S&P Global
Ratings

White Paper

Scenarios Show Potential Ways Climate Change Affects Creditworthiness

July 25, 2024

Editor's Note: Here, S&P Global Ratings presents plausible long-term scenarios to help illustrate the potential impacts of climate change on credit transmission channels and ultimately on creditworthiness. We incorporate takeaways from climate scenario analyses we have conducted, with the aim of providing possible common ground for similar analyses in the future.

This report does not constitute a rating action.

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As S&P Global Ratings describes in its White Paper: Assessing How Megatrends May Influence Credit Ratings, published April 18, 2024, climate change is a megatrend that can have material impacts on the creditworthiness of issuers and debt instruments. It is also one of the key risks we identify in our credit conditions publications (see www.spglobal.com/creditconditions). The impacts could manifest through:

- **Climate transition risks**, associated with the pace and extent of efforts to reduce greenhouse gas emissions and limit the global temperature rise to well below 2 degrees Celsius (2 C); and
- **Physical climate risks,** stemming from rising global temperatures, which the Intergovernmental Panel On Climate Change (IPCC) reports will result in increasingly frequent and severe physical climate hazards, such as wildfires, storms, and flooding; and chronic events like changing temperature and precipitation patterns, as well as rising sea levels.

Why it matters

The vast majority of countries have made commitments to keep global warming well below 2 C by the end of this century compared with pre-industrial levels, and to pursue efforts to limit the increase to 1.5 C, as per the Paris Agreement. We believe these commitments, if they result in measures leading toward significant emissions reductions, would likely transform many issuers' operating models, notably as economies lessen their reliance on fossil fuels.

For physical climate risks, the timing and potential magnitude of harm associated with climate hazards and events can be difficult to estimate. In addition, the impact of other factors, such as whether investments in adaptation and resilience will be effective, adds to uncertainty about how such events may influence creditworthiness, should they occur.

What we think and why

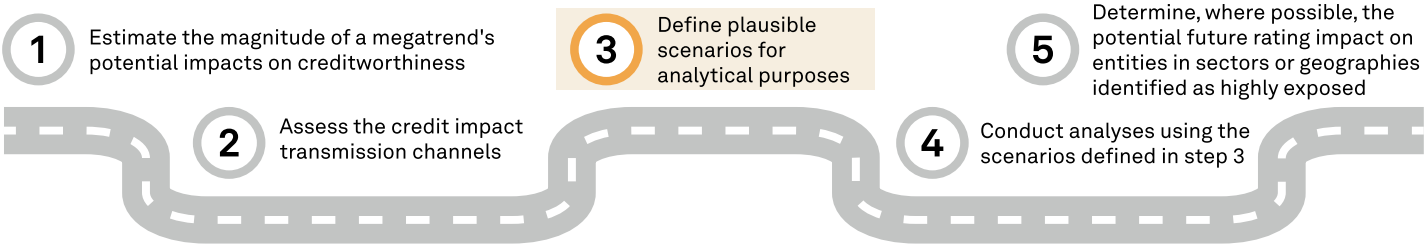
Clarity on how and when climate transition and physical climate risks are transmitted to creditworthiness is generally low, since the transmission channels tend to be indirect and vary across sectors.

Scenario analysis can help deepen understanding of how transition and physical climate risks in different sectors or regions may evolve over time and affect ratings. This type of analysis is particularly useful when uncertainties are high (as is generally the case for climate risks), since it can provide insight on a range of possible outcomes and highlight potential vulnerabilities.

Here, we define plausible scenarios for analytical purposes--three for climate transition risks, and four for physical climate risks--in line with Step 3 of our five-step process to assess the credit materiality of megatrends in "White Paper: Assessing How Megatrends May Influence Credit Ratings."

Chart 1

The road to credit materiality: Five steps from a megatrend to credit rating



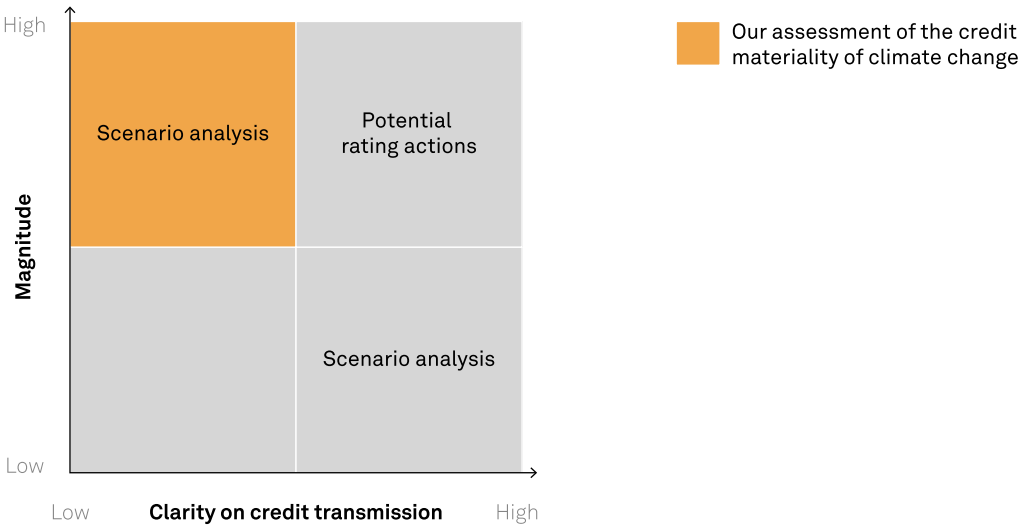
Source: S&P Global Ratings.

The Role Of Scenario Analysis

The impacts of a megatrend like climate change could be material to creditworthiness. For such credit materiality to be high (see chart 2: top right quadrant), and therefore potentially lead to a change in a rating or outlook, both the magnitude and clarity of credit transmission need to be sufficiently high (see White Paper: Assessing How Megatrends May Influence Credit Ratings). A combination of high magnitude events and low clarity of possible credit transmission channels underpins the need to understand the potential impacts of megatrends on creditworthiness. We do this using scenario analysis.

Chart 2

Assessing a megatrend's credit materiality



Source: S&P Global Ratings.

Scenario analyses can take various forms and use different analytical factors. For sectors and geographies we consider to be typically more exposed to climate-related risks, we will consider various factors taken from our sector-specific rating methodologies. Scenario analyses can range from simple sensitivity tests to analyze the effect of changes in one variable, to more-complex scenarios that take into account second-order effects or assumed changes in the macroeconomic environment.

Assumptions on climate transition risks described in this article are largely based on scenarios developed by S&P Global Commodity Insights, and our own interpretation of the scenarios. We complement these energy transition-focused scenarios with physical risk scenarios. For physical climate risks, estimating the timing and manifestation of impacts associated with climate hazards is quite challenging, including other dynamics, such as whether adaptation and resilience investments are effective. This contributes to uncertainty about the precise transmission channels to creditworthiness, should those climate hazards occur.

Scenario analysis can indicate potential inflection points. This refers to conditions in which climate-related credit risk drivers may affect our ratings beyond what we already assume. It can also indicate the likely magnitude of potential credit impacts for specific asset classes.

Scenarios are not forecasts, however. They are plausible descriptions of possible future states of the world that can inform us on key risks and their impacts, without necessarily attributing a probability to their realization. As clarity of transmission increases, and we move toward the upper right quadrant of chart 2, one of our plausible scenarios--or other scenarios--could become part of our base case; therefore, we would consider the assumptions in those scenarios in our rating analysis.

