Investing in sustainability

Risking It All

An Introduction to Climate Risk and Energy Scenarios

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Summary

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No matter the final objective - risk mitigation, identifying opportunities, creating impact, or all three – considering environmental and social factors alongside financial information leads to an information advantage for investors.

Should we fail to limit temperature rise to 2°C or less, climate change will almost certainly wreak global havoc and lead to vast costs (IPCC, 2014). To mitigate the costs and impacts of climate change, we have no choice but to reduce emissions as quickly as possible while building resilience in the areas that will be affected.

Investors that understand how their assets interact with the climate and know how to exploit the climate-related tools available to them will be better prepared to both manage their risks and seize the opportunities associated with the energy transition, all while creating positive impact if they so choose.

Scenarios are often cited in investment contexts, as investors compare their portfolios with scenario projections or ask companies to do the same. But, the assumptions underlying each can lead to diverging conclusions. Many points are common to all: energy efficiency will play an important role in reducing emissions, and rapid decarbonization in the electricity sector will be essential for meeting the climate challenge. But, some scenarios consider that nuclear power and/or negative emissions technology, especially carbon capture, use, and storage, will be the planet's saving grace. Whether this is realistic or not is debatable.

As such, investors should consider their goals carefully when evaluating their portfolios against scenarios or engaging with companies on the same basis. We encourage investors to avoid overreliance on a single scenario or emissions pathway, to instead embrace the multitude of potential green technologies and climate solutions. Especially when combined with robust methods for lifecycle carbon footprinting, we believe that this approach leads to more positive impact, new opportunities, and effective risk mitigation, while supporting innovation and effective engagement.

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Introduction

Climate and energy scenarios can help investors to understand the role their investments play in achieving or obstructing climate objectives and highlight the risks their assets face due to climate change. More aware than ever, investors have begun to demand action. Oil and gas companies are now expected to stress-test their product portfolios against ambitious climate action scenarios in line with ambitious climate action. Companies in all sectors are expected to more stringently evaluate the regulatory and long-term physical risk exposure of their assets.

Scenarios can also guide policymakers towards the most likely, or presumably most viable, paths for decarbonization. By their very nature, scenarios illustrate possibilities, which feels reassuring in the context of big issues like climate change. They provide concreteness, which is reassuring to investors and policymakers. They not only serve as our best guesses about what the future could look like, but also indicate what changes would need to be made, and when, to achieve climate objectives. While we believe they are clearly valuable tools, the usefulness of scenarios compounded with the reassurance they provide also makes them prone to misuse and overreliance.

Uncertainty is a key part of any forecast, but human nature tends to downplay the unknown. Policymakers and investors tend to settle upon a single number, a single scenario, which is not necessarily representative of the far more ambiguous reality. Each energy scenario illustrates a different climate pathway due to its underlying assumptions, so making decisions based on just one is a gamble that technology will develop as expected, that countries will meet their commitments, that people and the economy will behave as anticipated, and more. Most scenarios also only look at the energy sector, ignoring the approximately 25% of global annual emissions from agriculture, land use change, and forestry. The evolution of these sectors represents another unknown unaccounted for.

Within this ambiguous context, investors who use scenarios must proactively seek to understand their history and the key differences between them, as well as their individual and collective pros and cons.

1. Climate Risks

1.1 Transition and Physical Risk

Energy and climate scenarios are often used to help investors gauge the climate-related risks faced by sovereigns, infrastructures, and companies. There are two types of climate risk:

- **Transition risk** comes from being unprepared for abrupt changes to businesses and assets. For example, more stringent regulation on carbon emissions, like the introduction of a carbon tax, would suddenly make emissive coal plants less economically attractive to run.

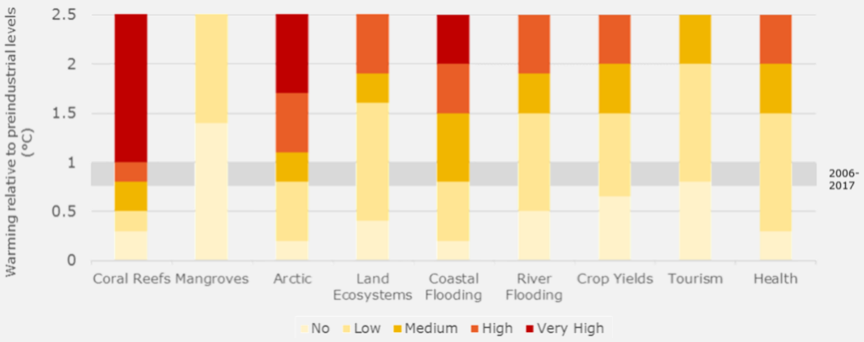
- **Physical risk** comes from the negative physical effects more extreme weather events would have on assets. Stronger hurricanes and flooding in tropical regions, for example, jeopardize the assets of businesses located there.

These two types of risk are inversely related. Transition risk is higher if global average surface temperature rise is limited to 1.5-2°C, in line with the international objectives set at COP21 in Paris. Physical risk, conversely, is higher the more temperatures increase towards 6°C.

Focus: From 1.5°C - 6°C in 2100 and beyond

As of 2018, the climate has warmed by approximately 1°C relative to preindustrial averages (IEA, 2018). Going forward, the best-case scenario (avoiding irreversible, severe negative impacts) is to stabilize long-term, global temperature rise at less than 2°C relative to preindustrial averages. This would require immediate and severe emissions cuts.

