Ceres

AUTOMAKER ROADMAP FOR CLIMATE SCENARIO ANALYSIS

Co-authors Doug Cogan and Joe Kruger

OCTOBER 2020

Automaker Roadmap for Climate Scenario Analysis

Commissioned by Ceres

ABOUT CERES
Ceres is a sustainability nonprofit organization working with the most influential investors and companies to build leadership and drive solutions throughout the economy. Through powerful networks and advocacy, Ceres tackles the world's biggest sustainability challenges, including climate change, water scarcity and pollution, deforestation and inequitable workplaces. For more information, visit www.ceres.org.

CO-AUTHORS
Doug Cogan is the principal of Cogan Climate Consulting LLC. He advises institutional investors and corporations on ESG investment strategies and how to speed the transition to a low-carbon economy.

Joe Kruger was formerly a principal at Kruger Environmental Strategies LLC. He has worked for more than 30 years on climate and clean energy policy in the public, private and non-profit sectors.

We would like to thank Ford Motor Company for its review of the framework.

For more information, contact Carol Lee Rawn, Senior Director, Transportation Program, Ceres at rawn@ceres.org.

Table of Contents

INTRODUCTION

Building an Automaker Roadmap for Climate Scenario Analysis

Meeting the goals set by the Paris Climate Agreement to avoid the most severe impacts of the climate crisis will require aggressive, near-term shifts in energy sources, production methods, business strategies and consumer behavior. Signed by more than 190 nations, the Paris Agreement forged a political consensus supporting limiting the increase in global average temperature to well below 2°C, with the ultimate aim of limiting it to 1.5°C.

Auto companies, like businesses in nearly every industry, face fundamental changes to their business models as they respond to this climate imperative. But with commitments from sector participants falling short, transportation is well off track for even 2°C scenario targets, according to research from the Science Based Targets Initiative. The World Benchmarking Alliance's 2019 rankings of the world's top 25 automakers highlights issues, including poor target setting and development of business model alternatives to passenger vehicles, that are contributing to this delay. Similarly, a 2020 analysis by the 2° Investing Initiative found that none of the 14 leading automakers' production plans were aligned with the Paris Agreement's goals.

Steering the sector back on course for a well below 2°C scenario will require at least 60% annual emissions reduction and cutting energy-based carbon intensity in half by 2050 versus 2010 levels, according to the IPCC. Pursuing a 1.5°C pathway would require deeper cuts in emissions by accelerating mitigation solutions.

The imperative for comprehensive and urgent action from auto companies is clear. The COVID-19 pandemic has shown what happens when we ignore a systemic risk that is known and predicted—how wide-ranging and compounding impacts can ripple with devastating effect throughout the economy and financial system. Robust and aggressive action is needed to prepare the industry for climate risks and to harness the opportunities created by the necessary transition to a net-zero carbon economy by 2050.

The window to act is rapidly shrinking. In the last 40 years, 1.1°C of warming has already occurred. At the current rate, global warming would eclipse the 1.5°C warming limit by the middle of this century and lead to at least 3° - 4°C of warming eventually. To limit warming to 1.5 °C, global emissions need to be cut by 45% below 2010 levels by 2030 to reach net-zero carbon emissions by 2050. This increases the urgency of peaking global carbon emissions in the near term, with the UN estimating that emissions need to drop by 7.6% per year between 2020-2030.

This report outlines how auto companies can use climate scenario analysis to assess climate change-related risks and opportunities in line with the latest science from the IPCC 1.5°C report.

This framework is intended to provide a basis for comparison among automakers, as well as scenario results from governmental and non-governmental organizations. The methodological approaches are consistent with other publicly available climate scenarios. They are also compatible with those of the Task Force on Climate-related Financial Disclosures (TCFD) and other initiatives for reporting climate-related risks and opportunities to investors.

The purpose of rigorous climate scenario analysis is to help inform and influence strategic planning, R&D policy priorities and other key aspects of corporate operations. The goal of this framework – and of climate scenario analysis generally – is to challenge the drivers and underlying assumptions used to develop such business plans.

Scenarios are not designed to predict the future based on past results, nor are they confined to adjusting indicators and conducting sensitivity analyses to support the case for an already-adopted business plan. Instead, the purpose of scenarios is to identify what could go wrong in making any forecast of the future and highlight the changes needed to build a more durable and resilient long-term strategy.

Scenario planning in this context recognizes that climate change poses unprecedented risks and opportunities for companies that require constant monitoring, as well as a willingness to adapt under constantly changing circumstances in a rapidly warming world. Through rigorous scenario analysis, auto companies gain insight to help them urgently make the transition to a zero-carbon economy.

Ceres Automaker Roadmap for Climate Scenario Analysis

Ceres commissioned this framework to provide guidance for automakers in conducting and utilizing climate scenario analysis in strategic planning and product development. It promotes transparent and consistent methodological approaches to facilitate comparisons with scenarios issued by independent scientific bodies and original equipment manufacturers (OEMs). Electric and fuel efficient vehicles, and the use models of autonomous and shared vehicles are examples of many factors to be considered in achieving climate scenario outcomes of well below 2°C, with an aspiration toward a 1.5ºC warming limit. All scenarios should be dynamic, challenge conventional wisdom, acknowledge uncertainties and support contingency plans for the most effective, durable and resilient responses to climate change.

Step 1 Establish Processes and Parameters

- **a.** **Pick a time scale** that reflects product life cycles, transportation infrastructure maturation rates and the pace of technological, regulatory and climatic change.
- **b.** **Encompass the full geographic scope** of the company, including all regions where it operates, sells products and has manufacturing facilities or key suppliers.
- **c.** **Identify key drivers and influences** that could lead to a future operating state that is fundamentally different than the company's current business conditions.
- **d.** **Extend the analysis** to include a broad set of political and social factors to better demonstrate the full range of possible climate-related developments and financial outcomes.

Step 2 Align with Climate Scenarios

- **a.** **Compare CO_2 levels** under a reference case to levels required under scenarios achieving a warming limit well under 2°C, with an aspiration toward a 1.5°C warming limit.
- **b.** **Run climate scenarios** employing different technology and policy pathways.
- **c.** **Discuss how OEM scenarios' abatement options compare with external climate scenarios.**
- **d.** **Discuss how abatement options compare with current trends** and how climate, policy and technology or other changes might impact them.
- **e.** **Consider 'glide path' analysis** in climate risk disclosure.

Step 3 Assess the Impacts

- **a.** **Assess key exposures to climate transition risk and opportunity**
- **b.** **Assess key exposures to climate physical risk and opportunity**
- **c.** **Consider the range of impacts** that each climate scenario has on existing classes of assets and planned capital expenditures.

Step 4 Integrate into Capital and Strategic Planning

- **a.** **Test outcomes and uncertainties** against company reference scenarios.
- **b.** **Develop strategies to increase portfolio resilience.**
- **c.** **Create a key indicator roadmap.**
- **d.** **Involve broad cross-functional teams and engage with the board.**

Step 5 Disclose and Engage

- **a.** **Disclose methodology, results, and key indicators of scenario analyses.**
- **b.** **Disclose material risks in financial statements.**
- **c.** **Engage with key investors and stakeholders.**

STEP 1
Establish Processes & Parameters for Automaker Climate Scenario Analysis

Companies should begin by setting key parameters, drivers and boundaries around the climate scenario planning process. While there are numerous factors to consider (see Box 1), key parameters include the time scale and scope of the exercise, policy and technology drivers that are specific to the auto sector and broader socio-political influences that bear on economic growth, globalization and trade.

Box 1	TCFD Recommended Parameters
Discount rate	What discount rate is applied to future value?
Carbon price	What assumptions are made about carbon taxes and emission trading frameworks?
Energy demand/mix	What is the forecasted energy demand and mix across different primary sources (coal/oil/gas/nuclear/renewables)? How does this change over time? What are the energy conversion efficiencies for each source category and end-use efficiency?
Commodity prices	What pricing assumptions are made over time for market prices of key inputs (oil, gas, coal, electricity, steel, aluminum, cobalt, etc.)?
Macro variables	What GDP rate, employment rate and other economic variables are used?
Demographics	What assumptions are made about population growth and/or migration?
Efficiency	How are efficiency gains/clean energy growth/physical changes built into scenarios?
Regional impacts	How are impacts differentiated across regions, markets, countries, asset locations?
Technology	What assumptions are made about energy efficiency, solar, wind, biofuels, nuclear, carbon capture and storage, and electric vehicles in key sectors and infrastructure?
Policy	What assumptions are made about different policy signals and their development over time (national carbon targets, technology standards, energy subsidies, etc.)
Climate sensitivity	What assumptions are made about temperature increase relative to CO_2 increase?

Source: Excerpted from Recommendations of Task Force on Climate-Related Financial Disclosures, Technical Supplement, June 2017.

A. Pick a time scale that reflects product life cycles, transportation infrastructure maturation rates and the pace of technological, regulatory and climatic change.

