

BLACKROCK®

Adapting portfolios to climate change

Implications and strategies for all investors



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Investors can no longer ignore climate change. Some may question the science behind it, but all are faced with a swelling tide of climate-related regulations and technological disruption. Drawing on the insights of BlackRock’s investment professionals, we detail how investors can mitigate climate risks, exploit opportunities or have a positive impact. Climate-aware investing is possible without compromising on traditional goals of maximizing investment returns, we conclude. We then reflect on steps that stakeholders in the climate debate are considering, including the use of carbon pricing as a cost-effective way to reduce emissions.

Our overall conclusion: We believe all investors should incorporate climate change awareness into their investment processes.

Summary

- We start by detailing how climate change presents market risks and opportunities through four channels: 1) physical: more frequent and severe weather events over the long term; 2) technological: advances in energy storage, electric vehicles (EVs) or energy efficiency undermining existing business models; 3) regulatory: tightening emissions and energy efficiency standards, and changing subsidies and taxes; 4) social: changing consumer preferences and pressure groups advocating divestment of fossil fuel assets.
- These factors can play out immediately (often the regulatory variety), in the medium term as economies transition to a lower-carbon world (often technological), and in the long run (often physical). Investor time horizons differ as well — and may require different approaches. The longer an asset owner’s time horizon, the more climate-related risks compound. Yet even short-term investors can be affected by regulatory and policy developments, the effect of rapid technological change or an extreme weather event.
- We then show how all asset owners can — and should — take advantage of a growing array of climate-related investment tools and strategies to manage risk, to seek excess returns or improve their market exposure. We explain how investors can gradually implement climate considerations into their portfolios and illustrate the complexities of a one-time portfolio makeover.
- We end by detailing what many see as the most cost-effective way for governments to meet emissions-reduction targets: policy frameworks that result in realistic carbon pricing. These could address a market failure as current fossil fuel prices arguably do not reflect the true costs of their extraction and use. Higher carbon prices could minimize the economic costs of reducing emissions, incentivize companies to innovate and help investors quantify climate factors. We see them as a scenario investors should prepare for.

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Setting the scene

A tide of new regulations to combat climate change is rising. The risks are underappreciated, yet could soon start to unfold. Significant spending on sustainable infrastructure and government incentives are needed to meet emissions-reduction targets. These present large investment risks and opportunities.

Most countries have signed the *Paris Agreement* to limit global warming to less than two degrees Celsius (2°C) above pre-industrial levels — the threshold where many scientists see irreversible damage and extreme weather effects kicking in. The countries have submitted plans to reduce carbon emissions in so-called intended nationally determined contributions (INDCs). Yet scientists say these commitments alone are not enough to keep temperature rises below 2°C. See *The Price of Climate Change* of October 2015 for details.

There is no one-size-fits-all solution to reducing emissions. Developed regions such as the European Union (EU) and U.S. are placing a greater emphasis on improving energy efficiency, while emerging market (EM) economies such as India and China are prioritizing low-carbon energy generation such as wind and solar power. See the chart on the bottom right. Coordinated action is key, since carbon emissions do not respect national borders. Emissions are a global problem.

No place to hide

The world is rapidly using up its carbon budget. To keep the average global temperature rise below 2°C, cumulative carbon dioxide emissions need to be capped at one trillion metric tons above the levels of the late 1800s, the Intergovernmental Panel on Climate Change *estimated* in its latest assessment in 2013. The problem? We have already burned through over half that amount. To meet the 2°C warming cap, three-quarters of proven coal, oil and gas reserves would have to remain in the ground, the World Resources Institute estimates. These assets could be effectively “stranded” — with their owners exposed to write-downs. See page 6 for details.

The sums at risk are enormous. The damage from climate change could shave 5%-20% off global GDP annually by 2100, according to the landmark *Stern Review* prepared for the UK government in 2006. The economic impacts are not just in the distant future. More frequent — and more intense — extreme weather events such as hurricanes, flooding and droughts are already affecting assets and economies.

Even if you are skeptical about the science of climate change, there is no escaping a swelling tide of climate-related regulation. Technological changes in areas such as renewables and batteries are already causing disruption, while pressures on companies and asset owners to support sustainability are increasing. We discuss four key climate-related risks in the next chapter: physical, technological, regulatory and social.

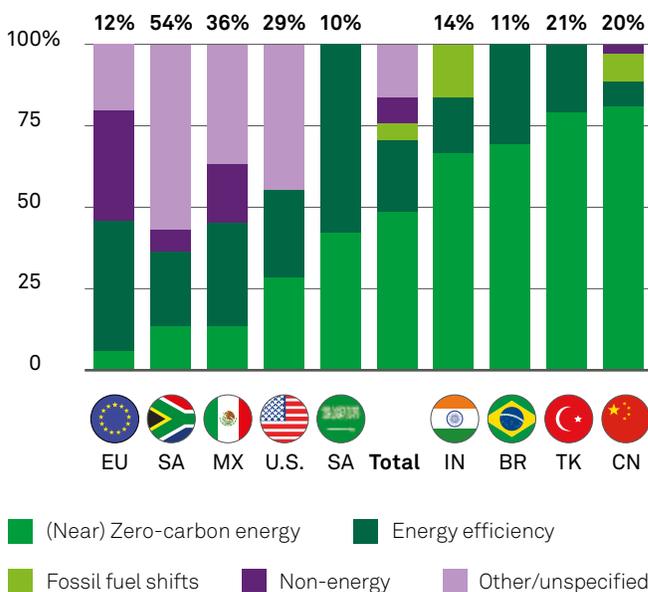
Governments, investors and consumers have been slow to appreciate climate factors. Why? Scientific uncertainty is one reason. Behavioral biases also offer some clues:

- Risks or opportunities that are unlikely to materialize over the next few years but could be significant over longer horizons tend to be underpriced or underappreciated. This is similar to a consumer who chooses a cheap, high-energy appliance over an expensive energy-efficient model that saves money in the long run.
- Markets tend to focus on the shark closest to the boat. Risks we can see, especially visceral ones, occupy most of our attention. Contentious elections, referenda and monetary policy decisions dominate headlines. The effects of climate change are less visible and perceived by many as distant. This leads to a bias toward inaction.

Bottom line: We believe climate factors have been underappreciated and underpriced. Yet this could change as the effects of climate change become more visible.

To each his own

Pledged emission reductions by 2030 by category



Sources: BlackRock Investment Institute and the Energy Transitions Commission, April 2016. Notes: Non-energy measures include changes in land use and forestry. The total emission reductions in the U.S., EU and South Africa are based on current policy baselines. China's and India's total reductions show the difference between the business-as-usual mode and what would happen if the countries were to deploy the listed measures.

Green infrastructure

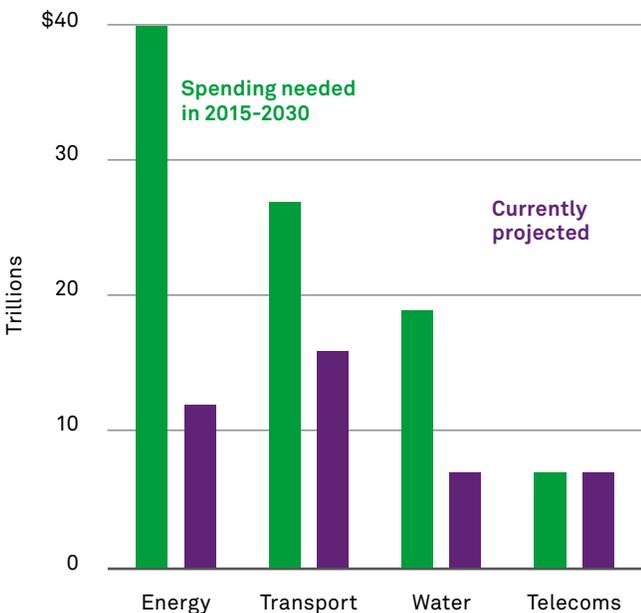
Meeting emissions-reduction targets requires steps such as retooling energy-inefficient infrastructure and reducing fossil fuel subsidies. This creates opportunities in areas such as renewable infrastructure and underscores the importance of using investment tools that incorporate climate factors.