Physical Impacts of Climate Change



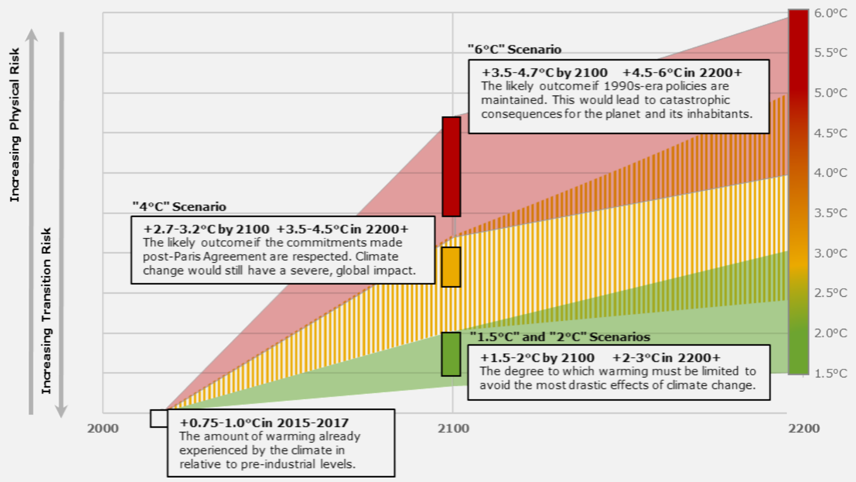
Ecosystems, human health, crop yields, and much more will be strongly and irreversibly affected by climate change should warming proceed far beyond today's levels. This translates into enormous physical risk.

Source: (IPCC, 2018)

Objectives and scenarios often use 2100 as the target year, which at first glance seems sufficiently long-term. But, emissions and warming effects are offset: on average it takes a decade or more for an emission to reach its maximum warming potential (Ricke & Caldeira, 2014). Larger pulses of emissions can take even longer (Zickfeld & Herrington, 2015).

About 70% of CO2 is reabsorbed by carbon sinks (oceans, forests, etc.) after 100 years. But 10-20% remains in the atmosphere for hundreds more years, and 10% lasts for thousands. These remaining emissions, if large enough, can still lead to substantial warming.

Climate Scenarios and Long-Term Stabilization



All temperatures are global average surface temperatures relative to pre-industrial averages (1850-1900). "Global average" temperatures do not represent the unevenness of warming effects. Some regions will experience greater warming than others: the Arctic, for example, has already warmed by +2.5-3°C, while some small areas of the Pacific Ocean have dropped in temperature (Berkeley Earth, 2018). The bars at 2100 and 2200 represent "likely" zones, according to the International Energy Agency and the Intergovernmental Panel on Climate Change.

Source: Mirova / (IPCC, 2014) / (IEA, 2017)

Anthropogenic emissions throughout this century certainly constitute a large pulse. Even if more than half of them dissipate within 100 years, the remaining emissions in the atmosphere would be sizeable. This means that peak warming would be reached slowly, delaying stabilization.

As a result, even if temperatures have been limited to 2°C by 2100, there is no guarantee - short of immediate and deep decarbonization - that they will not continue to increase through the following century. The slower emissions taper and the more emissions accrued by 2100, the more severe the growth post-2100.

1.2 Managing Climate Risk

Managing physical and transition risks while meeting the climate challenge will require both mitigation and adaptation.

MITIGATION

Mitigation corresponds to transition risk. Avoiding climate change as fully and as soon as possible, is the best way to reduce its long-term impacts. Greater mitigation efforts lead to greater transition risk: the more dramatic the energy transition, the greater the costs associated with it. At the same time, greater mitigation efforts today reduce physical risk (and the costs associated with it) tomorrow.

One of the biggest factors influencing mitigation cost (and transition risk) is the how long it takes before we start implementing meaningful emissions cuts. The longer we wait, the more abrupt and dramatic the energy transition will need to be. For example, continuing to hold off on reducing emissions could increase costs by 40% if the delay means 50% higher emissions in 2030 relative to a 2°C emissions scenario. Costs will also go up if countries don't work together, or if technologies cannot be deployed as expected. Without technology that captures and stores carbon rather than discharging it into the atmosphere, for example, the costs of limiting climate change could double (IPCC, 2014).

Costs of mitigating climate change
(stabilizing greenhouse gas emissions at <2°C)

	Per year (billion$)	How many years
IEA	1400	32
IPCC	908	20
Actual Financial Flows	382	

Source: (IEA, 2018) / (IPCC, 2014) / (Climate Policy Initiative, 2017)

The International Energy Agency estimates that mitigating climate change by switching from fossil fuels to low-carbon sources of energy will cost $1.4 trillion per year until 2050 - but the costs of switching will be paid for in fuel savings over the same period (IEA, 2018). The Intergovernmental Panel on Climate Change estimates that efforts to stabilize levels of greenhouse gas emissions would require investments of about $908 billion per year between now and 2030 (IPCC, 2014). In comparison, financial flows dedicated to mitigation were about $382 billion in 2016; substantially less than the IEA and IPPC estimates (Climate Policy Initiative, 2017).

ADAPTATION

Adaptation mostly entails physical risk management at the local level. It reduces vulnerability related to the impacts of climate change by preparing for sea level rise in low-lying communities, for example, or improving rainwater harvesting systems in areas likely to experience drought.

Estimates of global adaptation costs suggest that hundreds of billions of dollars per year will likely be needed between today and 2050. The greater the emissions over the next years, the greater adaptation costs will be. Since adaptation tends to be a local issue and many of the most affected communities are in developing areas, finding and securing financing can be challenging. To date, adaptation finance flows have not come close to the estimated needs.

In 2010, the World Bank projected adaptation finance needs would be $70-100 billion per year between 2010 and 2050 (World Bank, 2010). Seven years later, UNEP suggested that the costs described by the World Bank were severely underestimated; UNEP estimates that costs will range between $280-500 billion per year over the same period (UNEP, 2016). In 2016, $22 billion of finance flows addressed adaptation, again far below the estimates of the UNFCCC and UNEP (Climate Policy Initiative, 2017). This figure has also not grown substantially over recent years.