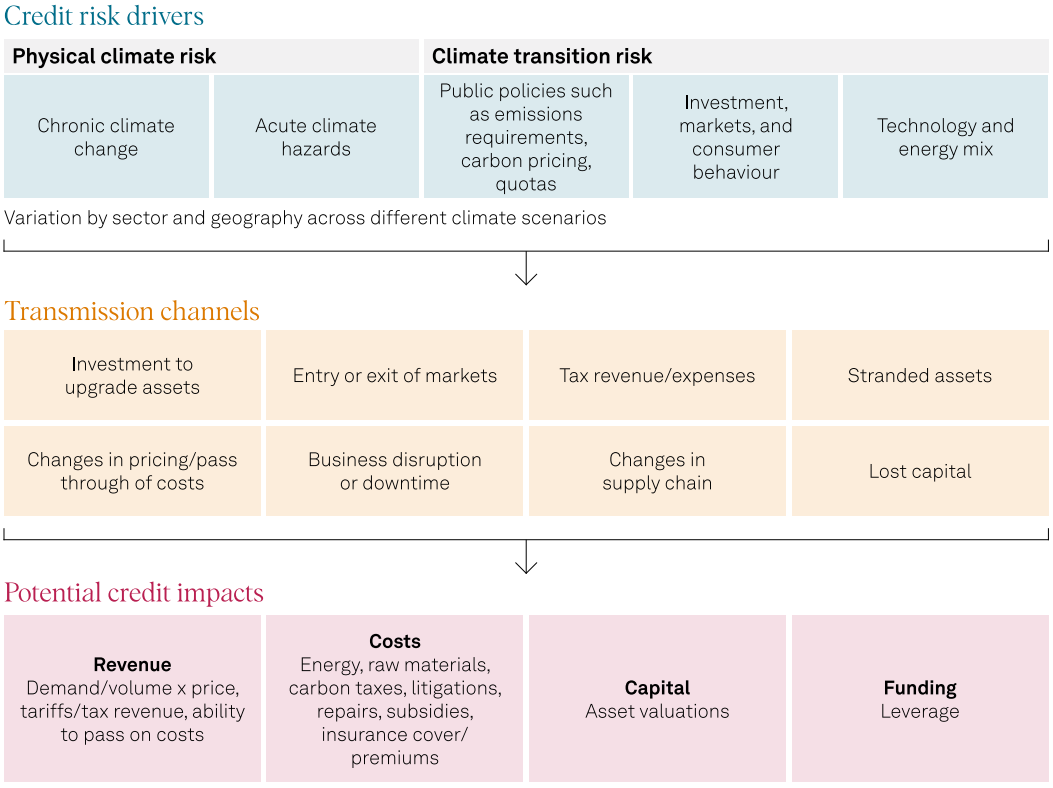
Defining Plausible Scenarios For Our Analysis

Here we present a sample of scenarios and illustrate the potential ways in which future changes in climate transition and physical climate risks might affect credit quality and, ultimately, ratings.

These scenarios are not exhaustive--and are not the only scenarios we may consider--but provide a starting point when analyzing climate-related credit transmission channels. We recognize that there are other published scenarios from a wide range of institutions, some of which follow similar narratives either in part, or in full, and all with their own unique assumptions and modelling techniques (such as the International Energy Agency, NGFS, or IPCC). Each may have different sectoral and/or geographic scopes, or are focused on different stakeholder groups. All can offer their own perspectives on how any given climate scenario might unfold.

Chart 3

How climate-related credit risk drivers can transmit to potential credit impacts



Source: S&P Global Ratings.

Unpacking The Credit Risk Drivers In Our Scenarios

Many aspects of the climate transition are still evolving--for instance technology, public policy, and consumer behavior--and can develop at different speeds and sometimes in different directions between regions.

At the same time, we believe that physical climate risks, whether chronic or acute, will materialize irrespective of today's policy choices. Here, we explore some of the main reasons why climate transition and physical risks are critical to our analysis and sources of uncertainties we have been considering.

Transition risks: Reducing carbon emissions implies policy, technology, and demand shifts

Decarbonization efforts require systemwide changes in terms of technology and practices that affect all parts of the economy, either directly or indirectly. Unlike during past industrial revolutions, the initial reason for change has not been technological advancement, but rather the negative economic impacts associated with rising carbon emissions.

Where environmentally friendly technology is not competitive, decarbonization efforts are most likely to come from a shift in policy and thus demand. Yet this will differ according to countries' constraints and priorities.

Policies and shifting preferences to move toward a low carbon economy are linked to the prospect of more frequent and severe climate hazards. Mounting economic losses from physical climate risks are likely to highlight the benefits of investing in adaptation (see "Investment In Climate Adaptation Needs Have High Returns On Growth," Jan. 10, 2024). However, they also increase the focus on decarbonization to avoid the worst impacts of climate change in the long term, where possible. How decarbonization is prioritized by different stakeholders will ultimately translate into changes in demand via policymaking and consumer preferences.

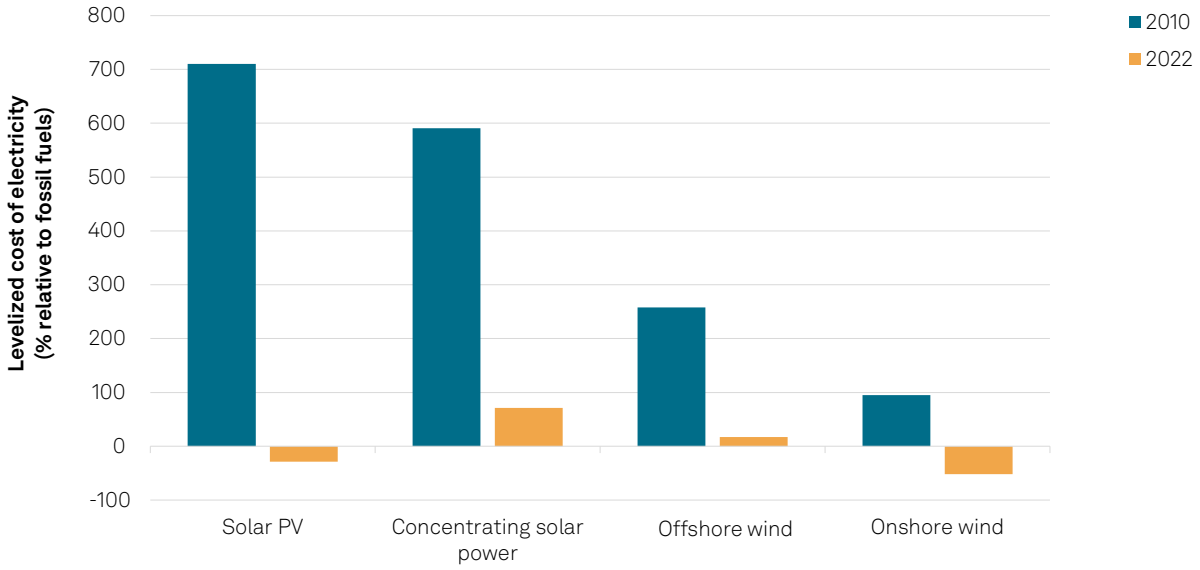
Changes in policy and preferences in support of decarbonization prompt adjustments on the supply side. This typically occurs through creating incentives to reduce the carbon intensity of production processes or imposing costs on certain activities. It takes time to upgrade and replace existing capital and implement new technologies, but policy can speed up this process (see "Shifting Green Growth Narratives Are Fostering The Transition To Net Zero," March 24, 2024).

The scale and pace of decarbonization is likely to be uneven across countries and sectors. This is partly because of diverging priorities, varying degrees of fossil-fuel reliance, uneven development trends, and different policy constraints. This could result in diverging international and domestic competitive pressures, highlighting distributional aspects of climate transition risks. How fast large emerging markets like China and India develop, and with which type of power supply, will be a key determinant of future global emissions (see "Economic Research: Development Needs Explain Transition Costs In Emerging Markets," published July 24, 2024).

Shifts in relative prices can inform on and reinforce the speed of technologies or market shifts in either direction. Those shifts can result from emerging environmental policy, policies to adjust the energy mix, demand pressures, or technological change. For example, when low-carbon technologies become more cost competitive than their fossil-fuel equivalents, technology will likely be the key driver of change and can create its own demand, even without policy support (see chart 4).