The global economy will require big investments in infrastructure as populations and the middle class grow — especially in energy systems and cities. The demand for new infrastructure could top \$90 trillion over 2015-2030, according to The New Climate Economy's 2014 report, *Better Growth, Better Climate*. The drive to cut carbon emissions changes the mix of this spending. Clean energy, efficient power grids and energy-efficient buildings are on the menu. The energy and transport sectors make up two-thirds of the needs, a *2016 McKinsey report* estimates. Water and waste take up a fifth. See the chart below. Most of the spending is needed in EMs.

There has arguably never been a better time for governments to finance sustainable infrastructure. Financing is cheap, with around one-third of government bonds in the developed world today yielding below zero. See our *Midyear Global Investment Outlook* of July 2016 for details. We expect more public spending on infrastructure as countries pivot from monetary to fiscal stimulus. Yet we also see the private sector playing a key role. The challenge is finding ways to leverage the available financing. The world is currently spending only half the amount needed to meet the \$90 trillion target by 2030, the New Climate Economy estimates. Private investors could fill much of the gap, with the right incentives. See page 13 for details.

Mind the gap

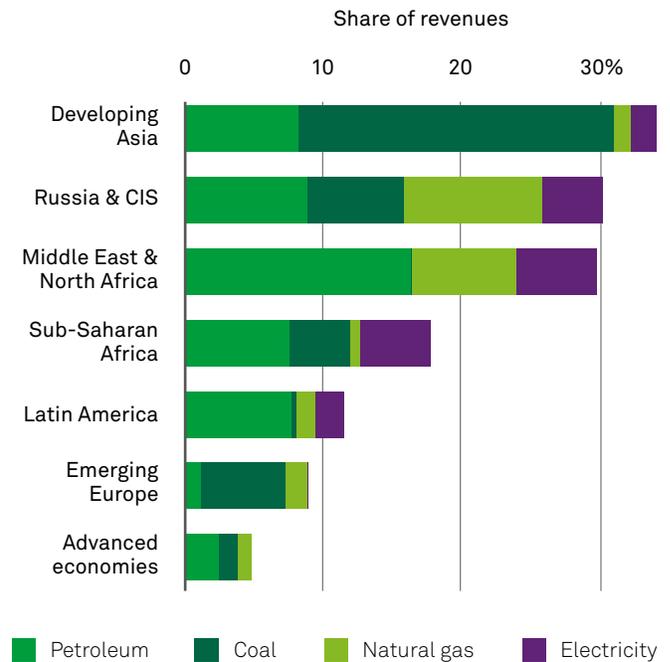
Global infrastructure spending needed vs. planned, 2015-2030



Sources: BlackRock Investment Institute and McKinsey Center for Business and Environment, January 2016. Notes: Currently projected spending is based on an extrapolation of historical data and the assumption of a continuation of real investment growth. Water includes waste management systems. All figures are in constant 2010 U.S. dollars.

Subsidy savings

Annual fiscal gains from removing energy subsidies, 2013



Sources: BlackRock Investment Institute and *2015 IMF working paper*. Notes: Middle East and North Africa includes Pakistan. CIS is the Commonwealth of Independent States.

Sustainable subsidies?

Renewable energy handouts attract a lot of headlines. Yet global fossil fuel subsidies are four times as large, the International Energy Agency (IEA) *estimates*. They effectively pay consumers and companies \$15 to emit each metric ton of carbon, the authors of the 2015 book *Climate Shock* estimate.

Scrapping energy subsidies could reduce global emissions and save governments some \$3 trillion a year, more than they collect from corporate taxes, according to the 2015 International Monetary Fund (IMF) working paper *How Large Are Global Energy Subsidies?* The study accounts for implicit revenue losses in the form of taxes that would be collected if carbon emissions were priced at their true social cost. The impact would be especially large in developing Asia, Russia and CIS, and the Middle East and North Africa. Removing subsidies could boost fiscal balances by 30% or more in those regions, the IMF estimates. See the chart above.

Reduced subsidies would incentivize companies to innovate, create more fiscal space for countries to invest in sustainable infrastructure and disrupt the energy and utility industries. Cutting subsidies that reduce fuel costs is complex and can be unpopular. Yet there are emerging success stories, as detailed in the 2013 IMF study *Energy Subsidy Reform: Lessons and Implications*.

Bottom line: Curbing carbon emissions requires significant spending on green infrastructure and a reduction in fossil fuel subsidies. This creates large investment opportunities in areas that attract capital or industries at risk of disruption.

Climate risks

We see climate change creating risks and opportunities to investment portfolios in four areas: physical, technological, regulatory and social. The relative importance of these factors depends on the trajectory of the pathway toward a low-carbon world and the asset owner's time horizon.

Risk 1: Physical

Climate variability and weather extremes are facts of life. Yet scientists believe physical climate risks are increasing due to human activity, and expect them to show up in two ways: 1) more frequent and extreme weather events such as storms, flooding, droughts and wildfires; 2) creeping rises in temperatures and sea levels over time. Consider the following U.S. examples, which we see playing out elsewhere as well:

- The frequency of extreme weather events causing \$1 billion or more in losses has risen sharply over the past decade, [data](#) from the National Oceanic and Atmospheric Administration (NOAA) show. See the chart on the bottom right. This poses risks to coastal real estate, agriculture and companies with supply chains in geographically vulnerable areas.
- We could see greater economic losses ahead. Economic growth in states hit by extreme weather events is 10% to 15% lower than usual in the month of the event and remains below trend even 12 months afterward, our Scientific Active Equity (SAE) team's analysis of NOAA and Federal Reserve data over the past 35 years shows.
- Rising temperatures have clear economic effects, even in developed nations with the financial means and technologies to adapt. Daily productivity typically declines by 1.7% for each 1°C rise in average temperatures above 15°C, a 2014 [study](#) of U.S. counties by Tatyana Deryugina and Solomon Hsiang concludes.

The physical effects of climate change are hard to model, and their impact is likely disparate across geographies. This means looking at the averages only is of limited use. Example: Alaska and the upper Midwest are expected to see the largest temperature increases, according to the [U.S. National Climate Assessment of 2014](#).

Major cities in Southeast Asia below sea level could be disproportionately exposed to floods and economic damage. And some cooler regions of the world, such as Canada and Russia, may actually see economic benefits from warmer temperatures, according to the Stern Review.

Broad measures such as investing in an impact index or reducing a portfolio's carbon footprint are broad tools to mitigate these sporadic risks and capture opportunities. A detailed assessment of geographic risks and advantages requires more granular modeling.

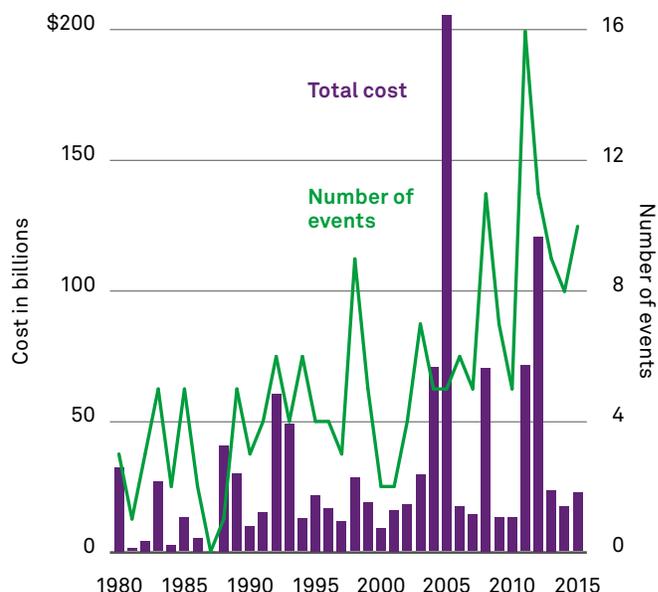
Risk 2: Technological

Technological advances and cost declines in renewable power and electric grids, EVs and batteries pose a threat to incumbent industries and demand for fossil fuels. Imagine, for example, 25 million EVs on the road in 2025, the equivalent of 10% of the U.S. passenger car fleet today. This could save almost 1 million barrels of oil per day, UK consultancy Trusted Sources estimates. This is roughly equal to the growth in global oil demand in 2016, according to IEA [forecasts](#).