Costs of climate change adaptation (for 2050)

	Per year (low estimate, billion$)	Per year (high estimate, billion$)
World Bank	75	100
UNEP	280	500
Actual Financial Flows	22	

Source: (World Bank, 2010) / (UNEP, 2016) / (Climate Policy Initiative, 2017)

Basically, addressing climate change as soon as possible by investing in mitigation and adaptation alike is essential to avoid catastrophic environmental and social impacts that would bring further adaptation costs along with them. Putting off climate action only leads to higher future costs, both mitigation and adaptation, and higher risk, both transition and physical.

To understand the consequences – both positive and negative, past and future – of our carbon emissions and energy use, a variety of models have been produced and studied. They attempt to explore some of the potential energy futures ahead. Investors can use these to study the exposure of their portfolios to climate risks and/or participate in decarbonization of the world economy.

1.3 Modeling Climate Risk

Historically, energy models have fallen into three broad categories:

- **Engineering models** are based on supply and demand. They are mostly used to define how power plants should adjust their output or assess the new transmission infrastructure that would be needed if electricity demand changes.

- **Economic models** are top-down. They treat the energy system as part of the macro-economy. Using energy as an input to economic growth under variables like labor, capital, and natural resources, top-down models are typically used to produce demand forecasts.

- **Climate models** describe how the Earth's systems would respond under a given set of conditions. They simulate global and regional effects on the atmosphere, land, oceans, and ice.

  It's worth noting that some climate models approximate positive feedback loops that would amplify as the climate warms, further exacerbating warming. For example, thawing Arctic permafrost would release methane (a potent greenhouse gas) into the atmosphere, making warming worse. Melting sea ice or dying forests could have similar effects (Steffen, et al., 2018). Triggering these feedback loops could lead to accelerated warming, so climate models that do not consider them are likely paint a more modest picture of warming compared to ones that do.

Integrated Assessment Models (IAMs) combine all three. Using socio-economic assumptions, IAMs output physical information about earth systems, like greenhouse gas concentrations in the atmosphere. But, since physical data is not always useful to other energy industry stakeholders, many turn to simpler hybrid models that combine engineering and economic models. These output economic and energy data that can be analyzed afterwards using climate models.

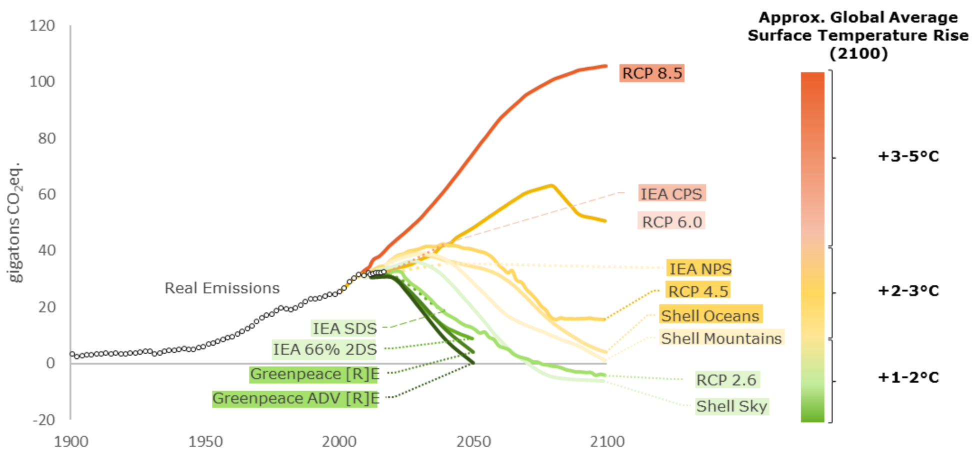
Even if from different angles, all three types of models help us look at how population, economic growth, and energy use affect and interact with physical earth systems. These scenarios can be used to inform climate and energy policies, business decisions, and more.

2. Focus on 2°C

Scenarios can be assembled into roughly three groups: “2°C” Scenarios, “Limited Action” Scenarios, and “No Action” Scenarios.

“2°C” Scenarios	“Limited Action” Scenarios	“No Action” Scenarios
Compatible with drastic policy action, limiting global temperature rise in line with the Paris Agreement and avoiding the most extreme effects of climate change.	Assume recent climate policy commitments are upheld and serve to mitigate climate change to some extent, though substantial effects would still be felt.	No policy measures are taken to combat climate change beyond those that exist today, leading to unmitigated and potentially catastrophic warming.
Examples: IPCC RPC2.6 IEA SDS Shell Sky Greenpeace [R]E Greenpeace ADV [R]E	**Examples:** IPCC RCP4.5 IPCC RCP6.0 IEA NPS Shell Mountains	**Examples:** IPCC RCP8.5 IEA CPS Shell Oceans

Annual Greenhouse Gas Emissions, by Scenario



For detailed information about the organizations that produce these scenarios (IPCC, IEA, Shell, Greenpeace) and information about each scenario individually, please see the appendix.

Source: Mirova / IEA / Greenpeace / IPCC AR5 / Shell New Lens Scenarios

Since reducing the risk of vast costs associated with the potentially catastrophic impacts of climate change is essential for generating long-term returns, we will focus on the 2°C scenarios going forward.

These scenarios allow investors to understand whether their investments contribute to or obstruct sustainable development, as well as how their portfolios fit into the energy transition. They can also serve as useful tools for understanding the climate risk companies face, especially when they are not analyzed or disclosed by the company. Furthermore, scenarios can serve as a basis for engagement with the companies that will need to play an active role in determining the future of energy and achieving climate objectives.

With that in mind, investors should be aware of some of the key differences between the 2°C scenarios. All the scenarios discussed share some fundamental assumptions that fall squarely in line with today’s trends and expectations. But, some also contain assumptions that we consider potentially problematic, either because they are unrealistic or may inadvertently encourage continued overreliance on fossil fuels through the coming years.

2.1 Unanimous Conclusions

There are three fundamental points of agreement between all the 2°C scenarios discussed, even if the final energy demand mix and emissions pathways vary between them:

- Energy efficiency will be a key part of achieving climate objectives.
- The electricity sector will be among the first to decarbonize, as renewable energy sources replace fossil fuels.
- A decarbonized electricity sector will play an important role in decarbonizing buildings, industry, and transportation.