Chart 4

Solar PV and onshore wind power sources have become more competitive than fossil fuels
Competitiveness of renewable energy relative to fossil fuels



PV--Photovoltaic. Sources: IRENA, S&P Global Ratings.

Where climate transition risks are visible, we may take a rating action. For instance, in January 2021, we revised our assessment of industry risk for oil and gas companies to moderately high from intermediate, which led to negative rating actions. The revision reflected our view of increased risk for the industry linked to the trajectory of oil and gas supply and demand, as well as the impacts of the increasing adoption of and transition to renewable energy alternatives to address climate change (see "The Change To The Industry Risk Assessment For Exploration & Production Companies And What It Means For Issuer Ratings," Jan. 25, 2021).

Physical climate risks: Disruption of economic activity is mainly through the supply side

Capital is destroyed when acute risks--such as storms and flooding--materialize, and productivity is impaired when chronic risk events--such as heatwaves or droughts--occur.

Such physical climate risks can affect demand indirectly by eroding wealth levels (such as when real estate value drops), inflationary pressures (like food shortages caused by drought), and changes in the geographic distribution of economic activity (for instance, due to tourism moving elsewhere). Without adaptation, under a slow transition, we estimate that, by 2050, up to 4.4% of the world's GDP could be lost each year because of worsening climate hazards (see "Lost GDP: Potential Impact of Physical Climate Risks," Nov. 27, 2023).

Worsening climate hazards are increasing the need for investments in adaptation and resilience, but progress on adaptation varies. Countries and companies' ability to adapt is uneven. Our research indicates that lower- and lower-middle-income countries are up to 4.4x more exposed to climate hazards than more developed economies and have the least capacity to cope and adapt. At the same time, while physical climate risks are on the rise, companies' progress on adapting to them still varies. Only about one-fifth of companies have an adaptation plan and less than half plan to implement their adaptation plans within the next decade, leaving some corporates vulnerable (see "Risky Business: Companies' Progress On Adapting To Climate Change," April 3, 2024).

Long-term relative losses in market shares and income levels could materialize where the impacts of climate hazards cannot be prevented. In situations where there is no climate adaptation and where there are limits to adaptation, such as inability to avoid sea-level rise due to economic and physical limitations, productive capacity is likely to weaken the most (see "Is Climate Change Another Hurdle To Economic Development?" Jan. 16. 2023). This could also result in policy changes that may affect asset value (for example, if areas where construction is prohibited are expanded due to flood risk).

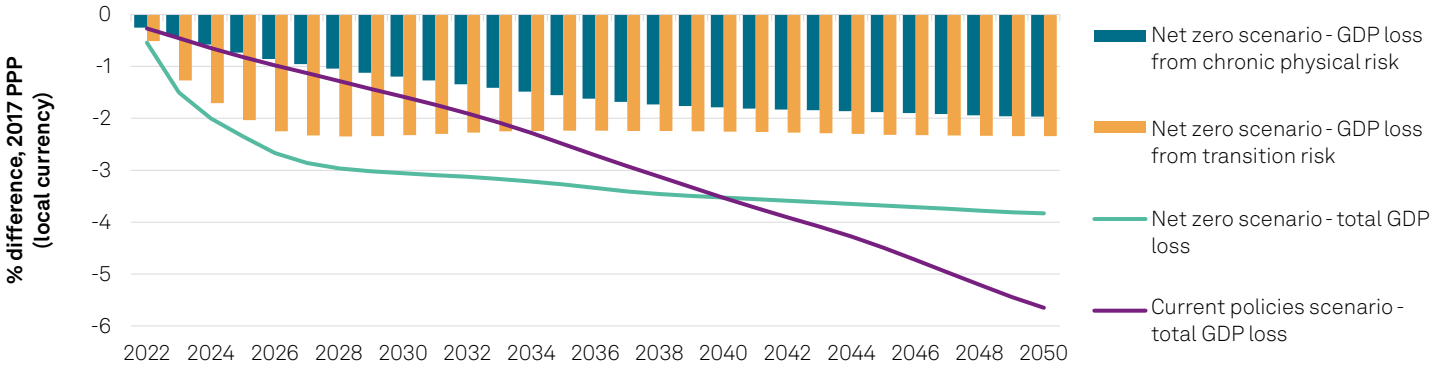
Decarbonization benefits materialize only over a long time frame

While often looked at in isolation, climate transition and physical risks are intrinsically linked across different scenarios. More rapid decarbonization will lead to less physical risks globally in the medium to long term. However, the related risk trends differ across time (see chart 5).

Chart 5

Economic losses from physical climate risks are rising while those from transition risks are more imminent

Potential GDP loss from climate-related risk



Note: Baseline refers to a world without climate risks; NGFS results from Phase III; in a current policies scenario, there is no additional transition risk, and the GDP loss is driven by physical risks. PPP--Purchasing power parity. Sources: NGFS, S&P Global Ratings.

Disruptive transition risks can be higher in the short term, but may gradually decrease once the transition has reached a more mature stage. Likewise, they may be more imminent in certain industries and in countries with stronger decarbonization commitments.

By contrast, the potential impacts of physical climate risks are set to increase as long as emissions continue, even if decarbonization is under way. This is because it can take several hundred years for greenhouse gases to leave the atmosphere completely, in the absence of carbon removal. As a result, a mix of climate transition risk and physical climate risk shocks are likely to materialize (see "Economic Research: Climate Change Will Heighten Output Volatility," Jan. 5, 2023).

Economies and sectors can be relatively more affected by one of the two risks, or by both in tandem, depending on their specialization and geographic location. Climate transition risks can be closely linked to economic concentration and policy, for instance with fossil fuel producers and combustion technology providers being more exposed if they have not diversified toward environmentally friendly technologies. Physical climate risks are, in particular, location and context specific. Water stress and extreme heat, for example, are projected to increase everywhere. However, countries with a higher temperature starting point as well as coastal areas and islands in the Caribbean and Asia-Pacific are set to be relatively more affected by climate change.

Climate-Related Litigation Is Another Evolving Risk

To date, climate litigation related to transition risk has not had a material impact on issuers' creditworthiness. However, given the trends in litigation activity, we expect climate-related lawsuits may be one of many mechanisms by which transition risk crystalizes for issuers. Such lawsuits carry the risk of damage to a company's reputation and financial profile, which can affect their creditworthiness. Recent wildfires leading to financial liabilities for some North American utilities illustrate rising credit risks that could result from the combination of regulations and the physical impacts of a changing climate (see "North American Wildfire Risks Could Spark Rating Pressure For Governments And Power Utilities, Absent Planning And Preparation," Nov. 29, 2023).

Most climate litigation is in the oil and gas sector, but similar lawsuits are being filed elsewhere. In fact, such lawsuits are increasingly being filed against companies in other sectors. We see a trend of so-called climate accountability lawsuits in the U.S., where mainly oil and gas companies are sued for their alleged role in climate-related damage and deception. A favorable ruling for plaintiffs in the U.S. could lead to similar lawsuits in the future, including in those U.S. states or countries facing costly impacts of climate change-related damage.

The overall volume of climate litigation has increased exponentially over the past 10 years, mainly focused on historical emissions-related damage. We believe the strategic and financial impact of climate litigation on companies could be significant but remains difficult to measure, in particular the direct and indirect costs. This makes it challenging to integrate climate litigation into credit analysis.

Despite a slowdown in new case filings since a peak in 2021, we expect the trend to continue. As the physical impacts associated with climate change become more pronounced, we believe more entities could face a rising number of courtroom challenges because of their strategies, action, or inaction, on dealing with climate change.

Please see "Climate Litigation: Assessing Potential Impacts Remains Complex" May 7, 2024, for more information.