Because climate scenario analysis is by definition a long-term planning exercise, it should incorporate, but not be limited to, economic cycles and business planning horizons that bear on strategic development and capital expenditure decisions.

With respect to automaker scenarios, time frames for carbon emissions regulatory risk, climate transition risks and physical risks should extend out to at least 2040 and be broken into intervals of between five and 10 years. This balances the need to focus on both short- and long-term business strategies and concomitant emission reductions. Such intervals are also broadly consistent with the manufacturing cycle of the auto sector. In the United States, for example, the National Highway Traffic Safety Administration sets fuel economy standards in five-year intervals.

Longer-term assessments that extend to 2050 or beyond can also provide valuable insights and should be considered, particularly with regard to the physical risks of climate change. Under this longer timeframe, the differential physical impacts of warming scenarios of less than 2°C and higher warming scenarios (e.g., 4°-6°C) become increasingly pronounced. Examining a warming scenario transition to 2050 also provides a greater understanding of interim targets and market changes that may be necessary in interim time periods to meet overall greenhouse gas reduction goals.

B. Encompass the full geographic scope of the company, including all regions where it operates, sells products and has manufacturing facilities or key suppliers.

The scope should also cover all regions where the company may be subject to costs or regulations imposed by governments or other market restrictions.

Large auto companies have manufacturing facilities, sales networks and supply chains that span the globe. For example, as of early 2019, Ford Motor Company had 67 manufacturing sites globally, 1,200 Tier 1 suppliers with 4,400 sites in 60 countries, and more than 10,000 indirect suppliers. Capturing this broad geographic scope is important to a robust scenario analysis because of the timing and reach of government, environmental and trade policies in multiple jurisdictions. These factors affect the economics of OEMs and key decisions about where to expand future operations. Moreover, the progression of climate change and extreme weather events could affect supply chains, as well as manufacturing facilities that are critical to ensuring the continuity of operations. (This is discussed further in Step 3).

C. Identify key drivers and influences that could lead to a future operating state that is fundamentally different than the company's current business conditions.

These drivers may include major demographic and economic trends, significant government policies and regulations addressing the auto sector and carbon emissions, technology disruptors and energy price breakthroughs and evolving consumer behavior and preferences involving personal transportation.

A good scenario exercise will identify the inter-connections between such factors and possible outcomes that might come from a combination of trends shifting in one direction or another. Depending on how these scenarios are constructed, the drivers and influences could work in support of steady progress toward achieving global warming limits. Alternatively, they could work at cross purposes with this goal – with a slow level of technology, policy and behavioral change raising the specter of greater economic disruptions and societal hardships as warming progresses over time.

Government policies and regulations are especially vital factors in shaping future business and investment decisions in the auto sector. While government actions are sometimes viewed separately from energy and technology markets, in the case of climate-related risk, they are intertwined. While not picking winners and losers, future regulatory policies may influence the price of competing technologies and the pace of their commercial introduction, deployment and market penetration. For this reason, auto-related greenhouse gas regulations – including pricing of carbon emissions and potential further bans on internal combustion engines – are especially critical policy drivers that should be addressed in any climate scenario analysis.

While vehicle- and fuel-specific standards and policies bear directly on the auto industry, there are regulatory policies that also affect the carbon footprint of the broader transportation sector on a regional or global basis. Such "Avoid-Shift" policies focus on overarching ways to limit personal vehicle use in favor of more mass transit, ride-sharing, biking and walking. This encompasses policies to build infrastructure, promote incentives and zoning regulations for electric vehicles, public charging stations and autonomous vehicles. Such policies are vital to reducing uncertainty and building a solid foundation for companies pursuing next-generation vehicles and new mobility services. Appendix A contains a more comprehensive discussion of auto sector policies bearing on climate change and carbon emission reductions.

In addition to government policy and regulatory drivers, other macroeconomic influences on the auto sector include:

- The pace of consumer behavioral change and preferences, especially as it relates to vehicle ownership, adoption of electric vehicles, ride sharing, use of public transit and development of infrastructure for autonomous transportation
- Scientific and technological advances in areas such as materials, battery technology, digitization and artificial intelligence
- The global rate of economic growth, especially in large emerging markets like China and India

D. Extend the analysis to include a broad set of political and social factors to better demonstrate the full range of possible climate-related developments and financial outcomes.

Royal Dutch Shell, BP, BHP Billiton and other industrial companies employ an expansive socio-political lens to provide added context for their climate scenario analysis. For example, Shell's "Sky" scenario looks out to 2070 to see what steps might be required to achieve net-zero carbon emissions and hold global warming to well under 2°C. This scenario assumes that strong political leadership and extensive societal cooperation work in tandem to address climate change. "Sky" also assumes that consumers strongly embrace climate-friendly products, hastening their introduction and broad market adoption. In contrast, other Shell scenarios, such as "Mountains and Oceans," assume political leadership and societal interests are not aligned and deter progress on addressing climate change.

Another important influence on climate scenarios is the growth of globalization and free markets relative to the persistence of protectionist policies and fossil industry subsidies. Trade wars, new tariffs and protection of domestic markets could slow global adoption of new carbon-reducing technologies and services. BHP includes these forces in its scenarios, using one climate scenario to explore the implications of protectionist policies and limited global cooperation, while another examines a world of accelerated technology innovation and political cooperation that is highly responsive to climate change.

STEP 2
Align with Climate Scenarios

The efficacy of climate scenario analysis hinges on selecting scenarios that are plausible, comparable and robust. This automaker framework recommends use of macro-level scenarios issued by the International Energy Agency (IEA) and the IPCC as an initial frame of reference. These globally recognized, independent bodies build climate scenarios under a range of economic and technology assumptions, which in turn produce an array of temperature and climate regimes, including those aligned with well below 2°C, with aspiration towards 1.5°C of projected warming.

The IEA scenarios are updated each year, reflecting the latest technology, policy, fuel and carbon price assumptions. The IPCC scenarios are updated on a five-year review cycle that brings together the latest peer-approved scientific research. At the end of this section, Box 3 describes the IEA scenarios and their associated warming levels. Box 4 provides summaries of other available scenarios, as referenced by the Task Force on Climate-related Financial Disclosure.

The TCFD's *Guidance on Scenario Analysis* observes that the IEA and IPCC scenarios are useful because they require "estimates of future population levels, economic activity, the structure of governance, social values, and patterns of technological change and hence can serve as 'meta-scenarios' to provide an overall context and set of macro trends for the development of company or sector-specific scenarios." These third-party scenarios are transparent, independent, globally recognized and data driven. Companies often refer to them for baseline analysis as they build out their own sector- and company-specific approaches and operating assumptions.

However, not all analysts agree with the assumptions built into these scenarios. The IEA scenarios, in particular, have come under fire from investors and scientists. The Ceres Oil & Gas Framework notes, for example, that IEA scenarios "have been criticized for being too slow to recognize trends and being overly optimistic about the advancements of carbon capture and sequestration." The IEA has also underestimated the market penetration rates of electric vehicles and has had to adjust its forecasts to catch up with recent trends.

A. Compare CO_2 levels under a reference case to levels required under scenarios achieving a warming limit well under 2°C, with an aspiration toward a 1.5°C warming limit.

The reference case in a climate scenario analysis is a company's own 'central' or 'anchor' scenario. It should reflect current and approved regional and global policies and regulations, as well as anticipated future policy and technology developments.

To ensure transparency and comparability, OEMs should be clear on the assumptions of their reference case (i.e., whether it represents 'business as usual' or something more evolved). Using sensitivity analysis, they may also alter the assumptions used in their own methodology, but should be explicit about their rationale for making any significant modifications.

B. Run climate scenarios employing different technology and policy pathways.

In addition to a reference case scenario, there should be at least two climate scenarios that explore alternative paths with different variables, assumptions and abatement options that honor a warming limit of well below 2°C, and progress toward a more aggressive limit of 1.5°C, (e.g., based on scenarios issued by the Intergovernmental Panel on Climate Change in their 2018 Special Report on Global Warming of 1.5ºC).

Automakers should compare their reference case to other publicly available macro-level climate scenarios. These include scenarios from the IEA and IPCC that set warming limits at 1.5°C and 2°C. In addition, at least one scenario should encompass CO_2 emissions, atmospheric concentrations and warming projections that are higher than 2°C. This may be the company's own reference (or business-as-usual) scenario or an additional scenario with greater warming (e.g., such as one similar to the IEA Current Policy scenario that projects 4° - 6°C of warming).

C. Discuss how OEM scenarios' abatement options compare with external climate scenarios.

OEMs should assess how the mix of abatement options selected for their climate scenarios relate to those used by the IEA, IPCC or in other publicly available climate scenarios.