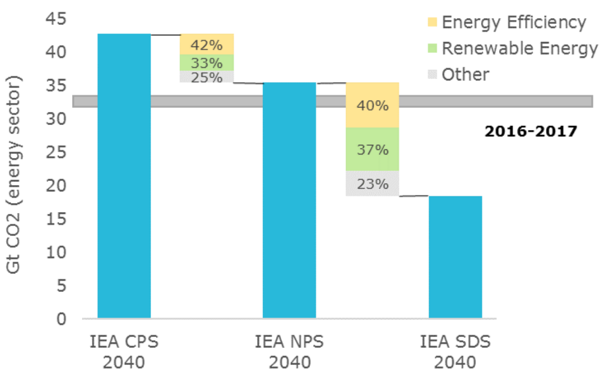
ENERGY EFFICIENCY WILL BE AN IMPORTANT PART OF ACHIEVING CLIMATE OBJECTIVES

Figuring out how to limit the negative climate impacts of growth without stymieing it is essential for meeting the 2°C challenge. By all accounts, improvements in energy efficiency will be among the main drivers of decarbonization.

Decoupling economic progress from energy consumption remains key for ensuring sustainable long-term growth. Overall energy consumption grows as populations and wealth increase, but the energy intensity of an economy tends to fall as development progresses.

Today, energy efficient technologies offer considerable promise for reducing the costs and environmental impacts of energy use. Many scenario providers (including the IEA, Greenpeace, IPCC, and Shell) predict that improvements in energy efficiency will lead to between one-third and one-half of the reductions in total energy-related CO_2 emissions in their 2°C scenarios. Without the expected improvements in energy efficiency, for example, the IEA estimates that the projected rise in final energy consumption would more than double (IEA, 2017).

IEA: Contributions to emissions reductions by scenario



Most of the differences in the emissions pathways implied by the IEA's scenarios come from renewable energy and energy efficiency assumptions. Ambitiousness of energy efficiency policy is the greatest differentiator between the IEA's scenarios.

Source: Mirova / (IEA, 2017)

Implementing and improving energy efficient technologies are key to achieving the positive climate impacts of these pathways, but have been historically underappreciated by consumers and businesses, even if they stand to benefit financially. This means that there is already substantial room for improvement in energy efficiency, should it be developed, marketed, and incentivized correctly (International Institute for Applied Systems Analysis, 2012).

Regulation has not yet adequately addressed the question of energy efficiency either. Over 68% of global final energy consumption remained uncovered by mandatory efficiency codes and standards in 2016 (IEA, 2017), though much of the demand reduction linked to energy efficiency has been achieved through government policies. Some of the most effective policies include mandatory energy efficiency regulations like minimum performance standards, fuel economy standards, building energy codes, and tradeable certificates linked to energy savings. Improvements can also be delivered through reductions in price, technological changes, and advances in energy management.

However, financing for large-scale energy efficiency projects can be difficult to secure, since they are still relatively small and fragmented. Financial institutions generally tend to be less familiar with energy efficiency than renewables, citing higher transaction costs and higher perceived risks.

All the 2°C scenarios outline the need for far greater deployment of energy efficiency measures. The basic technological components are already in place, so these are viable and feasible objectives. Next steps include developing a robust public policy framework, expanding awareness, and institutional reforms.

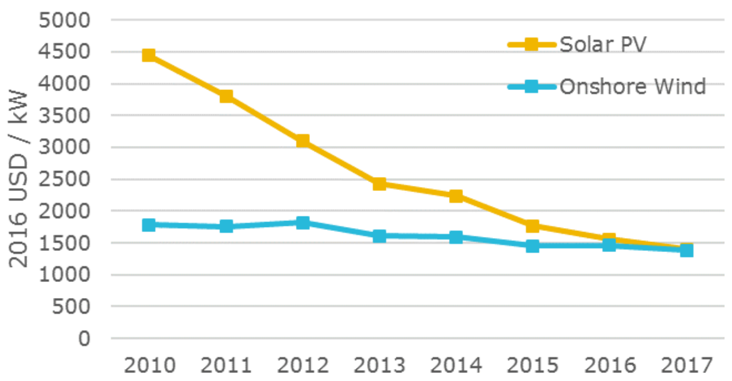
RENEWABLE ENERGY SOURCES WILL REPLACE FOSSIL FUELS IN THE ELECTRICITY SECTOR

Replacing fossil fuels is not possible in all applications. Coal is an essential part of steel/concrete production, gas is used both as a raw material and a source of heat, and oil is used to produce plastics and power transportation. None of these have simple, low-carbon replacements.

Energy generation and electric utilities do. There are technologically and economically feasible options to grow the share of low-carbon energy in the electricity mix: renewable energy systems like wind, solar, biomass, geothermal, and hydropower. As a result, all of the 2°C scenarios studied suggest a rapid decarbonization for the utilities sector relative to others.

Despite the many renewable energy options, wind and solar are typically presented as the predominant options for decarbonization of the utilities sector. Not only do both represent substantial climate benefit over fossil fuels, but both are becoming increasingly economically competitive, leading to high growth potential.