Climate Transition Risks: Three Plausible Scenarios

Here, we look at **three energy transition scenarios** from S&P Global Commodity Insights' Energy And Climate Scenarios to demonstrate the potential effect they could have on credit transmission channels if they were to materialize.

Each scenario describes different potential climate outcomes, implying different policy, technology, and socioeconomic drivers and responses. For more on this, see S&P Global Commodity Insights' Energy And Climate Scenarios (2023). These narratives provide a range of plausible outcomes that help identify:

- A more rapid transition to decarbonization ("Green Rules"),
- How key risk drivers might change under a relatively unchanged status quo ("Inflections"), or
- A slower, less ambitious decarbonization path ("Discord").

Note that the scenarios do not consider how the physical impacts of climate change could occur over time (which we discuss in the next section).

The three energy transition scenarios in a nutshell

Green Rules: Reduction of global emissions by 56% by 2050; an implied temperature increase of 1.8 C by 2100. Leaders and governments take more steps to address energy and climate security. Rapid reduction of dependence on fossil fuels becomes a central element of policy in many key markets. Changes in energy use and supply lead to lower emissions. However, global net-zero emissions by 2050 remains out of reach.

Inflections: Reduction of global emissions by 24% by 2050; an implied temperature increase of 2.4 C by 2100. The status quo is left relatively unchanged. Ongoing changes across governments, markets, and society set a sustained long-term energy transition in motion. Fossil fuel use declines only slowly and progress is mixed across the world. Global cooperation is weak. Energy security goals differ across countries based on domestic politics, energy-import dependency, and policy constraints. Most key markets pursue policies that drive steady change in their energy mix, but many remain largely centered on fossil-fuel-based energy.

Discord: Reduction of global emissions by 9% by 2050; an implied temperature increase of 3.1 C by 2100. Geopolitical tensions worsen, and the world becomes increasingly divided and prone to conflict. This weighs on economic growth globally. Lower resources, policy, and market volatility weaken individuals, countries, and companies' capabilities to address climate change. The energy transition advances in some key countries, but by 2050, global greenhouse gas emissions remain high.

Table 1

Key metrics from S&P Global Commodity Insights' energy and climate scenarios

	GDP CAGR 2023-2050	2050 TPED (change versus 2023)	2050 fossil fuel % of TPED	Change in GHG emissions versus 2023	Global temperature change (by the year 2100)
Green Rules	2.60%	-3%	41%	-56%	1.8 C
Inflections	2.50%	15%	59%	-24%	2.4 C
Discord	2.00%	10%	68%	-9%	3.1 C

Data compiled July 2024. C--Degrees Celsius. CAGR--Compound annual growth rate. GHG--Greenhouse gas. TPED--Total primary energy demand. Source: S&P Global Commodity Insights.

Credit drivers evolve differently under the three scenarios, with varying potential impacts on creditworthiness

Climate risks arising from a transition to a low carbon economy are driven by shifts in three key factors: **policy, technology, consumer behavior**, or market pricing (see "Decarbonizing Hard-To-Abate Sectors: Credit Quality Implications And Six Key Observations," June 25, 2024).

These types of risk drivers can be influenced by other non-climate-related trends. For example, geopolitical developments can lead to abrupt policy changes (for example, sanctions and related energy-security initiatives) that affect companies' supply chains, costs, or revenue. Technological change (such as AI) can affect companies' investment decisions and valuations, and energy consumption. And consumer behavior can trigger rapid changes in business models (for example, many companies moved to online sales platforms during the COVID-19 pandemic).

Such trends are difficult to foresee, but understanding how they may combine in any given scenario can help assess the potential impact in the future on issuers' revenue, costs, or other financial metrics (see "Decarbonizing Metals Part Two: Financial Strength Mitigates Rising Credit Risk," June 3, 2024). They may be more pronounced for heavy emitting sectors, but with potentially broader indirect effects.

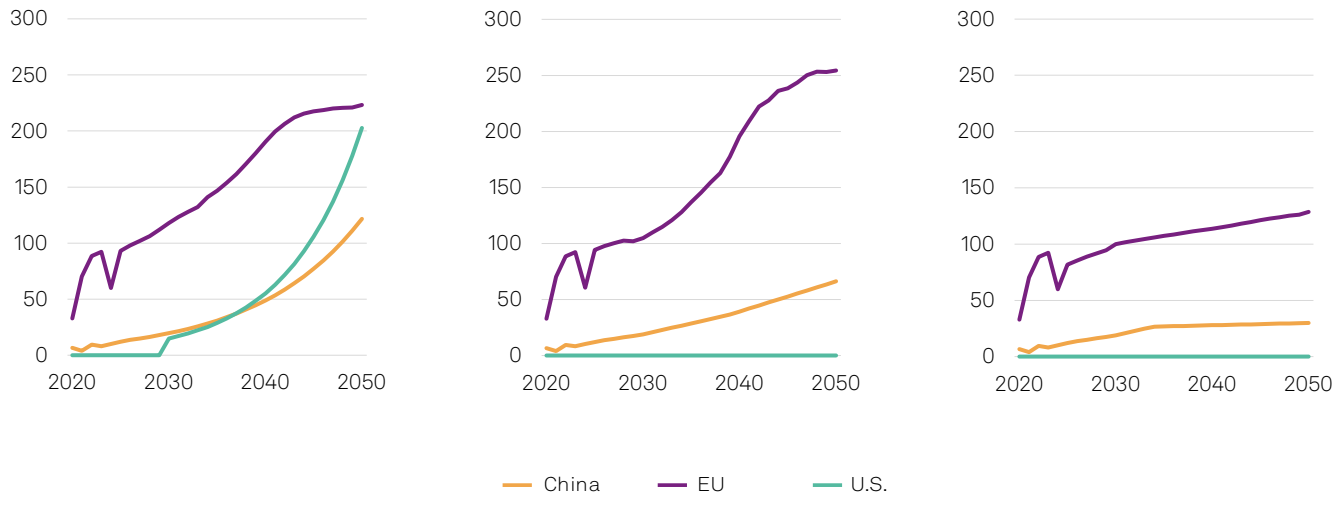
Potential impacts of public policies, regulations, and green industrial policies

Carbon pricing, investments and subsidies, and regulations are the main tools policymakers can use to steer the transition and manage its potential economic trade-offs (see "Economic Research: Green Spending Or Carbon Taxes (Or Both): How To Reach Climate Targets, And Grow Too, By 2030?" Nov. 4, 2021).

Table 2

How climate policy and regulations might develop under the three scenarios

Green Rules	Inflections	Discord
Strong policies, well implemented	← →	Weaker policies, poorly implemented
• Substantive progress in energy security in the 2020s provides a platform for broader clean energy industrial policies globally by 2030, affecting more geographies and sectors. • While still strained, international cooperation improves, with more consistent policies, including in carbon pricing and taxation.	• Increase in regulations and incentives that aim to address climate change, energy security, and volatility, particularly in developed markets, led by the recent pattern of policy in the EU, U.S., and China. • Longer-term geopolitical pressures mean global cooperation is only sub-optimal and carbon pricing uneven globally.	• Early 2020s' policy efforts falter in the degree to which they deliver meaningful progress. • Energy security policy outweighs climate considerations. • Political pressure increases uncertainty over the willingness to implement climate policy, increasing investment risks.
Example metric: Assumed carbon price in an Emissions Trading Scheme under each scenario ($ per metric ton of CO2, 2023 prices)		



CO2--Carbon dioxide. Sources: S&P Global Commodity Insights, S&P Global Ratings.

How changes in climate-related regulation might affect credit transmission channels

Significant changes in regulation are normally announced with time for affected industries to respond, but can be sensitive to changes in political regime and other macroeconomic factors. In some cases, companies might seek to move production to less regulated jurisdictions.

Carbon taxes or carbon emissions trading schemes can have a direct impact on costs and profitability for certain industries, or require additional clean investments, with indirect costs for customers. Greater coverage and cost of such regulations--such as in S&P Global Commodity Insights' Green Rules scenario--could be a significant credit transmission channel.