Scenario analyses should include such auto-specific technologies, policies and drivers, as well as abatement options and other developments in related sectors (e.g., electric power and transportation fuels) that may influence future automaker emission profiles. This includes analyses of Scope 1 emissions from OEM operations, Scope 2 emissions from purchased power and Scope 3 emissions from suppliers and, especially, customer vehicles.

D. Discuss how abatement options compare with current trends and how climate, policy and technology or other changes might impact them.

Pathways that keep global warming to well under 2°C will require unprecedented levels of technology and policy changes to transform and decarbonize the global economy.

Scenarios should consider future customer preferences, technology costs and oil prices, as well as climate-related policies, regulations and globalization trends. To meet climate goals, companies will need to shift to significant EV production in the next decade, while implementing aggressive improvements in fuel economy in the interim. Each climate scenario should provide a plausible narrative about what technology and policy changes could impact such trends to achieve a 1.5°C or well below 2°C warming limit. As warranted, companies should consider plans to introduce electric and more fuel-efficient vehicles and changes to alternative fuel sources for vehicles in future years.

E. Consider 'glide path' analysis in climate risk disclosure.

Recent climate scenario analyses for OEMs have used a carbon efficiency metric--expressed as grams of carbon dioxide equivalent per kilometer of vehicle travel (gCO_2e/km) -- to show how new vehicle carbon efficiency rates align with a warming pathway.

Ford Motor Company uses glide path analysis to show how fleetwide light-duty vehicle emissions might evolve over time to conform with a 2° C warming scenario. Using IEA modeling, Ford calculates a glide path that "tak[es] into account regional differences in vehicle size and fuel consumption and biofuel availability." In its 2017/18 Sustainability report, Ford notes that once it estimates regional glide paths for light-duty vehicles, it calculates a company-specific glide path "for our new vehicle lineups across our major operating regions."

Box 2 Pathways to Achieve Vehicle-related Carbon Emission Reductions

Pathways to achieve auto-related carbon emission reductions may employ scopes and methods that consider vehicle-related technological advances and policy requirements, as well as broader changes in transportation infrastructure and consumer behavior. A 2017 analysis by the **International Council on Clean Transportation** (ICCT) looks at three alternative pathways for transportation-related carbon emissions to see if they hold within a 2˚C warming trajectory through 2030 (note that the aspirational goal is limiting warming to a 1.5˚ scenario):

- The first pathway looks at current country pledges under the Paris Agreement and finds that they fall well short: The carbon emissions average of the global vehicle fleet is projected to fall from 143 gCO_2e/km in 2015 to 109 gCO_2e/km by 2030, an improvement of only 23%.
- A second pathway looks at global adoption of a European Union policy mandate that seeks a 70% carbon efficiency improvement for new passenger cars sold in the EU market by 2030. If adopted globally, these technically feasible improvements would drop the vehicle emissions rate to 41 gCO_2e/km and align better with a 2˚C warming limit.
- A third pathway considers broader changes in transportation policy and consumer behavior that would limit use of cars for running routine errands and commuting to work – and shift more travel in favor of ride-sharing, mass transit, telecommuting, walking and biking. Because these behavioral changes do not require technological advances under the hood, they allow for additional gains in transport-related carbon efficiency without putting all of the onus on vehicle improvements. Under this "Avoid-Shift-Improve" scenario, vehicles would need to raise their average carbon efficiency by only 44%, equal to 80 gCO_2e/km in 2030, to hold to a 2˚C warming limit.

IEA Scenarios

IEA WEO Current Policies Scenario (projected to generate warming of 6°C)
The Current Policies Scenario considers only those policies that have been formally adopted by governments. According to the UNEP, it sets out "a business-as-usual future in which governments fail to follow through on policy proposals that have yet to be backed-up by legislation or other bases for implementation and do not introduce any other policies that affect the energy sector."[22] This 'No New Measures' Scenario provides a comparison point against which new policies can be assessed.

IEA WEO New Policies Scenario (projected to generate warming of 4°C)
The New Policies Scenario is the central scenario of WEO. It takes into account the policies and implementing measures affecting energy markets that have been adopted, together with relevant policy proposals, even though specific measures necessary to put them into effect may need to be fully developed. The WEO report makes a case-by-case judgment (often cautious) of the extent to which policy proposals will be implemented. This is done in view of the many institutional, political, and economic obstacles that exist, as well as, in some cases, a lack of detail in announced intentions about how they will be implemented.[23]

IEA INDC Paris Agreement Scenario (projected to limit warming to 2.6°C)
The INDC Scenario assesses implications of the INDCs submitted before COP21 as the basis for the Paris Agreement. "The share of fossil fuels in the world energy mix declines, but is still around 75% in 2030. The rate of growth in coal and oil demand slows but demand does not decline, while gas use marches higher. Renewables become the leading source of electricity by 2030, but sub-critical coal-fired capacity declines only slightly. The carbon intensity of the power sector improves by 30%."[24] Carbon capture and storage (CCS) achieves no more than marginal penetration by 2030. Increased efficiency measures across sectors reduce the energy used to provide energy services, without reducing the services themselves.

IEA Bridge Scenario (keeps world on path to 2°C limit to 2025, but more needed after 2025)
The IEA sought to contribute to practical discussions about near-term GHG mitigation options amongst policymakers and business planners by developing the Bridge Scenario. The purpose of the Bridge Scenario is to facilitate adoption of methods through which the movement towards a peak in global energy-related GHG emissions can be achieved by each country or region individually. This Bridge Scenario is not, in itself, a pathway to the 2°C target – additional technology developments and policy requirements for such a pathway are set out in the WEO 450 Scenario.

IEA WEO 450ppm Scenario (projected to limit warming to 2°C)
The WEO 450 Scenario takes a different approach. "It adopts a specified outcome: achievement of the necessary action in the energy sector to limit the rise in long-term average global temperature (with a likelihood of 50%) to 2°C and offers steps by which that goal might be achieved."[25] Many separate efforts are required to reduce energy-related CO_2 emissions from 2015 to 2040, including stronger deployment of technologies that are familiar and available at commercial scale today, which will deliver close to 60% of the emissions reductions; the building of significant additional nuclear capacity; and rapid CCS expansion after 2025 matching the pace of expansion of gas-fired capacity between 1990 and 2010.

IEA Sustainable Development Scenario (projected to limit warming to well below 2C)
The Sustainable Development Scenario is generally aligned with the Paris Agreement's goal of "holding the increase in the global average temperature to well below 2C above pre-industrial levels and pursing efforts to limit the temperature increase to 1.5C. Under the SDS, energy-related carbon dioxide (CO2) emissions peak around 2020 and then decline rapidly. By 2040, they are at around half of today's level and on course toward net-zero emissions in the second-half of the century, in line with the goals of the Paris Agreement. A strong drive towards electrification (on-grid and off-grid) and provision of clean cooking facilities means the number of people without access to modern energy drops to zero, transforming the lives of hundreds of millions. Renewables become the dominant force in power generation, providing over 60% of global electricity generation by 2040.Wind and solar PV, in particular, soon become the cheapest sources of electricity in many countries and provide one-third of all electricity in 2040. Emissions reduction in transport, industry and buildings are achieved largely through greatly enhanced energy efficiency and increasing levels of electrification end uses. The IEA is also developing a scenario for below 1.5 degrees.

Other 2°C Scenarios

International Renewable Energy Agency (IRENA) REmap (2016)

This scenario outlines a plan to double the share of renewables in the world's energy mix by 2030. A renewable generation share of 36% is required by 2030, up from 18% currently and a quadrupling of "modern" renewables due to the phase out of traditional uses of biomass (e.g. fuel wood) energy. "REmap determines the realistic potential for countries, regions and the world to scale up renewables, starting with separate country analyses done in collaboration with country experts, and then aggregating these results to arrive at a global picture. The analysis encompasses 40 countries representing 80% of global energy use. The road map focuses not just on renewable power technologies, but also technology options in heating, cooling, and transport. In determining the potential to scale up renewables, REmap focuses on possible technology pathways."[26]

Greenpeace Advanced Energy [R]evolution (5th Edition)

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

Deep Decarbonization Pathways Project (DDPP)

The DDPP fills a gap in the climate policy dialogue by providing, in the form of deep decarbonization pathways (DDPs), a clear and tangible understanding of what will be required for countries to reduce emissions, consistent with the 2°C limit. "The DDPP framework has been developed and utilized by a consortium led by The Institute for Sustainable Development and International Relations (IDDRI) and the Sustainable Development Solutions Network (SDSN). The DDPP is a global collaboration of scientific research teams from leading research institutions in 16 of the world's largest greenhouse gas-emitting countries: Australia, Brazil, Canada, China, France, Germany, India, Indonesia, Italy, Japan, Mexico, Russia, South Africa, South Korea, U.K. and U.S."[27] The research teams developed these blueprints for change, sector by sector and over time, for each physical infrastructure of the 16 countries, to inform decision makers of the technological and cost requirements of different options for meeting their country's emissions reduction goal. DDPs begin with an emissions target in 2050 and determine the steps required to get there. This tool therefore allows the user to create any number of 2°C pathways.

