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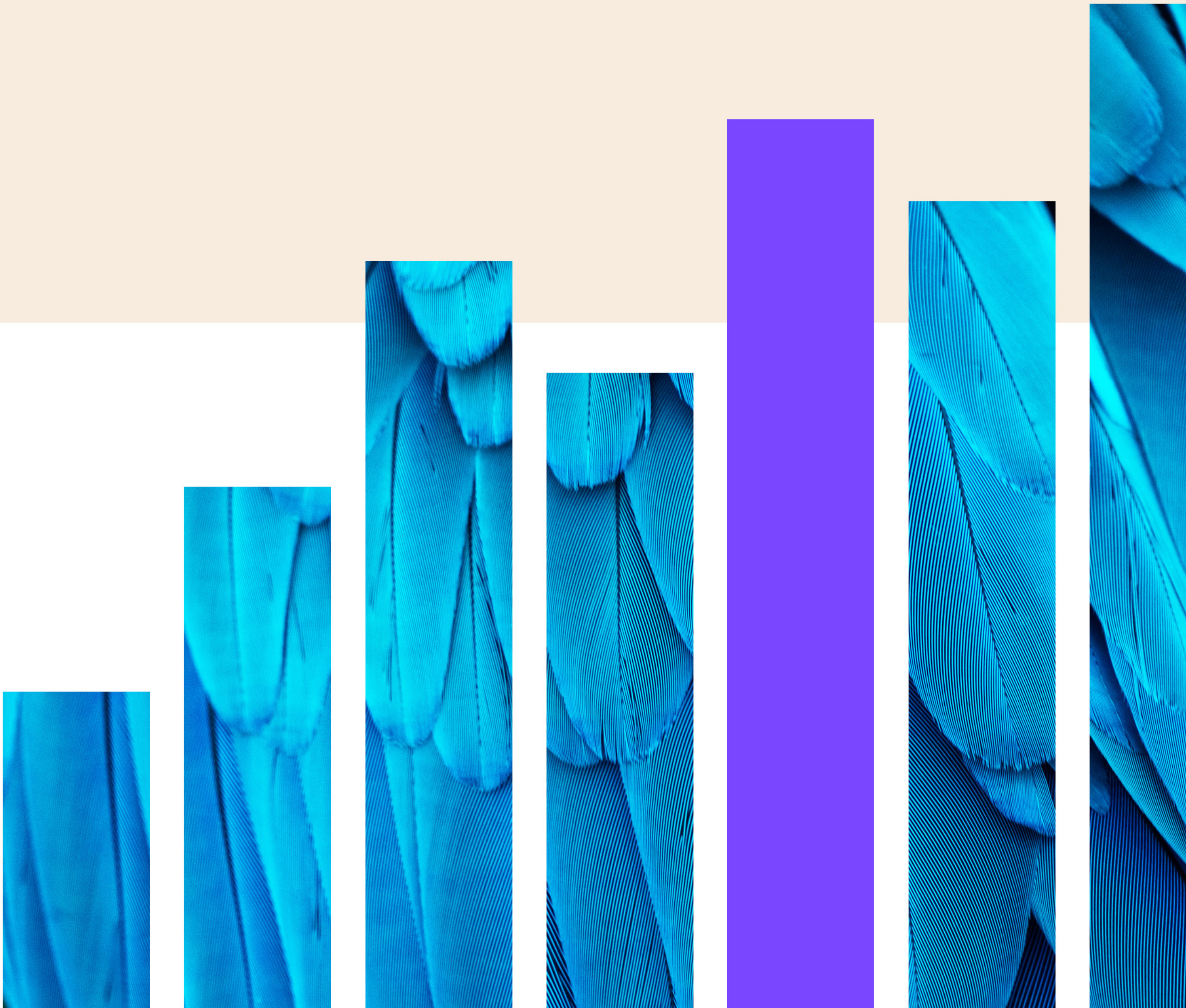
PERSPECTIVE

Net Zero: A Framework for Investors



PERSPECTIVE

NET ZERO: A FRAMEWORK FOR INVESTORS

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The Essential Science of Climate Change

Science has shown us that if the energy coming to the earth is greater than the energy escaping from the earth, the planet's temperature will rise. The layer of greenhouse gases (GHGs) around the earth is now trapping heat that previously (in the last million years) would have been emitted back into space.