Regulations can also stimulate the development of certain technologies or restrict the use of existing technologies. This could change the shape of affected sectors and the competitive position of individual companies, potentially mitigating certain financial risks of newer technologies, or requiring new investments or write-downs of older assets. Manufacturers of more mature transition technologies could also benefit from such regulations. However, under a slower transition, such as in the Discord scenario, incumbent technologies may face lower risks, at least in the short to medium term.

More recently, public investment and subsidies have taken on a bigger role in decarbonization policy. For more on this, see "Shifting Green Growth Narratives Are Fostering The Transition To Net Zero," March 24, 2024. Large investment and subsidy packages can influence the size and location of private investment (see "The U.S. Inflation Reduction Act Highlights Diverging Approaches With Europe," March 1, 2023).

At the same time, green industrial policies are also adding to trade frictions and igniting retaliatory tariffs in a fragmented world, as described in the Discord scenario, and can affect supply chains.

Potential impacts of technology and the energy mix

Shifts in policies and investments to decarbonize could drive technological change, leading to changes in companies' costs, investments, and market positioning.

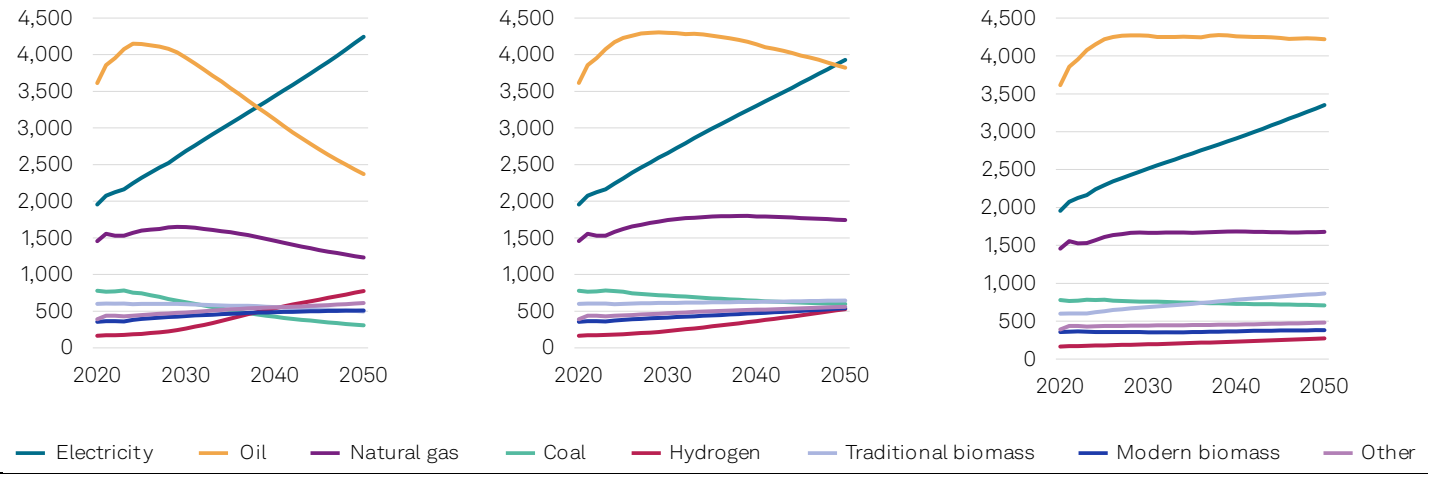
None of the three scenarios are predicated on a revolutionary breakthrough in technologies but the extent of change could affect creditworthiness.

Table 3

How the energy mix might develop under the three climate scenarios

Green Rules	Inflections	Discord
Faster, transformative	⟷	Slower, disorderly
• Oil demand peaks by the mid-2020s. coal demand is forced from industry. • Electricity becomes the dominant energy use by the 2040s. • Rapid resolution of project permitting and grid-connecting bottlenecks, accelerating deployment of renewables. • Hydrogen demand rises strongly across all major markets to 7% of energy demand in 2050.	• Oil demand peaks at about 2030 and declines slowly until 2050. • Electricity demand doubles between 2020 and 2050. • Renewable capacity additions accelerate following landmark legislation in major economies. • Hydrogen demand grows across most major economies, driven by a mix of energy security and climate interests.	• Demand for fossil fuels remains resilient. By 2050, the share of fossil fuels in the energy mix falls by 8%. • Electricity advances its share of final energy demand. • Renewables continue to expand, but are constrained by economic uncertainties. • Demand for hydrogen as an alternative to fossil fuels falters in a weak climate policy and investment environment.

Example metric: Global final energy demand mix (Mtoe)



Mtoe--Million tonnes of oil equivalent. Sources: S&P Global Commodity Insights, S&P Global Ratings.

How changes in technology and the energy mix might affect credit transmission channels

Technological advances in how energy is created and used have the potential to, directly and indirectly, affect almost all sectors.

Entities offering new low emissions-intensive products can eventually disrupt markets. This could lead to dislocation of traditional market players if demand shifts to more environment-friendly alternatives--especially if regulatory support is available--and may eventually become cost competitive even without such support. For other industries, this may lead to aggregate cost savings and increase consumers' purchasing power. But slower transitions, such as in the Discord scenario, might require less investment.

Improvements in energy efficiency typically alter energy demand in all three scenarios. Rising energy costs can also reduce demand for electricity, both from businesses and consumers. Some entities may respond by making investments in lower-energy solutions to remain competitive and mitigate the cost impacts, which may be more pronounced under the Green Rules scenario, for example.

Where technology is nascent, activities that rely heavily on energy or are very emissions intensive are exposed to rising energy costs, with differing abilities to pass those costs to customers. Companies in such a situation may decide to move production to where energy prices are lowest to stay competitive in global markets, potentially affecting the long-term prospects of local industries (such as cement, metal, and chemicals).

Shifts in how energy is stored, distributed, and consumed could also influence growth opportunities across sectors. For example, electrification could benefit electricity utilities at the expense of traditional energy companies and provide a more favorable starting point for the local rollout of renewable energy and related technologies.

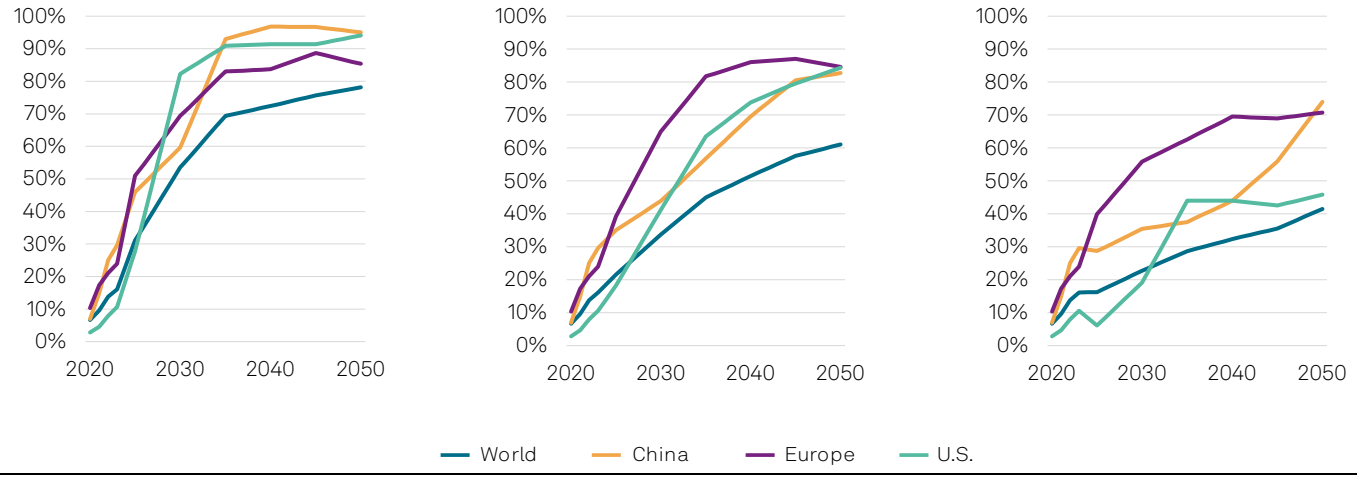
Potential impacts of markets, consumer behavior and long-term investments

Investment sentiment, how markets operate, and what consumers value could look very different under the three scenarios, with varying degrees of credit transmission and much uncertainty.