IPCC RCP 2.6

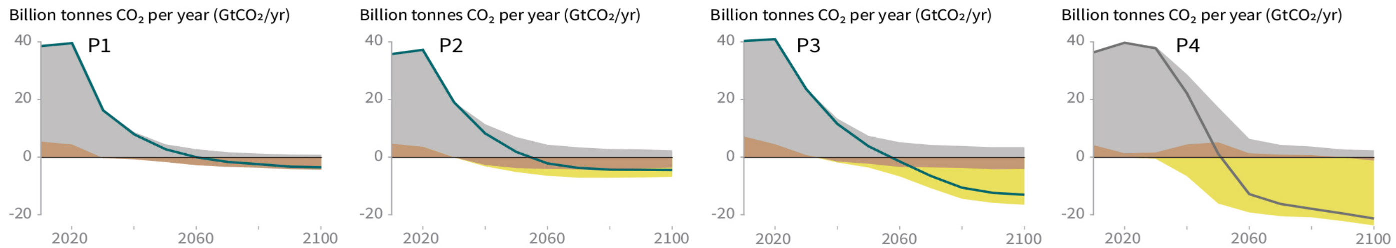
The IPCC draws on an authoritative group of academic scenario development teams around the world, many of them organised in the integrated assessment modelling consortium (IAMC). These teams have produced a set of GHG concentration scenarios that result in a range of warming outcomes. The scenarios from this can be found in the latest IPCC report (AR5) as well as an online database and spreadsheets with input and output variables. This diverse range of models show there are multiple pathways that can limit warming to 2°C, including decarbonising the power sector by mid-century, electrifying as many energy services as possible, substituting residual fossil fuel use in the transport, buildings, and industry sectors by biofuels and achieving negative emissions in the land-use sector ('carbon sinks') by end of the century. The scenarios also highlight efficiency enhancements and behaviour changes as a key mitigation strategy.

Characteristics of four illustrative model pathways

Different mitigation strategies can achieve the net emissions reductions that would be required to follow a pathway that limits global warming to 1.5°C with no or limited overshoot. All pathways use Carbon Dioxide Removal (CDR), but the amount varies across pathways, as do the relative contributions of Bioenergy with Carbon Capture and Storage (BECCS) and removals in the Agriculture, Forestry and Other Land Use (AFOLU) sector. This has implications for emissions and several other pathway characteristics.

Breakdown of contributions to global net CO_2 emissions in four illustrative model pathways

Fossil fuel and industry · AFOLU · BECCS



P1: A scenario in which social, business and technological innovations result in lower energy demand up to 2050 while living standards rise, especially in the global South. A downsized energy system enables rapid decarbonization of energy supply. Afforestation is the only CDR option considered; neither fossil fuels with CCS nor BECCS are used.

P2: A scenario with a broad focus on sustainability including energy intensity, human development, economic convergence and international cooperation, as well as shifts towards sustainable and healthy consumption patterns, low-carbon technology innovation, and well-managed land systems with limited societal acceptability for BECCS.

P3: A middle-of-the-road scenario in which societal as well as technological development follows historical patterns. Emissions reductions are mainly achieved by changing the way in which energy and products are produced, and to a lesser degree by reductions in demand.

P4: A resource- and energy-intensive scenario in which economic growth and globalization lead to widespread adoption of greenhouse-gas-intensive lifestyles, including high demand for transportation fuels and livestock products. Emissions reductions are mainly achieved through technological means, making strong use of CDR through the deployment of BECCS.

Global indicators	P1	P2	P3	P4	**Interquartile range**
Pathway classification	No or limited overshoot	No or limited overshoot	No or limited overshoot	Higher overshoot	No or limited overshoot
CO_2 emission change in 2030 (% rel to 2010)	-58	-47	-41	4	(-58,-40)
└ in 2050 (% rel to 2010)	-93	-95	-91	-97	(-107,-94)
Kyoto-GHG emissions in 2030 (% rel to 2010)*	-50	-49	-35	-2	(-51,-39)
└ in 2050 (% rel to 2010)	-82	-89	-78	-80	(-93,-81)
*Final energy demand** in 2030 (% rel to 2010)*	-15	-5	17	39	(-12,7)
└ in 2050 (% rel to 2010)	-32	2	21	44	(-11,22)
Renewable share in electricity in 2030 (%)	60	58	48	25	(47,65)
└ in 2050 (%)	77	81	63	70	(69,86)
Primary energy from coal in 2030 (% rel to 2010)	-78	-61	-75	-59	(-78, -59)
└ in 2050 (% rel to 2010)	-97	-77	-73	-97	(-95, -74)
from oil in 2030 (% rel to 2010)	-37	-13	-3	86	(-34,3)
└ in 2050 (% rel to 2010)	-87	-50	-81	-32	(-78,-31)
from gas in 2030 (% rel to 2010)	-25	-20	33	37	(-26,21)
└ in 2050 (% rel to 2010)	-74	-53	21	-48	(-56,6)
from nuclear in 2030 (% rel to 2010)	59	83	98	106	(44,102)
└ in 2050 (% rel to 2010)	150	98	501	468	(91,190)
from biomass in 2030 (% rel to 2010)	-11	0	36	-1	(29,80)
└ in 2050 (% rel to 2010)	-16	49	121	418	(123,261)
from non-biomass renewables in 2030 (% rel to 2010)	430	470	315	110	(245,436)
└ in 2050 (% rel to 2010)	833	1327	878	1137	(576,1299)
Cumulative CCS until 2100 ($GtCO_2$)	0	348	687	1218	(550,1017)
└ of which BECCS ($GtCO_2$)	0	151	414	1191	(364,662)
Land area of bioenergy crops in 2050 (million km^2)	0.2	0.9	2.8	7.2	(1.5,3.2)
Agricultural CH_4 emissions in 2030 (% rel to 2010)	-24	-48	1	14	(-30,-11)
in 2050 (% rel to 2010)	-33	-69	-23	2	(-47,-24)
Agricultural N_2O emissions in 2030 (% rel to 2010)	5	-26	15	3	(-21,3)
in 2050 (% rel to 2010)	6	-26	0	39	(-26,1)

NOTE: Indicators have been selected to show global trends identified by the Chapter 2 assessment. National and sectoral characteristics can differ substantially from the global trends shown above.

** Kyoto-gas emissions are based on IPCC Second Assessment Report GWP-100*
*** Changes in energy demand are associated with improvements in energy efficiency and behaviour change*

Figure 1 Source: IPCC 1.5C Report- Summary for Policymakers

STEP 3
Assess the Impacts

History has shown that auto markets are highly dynamic. Changing technologies, consumer preferences and oil prices have roiled the industry and may have significant impacts well into the future. Climate change, carbon regulations and the digital revolution are new variables that add complexities and widen the range of possible future outcomes. Climate scenario analysis takes these new variables into account and focuses on uncertainties that may alter future outcomes in disruptive and possibly transformative ways. Scenarios are not meant to be forecasts, therefore, but rather to question commonly accepted assumptions, knowing that the future will not be a repeat of the past.

Accordingly, the assessment phase of climate scenario planning should explore the potential risks and opportunities of possible material changes in government policy, technological innovation, consumer behavior and other transition risks and opportunities present in the auto sector. A good scenario not only identifies the inter-connections between these factors, but also possible "black swan" events that might occur if these forces all converge in one direction or new forces emerge unexpectedly.

A. Assess key exposures to climate transition risk and opportunity.

OEMs should assess key factors that could contribute to climate transition risks in each scenario. These factors are likely to be related to the key drivers, influences and parameters discussed earlier in Step 1 (Establish Processes and Parameters).

Climate transition risk factors affecting the auto sector include:

- Regulatory policy changes, including vehicle fuel economy/GHG emission standards and possible restrictions on ICE vehicle sales
- Carbon pricing and carbon taxes
- Oil price volatility and energy market fluctuations
- Trade policies and impacts
- Country- and region-level policies and incentives for electric vehicles and mobility as a service
- Technology disruptors that may affect the auto sector, as well as auto-sector technologies that may disrupt other sectors
- Consumer preferences and changing OEM business models

B. Assess key exposures to climate physical risk and opportunity.

Physical risk factors of climate change should also be evaluated that may have an impact on company assets and operations.

Scenario analysis should take account of the effects of these physical risk impacts. Acute impacts include heat and water stress, flash flooding and other extreme weather events. Over the long term, chronic risks may emerge from sea level rise, drought and socio-economic impacts from social unrest and climate-related migration. (See Appendix B for more information on physical risks of climate change.)

To assess physical risks, companies should be able to match potential future climate impacts to the geographic locations of their facilities and supply chains. Mapping tools and more granular assessments are starting to emerge to take inventory of the physical risks faced by companies.