Greater EV penetration could have a big impact on oil prices. The oil market is already under pressure from a flood of new supply in recent years from U.S. shale oil wells — itself the product of technological breakthroughs in fracking. Technological changes are disruptive and could shorten investment horizons. Exponential advances in EVs, coupled with driverless cars and shared rides, could trigger a slide in demand for traditional cars and gasoline — much quicker than markets may expect.

Costly weather

U.S. billion-dollar disaster events, 1980-2015



Sources: BlackRock Investment Institute and NOAA National Center for Environmental Information (NCEI), July 2016.

Notes: The line shows the number of climate events with losses exceeding \$1 billion. The data include droughts, flooding, severe storms, tropical cyclones, wildfires, winter storms and freezes. The bars show the total cost. The data are adjusted for inflation using 2016 dollars.

Dealing with disruption

Technological disruption driven by efforts to reduce carbon emissions is happening across industries. Consider:

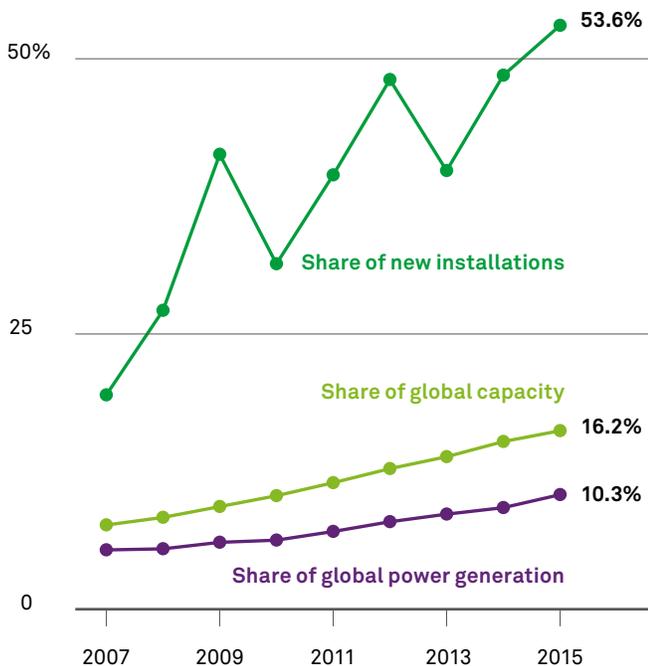
- Increased use of light-emitting diodes (LEDs) will cut power consumption from lighting by 40% from 2013-2030, the U.S. Department of Energy *forecasts*.
- Wind and solar generation could add as much to the global energy supply in 2015-2020 as U.S. shale oil did in the previous five-year period, Goldman Sachs *estimates*.

Renewable power has doubled its share of total global capacity to 16% since 2007, while making up over half of new installations. See the chart below. Low-carbon energy has become cost competitive and less reliant on subsidies. Also, many companies want to buy power directly from sustainable sources. Renewables allow buyers to lock in power prices for 20 years, without exposure to commodity price swings. This shift creates opportunities, particularly in renewable infrastructure with stable, long-term income. It may also erode traditional utilities' credit ratings and ability to pay dividends.

Advances in battery technology could help electric grids better match renewables supply with demand. Widespread deployment of storage could make financial sense as soon as 2020, rather than previous estimates of 2045, consultancy Carbon Tracker estimated in a 2015 *report*. Many of these new players are too speculative to be investable yet or need a catalyst such as carbon pricing or a reduction in fossil fuel subsidies. Fierce competition, especially from China, also could drive margins lower. Selectivity, therefore, is key.

Rise of renewables

Renewable power generation and capacity share, 2007-2015



Sources: BlackRock Investment Institute and Bloomberg New Energy Finance, March 2016.
Note: Renewables exclude large hydropower facilities.

Stranded assets

The term “stranded assets” has become synonymous with asset owners divesting their holdings in fossil fuel-related companies. But what exactly does it mean? An asset is stranded when it is no longer usable (submerged real estate) or the cost to use or extract it exceeds its revenue potential.

The cost of extracting resources such as oil has been dropping due to advances in fracking technologies. The problem? This notional cost does not reflect the environmental costs of extracting the resource and burning it. Governments may “tax” fossil fuels to an extent that it is no longer feasible to develop them.

This has implications for the capital allocation of fossil fuel companies. Such companies typically spend five times more on seeking new reserves than they do in returning capital to shareholders, according to *2013 research* from Carbon Tracker and Grantham Research Institute. Yet much of this capex may make little sense if the new reserves are incompatible with a low-carbon pathway, the study argues.

The stranded assets debate today is playing out most dramatically in electric power generation. Utilities with outdated nuclear and coal-fired power plants are under pressure from tougher regulations and renewables competition. Many utilities that have adapted to the shift to renewables are thriving. This illustrates a need to be selective: Not all incumbents will be losers, and not all renewables will be winners.

Assessing whether an asset is stranded depends on your view on fossil fuel prices and the speed of transition to a low-carbon world. We believe market prices do not yet reflect the effect of rapid changes in regulations, business models and technology. Conversely, markets can also overreact to stranded asset risk and create opportunities. Assets that may be stranded in the long run can be attractive on shorter horizons. Price declines could make fossil fuels more competitive. And underinvestment in oil or coal exploration today could result in supply shortages and asset appreciation in the years ahead.

Not all fossil fuels are created equal. Gas, for example, is relatively clean aside from methane leaks from wells and pipelines. We see gas as a key component of the global energy mix for years to come. Companies with major exposure to this trend should perform well in the medium term, we believe.

Risk 3: Regulatory

Regulatory risks stemming from efforts to combat climate change are increasing. We believe many governments will follow through on their emissions-reduction pledges, and could see them ratcheting up targets over time. These are waves in a swelling regulatory tide that also includes carbon taxes (see page 15) and subsidies for alternative energy or energy-efficiency measures. New regulations can pop up at any time, surprising investors. They can upset the status quo, favoring some industries and companies over others.

Unlike slow-burning and sporadic physical climate events, regulatory risks are here and now. They can have an immediate — and often negative — effect on cash flows by raising the cost of doing business. More regulations also raise the risk of compliance failures. Think of the recent spate of scandals involving auto companies that cheated on emissions standards tests. Or consider energy companies that violated regulatory safety or environmental requirements and caused oil spills. Compliance failures can trigger big fines, legal bills and sudden implosions in asset prices. Lastly, regulatory risk can jump unexpectedly across borders. Example: Japan's 2011 tsunami resulted in curbs on nuclear power in Germany.

The long-term impact of new regulations or subsidies is not always immediately obvious. Three examples:

Exhibit A: Regulations can involve short-term pain but long-term gain. Power utilities in California, for example, face some of the toughest regulations in the U.S. This may increase their costs, raise credit risk and curtail dividend payouts — and penalize their investors in the short run. Yet these utilities could achieve a stronger competitive position in the long term versus peers in U.S. states where regulation has yet to catch up. We see the same reasoning applying to countries that take their climate change medicine now, rather than later.

Exhibit B: Subsidies can initially boost cash flows of targeted industries, but often trigger an influx of capital and capacity. Spanish solar panel subsidies are a case in point. Government subsidies led to an unprecedented boom in solar power deployment in 2008. The industry collapsed when those subsidies proved to be too generous and the government cut them, and is only now crawling back. The U.S., German and Japanese solar markets show similar boom-to-bust dynamics in the past decade, according to Goldman Sachs research, against a backdrop of Chinese competition driving margins ever lower. As a result, these industries do not always make for great equity investments. The best opportunities are often less obvious. Example: We like semiconductor makers benefiting from the structural demand for EVs.

Exhibit C: Regulations can change consumer behavior, spur business innovation and change the business model of an entire industry. Take the advent of LED lighting. The mandated phasing out of energy inefficient incandescent light bulbs in many countries spurred new investments into LEDs. The result: LED prices have fallen by 90% since 2010, and today's lights last 84% longer. See the chart on the right.