The rapid increase in CO_2 and other GHGs has resulted from the rate at which we humans burn fossil fuels. These fuels were created over countless millennia by plants, which converted the sun's energy into organic molecules that then were stored in the earth and sea. By burning these fuels, we release both the energy and the carbon that have been lying dormant.

As the planet warms, glaciers melt, sea levels rise, weather patterns change, and droughts and floods occur in different locations and intensities. These changes, unprecedented since humans first inhabited the earth, have occurred through other causes in the millions of years before. The fossil records show us that there were times when many species became extinct, water covered much of the land we now live on, and temperatures were much higher than today.

The planet will probably survive what we are doing to it. But we may not.

Long-Term Risk

A risk is a bad event that might occur, and a long-term risk is a bad event that might happen far in the future. Climate change is full of long-term risks—excessive heat, drought, storms, wildfires, floods, and sea-level rise. Clearly, uncertainty exists about the timing, location, and impact of these events—hence the term "climate risk"!

These are physical risks. We also face transition risks in response to policies that aim to mitigate climate change. Transition risks are even more uncertain than physical risks because they depend on the political process.

Suppose we decide to stop emitting carbon into the atmosphere. What would happen? Governments and companies would scramble to purchase solar panels, wind turbines, and maybe nuclear reactors to generate power. Fossil fuel–based energy companies would be forced to either adopt new technologies or cease operating. The winners would be deluged with capital from investors, while the losers would see their stock prices head toward zero. This outcome is an example of transition—clearly a risk for some companies and an opportunity for others.

Physical risk and transition risk often move together. With scientific evidence that the climate is warming faster than previously expected, both the physical risk of extreme weather and the transition risk of rapid decarbonization will rise. Other events, however, move these two risks in opposite directions. For instance, news that climate mitigation policies have been put in place will reduce physical risks but increase transition risk. Similarly, news that mitigation policies are canceled will increase physical risks.

How Can We Reduce Climate Risk?

Almost 10 years ago, most of the world's nations signed an agreement in Paris that committed them to make their economies emit no net emissions (net zero) by 2050. This commitment reflects a landmark shift from using the price of carbon as a target to using the quantity of emissions as a target. Countries can choose their own approach to reaching net zero.

Scientific research assures us that if the planet entirely achieves net zero by 2050, we will avoid the worst damages of global warming. Commitment to achieve net-zero emissions means that negative-emission strategies can potentially be used to offset positive emissions. The agreement is not binding, however, except as public pressure can enforce it or domestic legal actions can police performance.

Governments can choose among four broad types of policies to reach emission targets such as net zero:

- **Tax carbon emissions.** An example is cap-and-trade markets for emission certificates, such as the European Union Emissions Trading System (EU ETS).
- **Subsidize renewable energy and decarbonization.** Examples include electric vehicle subsidies and carbon capture and sequestration research in the United States, as part of the Inflation Reduction Act.
- **Regulate emissions.** Two examples of regulation are automobile emission standards and building code insulation requirements.
- **Hope.** Some would describe this approach as "do nothing." The hope, however, is that the private sector—including consumers, employees, investors, and corporations—will voluntarily adopt greener behavior. Although economists typically are pessimistic that hope will be sufficient to achieve net-zero targets, the idea surely has some promise.

A theoretical analysis of these policies by Acharya, Engle, and Wang (2025) finds justification for such a range of policies. The well-understood cause of climate change is the emission externality. A company that emits GHGs pays nothing for the emissions, but the whole world suffers damages. Conversely, if this company were to stop emitting, it would have to pay for some type of decarbonization but the rest of the world would receive the benefits. Whenever the beneficiaries of a project are not the ones paying for it, government intervention is needed to achieve the best outcome. An emission tax is the natural policy, as first pointed out by Pigou more than a century ago (see, e.g., Nicholson and Snyder 2016).

Acharya Johnson, Sundaresan, and Tomunen (2024) then propose that a second externality exists: green innovation. When one company reduces its emissions intensity by carrying out a green innovation, then the technology for doing so becomes cheaper for everyone else. Again, the company paying for the innovation is not getting all the benefit, and a government action would be needed to achieve the best outcome. In this case, a green innovation subsidy would be the natural policy.