For example, the consulting firm Four Twenty-Seven provided a climate risk typology in a report for Deutsche Asset Management's Global Risk Institute that divides company physical risks into three broad categories:

- **Operations risk** reflects the risk at specific company assets and facilities, including factories, distribution centers, retail centers and other facilities. Physical risks at these facilities depend on their locations and their vulnerability to various climate-related impacts.

- **Supply chain risk** reflects potential impacts of climate-related effects on natural resources or components in a company's global supply chain. These types of disruptions could affect production schedules, input costs, sales and other factors that could have a direct impact on production costs and operating margins.

- **Market risk** reflects how consumer behavior and preferences might change in different geographic regions as a result of climate impacts. For example: Will people drive less in hotter and more extreme weather? Will driverless vehicles operate as safely and reliably in adverse weather conditions? These are just two examples. Ultimately, the key issue is understanding what types of acute and chronic physical risks might affect a company's general operating condition.

Finally, implicit in an assessment of multiple climate scenarios is the trade-off across scenarios between physical and transition risks. For example, higher warming scenarios that assume less stringent policy actions have greater physical risk but less transition risk, while scenarios that assume less warming may have lower physical risk but higher transition risk (e.g., they assume more stringent regulatory actions.). By placing physical risks and transition risks side by side in a dynamic scenario planning exercise, the relative trade-offs between different warming scenarios may become more apparent.

C. Consider the range of impacts that each climate scenario has on existing classes of assets and planned capital expenditures.

OEMs should assess and disclose material risks on their operating assets and financial performance from climate change.

Particular attention should be paid to future business and product lines that affect planned capital expenditures, investments and research & development budgets. Companies should also articulate how they plan to manage uncertainties in their budget planning process.

Affected financial metrics may include:

- Commodity costs and other supply costs
- Operating costs
- Costs of capital
- Research & development
- Capital expenditures
- Impairment of physical assets and early retirements
- Liabilities and reserves
- Revenues (including demand reduction)
- Profits
- Intellectual capital
- Enterprise and intangible value (i.e., reputation risk)

STEP 4
Integrate into Capital and Strategic Planning

Once a company has created and assessed the impacts of its reference climate scenario against their chosen suite of scenarios outlined in Step 3, the next step is to incorporate the relevant findings into the corporate planning process. For the auto sector, the fuels and powertrains of next-generation vehicles are especially critical issues. So, too, is a changing business model that may transform personal ownership of mostly gas-powered cars and trucks into a new “Passenger Economy” of service-based vehicles that are increasingly electrified, autonomous and shared.

Since planning and production cycles can span nearly a decade, this makes integration of climate-related scenario planning especially timely.

A. Test outcomes and uncertainties against company reference scenarios.

Climate scenario planning is a disciplined method of transforming present-day conditions to a future global operating environment with more than one possible set of linkages and building blocks (a.k.a., ‘glide paths’).

While *reference* scenarios often present best-case business forecasts based on currently available information, climate scenarios go beyond information that is readily known and easily gathered to invite more “blue-sky thinking.” In particular, climate scenario analysis presents a unique opportunity to challenge conventional wisdom as expressed in reference scenarios and examine alternative glide paths where transportation systems are fundamentally transformed. As automakers roll out new electric vehicles, develop self-driving models and move toward ‘mobility as a service,’ their very business model is in flux. Against the backdrop of changing climate patterns and more stringent greenhouse gas policies, these companies have an opportunity to assume new roles in human transport and freight delivery systems. Properly constructed climate scenarios offer direction on whether their strategic plans are well aligned with these converging forces or on a collision course.

B. Develop strategies to increase portfolio resilience.

Another key goal of climate scenario analysis is to design more flexible and resilient business plans that stand up to changing market, regulatory and climatic conditions. This means that drivers of scenario analysis should be continually monitored as new events unfold, re-tested for their accuracy and relevance as business models evolve and leave room for mid-course corrections as circumstances warrant.

The analysis should yield useful insights on the risks and returns of allocating resources to various geographic regions, based on evolving regulatory and climatic conditions, and to inform capital spending prioritization for different vehicle platforms and service innovations. Risk management teams should leverage these dynamic climate scenarios to anticipate how organizational, operational and financial requirements might shift under such evolving business and operating conditions – building what is often referred to as a ’no regrets’ strategy. In addition, climate scenarios should be sufficiently expansive to capture developments that have a low chance of occurring but high potential impacts. Stress testing of these low-probability variables simulates how asset and liability portfolios might react should such ‘black swan’ events occur. The risk factors identified in Step 3 are candidates for stress testing as part of the ongoing scenario planning process.

C. Create a key indicator roadmap.

A key indicator roadmap lays out the key policy and technology drivers in climate scenario analysis, their anticipated directional trends and linkage to projected scenario outcomes.

By acknowledging that uncertainties exist and that intervening factors may alter expected outcomes, a key indicator roadmap tracks underlying parameters and whether they are staying aligned with scenario projections or are veering off course. They also give rise to possible workarounds and contingencies to maintain durable, no-regrets business strategies. Properly updated and maintained, such roadmaps may instill confidence that companies are staying ahead of the curve, avoiding tunnel vision and able to adjust quickly in the face of possible regulatory or climatic adversity.

To promote transparency and regular communication with stakeholders, companies may consider issuing regular progress reports to address modifications to key indicators and other model refinements to maintain the integrity of the scenario planning exercise.

Key roadmap indicators for automaker scenario analysis may include:

- Oil price volatility and pricing and availability of biofuels
- Fuel economy, electrification and GHG emission standards for light-duty vehicles by region
- Adoption of carbon pricing and carbon trading by region
- Pricing of key manufacturing components, such as batteries and lightweight structural materials
- Power sector CO_2 emission factors by region
- Evolving regulation of autonomous vehicles and mobility as a service by region

D. Involve broad cross-functional teams and engage with the board.

Climate change presents strategic and enterprise-wide risks and opportunities for OEMs. As such, the issue should be covered as part of the company's overarching risk management function.

Subject matter experts in a range of company departments may be integrally involved through the climate scenario planning exercise, including:

- Research & Development
- Product Development
- Operations
- Supply chain and logistics
- Environmental affairs
- Legal affairs
- Government relations
- Investor relations
- Public relations
- Mobility services (if applicable)

Analysis derived from the scenario process and related asset and revenue modeling, should be presented and discussed at regularly scheduled meetings of the Board of Directors. The analysis should encompass company alignment with climate-resilient objectives, strategic implications for business units and corporate assets and effects on capital deployment, asset sales, budgets and financing.

Companies may benefit from inviting external participants into the scenario development process, such as academic experts, former government officials or specialist consultants. This may facilitate a broader view on trending key issues and a deeper dive into new or complex issues that emerge through the scenario planning exercise. External presenters should be selected to offer a point of view that challenges house assumptions, offers cross-examination and looks beyond conventional business planning horizons.

The Board of Directors may also designate a committee, one of its members or a top executive to oversee climate risk evaluation and develop the agenda items for Board discussion and decision making. Some companies have integrated the performance and monitoring of climate scenario analysis into the mandate of their Board governance committees.

For its part, Ceres has issued a report, View from the Top: How Corporate Boards Engage on Sustainability Performance, which recommends that companies "embed sustainability in committee charters, and in discussions on strategy, risks and incentives." The report also recommends that management "involve key staff responsible for enterprise profit and loss in board deliberations on sustainability." Climate scenario analysis and monitoring of key indicators should be incorporated in the risk management function, in support of the Board's key role to "systematically review corporate exposure to material sustainability risks and scrutinize management strategies to mitigate risks."

Ceres also recommends that companies provide robust disclosure on Board sustainability oversight and climate change issues. Areas ripe for disclosure include:

- Climate competence of selected board members
- Committees assigned to monitor and oversee climate-related issues
- Cycle of board reviews (at least annually and preferably quarterly) and recent climate-related agenda items
- Articulation of board-approved climate policies, company goals and targets
- Strategic partnerships working toward a low-carbon economy

STEP 5
Disclose and Engage

Scenario planning gives companies an opportunity to lay out alternative visions of the future, advocate for the enterprise value of their firms and support mission-critical objectives. In this way, disclosure of climate scenario methodology and embedded key parameters offers a window into the company's belief structure and guiding principles. At the same time, the process of building climate scenarios sets up a unique opportunity within a firm to challenge widely held beliefs and operating assumptions. The end result should lend a clearer perspective on the company's future and the attendant risks of climate change.

Companies should disclose information from climate change scenarios to shareholders, stakeholders and the public. Many companies do this via annual sustainability reports (posted for download on company websites) and annual shareholder reports.

A. Disclose methodology, results and key indicators of scenario analyses.

Investors and other stakeholders are interested in a full accounting of how companies are managing the risks and opportunities associated with climate change.

In its recommendations, TCFD identified four categories of information for public disclosures: governance, strategy, risk management and metrics and targets (Box 5). These topics provide important perspectives into how companies are actively managing the challenges associated with climate change.

