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INVESTORS SERVICE

SECTOR IN-DEPTH
10 March 2020

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Climate scenarios vital to assess credit impact of carbon transition, physical risks

» **Carbon transition, physical risks to have increasing relevance to credit analysis.** We expect a more pronounced decarbonization trajectory and more frequent and volatile extreme weather in the future. However, there is a wide range of possible outcomes across both sectors and geographies. As a result, we use scenario analysis to help assess the credit impact for rated issuers.

» **For carbon transition risk, we use two scenarios to help assess the credit implications.** We use as our starting point a decarbonization pathway that is consistent with the IEA Stated Policies Scenario (STEPS). This scenario assesses the implications of stated national policy commitments under the Paris Agreement. In addition, as a test of rated entities' resilience to a more accelerated decarbonization pathway, we also use a second scenario consistent with the IEA Sustainable Development Scenario (SDS). We then apply a sector-by-sector approach to assess the implications of these scenarios on rated entities. For the oil and gas industry and the unregulated power sector, policies aimed at accelerating decarbonization can increase stranded asset risk, and impact government revenues. Other sectors, such as the automotive industry, may require a change in product mix.

» **For physical climate risks, we use a single scenario and primarily focus on the implications for the next 30 years.** The physical effects of climate change are largely locked in through 2050 because of the continued impact of historical emissions. It is not until about midcentury that we expect there to be a meaningful divergence in long-term global temperature changes and other physical hazards under different emissions scenarios, commonly referred to as representative concentration pathways (RCPs). In light of historical emissions patterns and to account for the risk of tipping points and feedback loops, we base our analysis of physical climate risks to 2050 on RCP 8.5, a high-emissions scenario.

» **Modeled climate outcomes under the RCP 8.5 pathway can be grouped into high, medium and low tiers of severity, based on analysis from Four Twenty Seven, a Moody's affiliate**. Even under the same RCP pathway, each climate model is constructed with a unique set of initial conditions, parameters and assumptions. As a result, each model projects different climate outcomes such as warming or rainfall. To illustrate the full range of possible scenarios for physical climate change in the near term, it is essential to consider the distribution of outcomes within and across models to identify potential alternative outcomes.

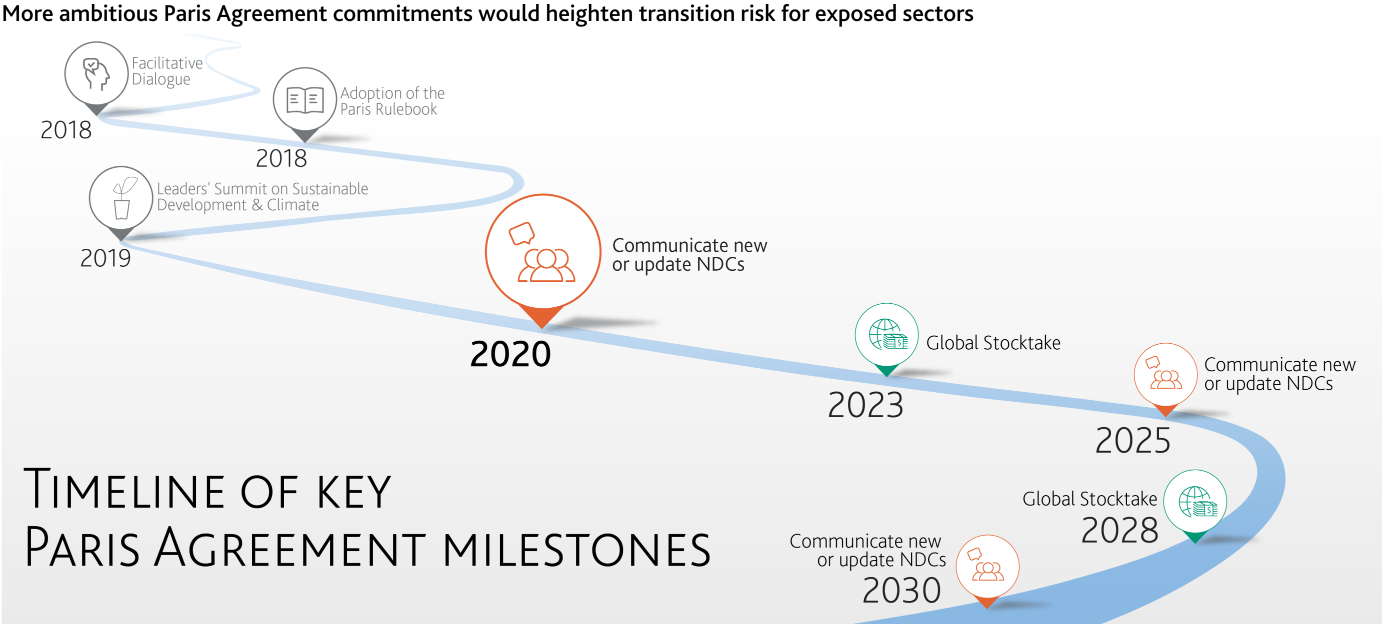
» **Integrating climate scenarios into our credit analysis process.** The credit impact of the energy transition and the physical risks of climate change will not be uniform across or within sectors. Consequently, climate scenarios are critical in providing consistent starting points for assessing the implications for rated entities across sectors globally. We first identify sectors that are most exposed to the risks highlighted by the scenarios and then assess the ways in which the risks indicated by the scenarios could transmit into a credit impact for issuers within those sectors. For example, our carbon transition assessment framework provides a tool for assessing the implications of transition risk under the IEA STEPS and SDS scenarios. This process provides a consistent way to understand at an entity level the possible implications of the scenarios and forms part of the credit analysis we undertake and which ultimately feed into our credit ratings.