Table 4

How sentiment and other factors might develop under the three scenarios

Green Rules	Inflections	Discord
Clean demand drives change	⟷	Other priorities dominate
• Market trends and changes in social and consumer behavior contribute to a dramatic shift in global energy use and supplies away from fossil-based fuels and toward clean energy. • Firms are forced to choose more explicitly between a growth path with unclear profit mechanisms and a defensive path focused on market share rather than overall growth. • Allocation of funds to the energy transition in private markets continues to rise.	• Globalization evolves through a mix of reshoring, nearshoring, and the revision of long-established supply chains. • Capital markets continue to play a role in forcing change via financial risk reporting conventions and climate-related restrictions on hydrocarbon investments. • Credible and actionable emission reduction strategies influence equity valuations for Blue Chip/Fortune 500 companies.	• Facing overwhelming profit headwinds and policy schizophrenia, investors stop allocating funds to the energy transition and abandon most meaningful efforts. • Capital retreats from low-carbon sectors, with credit metrics determining access to debt and resulting leverage ratios determining access to equity. • Clean technology matures before it scales, while fossil fuel supply reduces before demand actually declines.
Example metric: Electric vehicle share of light vehicle sales		



Source: S&P Global Commodity Insights, S&P Global Ratings.

How markets, consumer behavior, and long-term investments might affect credit transmission channels

Shifting consumer preferences may result in higher demand for some technologies than for others, especially in transportation. For example, in all three scenarios, sales of electric vehicles increase to 35% of total light vehicle sales, or higher, by 2040. This growth will be spurred by customer demand, stronger regulations, and more favorable price dynamics in some scenarios. Such demand can shift entire markets, with potential winners and losers throughout the value chain and in different countries.

Changes in the energy system--fueled by climate or energy security policies--can affect investment in the longer term. Large fossil fuel producers are more at risk of stranded assets if their capital bases don't evolve in line with regulatory changes, potentially increasing credit risks (see "National Oil Companies In GCC Can Absorb The Energy Transition Impact For Now," March 8, 2023). Sectors with high energy costs also face tough investment decisions, and potentially be attracted to more favorable regulatory environments, thereby changing the shape of the market and supply chains. By contrast, entities that provide low-carbon solutions may see new opportunities as they move past proofs of concepts or receive support from public investments.

Market pricing can change. Willingness to invest and availability of capital are closely linked to how investors view climate risks, which in turn reflects regulatory and technology developments that could differ across the three scenarios presented here. In future scenarios, where there is uncertainty on regulation, investment flows to more novel solutions may be limited, with the focus remaining on existing or legacy technologies. At the same time, investors and central banks looking at the long-term need for decarbonization may price environment-friendly solutions more favorably. The cost of debt can weigh more heavily on assets requiring large amounts of capital expenditure, such as renewable energy projects. In addition, availability of competitive financing is a key factor for broader deployment of renewable energy capacity, especially in emerging markets.

Physical Climate Risks: Four Plausible Scenarios

We believe that--regardless of the amount of uncertainty--the level of historical greenhouse gas emissions means that many of the physical risks from climate change will materialize irrespective of today's policy choices. Here, we explore credit transmission channels of physical risks using **four climate scenarios based on the IPCC's Shared Socioeconomic Pathways (SSPs)**.

Shared Socioeconomic Pathways (SSPs) Defined

The IPCC's SSPs are a set of scenarios for projected greenhouse gas emissions and temperature changes. They incorporate broad changes in socioeconomic systems, including population growth, economic growth, resource availability, and technological developments:

- **SSP1-2.6 is a low emissions scenario** in which the world shifts gradually, but consistently, toward a more sustainable path. **This SSP aligns with the Paris Agreement's target** to limit the average increase in global temperature to well below 2 C by the end of the century. The global temperature is projected to increase by 1.7 C (a likely range of 1.3 C-2.2 C) by 2050 or by 1.8 C (1.3 C-2.4 C) by the end of the century.
- **SSP2-4.5 is a moderate emissions scenario**, consistent with a future with relatively ambitious emissions reductions but where social, economic, and technological trends don't deviate significantly from historical patterns. This scenario is close to countries' **current pledges** but falls short of the Paris Agreement's aim of limiting the global temperature rise to well below 2 C, with a projected increase of 2.0 C (1.6 C-2.5 C) by 2050 or 2.7 C (2.1 C-3.5 C) by the end of the century.
- **SSP3-7.0 is a moderate-to-high emissions scenario, akin to a slow transition**, in which countries increasingly focus on domestic or regional issues, with slower economic development and lower population growth. A low international priority for addressing environmental concerns leads to rapid environmental degradation in some regions. This SSP projects a global temperature increase of 2.1 C (1.7 C-2.6 C) by 2050 or 3.6 C (2.8 C-4.6 C) by the end of the century.
- **SSP5-8.5 is a high emissions (limited mitigation) scenario**, in which the world places increasing faith in competitive markets, innovation, and participatory societies to produce rapid technological progress and development of human capital as a path to sustainable development. This SSP projects the global temperature increase at 2.4 C (1.9 C-3.0 C) by 2050 or 4.4 C (3.3 C-5.7 C) by the end of the century.

Emissions are already locked in, with little divergence until about 2050. The implication is that entities will continue to face worsening climate hazards in the coming decades, and certainly

before the middle of this century, regardless of efforts to limit greenhouse gas emissions. From about midcentury--and as policies to reduce greenhouse gases are rolled out--warming trajectories in each scenario may diverge. This will influence the extent of warming and the frequency and severity of climate hazards attributed to man-made warming. This reflects the relative impacts of policy choices taken now and in the short term.

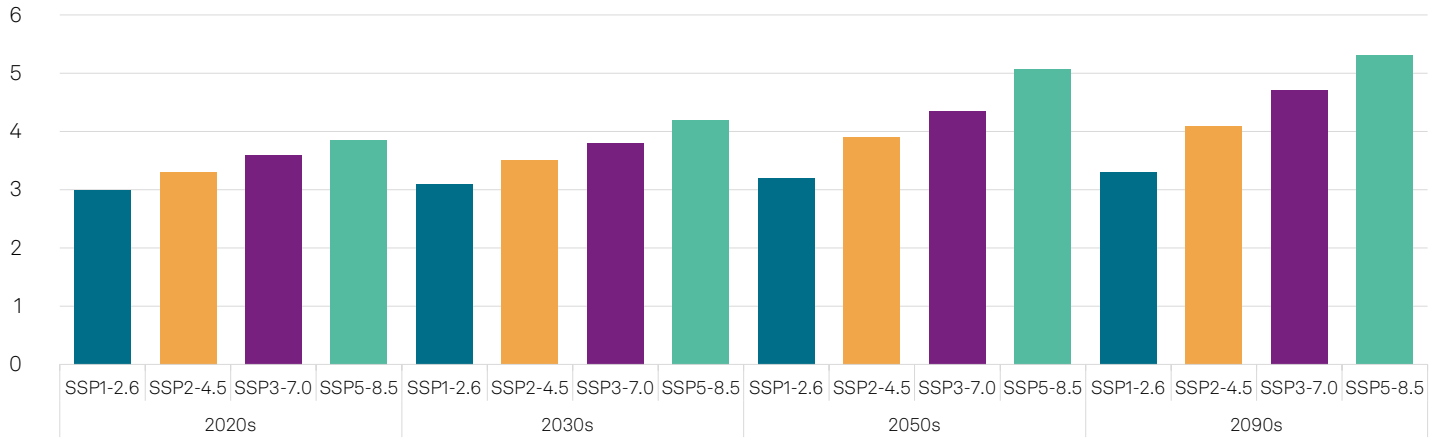
Between now and the midcentury, there is little difference in global temperature projections among the four climate scenarios. This is because of the time lag--of at least a decade--in the climate system's response to greenhouse gas emissions, while current emissions will continue to warm the planet over that period in the coming decades. Natural variability, which refers to changes in climate variables due to non-human causes, also has a role. In timescales of a few years, they mask the steady climate change signal, while for longer timescales, climate change is more clearly discernible for many climate hazards. For acute hazards, however, natural variability and climate change are both integral factors. This is because natural fluctuations are exacerbated to a greater extent by climate change. Given these uncertainties, selecting multiple scenarios can help explain different possible futures.