Key elements from the climate scenario process should be disclosed to the public. This may include:

- How the methodology was developed
- Which variables were key drivers of the process
- How the main variables interacted with other factors, and
- Which results were selected for ongoing evaluation

In addition, companies may identify how the company's methodology, treatment of variables and final assessment differ from other independent assessments. Appendix C provides some examples of how relevant key indicators might be disclosed.

Box 5. TCFD Core Elements of Climate-Related Financial Disclosure

Governance	Strategy	Risk Management	Metrics and Targets
Disclose the organization's governance around climate-related risks and opportunities.	Disclose the actual and potential impacts of climate-related risks and opportunities on the organizations businesses, strategy, and financial planning where such information is material.	Disclose how the organization identities, assesses, and manages climate-related risks.	Disclose the metrics and targets used to assess and manage relevant climate-related risks and opportunities where such information is material.

B. Disclose material risks in financial statements.

Identifying material financial risks is key to the final distillation process in climate scenario analysis.

This summation captures relevant macroeconomic trends, technological developments, demographic and cultural shifts and possible geopolitical changes that may bear on climate scenario outcomes. It frames these parameters around factors more under the company's control, such as research & development, capital investments in product manufacturing and innovation, and governance of climate transition and physical risks and opportunities. To the extent that climate-related risks and opportunities are quantifiable and meet a materiality threshold, they may also compel disclosure in company financial statements.

The company should determine which material climate change risk factors should be reported in various corporate reporting venues, including:

- Annual shareholder reports
- Quarterly financial statements (e.g., Form 10-Q)
- Annual financial statements (e.g., Form 10-K)
- Annual proxy statements

Best practice companies may disclose the results of their climate scenario analysis in a stand-alone report, providing both the appropriate level of technical details and a compelling narrative that lets investors and stakeholders understand how a company's long-term vision of climate risks and opportunities factors into its future business plans.

C. Engage with key investors and stakeholders.

While climate scenario analysis may be designed as an internal planning exercise, it benefits from outreach to stakeholders who operate beyond the company gate.

This engagement lets the company communicate more effectively about its role in the transition to a low-carbon economy.

Stakeholder groups that are candidates for engagement include:

- Institutional shareholders
- Customers (including those contacted through surveys)
- Key suppliers
- Advocacy groups and civil society stakeholders
- Climate scientists
- Futurists
- Journalists and opinion makers
- Strategic partners (including technology companies)
- Industry peers
- Government regulators (at the local, state, federal and international level)

OEMs can expect to be asked to engage with stakeholders on climate-related corporate governance issues, such as:

- Internal risk management processes for identifying and assessing climate-related risks, including how their significance is measured, managed and ranked in relation to other business risks
- Compensation and other financial incentives provided to board members, senior executives, line employees, suppliers and auto dealers for achieving specific climate-related goals, including emission management programs, carbon reduction targets and sales of low-carbon vehicles and related mobility services
- Funding and participation in industry trade associations and lobbying groups, and how their policy positions compare with those advocated directly by the firm and its designated company
- Other advocacy groups that receive funding or in-kind support on climate-related issues

A successful public engagement process will help companies communicate management's level of preparedness to a rapidly changing world.

APPENDIX A

Trends and Policy Drivers for the Auto Sector

LIGHT-DUTY VEHICLE GHG EMISSIONS AND MARKET TRENDS

Globally, transportation from all modes (air, freight, passenger vehicles, rail and shipping) produces nearly 25% of fossil CO_2 emissions, compared to about 42% from the production of electricity and heat. This percentage is growing quickly—the IPCC reports that emissions from the transportation sector have grown faster than any other sector over the last 50 years. Emissions from transportation are even more pronounced in the US, with the EPA reporting that the transportation sector surpassed emissions from the electric power sector in 2017.

Some 1.1 billion light-duty vehicles remain the largest source of transportation emissions, representing 40% of total sector emissions. Light-duty vehicles are expected to nearly double to two billion vehicles by 2040, resulting in a significant increase in transportation-related carbon emissions. In the U.S, transportation CO_2 emissions increased by 23% between 1990 and 2017. This increase in emissions can be attributed to a trend towards larger vehicles and more vehicle miles travelled (VMT), despite increasingly stringent fuel efficiency regulations.

Today's auto fleet is dominated by vehicles with internal combustion engines, with SUVs currently composing 39% of total car sales. Globally, SUVs were the second-largest contributor to CO2 emissions growth from 2010-2018, as a direct result of the doubling of the share of SUVs over the last decade. This shift to larger passenger vehicles comes at a cost, because they require about a quarter more energy than medium-sized cars. If current trends continue, oil demand from SUVs in 2040 would offset the oil savings from nearly 150 million electric cars.

The auto sector is also global and highly competitive. Production centers and regional emission profiles are changing rapidly. For example, in 2000, North America and Europe accounted for two-thirds of the world's auto production, while China's share was just 4 percent. Now, Asia—led by China, accounts for more than half of global vehicle production. By some estimates, the global amount of vehicle miles traveled will increase by some 65% – from 6.7 billion miles in 2017 to 11 billion miles in 2040—also led by China, India and other Asian countries.

POLICY DRIVERS

As discussed in Step 1 of the framework, government policies and regulations are a key driver in any climate change scenario analysis. Following is a brief description of some of the key policy parameters that governments may adopt regarding greenhouse gas regulations for the auto sector at the national, regional and local levels.

GREENHOUSE GAS STANDARDS

The most direct form of regulation of the auto sector is GHG emissions and fuel economy standards for different types of vehicles, which have been adopted by the U.S. and Canada, the 28 EU nations, China, Brazil, India, Japan, Mexico, Saudi Arabia and South Korea. In addition, Australia, Thailand and Vietnam are planning to adopt such regulations. Although these regulations limit the greenhouse gas emissions and establish standards governing the fuel efficiency of vehicles, they differ in important ways, including the regulated metric, the attributes upon which the target is based, testing methods used for setting the standard and additional flexibilities built into calculating compliance (e.g., credit for air conditioner refrigerants with lower global warming potential) and the target year.

ZERO EMISSION VEHICLE MANDATES

Some governments have adopted policies that require the sale of zero-emission vehicles (ZEVs). In the U.S., California and nine other states require automakers to offer for sale specific numbers of clean cars, including battery electric, hydrogen fuel cell and plug-in hybrid vehicles. China has also adopted a ZEV policy known as the New Energy Vehicle (NEV) mandate, with a goal of 20% ZEV sales by 2025.

INTERNAL COMBUSTION ENGINES (ICE) BANS

Several countries have announced future bans on the sale of new ICE vehicles. Norway plans to ban the sale of new ICE vehicles by 2025. India has set a 2030 target. The U.K. and France have set ICE bans for 2040. China is weighing a ban on the production of vehicles with traditional engine technology "in the near future." Several cities have announced ICE bans as well. In most cases, these bans are not yet legislated or otherwise codified into law, making the timing and scope of implementation uncertain. Still, as the urgency for climate action mounts and the cost of EV models continues to drop, bans in these and other countries and cities may continue to grow. Municipal governments may also be motivated by the need to reduce conventional air pollution and to gain a foothold in manufacturing electric vehicle technology. Congestion fees levied on ICE vehicles in cities like London have also proven to be a strong deterrent to ICE vehicle use in certain metropolitan areas.

CARBON PRICES

Virtually all climate scenarios assume some level of carbon price to help drive decarbonization. Applied either through taxes or emissions trading markets, carbon pricing drives shifts toward low- and no-carbon fuels, including in the electric power sector, which will bring additional carbon benefits to battery-powered vehicles. Carbon prices will also affect oil prices and could alter the overall economics of purchasing EVs, especially as gas prices for ICE vehicles rise.

Carbon pricing has been in place for more than a decade in the E.U.'s Emissions Trading Scheme (ETS). In North America, California, the Northeastern and Mid-Atlantic Regional Greenhouse Gas Initiative (RGGI) states, Quebec and Ontario participate in cap-and-trade programs. British Columbia and Alberta have levied carbon taxes. China also has an emissions trading system under development. Other countries are considering or are implementing carbon pricing policies.

AVOID AND SHIFT' POLICIES

In addition to vehicle- and fuel-specific standards and policies, broader regulatory policies are being put in place to reduce emissions from the transportation sector on a regional or global basis. One group of 'Avoid' measures uses pricing incentives and other economic levers to reduce overall vehicle travel. These include electronic road pricing, parking restrictions, CO_2-based vehicle taxation, congestion fees and other policies. 'Shift' measures encourage alternatives to auto use, such as more use of public transportation, telecommuting, walking and cycling. As parties to the Paris Agreement compile their Nationally Declared Commitments, there will be more government, industry, and NGO initiatives that address a wide range of these approaches. The IEA Mobile Mobility model adopts the 'Avoid and Shift' paradigm through assumptions made on technologies and policy.