When both of these externalities are put into the same model, it then becomes socially optimal to have both an emission tax and a green innovation subsidy. When countries for some reason cannot do both, the remaining policy can achieve only a second-best outcome. For example, a country that cannot subsidize green innovation will find that decarbonization is more expensive than in the optimal case and therefore will need to set a higher tax on emissions to get the same outcome.

Not only have countries committed to net-zero targets, but states, regions, cities, sectors, and firms also have voluntarily committed to net zero. Why do they do this? Presumably these entities and organizations believe that such commitments will encourage customers to buy their products, employees to work for them, and investors to own their stocks. This is the set of mechanisms that could make the "hope" strategy work. It requires good intentions by its members and suffers if too many are free riders (i.e., members who do not adopt greener behaviors but benefit from a better climate anyway).

Even if no one will voluntarily change their behavior toward green causes, however, incentives may exist for large firms, industries, states, or other coalitions to commit to net zero. Acharya et al. (2025) explore these as a game theory strategy called "Stackelberg leader." The idea is that a large firm may choose to decarbonize and commit to net-zero targets purely for profit and can succeed because of the externalities. By investing in green technology, the firm lowers the cost of decarbonizing for other firms and therefore reduces not only its own emissions but also emissions from others. In this way, the country can more easily reach its net-zero targets without imposing such a high carbon tax. If the benefit from lower carbon taxes is greater than the cost of decarbonization, then the Stackelberg leader will have raised its profitability and justified its strategy.

A similar argument can be suggested for states, regions, cities, and sectors, and many examples demonstrate the effect. The larger the coalition, the more likely that it will be a successful Stackelberg leader.

The Market Response to Climate Risks

Asset prices are influenced by long-run risks and rewards. An asset exposed to long-run risk is less desirable than one that is not, all else being equal. Stocks exposed to climate risk trade at lower prices and higher expected return than similar stocks without these risks. This dynamic is important because these asset prices guide investment today. The cost of capital is greater for firms exposed to climate risk. If you think long-run risks do not matter, compare the P/E of 59 for shares of Tesla Inc. with the P/E of 5 for shares of General Motors Company.

In a series of papers, Bolton and Kacperczyk (2021, 2023) have shown that returns on stocks with high or rising emissions are greater on average than returns on other stocks after controlling for firm characteristics. Engle, Giglio, Kelly, Lee, and Stroebel (2020) and De Nard, Engle, and Kelly (2024) point out that when there is news that the climate is getting worse than the market expects, these stocks will fall in value as their risk increases. This relationship between climate news and stock returns of high emission firms provides a basis for forming and testing climate-sensitive portfolios.

Climate hedge portfolios are designed to outperform conventional market portfolios if climate risk rises more than the market expects and to underperform otherwise. They typically are formed by identifying firms that are exposed to climate risk and underweighting them relative to firms that are prepared for climate risk and may even profit from it. Such a portfolio is called a hedge portfolio because it reduces the exposure to climate and should lower the long-run variance of any conventional portfolio to which it is added.

A climate hedge portfolio is thus a risk-reducing portfolio because rising risk will be associated with outperformance. Naturally, a risk-reducing portfolio should have negative expected returns and, just like an insurance policy, should cost something. This dynamic is a consequence of underweighting stocks highly exposed to climate risk, which are earning a risk premium, and overweighting assets with low climate risk premiums. As mentioned earlier, however, when there is news that climate risk is rising, these portfolios should outperform.

Climate hedge portfolios are useful investment vehicles for investors who want to reduce their climate risk or for investors who believe that the climate will ultimately be worse than the market expects. Climate risk portfolios are short climate hedge portfolios and consequently have positive expected returns, which are compensation for bearing climate risk. Climate change deniers might find such portfolios attractive.

Climate hedge portfolios can be constructed by performing either fundamental analysis or statistical analysis. Fundamental analysis is based on firm characteristics that are available from balance sheet data, ESG data, or other measures. This analysis often formulates the risk that is to be hedged and then creates both portfolios that are highly exposed and portfolios that are negatively exposed or at least unexposed. The hedge portfolio is short or underweight the former and long or overweight the latter. In contrast, the statistical approach focuses on evidence from climate news events. It takes a short or underweight position in assets that fall with adverse climate news and overweights or takes a long position in those that rise with such climate news.