Carbon transition, physical risks to have increasing relevance to credit analysis

The transition to a low-carbon economy and the physical effects of climate change manifesting in more severe weather events are becoming increasingly relevant for global credit markets. We expect decarbonization efforts to intensify over the coming decades, as the economics and political impetus underpinning the energy transition favor a shift toward renewables and other low-carbon processes and products. This could also lead to increased divergence in policy as some governments have now set long-term net zero emissions goals and are outlining road maps with interim targets. Paris Agreement signatories may decide to significantly ratchet up their nationally determined contributions (NDCs) following the first global "stocktake" of commitments in 2023 (see Exhibit 1), leading to a tightening of policy tools such as carbon prices or emission standards to achieve a more rapid decarbonization trajectory.

Technology and market dynamics can also change in a relatively short time span, as has been illustrated by the precipitous fall in lithium-ion battery prices over the past decade. According to Bloomberg New Energy Finance, the price of lithium-ion battery packs fell 85% from 2010 to 2018 (see "A Behind the Scenes Take on Lithium-ion Battery Prices," BloombergNEF, 5 March 2019). Increased electrification and the deployment of renewables and energy storage may happen faster than established energy companies are expecting, making it valuable to consider more rapid transitions.

Exhibit 1
More ambitious Paris Agreement commitments would heighten transition risk for exposed sectors



Sources: Moody's Investors Service, World Resources Institute

This publication does not announce a credit rating action. For any credit ratings referenced in this publication, please see the ratings tab on the issuer/entity page on www.moodys.com for the most updated credit rating action information and rating history.

Global mean temperatures are rising; eighteen of the 19 warmest years since 1800 have been recorded since 2001 (see Global Land-Ocean Temperature Index, NASA's Goddard Institute for Space Studies), which can contribute to more severe weather events, including heat waves and cyclones. The Intergovernmental Panel on Climate Change (IPCC) Special Report on the Ocean and Cryosphere in a Changing Climate (2019) projects a 2 degree Celsius increase in global mean surface temperature by 2050 relative to 1850-1900 for RCP 8.5. Extreme sea level events that occurred once per century are forecast to occur annually in many low-lying megacities and small islands by 2050. Furthermore, coastal hazards will intensify because of an increase in the average intensity of storms, magnitude of storm surge and precipitation rates of tropical cyclones. An expected acceleration in decarbonization policies and more severe weather could have a disruptive credit impact on sectors with high exposure to these trends. Some issuers may need to reorient their business models and balance sheets to mitigate and adapt to climate risks.

Our 2018 global environmental risk heat map identified 16 sectors with a collective $3.7 trillion of rated debt with very high or high exposure to carbon regulation, and 15 sectors ($8.0 trillion of debt) with high risk exposure to natural and man-made hazards or water shortages. Issuers that fail to reduce their exposure to transition or physical risk, or exhibit a lack of preparedness, could face weaker operating profiles, lower profitability, and heightened investor scrutiny. In extreme instances, asset write-downs and reduced cash flow may restrict access to funding altogether, impairing their ability to raise, service or refinance debt.

There is substantial uncertainty and a wide range of possibilities for the precise trajectory of decarbonization that the world will take, including country paths that may differ from one another. From a physical risk perspective, the nature of climate models means that they produce a range of potential outcomes for a certain type of extreme weather event in a given region, but they cannot indicate exactly when and where such events will happen.

In the face of these uncertainties, we use scenario analysis to better understand the relative positioning and strategic response of companies, governments and assets to both transition and physical risks that are possible. These scenarios describe plausible trajectories for decarbonization and plausible climatic outcomes against which to test the resilience of issuers in the most exposed sectors, including how exposed they are and what is their ability to adapt business models and policies over time to adjust for the possible outcomes.

Our credit analysis does not look over a specific time horizon and is intended to incorporate relevant credit considerations as far into the future as visibility permits. For climate risk assessment frameworks, we strike a balance between the need to assess a prolonged period during which the effects of climate change can crystallize and the reduced visibility, and hence limited impact, of extremely long time horizons on credit analysis.

Representative concentration pathways and shared socioeconomic pathways

To analyze physical risk, we refer to representative concentration pathways (RCPs) as adopted by the United Nations' Intergovernmental Panel on Climate Change (IPCC). An RCP is a scenario that incorporates an array of projections, such as through the year 2100 (and in some cases beyond that time) for a wide range of greenhouse gas emissions and concentrations that are based on a different set of assumptions. An RCP uses this data to estimate the positive "radiative forcing," or the warming effect, of those greenhouse gases in the atmosphere, as measured in watts per square meter. Climate models predict temperature, rainfall and other parameters for each RCP scenario. A number of climate models exist, resulting in a range of outcomes for climate parameters.

The IPCC's RCPs are RCP 8.5, RCP 6, RCP 4.5 and RCP 2.6, with the numbers representing the radiative forcing estimated in each scenario. Of the four, RCP 8.5 represents the most adverse climate impacts pathway, leading to a likely increase of 3.2 – 5.4 degrees Celsius in global mean surface temperature by 2100 in relation to historical levels (according to the IPCC's Special Report on the Ocean and Cryosphere, 2019). The Task Force on Climate-Related Financial Disclosure (TCFD) and other climate literature point to RCP 8.5 as a high emissions scenario and hence a plausible pathway to account for the largest climate outcomes. By contrast, climate impacts under RCP 2.6 (with a likely range of projected temperature increase of 0.9 – 2.4 degrees Celsius by 2100 in relation to historical levels) and RCP 4.5 (with a likely range of projected temperature increase of 1.7 – 3.2 degrees Celsius by 2100 in relation to historical levels) are likely to have material but less severe impacts after midcentury because their associated lower long-term emissions trajectories incorporate emissions reductions.