POLICIES AND INCENTIVES FOR NEW TECHNOLOGIES AND SERVICES

Finally, policies that promote infrastructure, provide incentives or reduce uncertainties for introduction of electric and autonomous vehicles are also part of the mix. This means for automaker climate-response strategies to succeed, a suite of national, regional and local policies may be necessary to change and disrupt fundamental aspects of the global transportation system. Such approaches may include government investments in transportation and communications infrastructure, policies to promote mass transit and new ride-sharing services and new safety and zoning regulations to facilitate the flow and function of autonomous vehicles.

APPENDIX B
Climate Physical Risks Facing the Auto Sector

Assessments by the Intergovernmental Panel on Climate Change (IPCC) and other recent reports, such as by the 2018 U.S National Climate Assessment, make clear that physical risks from climate change are likely to become more severe as the earth continues to warm. In Figure 2, the scenario labeled RCP 2.6 is closest to a CO_2 emissions rate and concentration level that would limit warming to "likely below" 2° Celsius. In its Fifth Synthesis Report, the IPCC found:

> "Surface temperature is projected to rise over the 21st century under all assessed emission scenarios. It is very likely that heat waves will occur more often and last longer, and that extreme precipitation events will become more intense and frequent in many regions. The ocean will continue to warm and acidify, and global mean sea level to rise."

The IPCC report notes that climate change will "amplify existing risks and create new risks for natural and human systems." Some risks will vary by region, while others will be global. The exact level of climate change that will trigger the most severe and irreversible changes remains uncertain. Adaptation measures can ameliorate rising physical risks posed by climate change. The IPCC stresses that "it is important to evaluate the widest possible range of impacts, including low-probability outcomes with large consequences."

More recently, the IPCC's Special Report on Global Warming of 1.5ºC found that limiting warming to 1.5°C significantly reduces the risks of many climate change impacts compared to 2°C of warming. The World Resources Institute has depicted the different impacts from this 0.5°C warming in Figure 2.

Scenario planning can help reveal the types of financial impacts that may result from the physical impacts of climate change and help bring about more resilient risk management systems. Impacts such as extreme precipitation, heat waves, droughts, flooding and sea level rise may have both acute and lasting impacts on manufacturing and supply chains. Changes in the climate may also affect market conditions, whether through short-term sales impacts or longer-term changes in consumer buying patterns and driving behavior.

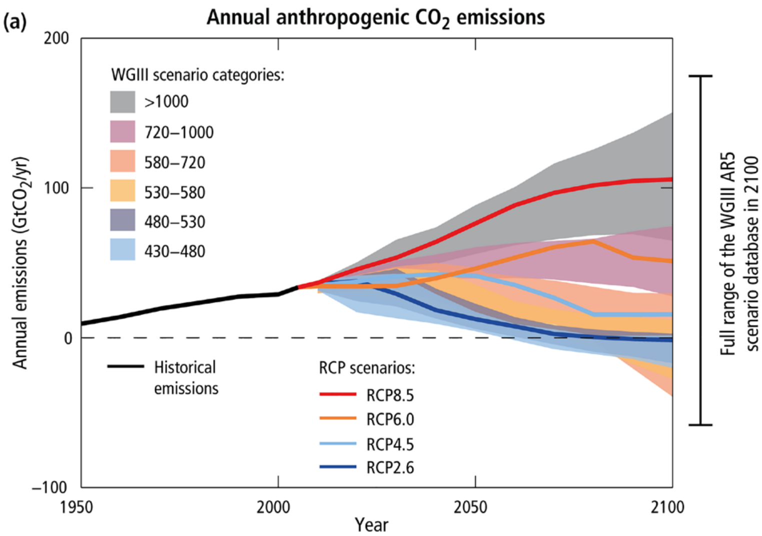
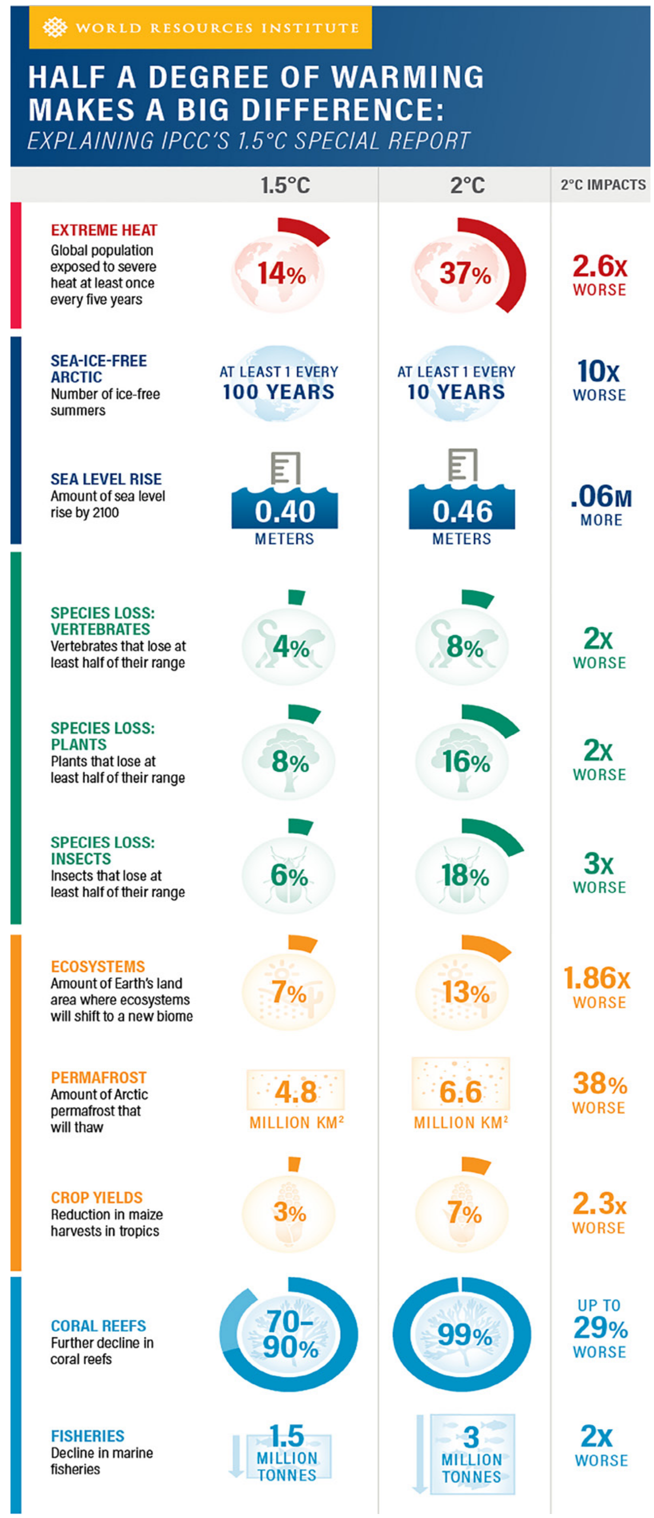


Figure 2. IPCC Climate Scenario

The IPCC's representative concentration pathways (RCPs) provide time-dependent projections of atmospheric greenhouse gas concentrations. The scenario labeled RCP 2.6 (blue line below) depicts a glide path for CO_2 emissions and concentration levels that would limit warming to "likely below" 2°C. It assumes rapid declines in fossil fuel use after 2020, with more deployment of renewables, biofuels, nuclear power and carbon capture and storage. As shown in the second graphic from the World Resources Institute, physical impacts of climate change as projected by the IPCC are projected to be significantly greater at 2°C of global warming than at 1.5°C of warming. Sources: WRI and IPCC



Box 6 Case Study: Effects of Flooding on the Auto Supply Chain

One of the most observed effects of climate change to date has been a greater incidence of extreme precipitation events. For each 1°C of warming, the air's capacity for holding water vapor goes up by about 7 percent. This creates conditions for more heavy rainfall and flash flooding in many regions of the globe.

In the United States, the incidence of extreme one-day precipitation events has risen about 75% since 1990, especially in the Midwest and Northeast. In August 2017, Hurricane Harvey dumped 48 inches of rain on the Houston metropolitan area over three days – breaking the U.S. record for most rainfall from a single precipitation event. This hurricane also demonstrated that the biggest threat from tropical storms is not always from coastal flooding and wind damage. Up to 500,000 flooded vehicles in the Houston area needed replacement after the storm, with some local car dealerships sustaining complete inventory losses.

The impacts of flooding can be far greater when it strikes key auto suppliers – even those located thousands of miles away. In 2011, Thailand experienced its worst flooding in a half-century. With two-thirds of its land area inundated by floodwaters, economic damages approached $50 billion. Toyota had to shut down its operations in Thailand for 42 days. Nissan's Thai facilities were closed for 29 days. One Honda factory in Thailand was shut for 174 days. As a result of the flooding and interruptions in manufacturing, Honda, Toyota and Nissan lost $1.4 billion, $1.25 billion and $70 million, respectively, in operating profits. In July 2018, 70 inches of rain fell in central Japan. Local flooding and landslides closed auto plants for Mitsubishi, Mazda and battery maker Panasonic. Supply chains were disrupted and many employees could not get to work. Area losses amounted to several billion dollars.