Total installed costs of onshore wind and solar PV projects (global weighted average, 2010-2017)

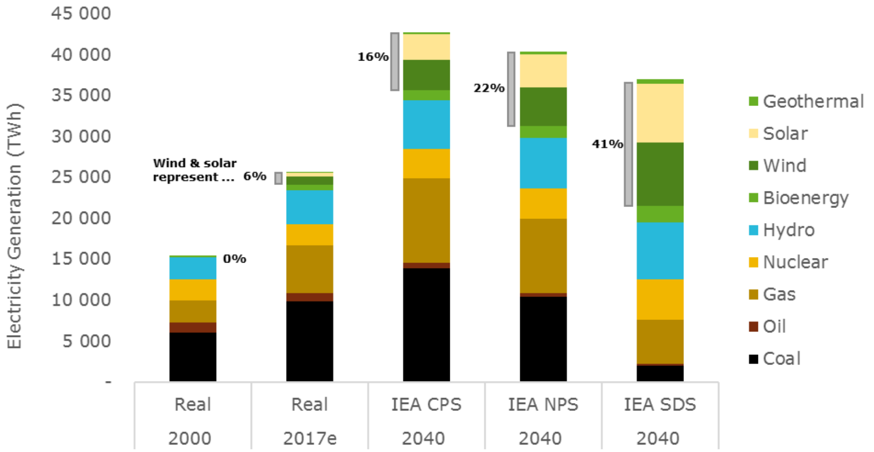


Note that the costs of wind and solar power have yet to fully account for the intermittency of these energy systems, which may require adapting the grid and/or investments in storage to manage.

Source: Mirova / (IRENA Renewable Cost Database, 2018)

All the 2°C scenarios predict that wind power, both onshore and offshore, will continue to expand as it becomes the least expensive energy source in regions with good wind resource. Some, most notably the Shell Sky scenario, suggest that solar power will become far and away the dominant form of energy in the second half of the 21st century, highlighting the potential of non-intrusive rooftop solar power generation.

IEA: Evolutions in the Electricity Generation Mix (TWh)



Source : (IEA, 2018)

Focus: Bioenergy

Bioenergy will be an important player in the energy transition, with many scenarios suggesting that it can play a major role in replacing fossil fuels.

In the electricity sector, biomass in the form of wood pellets can be used to replace coal in power stations. Both the IPCC's RCP2.6 and Shell's Sky scenario suggest that large-scale use of biomass could be used to generate net-negative emissions electricity if combined with carbon capture and storage.

Despite its widespread applicability, bioenergy has several caveats:

- Replacing existing food crops with energy crops for bioenergy could force some areas to choose between food and fuel.

- Burning biomass can release large quantities of CO2 and particulate matter into the air, potentially as much as burning coal. While biomass is considered carbon neutral because plants absorb CO2 during their lifetime, burning it does constitute an abrupt pulse of CO2 into the atmosphere. Given the time sensitivity of reducing emissions to mitigate climate change, this can lead to climate damage unless regrowth is takes place relatively quickly and is managed carefully.

In the scenarios, biomass' greatest role is in the transportation and buildings sectors: bioenergy can be used to replace natural gas in heating (biogas) and liquid hydrocarbons in cars (biofuels). Most of bioenergy's growth in the 2°C scenarios stems from its role in the transportation sector.

Focus: Other Renewables

Like wind and solar, hydropower and geothermal are low-carbon energy systems. But, unlike the wind and the sun, neither geothermal resource nor suitable rivers are present everywhere.

Since these technologies are mature and have low lifecycle costs, places with hydro and/or geothermal resource have already implemented these energy systems in most available sites.

Hydro and geothermal therefore exhibit relatively low growth in Europe, China, and the United States. None of the scenarios discussed suppose high growth in hydropower or geothermal capacity.

REDUCING ELECTRICITY’S CARBON FOOTPRINT WILL LEAD TO DECARBONIZATION IN OTHER SECTORS, TOO

Electricity is substantially easier to decarbonize than applications that depend directly on burning fossil fuels. As described in the previous section, there are more cost-effective and low-carbon options for reducing the carbon intensity of the electricity mix. So, switching from direct use of fossil fuels to using low-carbon electricity is one way that the buildings, industrial, and transportation sectors could decrease their emissions footprint.

Gas heating in buildings, for example, can be replaced by biogas, a lower-carbon alternative that relies on the existing gas transmission and distribution infrastructure. Heat pumps can also replace gas heating by using electricity to pull heat from a nearby heat sink (geothermal or air) and discharge it into a building’s interior. While not all electric heating is as efficient as heat pumps, it can lead to net positive climate impacts when the electricity mix is less carbon-intensive than gas.

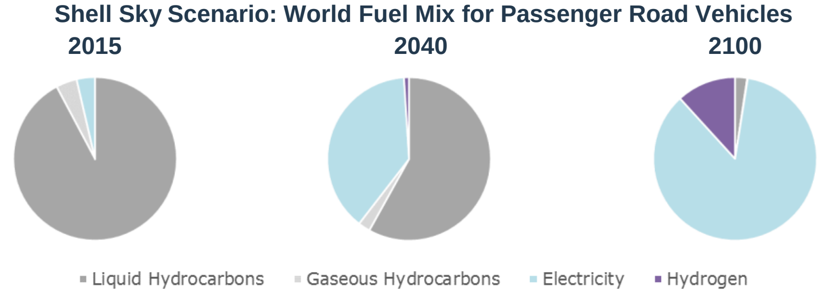
Industrial electricity consumption has remained flat since about 1990. The heterogeneity of industrial activities and limited data create challenges for assessing electrification opportunities, plus many industrial applications of fossil fuels depend on the byproducts of the fuels themselves, making these inputs irreplaceable. Electricity could nevertheless replace gas in process heating if cost-effective technologies for high-temperature use are developed (NREL, 2018).

The 2°C scenarios include slow but steady growth of electrification of buildings and industry but reducing the carbon footprint of these sectors mostly stems from energy efficiency. In transportation, however, electrification is treated as the primary pathway forward for decarbonization.

Today, transport represents about 23% of global carbon emissions and is the leading cause of air pollution in cities (IEA, 2017). By replacing the direct consumption of gasoline or diesel with electricity, electric vehicles can substantially reduce the environmental impacts of road transportation. Replacing conventional vehicles by electric vehicles would also reduce air pollution and its health effects, as the particulate matter, NO_x, and SO_x produced by cars are byproducts of fossil fuel combustion (NREL, 2018).