RCPs are based on target greenhouse gas emissions and lack a consistent set of socioeconomic assumptions. However, shared socioeconomic pathways (SSPs) would provide a consistent baseline and incorporate how such factors as population, economic growth, urbanization, education and technological developments affect climate change over the next century. As a result, SSPs can be linked to climate policies to generate different outcomes. The sixth IPCC Assessment Report, which is scheduled to be published in 2021-22, will incorporate SSPs. While climate researchers have mapped the alignment of some RCPs with SSPs, how this relationship will develop remains unclear. Accordingly, our approach may evolve to reflect any new major developments. The five widely cited SSPs are sustainable development (SSP1), middle-of-the-road development (SSP2), regional rivalry (SSP3), inequality (SSP4), and fossil-fueled development (SSP5).

For carbon transition risk, we use two scenarios to help assess the credit implications

The speed and scale of change in the supply and consumption of energy is hard to predict. However, the direction of travel toward decarbonization is clear, considering emissions targets in major countries, the improving economics of renewables and technological advances. We use transition scenarios to help us understand a range of future outcomes that may materialize. As our understanding of the policy and technology dynamics evolves, we may amend the scenarios to reflect the latest thinking.

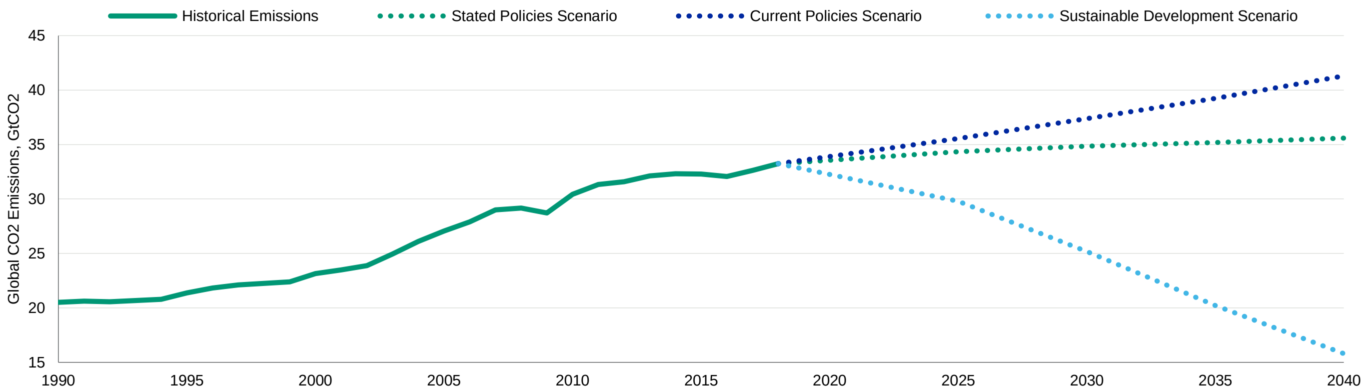
IEA's Stated Policies Scenario: our starting point for carbon transition analysis

The International Energy Agency's Stated Policies Scenario (STEPS), formerly known as the New Policies Scenario, incorporates national commitments to limit or reduce GHG emissions enshrined in the Paris Agreement's NDCs and which are estimated to result in a rise in average global temperatures of 2.7 degrees to 3.0 degrees Celsius above preindustrial levels by the end of this century. We use STEPS as a starting point to consider climate policy developments and commitments and what they mean for energy demand and production across the globe (see Exhibit 2). This scenario is not static and is updated every year in the IEA's annual World Energy Outlook.

Exhibit 2

Stated Policies Scenario is broadly consistent with existing Paris Agreement commitments

International Energy Agency's global emission scenarios



Note: Current Policies Scenario (CPS) assumes no change in policies or technology from today, Stated Policies Scenario (STEPS) includes policies and targets announced by governments and Sustainable Development Scenario (SDS) assumes an accelerated clean energy transition that puts the world on track to meet goals related to climate change, universal access and clean air.

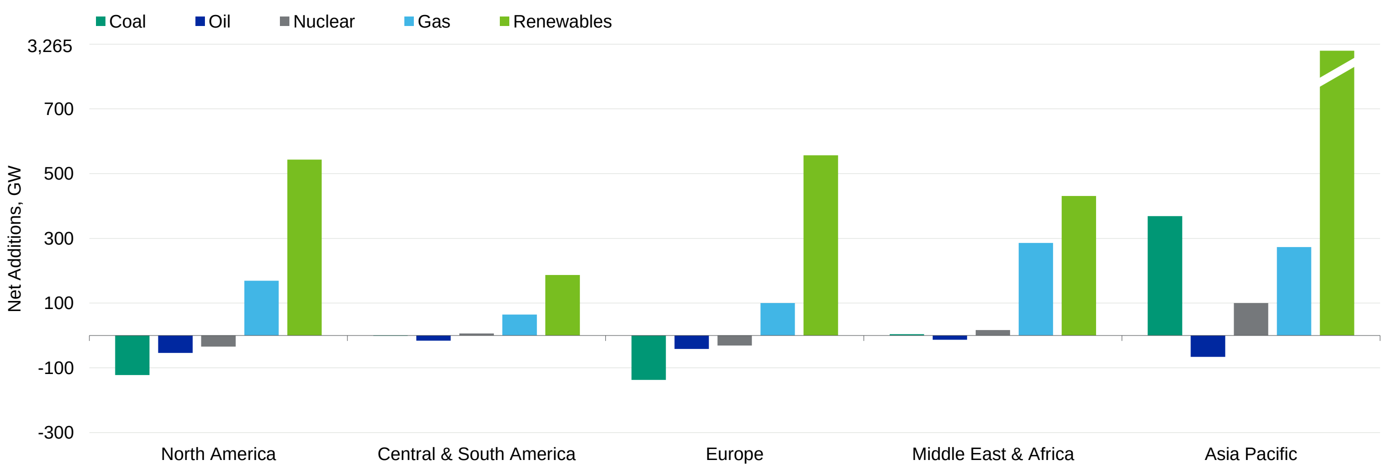
Sources: Moody's Investors Service, International Energy Agency

The global STEPS trajectory conceals significant variations in emissions pathways and underlying assumptions at a national or regional level. In part, this situation reflects the disparate stages of economic development in developed and emerging economies. For instance, while renewable energy capacity in the Asia-Pacific power sector is expected to increase substantially by 2040, it is also the only major region that sees net coal additions (see Exhibit 3).