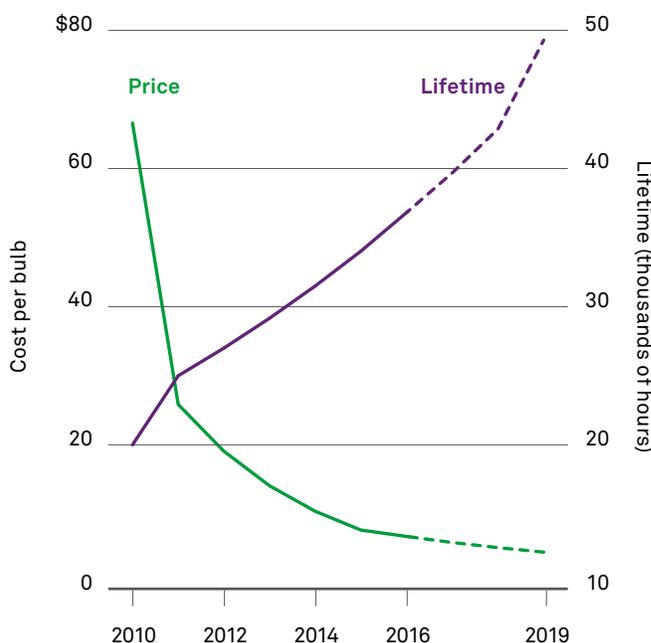
Some policies work better than others. Example: It is more efficient to raise fuel taxes to encourage the use of low-emissions cars than to set incentives for buying clean cars or to slap fees on polluting ones, a [2016 study](#) of Swiss cantons by Anna Alberini and Markus Bareit shows. As policymakers search for the best solutions, they are pressing asset owners for better disclosure, measurement and stress testing of climate factors. High-profile initiatives include:

- The Financial Stability Board — an international collective of financial regulators — has assembled a [task force](#) to work on new standards for climate reporting by companies. This dovetails with initiatives by the U.S. Sustainability Accounting Standards Board and others.
- France's [Energy Transition Law](#) requires France-domiciled asset owners and managers to report climate factors and carbon emissions footprints by December 2016.
- California's Insurance Commissioner has [called upon](#) insurance companies doing business in the state to divest from companies that derive 30% or more of their revenues from thermal coal holdings.
- The Dutch central bank has modeled the exposure of the Netherlands' banks, pension funds and insurers to fossil fuel producers and carbon-intensive sectors in an effort to pinpoint financial stability risks, [a 2016 report](#) shows.

The common thread: Regulators are starting to make climate awareness a part of good corporate governance. The same is true for the concept of fiduciary duty for asset owners, as we show in the next chapter.

The light that never goes out

LED cost and lifetime, 2010-2019



Sources: BlackRock Investment Institute, Quartz and U.S. Department of Energy (DoE), June 2016. Notes: Figures are based on the cost and lifetime of general service lamp LED bulbs. 2016 to 2019 are based on DoE forecasts.

Risk 4: Social

Social and corporate awareness of climate change are increasing amid a recent spike in global temperatures. Last year was the hottest since records began in the 19th century, surpassing 2014, according to the U.S. NOAA. The trends are increasingly driving changes in behavior. Two-thirds of global consumers today say they are willing to pay more for a sustainable brand, up from 55% in 2014, a [survey](#) from market research firm Nielsen shows.

Non-governmental organizations (NGOs), shareholders, activists and consumers are pressuring companies to make their supply chains more sustainable (using less energy and water, and producing less waste). The same groups are putting climate change on the agenda of asset owners, especially public funds or university endowments. Large investors are pledging to gradually decarbonize portfolios, divest fossil fuel companies or disclose carbon footprints. See the table below.

Rating the risks

The speed of the energy transition is key to assessing climate risks and opportunities. The less the world does today to curb carbon emissions, the further away it gets from a 2°C warming path. No action at all or current policies would lock in much more severe warming. See the chart on the right. Slow action would mitigate regulatory risk in the short run, but raise the possibility of extreme weather events. These events, in turn, could prompt more drastic policy actions down the road. The bolder the policy action taken today, by contrast, the greater the “transition risk” for industries and assets due to fast technological and other changes.

Investor time horizons play into this. Long-term investors are likely more exposed to physical risks, stranded assets and the impact of climate change on economic growth. Yet we also see them as better positioned to invest in new technologies that take time to bear fruit. Short-term investors tend to be more vulnerable to here-and-now regulatory risks.

Institutional activism

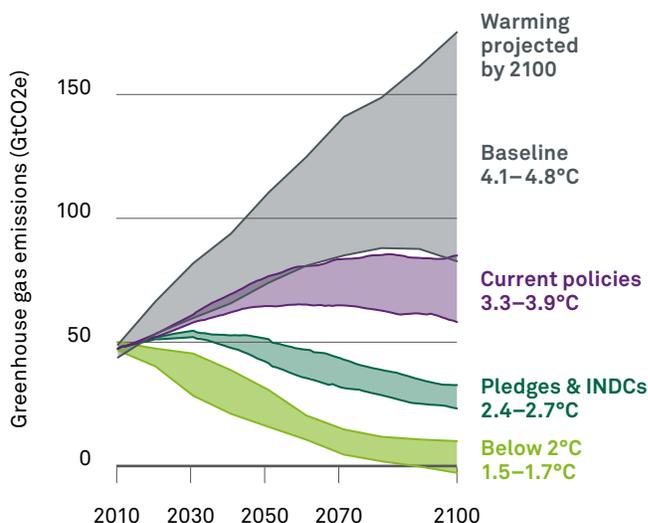
Climate-related actions and pledges by institutional investors

Organization	Goal	Commitments
UN Principles of Responsible Investing (PRI)	Investors aim to put the UN principles into practice, including recognition of the materiality of environmental, social and governance (ESG) criteria.	1,500+ signatories \$60+ trillion in assets under management (AUM)
Montreal Climate Pledge	Signatories commit to measure and publicly disclose the carbon footprint of their investment portfolios on an annual basis.	120+ signatories \$10+ trillion AUM
Fossil Fuel Divestment Commitments	An institution or corporation that does not have any investments in fossil fuel companies (coal, oil or natural gas) and is committed to avoiding any such investments in the future.	500+ institutions \$3.4 trillion AUM
Portfolio Decarbonization Coalition	Initiative to reduce emissions by mobilizing institutional investors committed to gradually decarbonizing their portfolios.	25+ signatories \$600+ billion AUM

Source: BlackRock Investment Institute, July 2016.

Warming paths

Scenarios for global temperatures, 2010–2100



Sources: BlackRock Investment Institute and Climate Action Tracker Project, July 2016. Notes: The chart shows the forecast path of emissions in metric gigatons of equivalent carbon dioxide (GtCO₂e) under different scenarios. The baseline area shows the path in the absence of climate policies; below 2°C shows the path needed to keep warming below two degrees Celsius from pre-industrial levels by 2100. The temperature ranges shown are the median pathways required to meet targets with 66% certainty. The pledges and INDC area is based on pledges or promises that governments have made, including in submitted INDCs as of Dec. 7, 2015. The ranges shown are 10th to 90th percentiles.

Risk for the long-term investor is not short-term portfolio volatility, but events that could lead to a permanent loss of capital. The effects of climate change need to be part of that equation, we believe. This is especially pertinent for pension funds with rising liabilities at a time when we expect low future returns across asset classes.

Yet even short-term investors would do well to integrate climate factors into their portfolios. We discuss various ways of doing so in the next chapter. This includes climate-optimization of benchmarks, using a climate scoring framework that aims to generate excess equity returns or climate-proofing a corporate bond portfolio in one swoop.

Portfolio applications

Maximizing returns is the guiding principle of financial fiduciaries. Yet the view of what is financially relevant is broadening. We describe how investors can incorporate climate factors to reduce risk and seize opportunities. We give examples of fine-tuning equity exposures, searching for excess returns, remaking bond portfolios and tapping the green bond market.

Paying heed to environmental, social and governance (ESG) factors was long thought to be inconsistent with maximizing financial returns. The first cracks in this view appeared when the UK's *Cadbury Report* of 1992 set standards for corporate governance. We have come to see good governance as synonymous with operational and financial excellence.

