to forecast changes in yields, production, and other outputs due to climate change.

[27] http://old.wbcsd.org/work-program/sector-projects/water/global-water-tool.aspx
[28] http://gaez.fao.org/

An increasing number of national governments and national meteorological offices are making projections of climate change at a local/national level and are conducting assessments and preparing toolkits that can form reference points and provide resources for use by organizations. Examples include:

- The UK Climate Impacts Programme (UK CIP) has gathered historical climate records and future climate projections. Climate projections cover low-, medium- and high-emissions scenarios and can be viewed through an online user interface and associated briefing report. The UKCP09 Weather Generator provides projections of future daily climate using 5km data baseline from 1961-1995, producing projections for specific future time periods.
- The U.S. Interagency Archive of Downscaled Climate Data and Information provides an archive of simulated historical and future climatology and hydrology; it is maintained at Lawrence Livermore National Lab by a consortium of federal and non-federal partners. Information available from this archive is free and open to all.
- In France, climate research is led by the program Management and Impacts of Climate Change (GICC). Meteo-France is the primary provider of climate projections out to 2100, covering temperature, precipitation and wind speeds, aligned with the IPCC's RCPs. Projections are provided for the medium term (2021-2050) and long term (2071-2100). Using regionalized models, it has been possible to achieve a resolution of around 12km.
- Similar resources are available in other countries including, but not limited to, Australia, Canada, Germany, Japan, the Netherlands, and South Africa.

E Glossary

Adaptation: Anticipating the adverse effects of climate change and taking appropriate action to prevent or minimize the damage they can cause or taking advantage of opportunities that may arise.[29]

Business-As-Usual (BAU): Business-as-usual projections are based on the assumption that operating practices and policies remain as they are at present. Although baseline scenarios could incorporate some specific features of BAU scenarios (e.g., a ban on a specific technology), BAU scenarios imply that no practices or policies other than the current ones are in place.[30]

Carbon Capture and Storage (CCS): A technology that can capture carbon dioxide (CO_2) emissions produced from the use of fossil fuels in electricity generation and industrial processes and store the CO_2 deep underground, preventing the CO_2 from entering the atmosphere.[31]

Emissions Scenario: A plausible future pathway of man-made emissions (e.g., greenhouse gases and other pollutants,) that can affect climate. These pathways are based on a coherent and internally consistent set of assumptions about determining factors (such as demographic and socioeconomic development, technological change) and their key relationships.

Energy Transition: A shift from a system currently dominated by mainly fossil-fuel based energy toward a system using a majority of low-emissions and renewable energy sources, and maximizing opportunities for increased energy efficiency and better management of energy demand.

Fifth Assessment Report (AR5): Report published by the IPCC in 2014 that provides an update of knowledge on the scientific, technical and socio-economic impacts of climate change.

General Circulation Models (GCM): These are numerical models representing physical processes in the atmosphere, ocean, cryosphere, and land surface.

Greenhouse Gas (GHG): These are a variety of gases that have the ability to trap heat when emitted within the atmosphere. Some of the most common GHGs are carbon dioxide, methane, nitrous oxide, and fluorinated gases.

Integrated Assessment Models (IAM): These models attempt to integrate knowledge from two or more domains of expertise or academic disciplines. They are constructed to address climate change by tracking emissions, the concentration of greenhouse gases in the atmosphere as well as other carbon sinks, temperature and other climate impacts arising from increased concentrations of greenhouse gases in the atmosphere, and damages resulting from those climate impacts. Emissions follow from economic behavior, and policies scenarios can be hypothesized to affect emissions along a number of dimensions.

Intended Nationally Determined Contribution (INDC): INDCs outline national efforts towards low emissions and climate resilient development in pursuit of the United Nations Framework Convention on Climate Change's objective and represent one of the main deliverables of the Paris Agreement. Following ratification of the Paris Agreement, INDCs are now known as NDCs; see Paris Agreement.[32]

A
Introduction

B
Scenario Analysis

C
Applying Scenario Analysis

D
Publicly-Available Climate-Related Scenarios

E
Glossary

F
References and Further Reading

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[31] Carbon Capture and Storage Association, "What is CCS?" 2016. http://www.ccsassociation.org/what-is-ccs/.