U.S. automakers have begun to report physical risk impacts from climate change. Ford lost 34,000 units of production from the 2011 flooding in Thailand. It acknowledged in its 2017 response to the annual CDP questionnaire that it has "both direct operations plants and indirect suppliers' facilities in areas at the risk of flooding." Both Ford and GM also report that water availability is at risk during droughts at some of their manufacturing facilities. In the case of Ford, "We have identified that approximately 25% of our operations, including the Cuautitlán, Mexico facility, are at risk to be water-scarce…." GM similarly noted in its response to the CDP questionnaire that an increase in the frequency of drought in Mexico "could disrupt production due to lack of water availability." Both companies note that they have risk management systems in place to monitor and address potential weather-related events that could affect production and disrupt supply chains.

Other auto-related risks posed by climate change include hail damage to car exteriors, heat stress on interiors, the interaction of electric vehicle batteries and grid-connected power during weather outages, and stress on service operations and transportation infrastructure.

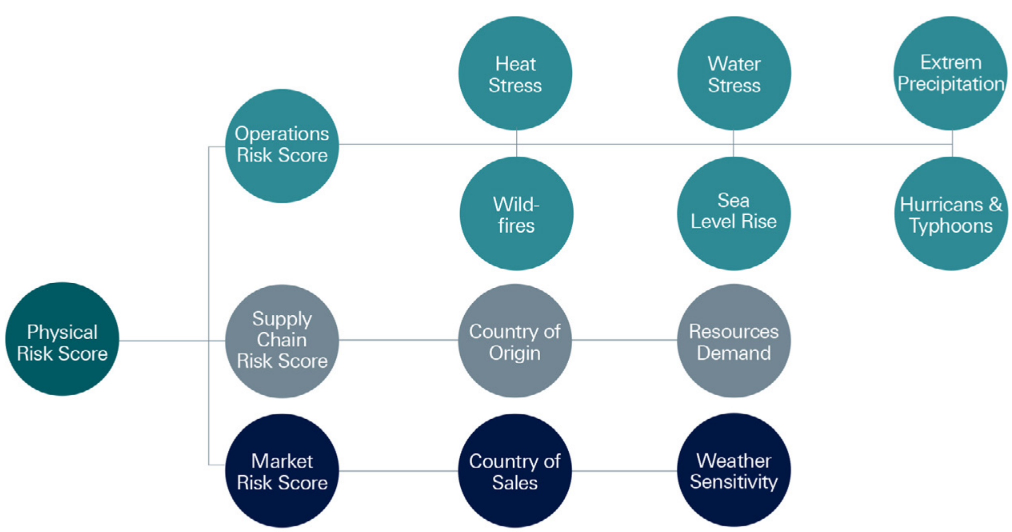


Figure 3 Source: Measuring Physical Climate Risk in Equity Portfolios

Resources Available on Physical Risks

Many resources are coming onto the market to assess the physical risks of climate change at an increasingly granular—and even company-specific—level. For example:

- The World Resources Institute's Aqueduct mapping tool provides indicators of water demand by sector for more than 15,000 watersheds worldwide. It includes data on water quality and supply (surface and groundwater, seasonal and year-to-year variability, droughts and floods), as well as projections of water scarcity and related risks that are based on climate models and economic and population growth.

- Four Twenty-Seven has developed a proprietary database that matches several climate impacts (such as wildfires, sea level rise and stress on water resources) to more than one million company facilities worldwide. It provides a physical risk score based on the operational, supply chain and market risks of companies. (See Figure 3)

- Bloomberg MAPS database assembles more than 200 datasets on energy, infrastructure, communications, traffic, terrain and streets with environmental datasets on weather, natural catastrophes, water risk and protected areas. It is working with 16 of the world's leading banks to better understand physical risks to companies in the banks' loan portfolios in the transport, energy, agriculture and real estate sectors.

- The Climate Impacts Lab consortium includes researchers from the University of California at Berkeley, University of Chicago, the Rhodium Group and others who are seeking to produce the world's first empirically-derived estimate of the social cost of carbon. Its analysis employs detailed, risk-based, probabilistic, local climate projections to analyze how these impacts may evolve as a result of a changing climate.

- CICERO, a Norwegian think tank, is documenting how historical emissions are already affecting the earth's climate. Its CLIMInvest tool is developing improved indicators, maps and software on forecasting physical climate risk. CICERO believes that 1.5°C of global warming is already "locked-in" the earth's climate system. It says the bigger question now is what impacts will arise from higher levels of warming. It recommends using a range of scenarios, including 3°C and 4°C scenarios, to arrive at a worst-case scenario for potential physical risks.

- Ceres' Climate Strategy Assessments for the U.S. Electric Power Industry and the TCFD's Technical Supplement on Scenarios also provide a thorough list of references for regional impact studies and tools for physical risk assessment.

More broadly, the TCFD and the Climate Disclosure Standards Board have launched the TCFD Knowledge Hub as the first online platform to provide information on quality climate-related disclosures in line with the recommendations of the TCFD. At the time of its launch, the Knowledge Hub housed more than 300 resources submitted by 32 contributors. Eighty of the resources cover governance, 236 strategy, 152 risk management and 125 metrics and targets, with many resources covering more than one topic. See Box 7.

In addition, the European Bank for Reconstruction and Development and the Global Centre for Excellence on Climate Adaptation (GCECA) have issued detailed guidance on Advancing TCFD Disclosure of Physical Risks and Opportunities. See Box 8.

BOX 7 Disclosure Guidance on Physical Risks of Climate Change

The most detailed guidance to date on disclosing the physical risks of climate change comes in a report called **Advancing TCFD Disclosure of Physical Risks and Opportunities**, issued in May 2018. The report was commissioned by two multinational groups focused on climate change adaptation and resilience: the European Bank for Reconstruction and Development (EBRD) is the leading multilateral development bank focused on private-sector climate resilience and the Global Centre for Excellence on Climate Adaptation (GCECA) is working to accelerate progress on financing mechanisms for climate change adaptation.

The guidance document includes 18 recommendations, five of which address scenario analysis specifically. It suggests that scenarios be used to gauge direct effects and second-order physical risks of climate change that are beyond the lifetimes of most operating assets and loans to "account for the uncertainty in climate policy and for the cascading impacts of climate change. " The starting point for such scenario analysis is set at 20 years into the future.

This guidance recommends running at least three physical risk scenarios to gauge the possible impacts of warming at 1.5°C, 2.0°C and the current pathway projection of 3.4°C (under adopted Nationally Declared Commitments). First-order impacts include: heat stress, extreme rainfall, drought, cyclones, sea-level rise and wildfires. Second-order impacts include: changes in the availability of natural resources, agricultural productivity and the geographic distribution of species, disruption to transport, changes to global trade routes, migration and macroeconomic indicators, such as GDP, employment and interest rates.

The guidance recommends that corporations disclose facilities at risk based on their geographic exposure to climate impacts and the estimated financial impacts from the risks they identify as being material. Metrics for projected impacts may include a combination of:

- Number of sites and business lines exposed to relevant climate impacts
- Projected changes in production, revenues, operational expenditure and capital expenditure due to climate change
- Value-at-risk from probabilistic estimates (for example, 1:100 or 1:200) of extreme weather event disruption to operations or production, key suppliers, customers or markets
- Annual average losses from projected climate impacts

The guidance recommends that companies disclose in their financial filings detailed information on recent impacts of extreme weather events, including metrics on days of business interruptions and associated costs, costs of repairs or upgrades, fixed-asset impairment, supply chain disruptions and lost revenues. Such metrics provide a baseline for assessment of possible future physical risks and trends in climate impacts.

Box 8 Physical Risk Recommendations Advancing TCFD Disclosure

	Supply Chain	Operations	Markets
Hazards	Assess exposure to heat stress, extreme rainfall, drought, cyclones, sea-level rise, wildfire and other industry-relevant and locally specific climate hazards across the corporate value chain		
Timeframe	Assess exposure to first-order impacts in the short- to medium-term (2-5 and 5-20 years) using a probabilistic approach and using scenario analysis to assess long-term risks (> 20 years) and possible exposure to second-order (indirect) impacts		
Geography	Location (country or city) of key supplier facilities and a measure of their importance	Location (country or city) of critical business facilities (production, support systems) and key distribution or logistics sites	Breakdown of sales by country and by segment
Impacts of recent weather-related events	Decreased output and revenues due to supply chain interruptions	• Reduced revenues, including if a significant number of staff are unable to get to work • Increase in opex (repair costs, insurance costs) • Increase in capex (asset impairment, inventory write-downs)	Reduced revenues from lower sales due to consequences of extreme weather events