Assuming all actions pledged by countries are put into practice and policy, this aligns with a global temperature increase of between 2.4 C and 2.6 C by 2100, as reported by the United Nations Environment Programme. This projection is close to the scenario represented by SSP2-4.5. We use the four scenarios and multiple timescales to describe a range of outcomes (see chart 6), due to the inherent challenges and uncertainties associated with long-term projections. That said, there is also uncertainty about countries' current commitments to reduce greenhouse gas emissions and the resulting increase in the global average temperature.

Chart 6

Economies could see rising losses with time and with more warming

Percentage of world GDP at risk annually under four Shared Socioeconomic Pathways (SSPs) (%)



Note: GDP at risk represents the share of GDP that could be lost annually due to high exposure to physical climate risks, in the absence of adaptation to climate risk, without accounting for changes in the economic geography and structure and assuming all hazards occur every year. Sources: S&P Global Ratings, S&P Global Sustainable1 (2023).

How physical climate risks might affect creditworthiness

Climate hazards, such as storms, heatwaves, or floods, may compound one another. This means they lead to greater impacts--especially if they stretch entities' ability to respond to such climate shocks--because they occur at the same time or consecutively.

Compound climate hazards may amplify impacts and losses. For example, droughts--a chronic risk--increase the likelihood that torrential rains will result in floods shortly afterward, which is an

acute risk. The co-occurrence of events (or compound events) is already apparent in historical data. A recent example is the 2022 floods in Pakistan, which submerged one-third of the country and were caused by a combination of heavier-than-usual monsoon rains and a severe heat wave.

Compound climate events can exacerbate the impacts from previous events and increase economic losses. They can also trigger broader changes in the natural environment or in the socioeconomic space, such as supply chain disruptions, commodity price swings, migration of populations, and/or conflict.

Physical climate risks can also worsen ongoing economic weakness or cause systemic stress when interdependencies are high. For example, an increased likelihood of simultaneous crop failure in global breadbaskets could have a profound impact on food security and prices worldwide, affecting consumers in countries not exposed to those risks. If warming continues unabated--such as under S&P Global Commodity Insights' Discord scenario, where the global temperature increase exceeds 3 C by 2100--the frequency of climate hazards is also more likely to increase. This implies a greater frequency of compound events (like extreme heat and wildfires), particularly in more exposed regions. This is likely to increase the emphasis on, and importance of, investments in climate adaptation and resilience.

Physical climate risks and credit impact

The way that physical climate risks may influence creditworthiness can vary. The impacts may be direct or indirect and/or emerge over different timescales.

- **Direct impacts.** These include unexpected or increasing operating costs. Acute physical climate risks, such as flooding, can damage infrastructure and assets, and/or cause operational disruption, resulting in higher-than-expected investments to rebuild and adapt buildings, roads, and bridges, for example. Such climate events can also put pressure on health systems and reduce productivity of the workforce. Chronic climate-related changes--such as water or heat stress--may require development of alternative water supply resources to safeguard agricultural and energy production or investment in cooling technologies. They may also require modifications of construction materials to allow buildings to withstand higher external temperatures and longer periods of extreme heat conditions.
- **Indirect impacts.** These may materialize as even greater financial risks, including due to supply-chain disruptions and resulting short-term inflationary pressures; reduced access to capital; higher cost of debt; increased insurance premiums; reduced insurance coverage; litigation; or unforeseen stakeholder reactions to the climate event (political, regulatory, or legal for instance). Furthermore, adaptation through geographic economic and/or demographic changes could result from extreme heat conditions, leading to higher property prices in less exposed areas and rebuilding costs in exposed areas. These factors could strain governments' financial resources (for example by eroding tax bases due to job losses).

These impacts can be difficult to foresee and may be intensified by uncertainties. For example, depending on how and when climate hazards occur, the possible impacts would be influenced by various factors, such as the role of insurance coverage and the effectiveness of adaptation and resilience measures. The precise transmission channels to creditworthiness from physical climate risks are therefore often unclear. This is partly why only a small proportion of our ratings on nonfinancial corporates have changed as a result of physical climate risks (see "Why Climate Risks Are Changing So Few Corporate Ratings," April 12, 2023). Fixed or immovable assets--like public infrastructure with useful lifetimes spanning multiple decades--may be less able to adapt

to physical risks in the near term, thereby increasing replacement and insurance costs (see "Physical Climate Risk: How Will Challenging Credit Conditions Affect Resiliency And Adaptation To More Costly Climate Hazards In 2024?" Dec. 4, 2023). Despite this uncertainty, understanding how climate hazards may combine in any given scenario can help assess the potential direct and/or indirect impacts on issuers (see "Model Behavior: How Enhanced Climate Risk Analytics Can Better Serve Financial Market Participants," June 24, 2021).

Adaptation and resilience investments can reduce impacts of physical climate risks

Here we explore the rising importance of adaptation and resilience in the context of worsening climate hazards, in view of locked-in greenhouse gas emissions, and unevenness in the challenges jurisdictions face.

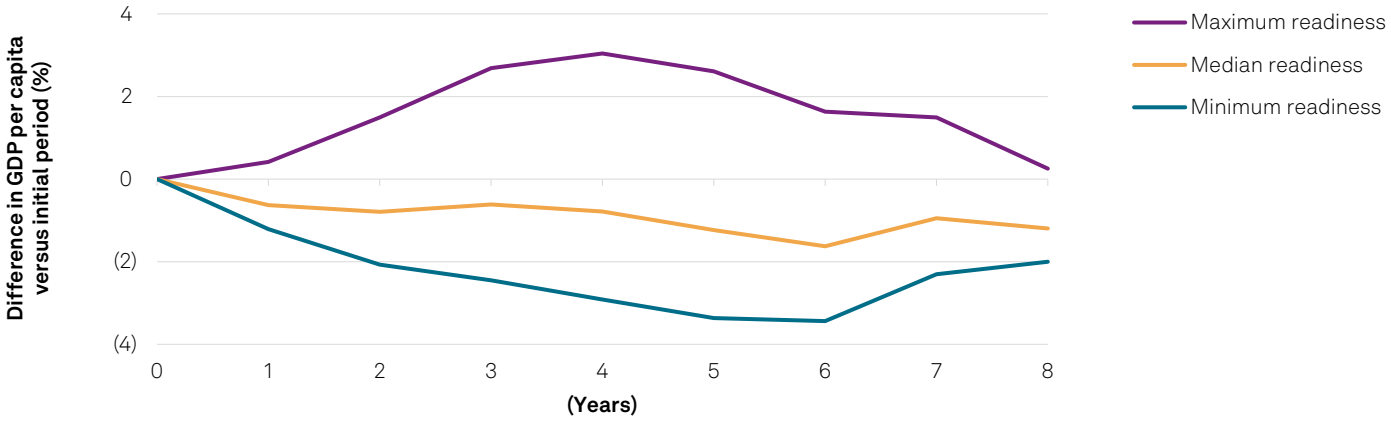
The impacts of rising global temperatures will not be evenly distributed. Lower- and lower-middle-income countries are more at risk than wealthier economies, and are less ready to cope (see "Lost GDP: Potential Impacts Of Physical Climate Risks," Nov. 27, 2023). They also face higher borrowing costs and have less access to financial markets. Financing debt in these countries poses greater credit risk for investors because higher macroeconomic and political activity increases uncertainty. Lagging investment in the technologies and interventions needed for climate adaptation is also widening the gap to advanced economies.