Shell considers that the share of oil products in the fuel mix of road vehicles will decrease substantially between now and 2040, with nearly all road vehicles running on low carbon fuel by 2100 (Royal Dutch Shell, 2018). This implies a substantial drop in oil demand and emissions from the transport sector. The Greenpeace [R]E scenario considers that autonomous hybrid and grid-connectable vehicles will make up nearly 100% of sales in 2050 in nearly every region but Africa (Greenpeace, 2015).

Shell Sky Scenario: World Fuel Mix for Passenger Road Vehicles



Source: Mirova / (Royal Dutch Shell, 2018)

Electrification is not currently viable for air transportation, because batteries are not yet able to meet the size and weight constraints while delivering sufficient power (IEA, 2017). 12% of air transport fuel could come from biofuels in 2030, however, reducing some of the industry’s carbon impacts until batteries improve in size and power density (UN Environment, 2017). Until then, air traffic will remain a major source of oil product demand and greenhouse gas emissions.

2.2 Differences

Investors should also be aware that there are some fundamental differences between the 2°C scenarios, some of which may be problematic for achieving climate objectives and reducing climate risk. These points are common to all the 2°C scenarios except for Greenpeace's:

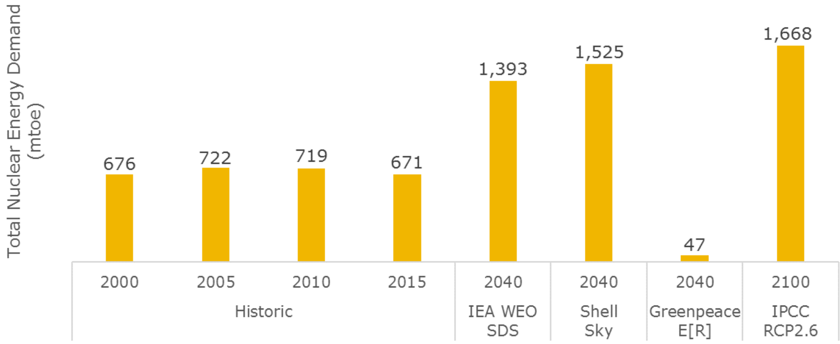
- Substantial new nuclear capacity will be installed in the next years.
- Carbon capture, use, and storage will be widely deployed in the second half of the century.

SUBSTANTIAL NEW NUCLEAR CAPACITY WILL BE INSTALLED IN THE COMING YEARS.

Nuclear power plays a prominent part in today's global energy mix, making up 10% of the electricity generated in 2017 (BP Statistical Review 2018). From a purely climate-focused view, nuclear power has impacts as positive as renewables. It emits zero carbon during its use phase and very little on a lifecycle basis. But, it carries substantial social risk in the form of accidents and waste, with public opinion in Europe, the United States, and elsewhere turning increasingly against it. In these areas, cost estimates for nuclear power reflect stricter regulation post-Fukushima and dismantling, making it far less competitive than it once was.

Nevertheless, some scenarios (notably Shell and the IEA) include major growth for nuclear power over the next decades.

Nuclear Power Demand by Scenario



Source: Mirova / (IEA, 2017) / (IPCC, 2014) / (Royal Dutch Shell, 2018) / (Greenpeace, 2015)

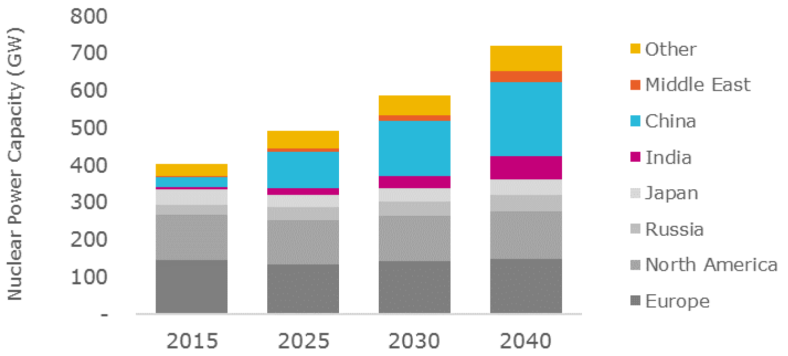
Nuclear plants produce large quantities of power and can reduce dependence on imported fossil fuels, making them attractive in situations where electricity demand is increasing quickly, pollution is becoming problematic, or local fossil resources are limited. This is the case in much of East and South Asia, where population and wealth are growing rapidly while pollution from coal use has become a major public health concern. Since new nuclear build is also relatively inexpensive in these regions, several countries (including China and India) are actively looking to expand their nuclear capacity to help meet increasing demand inexpensively while avoiding fossil fuel lock-in effects.

Accordingly, most of the nuclear power growth in the scenarios comes from East and South Asian countries. Even in these regions, the dropping price of renewables, uncertainty in long-term waste storage and decommissioning costs, more stringent regulation, and damaged public opinion of nuclear power post-Fukushima means that development has not proceeded as quickly as expected.

- In 2017, South Korea announced plans to halt the construction of new power plants and not extend the lifetimes of those currently operating (Reuters, 2017).
- Vietnam cancelled its nuclear power program in 2016, choosing to install large-scale solar, gas, and coal facilities in their stead (World Nuclear Association, 2017).

- Despite its high nuclear ambition in the 13th Five-Year Power Planning, China's nuclear power installation rate has stagnated in recent years (Xu, Kang, & Yuan, 2018).

Nuclear Power by Region (IEA SDS scenario)



Source: Mirova / (IEA, 2017)

However, the scenarios also assume stable levels of nuclear power in Europe and the United States. In the Shell Sky scenario, for example, nuclear capacity remains approximately stable between now and 2100, far beyond the lifetimes of existing nuclear plants. This implies new installations as existing plants are retired, which is difficult to imagine considering the current public, political, and financial skepticism around nuclear power, especially relative to renewables, in these regions. The IEA's projections only extend until 2050, but even over the shorter timeframe, new installations would be required.