Exhibit 3

STEPS assumes significant ramp-up in net additions of renewable energy generating capacity

Power sector net capacity additions under IEA's Stated Policies Scenario, 2019-2040



Sources: Moody's Investors Service, International Energy Agency's World Energy Outlook 2019

Our analysis may take into account a region or sector that is moving faster than indicated in STEPS, which reflects the speed of the transition. For example, we already expect the deployment of electric vehicles to be faster than is indicated in the 2019 STEPS (see "Automotive Industry – Global: Automakers fully engaged on Battery Electric Vehicles, but the transition will pressure returns," 23 January 2018). In the US, we expect the power sector to reduce coal generation to 11% by 2030, which is ahead of the 2019 STEPS (see "Power generation – US: FAQ on the economics of renewable energy, battery storage and fossil-fuel power plants," 12 June 2019).

We also conduct more detailed analyses in regions when policy road maps are agreed upon. For example, each member state of the European Union has outlined how it intends to decarbonize its power sector by 2030 through targets to increase renewables and policies to phase out coal generation (see "Cross sector - Europe: EU decarbonization strategy accelerating energy transition," 19

November 2019). We estimate that $500 billion of capital investment in renewables is required over the next decade. Alongside this, over half of the existing coal generation fleet in the EU is expected to close, bringing forward asset impairments.

A range of possible energy mixes can result in the same emissions and warming outcomes. In other words, there is more than one feasible pathway that could deliver the same long-term results. When comparing scenarios from different sources, it is important to understand each scenario's assumptions for such factors as:

» scope of greenhouse gases and sectors/activities covered;

» macroeconomic and population growth;

» timing and extent of policy and technology changes;

» deployment of carbon capture and storage or negative emissions technologies; and

» probability and degree of global warming.

The direction of travel indicated by the scenarios is still informative, given the fact that any particular scenario that is selected is unlikely to be 100% correct.

IEA's Sustainable Development Scenario: an alternative to assess an issuer's resilience to a more accelerated transition

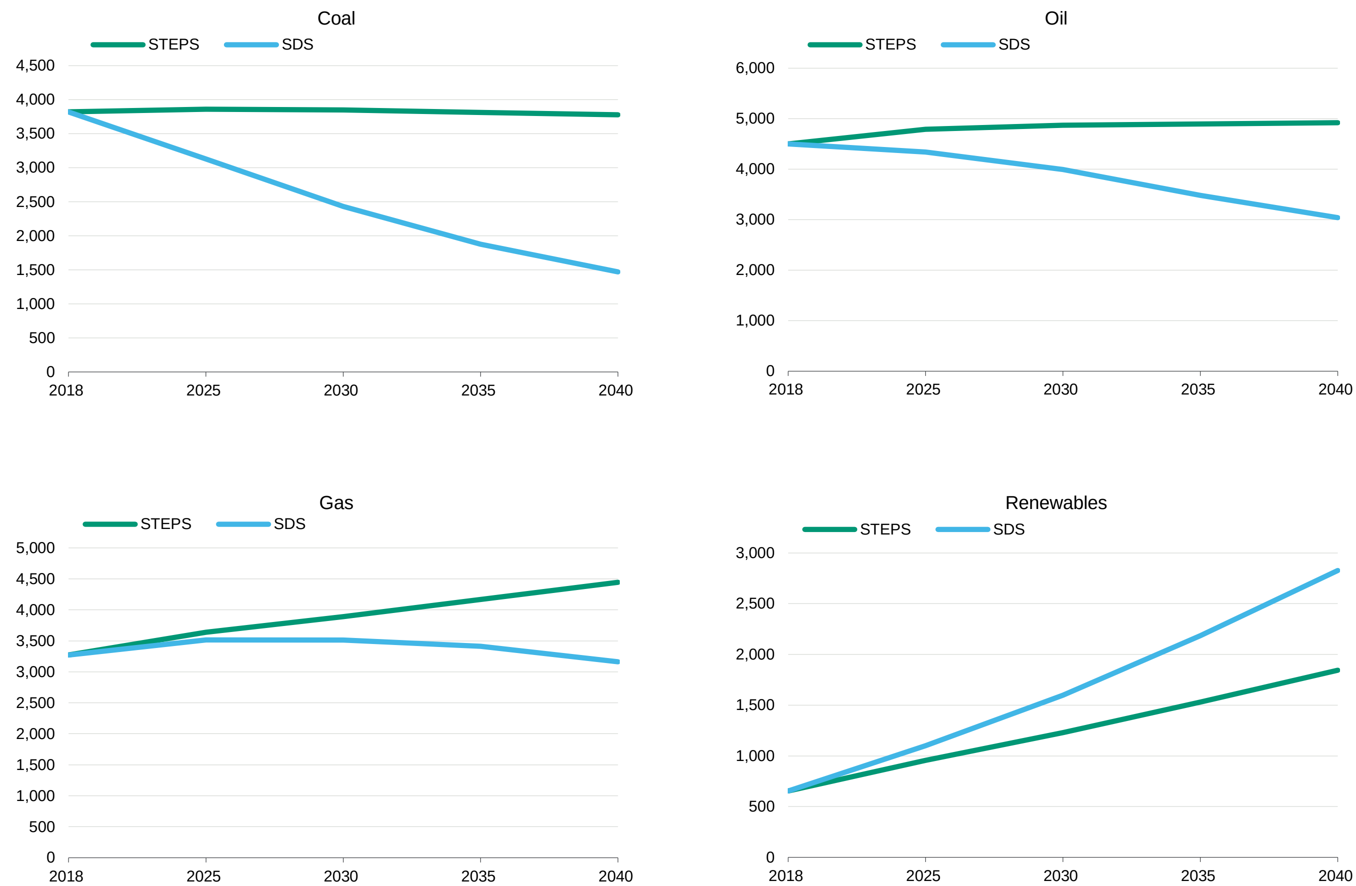
To provide insight into an issuer's resilience, we also use the IEA's Sustainable Development Scenario (SDS) to provide a more ambitious low-carbon transition scenario. The SDS goes beyond climate targets by incorporating air pollution and energy access goals. It provides a feasible scenario that assumes a more rapid carbon transition than most incumbents in the energy sector are currently planning for. On climate change, the SDS is aligned with reaching global "net zero" carbon dioxide (CO_2) emissions in 2070. If net emissions stay at zero after this point, this is estimated to mean there is a 66% chance of limiting the rise in the global average temperature to 1.8 degrees Celsius above pre-industrial levels.