There has been a leap in the quality and quantity of ESG data in recent years. We believe financial fiduciaries now can — and should — integrate relevant ESG factors in their investment processes or principles. Some investors are starting to pay special attention to the “E” component to reduce climate risks, exploit opportunities and adapt to the transition toward a lower-carbon economy.

Policy is also moving in this direction. The UN Principles for Responsible Investment in 2015 called on regulators to ensure that fiduciary duty requires investors to take account of all ESG factors in their investment process. Many regulators have yet to take action, but signs of change are emerging. The U.S. Department of Labor's *2015 guidance* for private pension funds urges fiduciaries to consider ESG factors that could influence risk and returns. The UK Pension Regulator used similar language in a *July 2016 guide* for trustees.

Necessity, not a choice

Motivations matter. Is the aim to protect against climate change's impact on the portfolio? Or is the objective to invest in companies poised to benefit from the transition to a lower-carbon economy and/or have a positive impact? Some investors try to avoid return-adverse outcomes while adding potential return boosters. Others want to *shape* outcomes.

Investing with the aim of mitigating climate change may be a matter of choice for most investors. Yet we see climate-aware investing — incorporating climate considerations in the investment process — as a necessity. This does not mean giving up returns, we believe. Benchmarks that take climate into account have the potential to perform in line with or better than regular counterparts. The MSCI Low Carbon Target Index, for example, has modestly outperformed the MSCI ACWI since 2010, MSCI data show. We could see climate-aware portfolios outperform amid tighter regulations, faster technological changes or more frequent weather events.

Bottom line: We see climate-proofing portfolios as a key consideration for all asset owners.

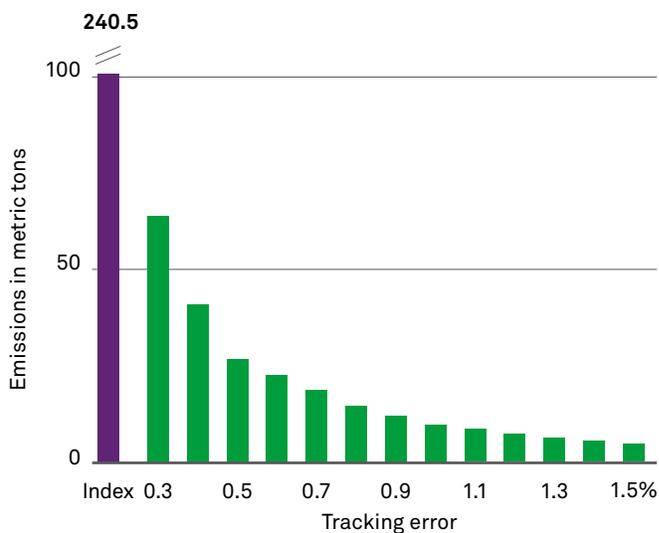
Building better beta

Many asset owners address climate change by adjusting existing portfolios. This often includes investments in renewable infrastructure and promising but risky new technologies, as well as some exclusion of resources or utility companies. Yet a growing number of tools is available to more systematically integrate climate factors.

One such approach is to optimize benchmarks for climate factors. This means overweighting green companies and underweighting climate offenders, while keeping a portfolio's return profile as close to the benchmark as possible. The tradeoff? The more climate friendly a portfolio becomes, the larger the tracking error (the deviation of returns from the benchmark over time) tends to be. Smallish tweaks can have a big impact, we found when we tried to optimize the MSCI World Index to minimize carbon emissions. It is possible, for example, to cut a portfolio's carbon footprint by around 70% while keeping the tracking error within 0.3%, our simulation showed. See the chart below.

Small difference, big impact

Carbon emissions of optimized global equity portfolio, 2015



Sources: BlackRock Investment Institute and MSCI, July 2016. Notes: The above is a simulation that aims to minimize a hypothetical portfolio's carbon footprint. In constructing the hypothetical portfolio, BlackRock takes all companies in the MSCI World Index and MSCI emissions data and performs a standard mean variance optimization for each given tracking error. Emissions data are measured in metric tons per million U.S. dollars in total capital (total equity and debt). The forward-looking tracking error is an estimation that uses the BlackRock Fundamental Risk for Equity model. This does not represent an actual portfolio, fund managed by BlackRock or investable product, nor is it a recommendation to adopt any particular investment strategy.

Aiming for alpha

Corporate information on climate factors is improving but still has holes (see *Digging for data* on the right), and the timing and intensity of climate-related events are unknowns. These vagaries create opportunities for generating alpha (returns in excess of the market) for those willing to do detailed research.

This means asset owners and managers can fulfill their fiduciary duties under both the old-fashioned interpretation of maximizing returns and the new view of including climate-related ESG factors.

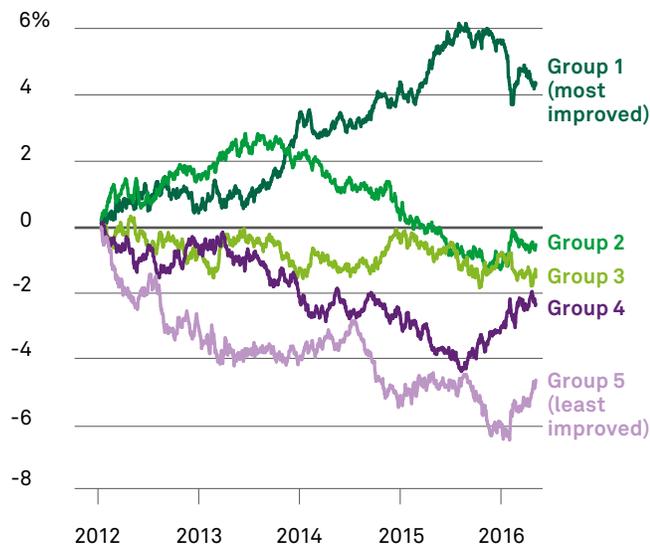
Our SAE team started to research climate alpha generation in 2015 by using simple measures such as companies' self-reported Scope 1 and 2 carbon emissions (direct emissions and those generated by use of energy). The team calculated emissions as a percentage of sales and focused on year-over-year changes. The thesis was that improving carbon efficiency may signal operational excellence — and could offer the prospect of outperformance.

Global companies that reduced their carbon footprints the most have indeed outperformed carbon-cutting laggards in recent years, the research showed. See the chart below. There are plenty of caveats, including the small sample size, limited time period and self-reported nature of the emissions data.

The team has now moved beyond crunching carbon emissions numbers to developing a holistic climate scoring system that can be used to climate-proof portfolios. We are using this evolving concept as a building block in our actively managed impact investing strategies. See the next page.

Efficiency improvement race

Equity performance by carbon intensity, 2012-2016



Sources: BlackRock Investment Institute, ASSET4 and MSCI, July 2016. Notes: The analysis above calculates the carbon intensity of all MSCI World companies by dividing their annual carbon emissions by annual sales. Companies are ranked and bucketed in five quintiles based on their year-over-year change in carbon intensity. We then analyze each quintile's stock price performance versus the MSCI World Index. Most improved means the 20% of companies that posted the greatest annual decline in carbon intensity. Data are from March 2012 through April 2016. The example is for illustrative purposes only. Past performance is no indication of future results.

Digging for data

The measurement and disclosure of data to score companies and climate-optimize portfolios are far from perfect. Data on climate factors are often incomplete, self-reported and not comparable. Yet common standards are developing, and the volume and quality of data are increasing fast. It now is possible to incorporate climate factors into the investment process. We suggest the following menu:

Starter package: ESG data, particularly the “E” part, are essential for a first pass. Various providers now include information on fossil fuel use, carbon emissions, water consumption and waste management. The data are becoming more granular and consistent. This makes it easier to implement ESG and impact investment strategies. The data are largely self-reported, however, and need analysis to track improvement by individual companies.

Climate-friendly indexes: Useful as broad-brush tools to integrate climate factors and as benchmarks for custom-made climate portfolios. Drawback is that they exclude private companies.

Revenue and geographic exposures: Important for hedging climate risk, for example, by excluding companies reliant on fossil fuels. The exposures are static, however, and do not take into account individual company supply chain risks and initiatives to improve sustainability and energy efficiency.