Scenarios take a favorable view of nuclear because it of its very low carbon emissions, historically low price, and consistency with the existing power supply and distribution model. Nuclear helps align scenarios with low warming climate targets while maintaining the centralized power distribution model, providing large quantities of electricity and not requiring adjustment of the parameters associated with modeling the grid (as renewables require, at scale). Furthermore, any cost-optimization models are likely to favor nuclear, as the cost per unit of electricity produced by nuclear plants is typically low. However, its dismantling, waste storage, and decommissioning costs are not fully realized in most assessments, meaning that its real costs may be higher than assumed.[1]

CARBON CAPTURE, USE, AND STORAGE (CCUS) TECHNOLOGIES WILL BE WIDELY DEPLOYED IN THE SECOND HALF OF THE CENTURY.

Most scenarios – all of those previously discussed except for the Greenpeace scenarios - indicate that peak oil is still before us, perhaps by as much as 20 years or more, with peak gas even further in the future. The timeframes for fossil fuel phaseouts have direct impacts on warming since longer phaseouts mean more carbon is emitted into the atmosphere.

Paradoxically, some scenarios have long fossil fuel phaseouts and are still in line with limiting temperature rise to 2°C (see Shell Sky, IEA SDS, and RCP 2.6). They maintain high levels of fossil fuels in the energy demand mix by considering that vast deployment of CCUS will pick up the slack in emissions after 2050.

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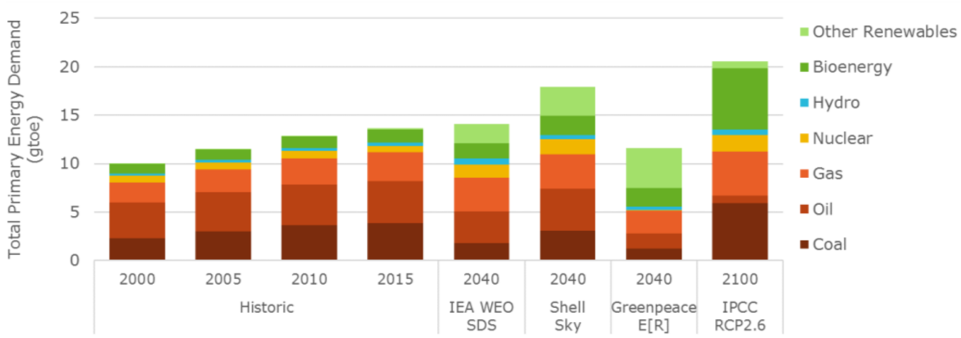
[1] For more information about our view on nuclear power, please see our publication entitled *Nuclear's Unclear Future* (Mirova, 2017).

Total Primary Energy Demand by Scenario



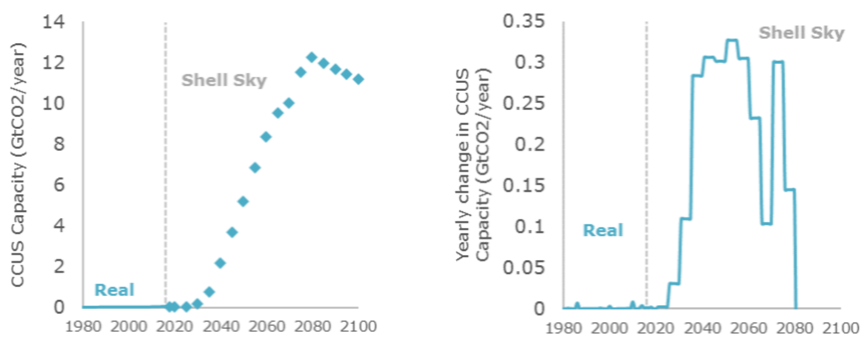
Source: Mirova / (IEA, 2017) / (IPCC, 2014) / (Royal Dutch Shell, 2018) / (Greenpeace, 2015)

The IPCC RCP 2.6 has coal, gas, and bioenergy dominating the energy mix in 2100. This suggests a very high carbon intensity. The RCP 2.6 justifies its assessment as in line with very little warming by considering that bioenergy plus CCUS will lead to deeply net-negative emissions (since bioenergy is considered carbon neutral) and that coal/gas will all be outfitted with CCUS, limiting emissions. As a result, looking at the energy mixes alone paint an incomplete picture; policymakers and investors must also consider the substantial development and investment needs of CCUS behind each (IPCC, 2014).

However, there are no net negative emissions technologies currently viable at the scale needed to compensate for a slow fossil fuel phaseout at the end of the century. CCUS has been technologically proven but remains extremely limited in practice. It is expensive and requires specific geological structures. Figuring out how to ensure safe storage of unused carbon over essentially infinite lifetimes, how to reassure communities that it poses no risks to them, and how to manage the associated costs of what could be effectively infinite storage remain unknowns (Global CCS Institute, 2018).

After decades of the energy industry touting CCUS as a major part of the solution to climate change, only 22 CCUS projects are in operation today. 16 of them are linked to “enhanced oil recovery” - re-injecting CO2 into extraction wells to extract even more oil - which is generally not net negative. The others do indeed lead to net negative emissions but on a small scale. The ability of CCUS to be deployed at scale remains a major uncertainty (IEA (CCS), 2018).

CCUS in the Shell Sky Scenario



Source: Mirova / (Royal Dutch Shell, 2018) / (Global CCS Institute, 2018)

Since slow phaseout scenarios (that later assume wide use of CCUS) in do not fix particularly exigent decarbonization objectives, they can drive policymakers to continue their support for fossil fuels and give investors an incomplete picture of the regulatory and climate risks faced by their investments. In short, these scenarios can support long-term fossil fuel dependence.

Furthermore, oil and gas companies that stress-test against these scenarios do not report major stranded asset risks in the short- or mid-term, nor do they allocate a research and development budget in line with the increase in CCUS that would be required to compensate their short- to mid-term emissions.