Under the IEA's SDS, demand for fossil fuels will be much lower than under STEPS (see Exhibit 4). While natural gas consumption would remain relatively flat under SDS, demand for coal and oil would fall sharply. At the same time, consumption of renewable energy would increase at an even faster pace than under STEPS. For all such sectors, the divergent demand pathways over the next 20 years highlight a significant uncertainty given the long life capital investment decisions involved and the implications for returns.

Exhibit 4

SDS assumes declining demand for coal and oil and sharper increase in renewables

Primary energy demand assumptions under IEA's Stated Policies Scenario and Sustainable Development Scenario (Mtoe)



Note: Renewables include hydro, bioenergy and other renewable sources. Coal, oil, gas and renewables demand measured in Million tonnes of oil equivalent (Mtoe).
Sources: Moody's Investors Service, International Energy Agency's World Energy Outlook 2019

Integration of transition scenarios into credit analysis and ratings

The credit impact of the energy transition will not be uniform across sectors, and the application of scenarios is used to provide consistent starting points for assessing the implications for rated entities across sectors globally.

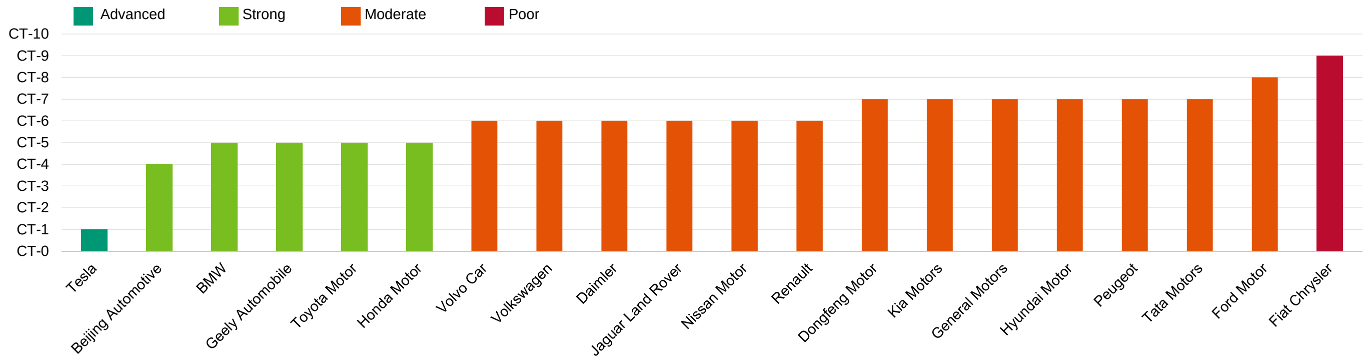
In considering the implications we have first identified the 16 sectors most exposed to carbon transition in our environmental heat map. For the non-financial corporate sectors, we have analyzed the credit effects of carbon transition by looking at three primary transmission channels; policy risk, market risk and technology risk, (see Sector In-Depth reports in the related publications section of this report). Following this, we developed our carbon transition assessment (CTA) framework which creates a scoring tool that allows us to compare the impact for rated entities, sector by sector, of transmission pathways under the IEA STEPS and SDS scenarios.

The first sector to be scored using this scenario based approach is the automotive sector. As shown in Exhibit 5, our CTA scores for 20 leading global automotive manufacturers indicate that most automakers are not strongly positioned for the transition to a low-carbon future (see "Automotive manufacturing – Global: Substantial variation exists in automakers' carbon transition risk profiles," 4 November 2019).

Exhibit 5

Substantial variation exists in automakers' carbon transition risk profiles

Carbon transition assessment (CTA) scores for 20 leading automakers



Note: CTA scores only consider issuer's light vehicle operations and exclude commercial trucks. Scores for parent companies reflect consolidated operations including subsidiaries. Beijing Automotive and Dongfeng analysis reflects light vehicle unit production from their own brand operations and do not include those from their joint ventures. Joint venture production is attributed to the foreign car brand (e.g., Beijing-Benz is attributed to Daimler AG). Geely's analysis includes unit production from its Lynk & Co joint venture.
Source: Moody's Investors Service

Comparing the impact of these long-term scenarios provides the ability to test relative positioning against an assumed direction of travel. The sector analysts then use this information as an informational input into their assessment of the credit risks facing individual rated entities and the implications for the credit ratings of these entities.