[32] UNFCCC, Synthesis Report on the Aggregate Effect of Intended Nationally Determined Contributions (INDCs). 2013. http://unfccc.int/files/focus/indc_portal/application/pdf/synthesis_report_-_overview.pdf.

International Energy Agency (IEA): An autonomous organization that works to ensure reliable, affordable and clean energy for its 29 member countries and beyond. The IEA has four main areas of focus: energy security, economic development, environmental awareness, and engagement.

IPCC: Intergovernmental Panel on Climate Change. An international forum of experts established in 1988 and used by the United Nations to undertake periodic assessments that address how climate will change, what its impacts may be, and how we can respond.[33]

Land Use/Land Use Change/Forestry (LULUCF): A greenhouse gas inventory sector that covers emissions and removals of greenhouse gases resulting from direct human-induced land use, land-use change, and forestry activities.[34]

Mitigation: Refers to efforts to reduce or prevent emission of greenhouse gases. Mitigation can mean using new technologies and renewable energies, making older equipment more energy efficient, or changing management practices or consumer behavior.

Organizations: Unless otherwise specified, the use in this report of the term "organizations" refers to both financial and non-financial organizations.

Paris Agreement: In 2015, Parties to the UNFCCC agreed in Paris to keep the global temperature rise this century well below 2°C above pre-industrial levels and to pursue efforts to limit the temperature increase even further to 1.5°C. The agreement requires all Parties to put forward "Nationally Determined Contributions" (NDCs). There will also be a global stocktaking every five years to assess the collective progress towards achieving the agreement and to inform about further individual actions by Parties.[35]

Physical Risks: Risks associated with physical impacts from climate change that could affect carbon assets and operating companies. These impacts may include "acute" physical damage from variations in weather patterns (such as severe storms, floods, and drought) and "chronic" impacts such as sea level rise, and desertification.

Pre-industrial Levels: Pre-industrial average temperature using an 1850-1900 reference period.

Representative Concentration Pathways (RCPs): Four independent pathways comprising sets of projections of radiative forcing that serve as inputs to climate modeling, pattern scaling and atmospheric chemistry modeling. These are based on the forcing of greenhouse gases and other forcing agents.

Scenario: A plausible description of how the future may develop based on a coherent and internally consistent set of assumptions about key driving forces (e. g., rate of technological change, prices) and relationships. Note that scenarios are neither predictions nor forecasts, but are useful for providing a view of the implications of developments and actions.[36]

Single Simplified Climate Model: Referred to as 'Simple Climate Models' in the IPCC Second Assessment Report and used to provide projections of global mean temperature and sea level change in response to the IS92 emissions scenarios and carbon dioxide stabilization profiles.

[33] Intergovernmental Panel on Climate Change (IPCC), 2014: Annex II: Glossary [Mach, K.J., S. Planton and C. von Stechow (eds.)]. In: Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland, pp. 117-130. https://www.ipcc.ch/pdf/assessment-report/ar5/syr/AR5_SYR_FINAL_Glossary.pdf.

[34] Ibid.

[35] United Nations Framework Convention on Climate Change, "The Paris Agreement." 2016. https://unfccc.int/paris_agreement/items/9485.php.

[36] Intergovernmental Panel on Climate Change (IPCC), 2014: Annex II: Glossary [Mach, K.J., S. Planton and C. von Stechow (eds.)]. In: Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland, pp. 117-130. https://www.ipcc.ch/pdf/assessment-report/ar5/syr/AR5_SYR_FINAL_Glossary.pdf.

Transition Risks: Risks related to the transition to a lower-carbon economy. The risks can be grouped into four categories: policy and legal risk; technological risk; market risk (e.g., consumer preferences); and reputational risk.

Value Chain: Terminology used to describe the upstream and downstream life cycle of a product, process, or service, including material sourcing, production, consumption and disposal/recycling. Upstream activities include operations that relate to the initial stages of producing a good or service, e.g., material sourcing, material processing, supplier activities. Downstream activities include operations that relate to processing the materials into a finished product and delivering it to the end user (e.g., transportation, distribution and consumption).

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