Carbon emissions: Good for measuring the carbon intensity of companies and for adhering to regulatory reporting requirements. Partial and self-reported disclosure of the data are drawbacks. Methodologies are evolving, with a current focus on Scope 3 emissions from sold products and carbon offsets. This can increase a company's carbon footprint (a car maker) or reduce it (a wind turbine maker).

Big data: Big data analytics go beyond traditional sources to uncover corporate risks throughout supply chains. This is similar to home insurers using external inputs from real estate websites and crime statistics with the aim to speed up overall claim adjustments and focus time-consuming investigations on outliers.

Sovereign risks: Increasing output from rating agencies and others helps quantify the fiscal, economic and societal effects of climate events on countries, as well as the possible impact of stranded assets on government revenues.

Keeping score

SAE's evolving BlackRock climate score uses 17 measures that rank U.S. companies in three areas: resource efficiency, climate risks and climate opportunities. See the graphic below. We use both absolute levels and the annual rate of change in these metrics to capture the evolution of climate factors at companies and their impact on the environment.

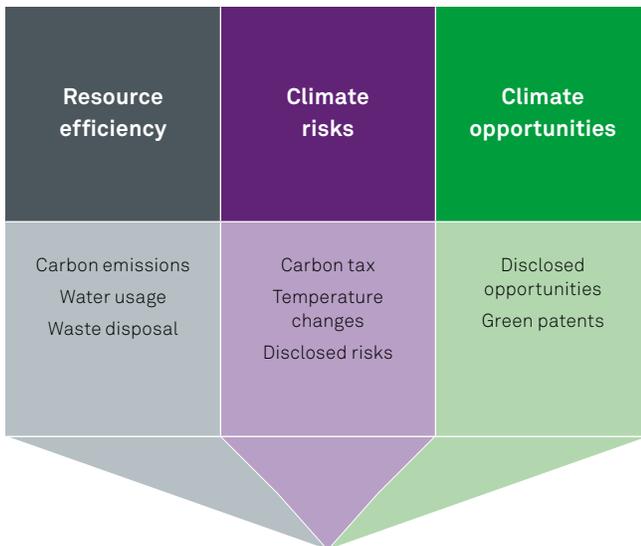
Resource efficiency: The first cut. Companies that generate more sales with less carbon, water and waste are deploying resources more efficiently. Companies that recycle, for example, are rewarded with a higher score while those contributing to landfills are penalized. Decomposing landfills produce one-fifth of U.S. human-related methane emissions, Environmental Protection Agency 2016 *estimates* show.

Climate risks: Next is estimating risks to companies, ranging from the effects of possible carbon taxes to the impact of extreme weather events on labor productivity. To capture the latter, SAE first measures a company's exposure to each of the 50 U.S. states. The team then estimates temperature-induced income shocks. Lastly, it captures how firms perceive their exposure by counting the absolute number and change in disclosed climate-related risks.

Climate opportunities: Finally, the team aims to identify potential winners by tracking filed green patents and disclosed climate opportunities, and the annual change on these metrics. This is meant to capture corporate shifts toward alternative energy and innovations such as cleaner chemicals, new waste-water treatments and energy storage.

Scoring rules

Framework, categories of BlackRock climate score, July 2016

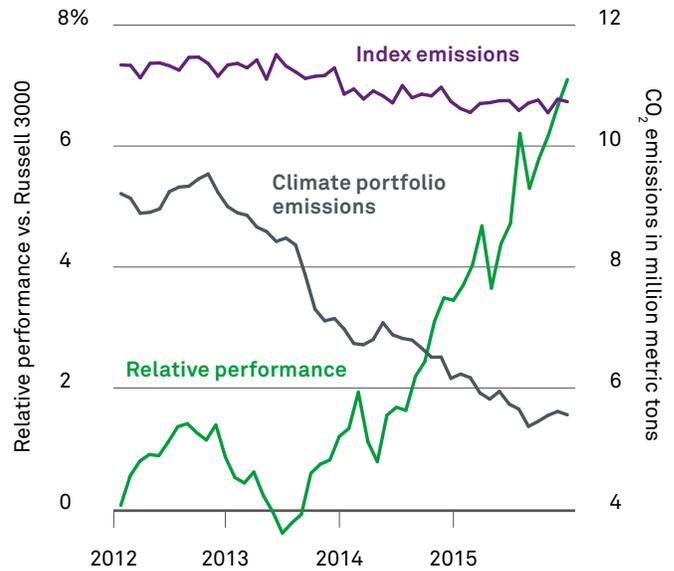


BlackRock Climate Score

Source: BlackRock Investment Institute, July 2016.

Climate is king

Climate strategy relative performance and emissions, 2012-2015



Sources: BlackRock Investment Institute and Russell Index data, July 2016. Notes: The analysis above uses a simulated backtested portfolio to illustrate the performance of a strategy optimized for climate risks. In constructing the hypothetical portfolio, BlackRock takes all companies within the Russell 3000, ranks each with a climate score (utilizing the measures described on the left) and then applies a risk weighting. These data points are then used in a standard mean variance optimization. Performance is net of historical trading costs. This does not represent an actual portfolio, fund managed by BlackRock or investable product, nor is it a recommendation to adopt any particular investment strategy.

Putting it to the test

Our thesis was that companies that use resources efficiently, mitigate weather-related risks and exploit climate opportunities should have stronger fundamentals. And indeed, SAE's research found that U.S. companies with higher climate scores tend to be more profitable and generate higher returns on assets.

How about investment returns? The SAE team tested this by simulating a portfolio that overweights selected Russell 3000 Index companies with the highest climate score on a monthly basis — while keeping the annualized tracking error within 1% of the index. This limitation meant the simulated portfolio became climate friendlier only gradually over the period 2012 to 2015. It only becomes clear over time which companies are most resource efficient. The portfolio's weighted average of CO₂ emissions was almost 50% below the benchmark's at the period's end. See the grey and purple lines in the chart above.

The simulated portfolio would have beaten the Russell benchmark by seven percentage points over the period after average historical trading costs. See the chart's green line. An implosion in resource stocks (which have a higher chance of receiving poor climate scores) helped the outperformance. The portfolio held 1,600 to 1,800 companies over the period, versus 3,000 for the benchmark.

Bottom line: Our research suggests there can be little downside to gradually incorporating climate factors into the investment process — and even potential upside.

Bond portfolio makeover

We kept close to original benchmarks in our previous illustrations of how to implement climate factors in investing. This approach reflects the preference of many asset owners to stick closely to market gauges. What if an asset owner wanted to do a one-time portfolio makeover, either because of regulatory requirements or a desire by stakeholders to do so? As an experiment, we explored this for an insurance client's \$150 million non-financial corporate bond portfolio. The aim of the exercise was to reduce climate risks on the portfolio while maximizing any beneficial effects on the environment.

We simulated a new portfolio using rules that either excluded or added issuers, as the table below shows. The exclusions wiped out 77 bonds, or two-fifths of the portfolio's bonds by value. Why such drastic change? The portfolio's narrow mandate of no financials meant it was overweight "old-economy" sectors. We found nine green and cleantech bonds that fit into the portfolio's mandate, and re-allocated the remainder to bonds that had survived our exclusionary rules.

The outcome of our simulation? The new portfolio had 70% less CO₂ emissions per invested dollar and an improved environmental ESG score. The biggest sector changes were in energy (2% versus 17%), consumer non-cyclical (27% versus 19%) and consumer cyclicals (17% versus 10%). The simulated portfolio's yield was essentially unchanged at 2.17% but its duration rose to 5.0 years, from 4.6.

Discussing the results with the client, three themes emerged:

Small green pipes: We found just a few green securities that complied with the portfolio's mandate. This speaks to a larger challenge: The green and cleantech credit markets cannot yet accommodate the money flows needed to hedge against or halt harmful effects of climate change. Greater incentives to promote green bond financing are needed to widen the pipes. See page 13 for details.

Miscarriage of justice? Large energy companies arguably are part of the solution. They have the technology and capital to develop clean energy. Yet our exclusion rules ruthlessly eliminated them. Are we punishing the wrong players? Possibly: Integrated energy firms could issue green bonds to fund specific cleantech projects. As a large asset manager, we generally prefer to work with companies on their climate plans rather than divesting.