In addition, the scenarios can also be used to understand the possible implications for other sectors with an exposure to carbon transition risk. For example, we can look at the implications of different transition scenarios for economic growth, fiscal revenue and energy trade balances of hydrocarbon exporting sovereigns (see "Sovereigns – Hydrocarbon exporters: Carbon transition manageable for most; significant credit pressure in event of more ambitious transition," 3 July 2018). Or the scenarios can help provide deeper insight into the implications of sectors on both supply and demand sides. For example, our analysis of the implications for the mining sector of demand for different types of energy fuels and battery metals applies our forecast for electric vehicle deployment in the automotive sector (see "Metals & Mining – Global: Metal supply shortfall likely to slow battery electric vehicles near term production rates," 30 April 2018). And looking across sectors, we can consider the potential upsides and downsides of changes to personal mobility, as they affect auto manufacturers and their captive finance units, parts suppliers, mining companies, insurers and technology companies (see "Cross-Sector – Global: Auto sector transformation will drive global multi-sector credit trends," 16 July 2018).

How climate scenarios are incorporated into disclosure standards and regulatory frameworks

The use of scenario analysis has emerged as a helpful approach to assess physical risk and carbon transition risk across the capital markets. Advances in pathway development and modeling have been instrumental in developing climate change scenarios, the most prominent of which are incorporated into the forward-looking sections of the IPCC and IEA reports.

Recommendations from the Financial Stability Board's Task Force on Climate-related Financial Disclosures (TCFD) have stimulated significant interest in applying climate scenarios to assess financial risk. Indeed, the TCFD recommends that companies provide disclosures that focus on the resilience of an organization's strategy, taking into consideration different climate-related scenarios (see "Final Report: Recommendations of the Task Force on Climate-related Financial Disclosures," Financial Stability Board, June 2017). However, mainstream application is still at an immature stage. According to TCFD's June 2019 review, disclosure of climate-related financial information is growing, but only 9% of the 1,100 companies surveyed disclosed information in 2018 on the resilience of their strategies, including the consideration of different climate-related scenarios (see "TCFD: 2019 Status Report," Financial Stability Board, June 2019). We also recently noted that even for large US and EU companies operating in sectors with elevated environmental exposures, disclosures seldom quantify the potential financial impact of climate change (see "ESG – Europe and US: Companies' climate-related disclosures seldom reveal potential financial impact," 21 October 2019).

Most TCFD disclosures by both issuers and investors have been related to carbon transition risk; for example, the largest companies in carbon-intensive sectors have established scenario teams that are disclosing increasing amounts of scenario analysis. Scenario analysis is starting to appear in physical risk disclosures but in a cursory way without significant differentiation on the expected impacts, by hazards, time frames and geographies. When physical risk disclosure does appear, the focus is usually on describing hazards and exposure in a qualitative manner, with relatively less quantification of their potential financial impact or explanation of adaptation strategies to manage the risks.

Central banks are piloting scenarios to stress-test the resilience of financial systems and, as a result, banks are starting to consider their lending portfolio exposure. The Central Banks and Supervisors Network for Greening the Financial System (NGFS) has outlined recommendations for central banks on assessing and managing climate risks. A number of central banks are consulting on how to apply climate scenarios. For example, the Bank of England Prudential Regulatory Authority (PRA) has included climate change scenario analysis as an exploratory topic in the 2019 General Insurance Stress Test with plans to do so for banks in the future (see "General Insurance Stress Test 2019: Scenario Specification, Guidelines and Instructions," Bank of England PRA, 18 June 2019). The Bank of England PRA has put forward three scenarios, including a sudden transition ensuing from rapid global action and policies; a long-term orderly transition that is broadly in line with the Paris Agreement; and a scenario with failed future improvements in climate policies, with global temperatures increasing in excess of 4 degrees Celsius relative to preindustrial levels by 2100.

For physical climate risks, we use a single scenario and primarily focus on the implications for the next 30 years

Physical risks from climate change manifest themselves in destructive weather events, such as hurricanes, floods, droughts and wildfires, as well as chronic, slow-moving trends, like gradual temperature increases and rising sea levels. These immediate and long-term developments increase the risk of widespread economic losses and have the potential to pressure credit quality across various sectors. For example, the credit profiles of small, agriculture-reliant countries are susceptible to physical climate risks, although the impact is often mitigated by access to multilateral financial support. More broadly, national, state and local governments face a variety of climate risks such as sea level rise, wildfires, storms, heat stress and other hazards.

Private sectors, such as investor-owned utilities and housing-related sectors, also have significant exposure to the economic consequences of climate change, such as hurricane and flood damage to coastal properties because of rising sea levels and storm surge.

As climate-related hazards increase in severity and frequency, we expect them to have more adverse economic and social ramifications for issuers, such as impaired asset values, costs to repair and rebuild infrastructure, lost economic opportunity, business disruption, health and safety risks, food insecurity and population displacement. These all have the potential to hurt credit outcomes, although the actual impact will vary significantly across regions.

Our approach to physical risk analysis and choice of scenarios draw significantly on our affiliate Four Twenty Seven's views on physical climate scenarios, as laid out in its December 2019 publication "Demystifying Climate Scenario Analysis for Financial Stakeholders." Four Twenty Seven's approach is characterized by the following key features, as illustrated in Exhibit 6:

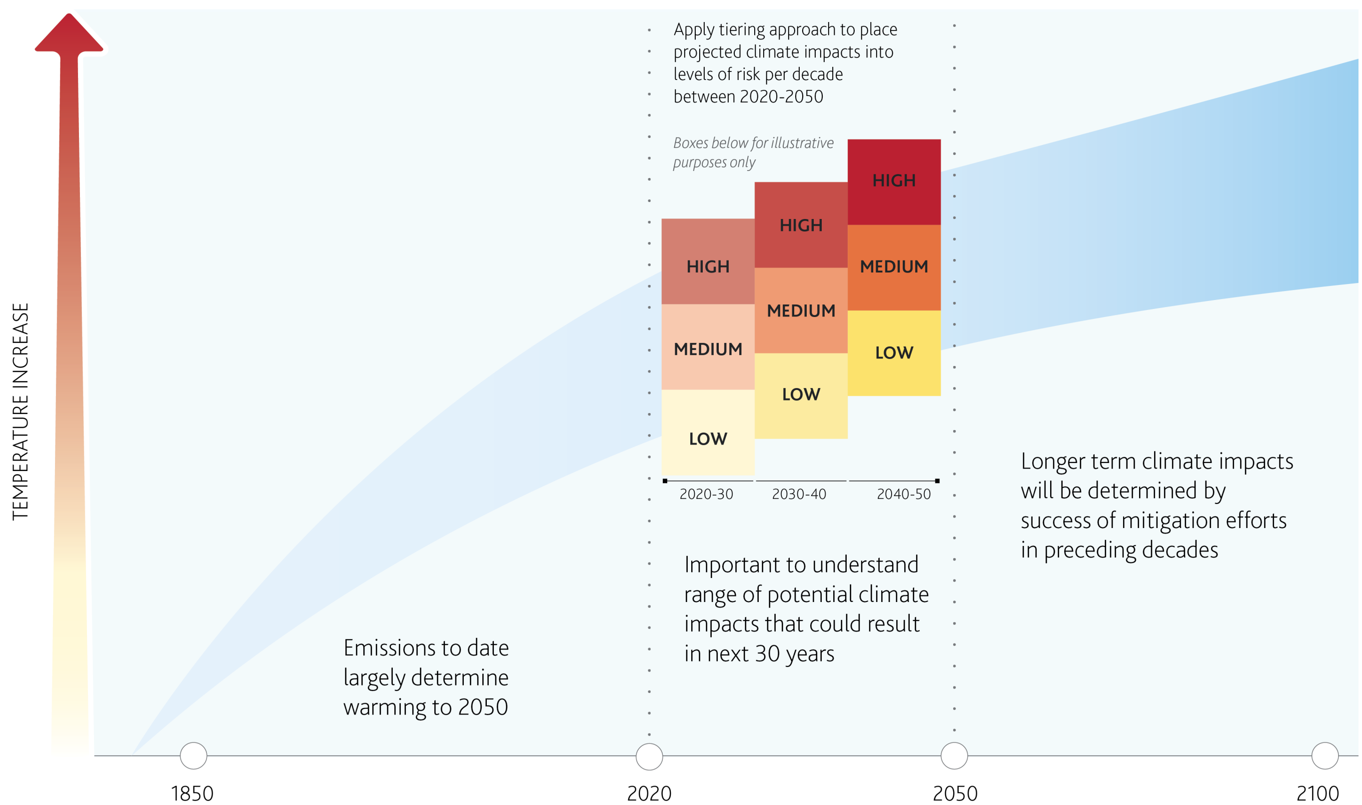
1. Because of the inertia and time lag involved in how carbon emissions affect the earth's climate, the negative effects of climate change through 2050 are largely already locked-in by emissions to date.

2. Given the historical high emissions pathway observed, and taking into account the risk of tipping points and feedback loops, it is a reasonable approach to apply RCP 8.5 to assess the broad range of possible climate outcomes through to 2050. Even if we significantly reduce emissions in the next 30 years consistent with other RCP pathways, the divergence in climate outcomes from those of RCP 8.5 will only be felt beyond 2050 because of the time lag effect mentioned above.

3. Until 2050, the range of potential physical climate outcomes may be represented by the variability in RCP 8.5 climate models themselves, i.e., the range of possible outcomes projected because of the climate impact of emissions to date.

4. It is possible to group the climate outcomes of various climate models under RCP 8.5 into high, medium and low tiers. This is one approach to exploring the range of potential outcomes. These percentile based tiered scenarios represent lower to higher risk climate outcomes that can then be used to assess the climate risk faced by individual rated entities in the most exposed sectors.

Exhibit 6
Physical climate impacts over different time frames
Climate impacts are 'locked in' over the next 30 years and then start to differ based on mitigation pathways post midcentury



Source: Moody's Investors Service, Four Twenty Seven

Physical hazards likely to intensify over the next several decades because of 'locked in' effects

A key difference between physical risk and transition risk is that changes in climatic conditions over the next few decades are already "locked in" regardless of mitigation actions. Such actions, if successful, will play a much more significant role regarding the magnitude of climate impacts post midcentury. The delayed warming effect of accumulated greenhouse gas emissions, as well as the thermal inertia of oceans, means that climate change for the next several decades will be driven mostly by emissions that have already been released into the atmosphere. (For example, see Clark et al, "Consequences of Twenty-First-Century Policy for Multi-Millennial Climate and Sea-Level Change," Nature Climate Change, 8 February 2016; Mauritsen et al, "Committed Warming Inferred from Observations," Nature Climate Change 31 July 2017; Solomon et al, "Irreversible Climate Change Due to Carbon Dioxide Emissions," Proceedings of the National Academy of Sciences, 10 February 2009; and various IPCC reports.) Furthermore, "locked-in" effects ensure that trajectories for temperature change and other physical hazards under different RCPs do not show significant differences through 2050. The differences among the RCPs only become meaningful beyond approximately 2050. As shown in the IPCC's Fifth Assessment Report and as mentioned in Four Twenty Seven's Climate Scenarios Paper, the range of climate related outputs (such as temperature increase) within models that comprise each of the RCPs is much larger than the range of differences between the RCPs before midcentury. After 2050, the differences between RCPs pathways begins to outweigh the differences within the RCPs.