The choice to hail CCUS as the climate's end-of-century savior and promote the continued use of fossil fuels is perilous; should CCUS development fall short of expectation and fossil fuels continue to make up a substantial part of the global energy mix, warming would very likely be far beyond 2°C. In our view, we need to be prepared for this possibility. Making policies – or investments - based on scenarios that emit far too much carbon in the short-term with the expectation that CCUS will compensate for it later is making a wager with the future of the planet at stake.[2]

3. Applying Climate Considerations

Investors need to be well-informed about scenarios they use for the sake of their investment strategies, no matter whether the ultimate goal is to reduce portfolio risk or contribute to the fight against climate change. 2°C scenarios play an important role in helping policymakers, investors, and the public to understand the challenge before us. They underscore the urgency and the difficulty of the energy transition.

But, while scenarios can be useful for imagining some of the many paths forward, they must be treated carefully; used prescriptively, partially, or interpreted too literally, they could lead to unintended effects.

Creating a portfolio today that mirrors the ideal portfolio in 2050 according to a single scenario could lead to a feedback loop: scenarios suggest potential futures, investors and policymakers act in ways that support them, and scenarios reflect these new actions, retrenching their original ideas. While that is not necessarily bad, solving climate change and achieving the other Sustainable Development Goals will require technological, organizational, societal, and governmental collaboration on an unprecedented scale. Too much reliance on one pathway may allow some of these opportunities to slip away undeveloped and unexplored.

We therefore encourage investors to avoid the temptation of overreliance on one decarbonization scenario, and to embrace the multitude of pathways for achieving a low-carbon future. We believe this allows for better stock-picking as investors can allocate capital to energy efficiency, renewable energy, or other innovative climate plays as opposed to being constrained to one sector.

In our view, this approach can also lead to more effective engagement. Instead of asking oil and gas companies to assess their physical and transition risk against scenarios that are relatively favorable for them (as is the case today), asking for a wider study would be beneficial to investors. As simple as it is, asking what the company sees as "best-case," "base-case," and "worst-case" in terms of climate, regulation, demand, etc. could lead to deeper insight.

Finally, more and more investors are focused on forward-looking data. This includes data that considers structural or technological changes by sector, as well as company-level strategic evolutions. At Mirova, we are not convinced that forward-looking data is accurate enough at this stage to build climate-resilient and/or impactful investment strategies, nor do we feel that it is necessary. Lifecycle carbon data for the past and present, can be supplemented with qualitative analysis company-by-company to reflect a company's strategic plans, the credibility of these plans, and sector/technological trends. Forward-looking data is otherwise very reliant on one single scenario and/or companies' stated commitments, both of which unnecessarily introduce substantial uncertainty in our view.

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[2] The same could be said for geoengineering, the idea that solar radiation could be reduced through chemical intervention in the atmosphere. This is less popular than CCUS, however, and is not included in any of the scenarios discussed in this paper.

Mirova's approach: Carbon Impact Analytics

Useful data for assessing a company or portfolio's carbon impacts are not always available to investors. Carbon data that only covers a company's direct activities leads to incorrect assessments of climate risks, or an incomplete understanding of how the company's activities contribute to mitigating climate change. So, Mirova developed a partnership with Carbone4 in 2015 to create carbon data that looks at the emissions financed and avoided throughout the entire value chain of a company's activities (Mirova, 2018) (Carbone4, 2016).

Applying this data allows us to:

- **Reduce our climate risks**, by identifying the sectors and areas of activity most likely to be exposed to risks stemming from climate change. Our method assesses the climate impacts of a company's direct activities as well as its supply chain and the use of its products.

- **Capture climate-related opportunities**, by identifying a company's avoided emissions relative to a relevant baseline. This metric illustrates to what extent the company creates low-carbon or energy efficient products, and to what extent the company might benefit from greater investments in the energy transition.

Finally, we verify the alignment of our investment portfolios with a <2°C scenario. We seek to participate in the energy transition and to ensure long-term, sustainable returns. Carbon footprinting and emissions scenario alignment – without overreliance on a single energy scenario - are invaluable tools for achieving these goals and monitoring our progress along the way.

For more information, see our study *Estimating Portfolio Coherence with Climate Scenarios*[3].

[3] http://www.mirova.com/Content/Documents/Mirova/publications/va/Research_paper/EstimatingPortfolioCoherenceWithClimateScenarios2018.pdf

Conclusion

Analyzing portfolios against one 2°C-aligned technological breakdown might seem like a simple way to facilitate the switch from investments from fossil fuels to green solutions. However, investing in line with one scenario does not reflect the multitude of decarbonization pathways before us: not only is it making a technological wager, but it is also incompatible with the flexibility desired by investors. Increasing investments in one green technology or decreasing fossil fuel investments beyond the level suggested by the scenario could still lead to investments compatible with a 2°C world.

We are therefore convinced that a comprehensive carbon footprinting method – considering both lifecycle and avoided emissions - is the most efficient way to build investment portfolios that effectively reduce climate risk and/or participate in the fight against climate change. At Mirova, we have used this approach to reduce the consolidated carbon footprint of our equity portfolios from 3.5°C in 2015 to 1.7°C in 2018. We prioritized investments in energy efficiency, renewable energy, and other energy transition solutions while divesting from coal and oil extraction and limiting investments related to other fossil fuels related technologies.

We have also developed a series of Carbon Neutral funds, which present an index-based approach to reducing climate risk in portfolios. These funds seek to reduce induced emissions by a factor of 5.5 relative to the market index, representing the needed cuts according to international objectives. It then balances induced and avoided emissions, for overall carbon neutrality (and climate benefit!).

Change is inevitable. The global energy system will change to either stave off or adapt to climate change, affecting every sector in our investment portfolios. Not only do investors matter for the transition, but the transition matters for investors.

The way investors allocate capital can and will make a difference in meeting global sustainability challenges and succeeding in the energy transition. Understanding the difficulties ahead and mastering the tools to adapt in this time of momentous change has become imperative.

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