Tradeoffs are complicated: The portfolio's narrow mandate caused a drastic makeover, resulting in a more concentrated portfolio with a different risk profile. And then there are trading costs, liquidity challenges and tax implications. The easiest fix would be to change the portfolio's benchmark to a climate-friendly index. Another solution would be to pursue climate-proofing objectives gradually over time. An asset owner, for example, could re-invest maturing bonds in green and cleantech bonds. This approach would jibe with our earlier examples of trying to maximize a portfolio's climate score while staying as close as possible to the benchmark.

Climate change rulebook

Rules used to make an insurer's corporate bond portfolio climate friendly, July 2016

Exclusions	Rule	Reasoning
Fossil fuel reserves	Companies reporting fossil fuel reserves as assets — unless 25% or more of their revenues are from renewables.	Reduces risks from the transition to a less carbon-intensive world and from stranded assets.
Carbon emissions intensity	Energy, materials, utilities and industrial companies with a carbon intensity greater than their subsector's average.	Screens out the worst performers in four sectors that account for the majority of CO ₂ emissions.
Coal revenue or generation	Companies that receive 30% of revenue from extracting coal or using it for power generation.	Companies relying on coal face high regulatory, technological and energy transition risks.
Water withdrawal intensity	The top 50% most water-intensive companies in the metals and mining, beverage and utility sectors.	Companies that use the most water are most exposed to scarcity and regulatory risks.
Toxic emissions	The bottom 50% of companies that have toxic emissions as an environmental key performance indicator.	Reduces toxic emissions to limit damage to the environment and air pollution.
Forestry commitments	Companies failing to address deforestation risks in their supply chains, including retailers and food producers.	Deforestation and forest degradation contribute to 10%-20% of global CO ₂ emissions.
Additions	Rule	Reasoning
Green bonds	Green bonds with similar maturity and risk profiles. They can be of excluded companies as proceeds are ring-fenced.	Uses debt capital markets to finance projects that have a positive impact on the environment.
Clean tech or green companies	Companies deriving 50%-100% of revenues from clean technologies such as renewables and energy efficiency.	Increases exposure to climate change solutions and sustainability initiatives.

Source: BlackRock Investment Institute, July 2016. Notes: The example is for illustrative purposes only. It does not represent an investment recommendation, nor a portfolio BlackRock currently manages.

Green bond game changer?

How can fixed income investors make a positive impact on climate outcomes? Green bonds are an evolving solution. The proceeds of green bonds are ring-fenced to fund eligible climate change mitigation projects, with a focus on renewables, energy efficiency and transport.

The green bond market has some \$130 billion of debt outstanding as of July 2016 according to Bloomberg data, or just 0.15% of the total global fixed income market. Yet the market is growing fast, and we expect to see up to \$50 billion of issuance in the second half of 2016. Highlights:

- The universe already includes more than 600 bonds from 24 countries, in 23 currencies. A big chunk is AAA-rated government issuance, including supnationals. Yet bonds span the ratings spectrum. See the chart on the right.
- Non-government issuers include banks, property companies, car makers, food producers, conglomerates and cleantech companies.
- Development banks were the first movers and drove innovation. Yet companies increasingly have been tapping the market, making up roughly 45% of 2015 green bond issuance according to Bank of America Merrill Lynch.

We see green bonds becoming their own asset class. Several index providers have launched green bond indexes; S&P and *Moody's* are developing green bond ratings methodologies; and public bodies are seeking ways to encourage the development of this nascent market.

Asset managers including BlackRock, issuers and underwriters have developed a set of *green bond principles* that include specifics for the use of proceeds, project evaluation and impact reporting. Harmonization and toughening of standards arguably create more work for issuers — but are needed to build a credible and durable foundation for the sector, in our view. Asset owners, investors, issuers and rating agencies have adopted the principles, as have public entities such as the People's Bank of China.

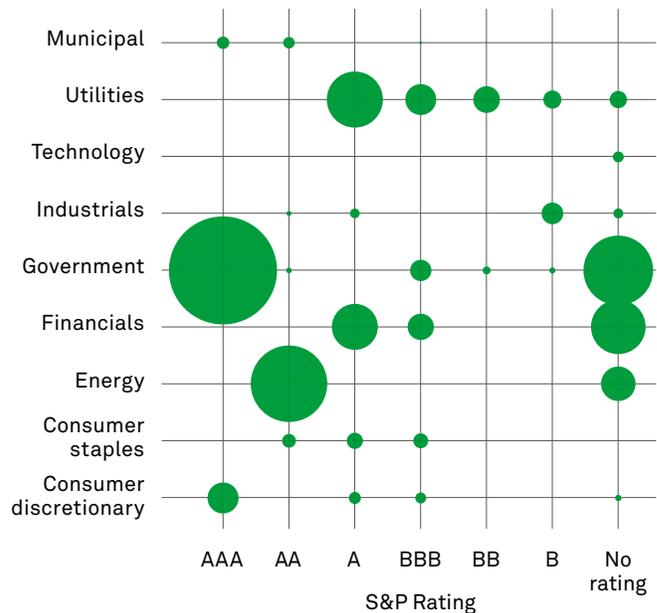
Green bond holders do not have to give up liquidity or returns, in our view. Issuers tend to be big companies or entities that issue liquid debt securities. We have yet to see pricing differences with traditional bonds of comparable credit ratings and maturities. This may change, however. We could see green bonds starting to trade at a premium to peers.

Asset owners appear to have a big appetite for green bonds, especially for issuers who provide thorough impact reporting and have the environmental benefits of their projects rated by outside sources.

Yet the market cannot yet accommodate large-scale portfolio allocations. Cheaper and more widespread green bond funding is needed to drive more investment toward climate-beneficial projects. Governments have a role to play in facilitating climate finance; joint efforts such as the G20 Climate Finance Study Group are leading the debate on how to best do this.

Green bonds

Outstanding green bonds by sector and rating, 2015



Sources: BlackRock Investment Institute and Bank of America Merrill Lynch, November 2015. Note: The size of each bubble reflects the U.S. dollar amount of the outstanding green bonds of each category and S&P rating. The universe of green bonds reflects the \$96 billion of outstanding issuance as of November 2015.

We see green bonds as part of the solution to finance the estimated \$90 trillion of global infrastructure needed by 2030 to limit climate change. There has been a lot of investor talk about infrastructure, but little action. Average pension fund allocations were stuck around 3.5% of assets in the period 2011-2014, according to a 2015 OECD *survey*. Legal frameworks are needed in many countries to enable pension funds and insurers to lend to infrastructure finance — without diluting lending standards. Illiquidity and long lock-ups also take infrastructure assets outside many portfolio mandates.

Many potential projects are located in EMs with regulatory uncertainties and political and currency risks. Tax incentives and public guarantees may help entice private capital. Examples: using development banks and export credit guarantees to lower financing costs and reduce risks.

We also believe creative financing could galvanize the pools of capital needed. For example, a supranational organization could first pool EM bank loans to multiple renewable projects across different countries. This would mitigate project- and country-specific risks — key concerns of many investors. A second step would be to create different credit tranches. The supranational would own a junior tranche that would absorb the first potential losses. This would effectively be a first-loss cushion for private holders of senior tranches.

We discuss other ways governments can help mobilize private capital and better align incentives in the next chapter.

Bottom line: Green bonds are a growing investment opportunity and funding tool for sustainable infrastructure.

Next steps

What can be done to smooth the transition to a lower-carbon world? We show how the interests of stakeholders can be aligned. Economists, governments and companies increasingly see higher carbon prices as a cost-effective way to hit emissions-reduction goals.

Asset owners: new processes

What can asset owners and investment managers do? Here are broad strokes:

- **Data:** Put the people and tools in place to analyze the fast-growing pile of ESG data. Nudge data providers to fill holes and solve inconsistencies.
- **Integration:** Integrate climate factors into the investment process to identify and manage risks and opportunities. This helps asset owners and managers provide investment boards, clients or regulators with portfolio carbon footprints, screening strategies and detailed reports that include climate factors for individual securities.
- **Engagement:** As a large asset manager, we prefer dialogue over divestment. The biggest polluters have the greatest capacity to move the dial if they modify their behavior. Just 80 companies are responsible for more than half the global emissions by publicly listed companies, our analysis of MSCI data shows. Engagement can help nudge some in the right direction.