Given the relative lack of differences in climate outcomes under different RCP to midcentury and the historical high emissions pathway observed and taking the risk of tipping points and feedback loops into account, we believe it is a reasonable approach to apply RCP 8.5 to assess the broad range of possible climate outcomes through to 2050. Tipping points refer to the crossing of critical thresholds at a regional or global basis leading to potentially irreversible changes to the climate system, while feedback loops are processes that can amplify or diminish the effects of climate forcings. Examples include the release of methane emissions from permafrost melting, and loss of ice decreasing the amount of energy reflected back into space and thus accelerating warming. Tipping points and feedback loops are enormously complex and hence not fully understood or completely reflected in climate models, but can accelerate the pace and severity of climate impacts including the potential for abrupt, irreversible and cascading events.

Variability in climate model outputs best represents the range of possible outcomes between now and midcentury

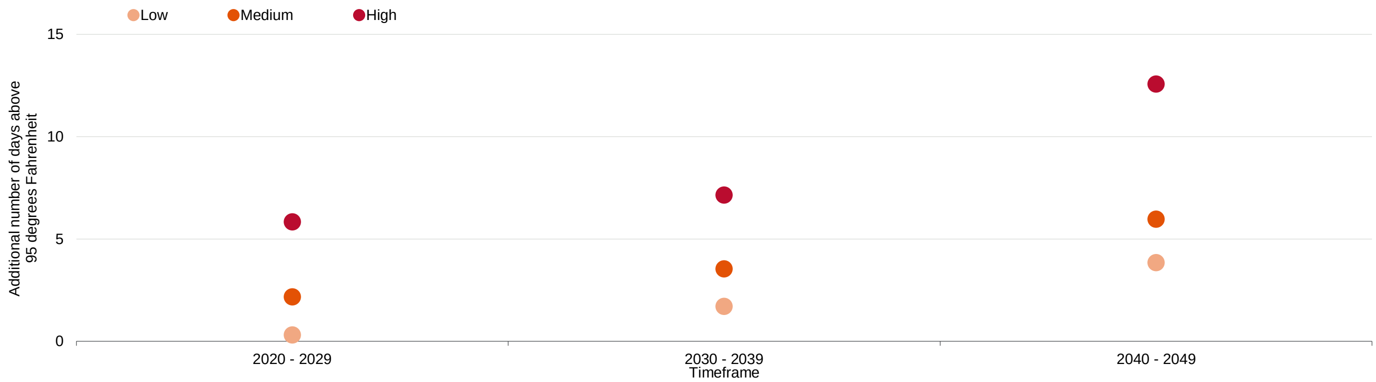
Climate outcomes over the next 30 years are uncertain because we cannot predict exactly how the climate will respond to a given concentration of greenhouse gases in the atmosphere. There are many climate models, each with their own unique capabilities and assumptions, that provide a range of possible outcomes for climate parameters under the RCP 8.5 pathway. A single climate model cannot represent the full range of possible outcomes, nor does an average of all climate model outputs accurately indicate the lower and upper bounds of possible futures.

However, to assess the implications of the RCP 8.5 scenario it is possible to consider the range of hazard outcomes (such as additional days of extreme heat or rainfall intensity) from relevant models and cluster them into relevant tiers. This approach, currently being developed by Four Twenty Seven, clusters outputs of up to 18 climate models for each climatological variable under the RCP 8.5 pathway into "high," "medium," and "low" percentile tiers for a specific hazard and location. This is illustrated in Exhibit 7, which shows that for each decade during the 2020-50 period, the model outcomes under RCP 8.5 for extreme heat in Los Angeles can be grouped into three tiers. Beyond 2050, multiple RCPs need to be used to assess climate impacts.

Exhibit 7

Percentile-based analysis of climate model outputs helps illustrate projected risk of extreme heat in Los Angeles

Tiered projections for additional number of days above 95 degree Fahrenheit in downtown Los Angeles in 2020-2050 compared to 1985-2015



Source: Four Twenty Seven

Comparing the impact of the "low" and "high" scenarios is a quantifiably meaningful way to understand the range of possible exposure outcomes for an issuer as possible. This allows us to assess gross exposure in a globally consistent manner based on a common climate scenario and independent of issuers' own assumptions through climate data from Four Twenty Seven. We can then additionally assess the economic impact, as well as resilience investments that may be required, through issuer engagement, research and analysis.

Incorporating physical climate scenarios into our credit ratings analysis

Similar to our approach to carbon transition, the credit impact of physical risks of climate change will not be uniform across, or within, sectors. Our approach to assess the credit implications is to first identify those sectors we see as most exposed to the physical risks of climate change in our 2018 global environmental risk heat map. For each of these sectors, we are developing approaches and frameworks to assess the ways in which such physical risks will transmit into credit implications for those sectors. Examples of this approach include those adopted for sovereigns, US local governments, Australian states, European cities and US utilities. For example, we recently examined the main climate hazards that US regulated electric utilities face across their service territories, determined overall risk profiles for each and identified areas of highest risk by hazard (see "Regulated electric utilities – US: Intensifying climate hazards to heighten focus on infrastructure investments"). In another recent research report, we analyzed the long-term sovereign credit impact from sea level rise (see "Sovereigns – Global: Sea level rise poses long-term credit threat to a number of sovereigns").

By adopting a common scenario and risk-based approach to the implications of that scenario for each sector, we can assess the implications globally across sectors from a consistent starting point. Adopting a scenario-based approach that is consistent with our affiliate Four Twenty Seven enables us to apply forward-looking climate data and indicators to highlight entities within sectors that exhibit exposure to climate risks that are greater than others in their sector.

Moody's related publications

Sector In-Depth

- Sovereigns – Global: Sea level rise poses long-term credit threat to a number of sovereigns, January 2020
- Regulated electric utilities – US: Intensifying climate hazards to heighten focus on infrastructure investments, January 2020
- Power Generation – North America: Demand for sustainability drives appetite for hydroelectric generation, January 2020
- Cross sector - Europe: EU decarbonization strategy accelerating energy transition, 19 November 2019
- Renewable Energy – China: Policy will continue to drive sector growth and is accelerating non subsidization era, November 2019
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