Some Examples of Climate Hedge Portfolios

Suppose the risk being hedged is the demise of the coal industry. In this case, a hedge portfolio would naturally be short coal and related stocks and could be long a broad market index. The Volatility and Risk Institute (VRI) has used a specific version of this portfolio, proposed by Robert Litterman, for several years. The portfolio is short 70% of a coal exchange-traded fund (ETF) and 30% of the broad energy ETF called XLE, and it is long the S&P 500 ETF called SPY. This portfolio is labeled as the stranded asset portfolio in VRI research and on V-Lab.[1]

If the risk to be hedged is a carbon tax, however, then the biggest GHG emitters are likely to be most exposed. Thus a hedge portfolio can be short an emission-weighted collection of stocks hedged by SPY. Similar arguments can be made for policies that subsidize clean energy or that regulate emissions or emission intensities.

Similar approaches can be used for physical risk by recognizing that most physical risks are location specific. Heat is an exception, and Acharya et al. (2024) have a suggestion for how to measure this. Location-specific physical risk factors have been created from REITs and from property insurers, as described in Jung, Engle, Ge, and Zeng (2023).

The statistical approach to forming climate hedges can be implemented by looking at the behavior of individual stocks or by looking at publicly available funds with a sustainability mandate. De Nard, Engle, and Kelly (2024) document this strategy: They regress the daily return of each of about 200 funds on standard risk factors and a measure of climate news. The coefficient on the news is allowed to change over time, and the firms with the largest or most significant climate news betas are good candidates for hedges in the future. This implementation creates a long-only hedge portfolio, designed to have out-of-sample minimum variance and maximum correlation with climate news.

[1]https://vlab.stern.nyu.edu/climate.

How Investors and Risk Managers Can Use Hedge Portfolios

Climate hedge portfolios are constructed to be investable and can be useful additions to portfolios of investors who do not want to be overly exposed to climate risk or who believe that the climate will be worse than the market expects. These investors may similarly be interested in holding stocks or funds that are correlated with the climate hedge portfolios, because such investments should deliver the same benefits.

To measure these betas, V-Lab regresses the return on sustainable funds on standard risk factors and climate hedge portfolios. The betas on the hedge portfolios, posted on V-Lab, can be sorted to see which funds have the best response to hedge portfolios. To see the results for today, click on "Security Climate Betas"[2] and scroll down to the security tabulation.

Risk managers and regulators are particularly interested in whether financial institutions' returns are correlated with climate risks. If increases in climate risk portfolios (decreases in climate hedges) correlate with bank stocks, then the financial institution is likely exposed to climate risk. The bigger the beta, the bigger the exposure.

This relationship leads naturally to stress tests by considering extreme but plausible increases in climate risk. This approach measures the change in stock price under stress, which can be interpreted as a fall in market capitalization. The dollar value of this decline, called marginal CRISK, is a measure of how many dollars the assets of the institution will lose if climate risk rises. The capital adequacy of a firm under stress can also be estimated. Assuming a standard operating leverage, the capital shortfall of a financial institution after a climate event is now measurable, and this metric is posted on V-Lab with updates every week.[3] These measures—shown for the whole world, for countries, and for individual financial institutions—serve as monitors of climate exposure.

The analyses in this section focus on long-run climate risks. Over time, some of these risks may be realized. For example, when a carbon tax is implemented, the risk becomes a reality and markets reprice financial assets. In fact, often policies may be in place but not yet fully operational and can be considered as realizations for some purposes.

If transitional policies have been put in place and no further policies are contemplated, then there may no longer be any transition risk to price or hedge. Portfolio selection can then be conducted using standard analyses, such as Markowitz mean–variance analysis or other, more recent factor or risk budgeting approaches. The stock prices of companies that were facing transition risk

[2]See https://vlab.stern.nyu.edu/climate.

[3]Go to https://vlab.stern.nyu.edu/climate/CLIM.WORLDFIN-MR.CMES.

will already have fallen and can now be held based on their expected future performance. Of course, there could still be further climate news and pressure for additional transition policies, so an argument to maintain climate hedges could be made.