Companies: better data

We see three key steps companies can take to manage climate-related risks and seize opportunities:

- **Plan:** Incorporate climate factors into strategic planning. BlackRock has long *advocated* for corporate executives to set long-term strategic plans that include consideration of relevant ESG factors. Consider issuing green bonds.
- **Engage:** Help investors understand how the company is dealing with climate risks and opportunities — and how these affect the firm's long-term value and sustainability.
- **Disclose:** Improve disclosure of climate factors. This includes making the disclosures more forward looking, granular and standardized (adapted to the needs of industries).

Governments: good incentives

Governments can help ensure the transition to a low-carbon economy is smooth by doing things only governments can do: making up for market failure or private sector inaction.

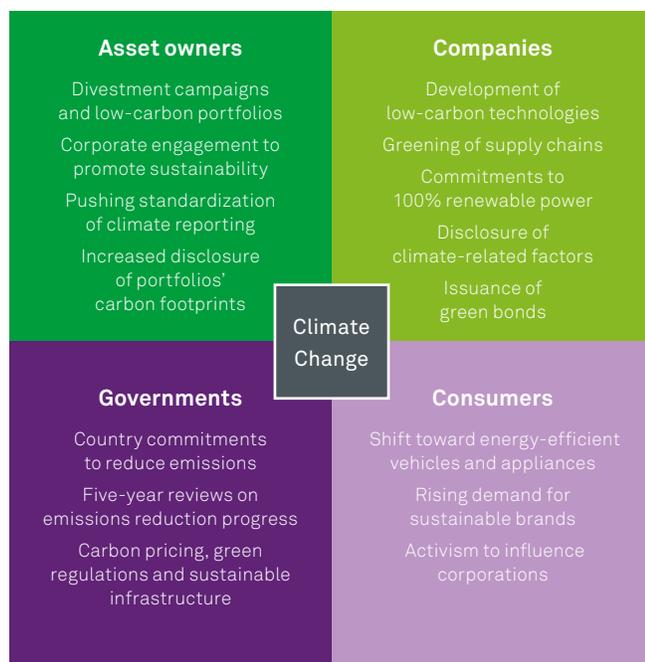
Their actions shape the incentives for a mosaic of stakeholders — companies, asset owners and consumers — to modify their behavior. See the graphic on the left. Most importantly, governments need to provide clarity and predictability around climate-related policies and regulations. Key steps that governments are taking include:

- Creating policy frameworks that result in higher and more consistent carbon prices. Economists see this as a cost-effective way to achieve emissions-reduction goals. It could also help reduce investor uncertainty and encourage corporate innovation to cut greenhouse gases and raise energy efficiency. See page 15. Reducing subsidies for fossil fuel extraction and use could also nudge consumers and businesses toward more efficient energy use.
- Mandating higher energy efficiency via rules such as vehicle emission standards.
- Setting standards for consistent measurement and reporting of climate factors. This is a work in progress. We see it helping companies and asset owners find better ways to mitigate risks and capture opportunities.

See *Exploring ESG* of June 2016 for further details on actions for governments to consider.

Climate action mosaic

Key climate change stakeholders and their actions



Source: BlackRock Investment Institute, July 2016.

Pricing carbon

The cost of emitting carbon is minimal or even negative for producers and households. This is because current market prices arguably do not yet reflect the social costs of burning fossil fuels. The result is over-consumption. This externality is at the core of the climate challenge. Higher carbon pricing would help address this and would be the most cost-effective way for countries to meet their Paris Agreement pledges, many economists believe.

Governments are pressing ahead with carbon taxes or emissions-trading schemes (ETSs). See the table below. Economists believe it is better to employ one tool to tackle climate challenges across the economy than to use different sticks and carrots for each sector. But less-efficient “command and control” policies such as green car subsidies are often preferred. The future policy mix in many regions is still unclear. Yet higher and more consistent carbon pricing is a scenario that investors should prepare for. It would incentivize companies to innovate to cut carbon emissions. This, in turn, could be a key catalyst for investment risks and opportunities related to technological disruption. It could also help investors better quantify the carbon risks embedded in their portfolios.

The momentum for carbon pricing is growing. Six major oil companies in 2015 *called* for “stronger carbon pricing,” and a coalition of 130 investors with more than \$13 trillion under management in 2016 made a similar *plea* to policymakers. Some 1,000 global companies are using an internal price on carbon or plan to do so soon, in an effort to mitigate risks from future regulation, a 2015 Carbon Disclosure Project (CDP) *survey* shows. Yet there is a wide range of prices — within and between industries. See the chart on the right.

Putting a price on carbon

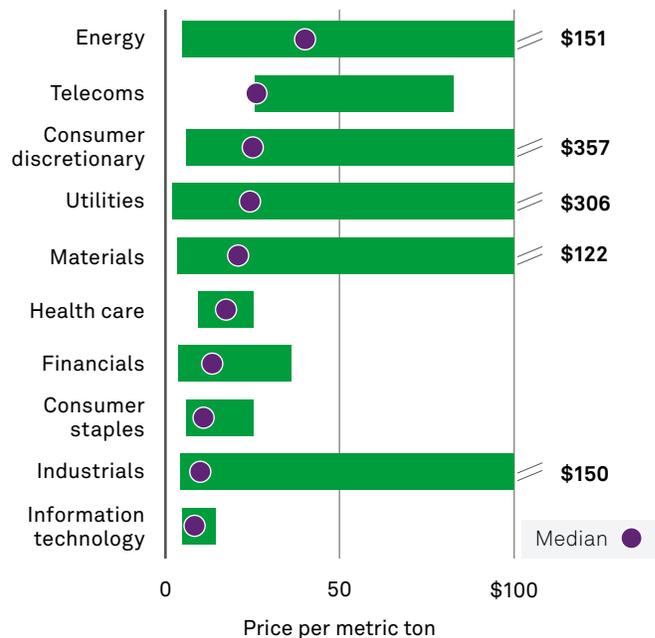
Features of carbon tax vs. emissions trading

	Carbon tax	Emissions Trading Scheme (ETS)
Description	A tax on CO ₂ emissions. Levies fees on emissions from fossil fuel production, distribution and use.	A market system established to set a price for the right to emit CO ₂ above a set level. Caps emissions overall and/or by industry.
Price	The set price level provides certainty. This is desirable because investment in low-carbon technology requires confidence in sufficiently high, long-term carbon prices.	Prices are set by trading in the market — and, therefore, can be volatile. Prices swing with economic cycles and restrictions on the quantity of emissions allowances.
Emissions reductions	The tax is not directly tied to an emissions reduction target because it is derived by modeling the cost of cutting emissions.	An ETS delivers emissions reductions by limiting allowances.
Flexibility	Tax rates can be altered to reflect progress in emissions cuts. They can also target specific groups such as car users.	The supply of emissions allowances can be modified to influence prices.
Administration	Can build upon existing tax infrastructure. It does require measuring, reporting and verification. Tweaking tax rates can raise administrative burden.	Complicated to implement. It requires the creation of emissions allowances, the allocation of these allowances, a market for trading them, and needs measuring, reporting and verification.
Examples	Mexico, Japan, Denmark, Finland, France, Norway, Portugal, Sweden, Canada (to be decided), S. Africa (2017), Chile (2018).	EU, California, Regional Greenhouse Gas Initiative, China (merging seven regional pilots into a national ETS in 2017).

Sources: BlackRock Investment Institute and *Carbon Pricing Watch 2016* by World Bank Group/Ecofys, July 2016.

Carbon pricing

Range and median of internal carbon prices by sector, 2015



Sources: BlackRock Investment Institute and CDP, September 2015.

Notes: The chart shows internal carbon prices reported by global companies to CDP by sector. The bars show the range of prices; the dots the median.

What is the correct price of carbon? It is hard to say. A 2015 U.S. government *study* estimated \$36 of economic damages for each metric ton of carbon emitted. Yet estimates are rising: A 2015 Stanford University *study* points to \$220 per metric ton. A single price may not be needed — just a sensible floor.

Bottom line: Investors should prepare for higher carbon prices — and their potential impact on portfolios.

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