With this in mind, we believe climate-adaptation financing will become as important as climate transition financing in protecting wealth and lives over the next few decades (see "Crunch Time: Can Adaptation Finance Protect Against The Worst Impacts From Physical Climate Risks?" Jan. 13. 2023). In our view, adaptation is key to avoiding short- and long-term negative impacts on GDP. We believe that, when readiness to adapt is high, temperature increases will not have a long-lasting impact on GDP per capita, even in warmer climates (see chart 7 and "Investment In Adaptation Needs Have High Returns On Growth," Jan. 10, 2024). The implication is that, under scenarios of increased warming--such as the Discord scenario--delayed or no adaptation may increase the costs and amount of change required to adapt to climate change.

Chart 7

Countries with lower readiness display a long-lasting impact on GDP per capita

GDP per capita response over time to a 1 C annual average temperature rise from 24 C, by readiness



Note: The results describe the relationship of the variable shown with average annual temperature using a panel model estimation with country fixed effects and regional time fixed effects. We derive impulse response functions using local projections and controlling for lags and forwards of the temperature. Readiness as defined by ND-GAIN indicators. C--Degrees Celsius. Sources: Authors' calculations, S&P Global Ratings.

Slower decarbonization pathways may also make it more difficult to adapt to certain physical climate risks. Limits to adaptation--that is, the point at which objectives or system needs cannot be insulated from intolerable risks through adaptation (see Klein et al. 2014)--suggest some areas may be unable to be protected. An example is inability to protect low-lying islands from sea-level rise due to economic and physical limits, when expected costs exceed the impacts averted. This may be a particular challenge for more vulnerable countries, emphasizing the urgency of adaptation and resilience investments in the short term and under warmer scenarios ("Risky Business: Companies' Progress On Adapting To Climate Change," April 3, 2024).

Looking Ahead

There are many ways in which climate transition and physical climate risks could affect the creditworthiness of rated issuers and rated debt instruments.

We have identified some of the main credit transmission channels for climate transition and physical climate risks. These include business disruption and depreciation of capital (from chronic climate change and acute climate hazards), competitive pressures (public policies and technology), investment needs (due to transition and adaptation), and cost of capital (market pricing).

These channels exist in a world where companies and countries can adapt and respond to evolving climate-related risks. Yet all entities also face other pressures, ranging from managing supply chains amid geopolitical risks, to adjusting to higher interest rates and the need to invest in digitalization and AI (see "Global Credit Conditions Q3 2024: Soft Landing, Fragmenting Trajectories," July 1, 2024, to see all the risks we monitor).

Scenario analysis helps us understand the possible channels through which a megatrend such as climate change may influence creditworthiness. Scenarios are particularly useful when we have limited visibility of how risks may develop. The nature of the scenarios we may use, our approach to assessing their possible impacts, and the sectors we apply them to, will evolve over time. That process will be informed by increased visibility over policy choices, technological developments, and changes in customer preferences, as well as by actions taken by issuers to adapt and the idiosyncrasies of specific sectors, among other factors.

We don't view the scenarios presented in this exploratory article as exhaustive. Rather, they serve to provide common ground for future scenario analyses we may carry out, acknowledging that we may use other relevant climate scenarios. This allows us to revisit these initial considerations after gaining further insights and knowledge in the future, through our own research and data sources or through market engagement.

Related Research

- Climate Litigation: Assessing Potential Impacts Remains Complex, May 7, 2024
- Navigating Uncertainty: Physical Risk And U.S. Govts, April 23, 2024
- White Paper: Assessing How Megatrends May Influence Credit Ratings, April 18. 2024
- Risky Business: Companies' Progress On Adapting to Climate Change, April 3, 2024
- Shifting Green Growth Narratives Are Fostering The Transition To Net Zero, March 24, 2024
- Investment In Adaptation Needs Have High Returns On Growth, Jan. 10, 2024

- Physical Climate Risk: How Will Challenging Credit Conditions Affect Resiliency And Adaptation To More Costly Climate Hazards In 2024? Dec. 4, 2023).
- North American Wildfire Risks Could Spark Rating Pressure For Governments And Power Utilities, Absent Planning And Preparation, Nov. 29, 2023
- Lost GDP: Potential Impacts Of Physical Climate Risks, Nov. 27, 2023
- Is Climate Change Another Obstacle To Economic Development? Jan. 16, 2023
- Why Climate Risks Are Changing So Few Corporate Ratings, April 12, 2023
- Crunch Time: Can Adaptation Finance Protect Against The Worst Impacts From Physical Climate Risks? Jan. 13, 2023
- Climate Change Will Heighten Output Volatility, Jan. 5, 2023
- Economic Research: Green Spending Or Carbon Taxes (Or Both): How To Reach Climate Targets, And Grow Too, By 2030? Nov. 4, 2021
- Model Behavior: How Enhanced Climate Risk Analytics Can Better Serve Financial Market Participants, June 24, 2021
- The Change To The Industry Risk Assessment For Exploration & Production Companies And What It Means For Issuer Ratings, Jan. 25, 2021
- Climate Change Is A Global Mega-Trend For Sovereign Risk, May 15, 2014

External Research

- S&P Global Commodity Insights' energy and climate scenarios (2023)
- Bank For International Settlements, (BIS, April 2021) Climate-related risk drivers and their transmission channels, 39pp
- European Environment Agency (EEA), Assessing the costs and benefits of climate change adaptation, March 3, 2023.
- Klein, R.J.T., G.F. Midgley, B.L. Preston, M. Alam, F.G.H. Berkhout, K. Dow and M.R. Shaw, 2014: Adaptation Opportunities, Constraints, and Limits, in Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects; Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change Field, C.B., V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L. White (eds.)]. Cambridge University Press, Cambridge, UK and New York, NY, USA, pp. 899–943. ISBN 978-1107058071
- UN Environment Programme (UNEP; 2023) Adaptation Gap Report 2023: Underfinanced. Underprepared – Inadequate investment and planning on climate adaptation leaves world exposed. 112pp.

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Glossary

Creditworthiness is driven by ability and willingness to pay interest and repay debt in full and on time

Credit risk drivers are variables that have affected or may affect ability and willingness to pay through for example:

- Changing revenue,
- Changing costs, and thereby
- Changing cash flows that are needed to pay interest and repay debt.

Climate credit risk drivers are variables that include:

- Climate policy and regulation;
- Climate-related changes in sentiment and in financial markets, including changes in consumer purchasing behavior and the cost of and access to financial products;
- Physical climate risk changes and events; and
- Climate-related technological changes that can, for example, influence the relative economics of different products.

The credit transmission channel is the channel (s) or means through which a climate credit risk driver affects creditworthiness, often by changing cash flows.

For example, credit transmission channels of climate policy and regulation can include changes in revenue and costs; and through these, also changes in cash flows. Those changed cash flows affect creditworthiness. For example, a government policy to decarbonize its economy (which represents a risk to carbon-intensive entities) leads to the introduction of carbon taxes that increase costs. These new taxes result in a reduction of cash flows and a change in the creditworthiness of affected entities. The climate credit risk driver of decarbonization policy and CO2 tax regulation results in weaker creditworthiness for affected entities through the transmission channel of higher tax costs that result in lower cash flows.