Termination Risk

A particular form of long-run risk, relevant for analyzing climate risk, is called termination risk. It is the risk faced by a company that its business will be unable to continue at some uncertain point in the future. This is called a risk because it might happen or it might not. The following discussion first considers how a firm facing termination risk should be managed and then examines how it is relevant to climate risk.

To focus on the management issues, consider managing a luxury beachfront hotel that will likely be destroyed by sea-level rise at some point in the future. Although a natural strategy might be to sell the hotel, any potential buyers will also understand these risks. A second strategy is to reconsider any long-run investments, such as expanding or upgrading the hotel. If the payback period for such investments is long relative to the likely termination date, then these investments are unlikely to be wise. Even routine maintenance may not be appropriate from a financial standpoint. The net effect of this strategy will be reduced costs and higher net income for a shorter time. This policy will reduce the supply of luxury rooms, and if competitors follow the same logic, prices are likely to rise further, increasing income.

Will equity investors be willing to invest in the hotel? Yes, because it still has cash flow. Finance theory says the stock should be worth the present discounted value of the cash flow until termination minus a risk adjustment. Over time, the market cap will decline as termination approaches, and this decline will happen through big dividends and cash buybacks so that investors can receive a risk premium even as the market cap falls.

The relation between the stock price and cash flow is particularly significant. Because termination may come in the immediate future, the P/E is likely to be low. Further, the book value of the hotel is likely to be far below the market value, so P/B is typically low. Bond investors will also be willing to invest in the hotel but may require a big spread to lend beyond the expected termination date.

With large cash inflows, the manager may be tempted to develop other businesses that could continue after termination. Unless the new businesses have substantial synergies with the existing hotel business, however, such an approach would likely affect the stock price negatively. Investors would prefer to have the cash than have the manager invest it for them. In other words, the investors can diversify their own holdings without the manager doing it for them.

In this setting, we might expect to see consolidation of the hotels in a neighborhood. If some hotels independently lower prices to gain market share, then a price war may make all of them worse off, and they will still be facing termination. If one hotel buys another, then it can better manage the decline and access monopoly rents. This approach does not expand the business, and if the capital comes from equity, then it need not be diversified by the manager.

The features of the beachfront hotel are closely related to the features of a typical fossil energy company. If the Paris Agreement targets are met, such an energy company will be out of business by 2050 and possibly before. If they are not met, the business may continue but may still ultimately be terminated. We already have seen dramatic declines in the market cap and output of coal firms, static demand for oil, and rising demand for natural gas. Some of these dynamics, however, have been driven by the Ukraine war and may decline when it ends and as renewable energy continues to rise. We see low P/E and P/B ratios for fossil energy and higher bond spreads when the energy sector is under stress. Consolidation is active, with mergers of oil companies and frackers. Physical measures of investment such as drilling rigs are down.

Assuming that this description captures key features of the fossil energy markets, we should expect to see energy stocks rise when demand for energy rises and also when environmental regulations and laws are relaxed so that termination appears to be farther in the future. These same factors make climate hedge portfolios and sustainable funds underperform. Nevertheless, termination risk suggests that decarbonization is in the long-run plans of fossil energy firms. Higher energy prices, although bad for consumers and for inflation, are actually good for the environment. They encourage consumers to reduce consumption of fossil energy products and hence their GHG emissions.

Termination Risk for Countries

Countries also face termination risk when their largest industry is fossil energy. Many countries face this risk, and their solutions differ widely. For instance, Saudi Arabia and other Middle East Gulf Cooperation Council nations face the possibility that their most profitable business may terminate. In preparation, these countries are actively following strategies to diversify their economies by investing in tourism and luxury airlines, in sports franchises and events such as the FIFA World Cup, and in education. They are also saving massively in sovereign wealth funds. In light of these decisions, I believe the leaders in these countries could not possibly be denying the threat of climate change.

Two other prominent nations are facing termination risk. Both Russia and Iran are taking steps to improve their future that have led to wars. Iran is backing a wide range of disruptive groups in the Middle East. Its goal with this approach is unclear, but Iran is certainly hoping to strengthen its role and perhaps disable its competitors. This now appears to be a failed policy.

Russia chose to invade Ukraine, possibly to gain access to agricultural resources and products that Russia does not export. Russia could see that in a decade, its fossil energy business would be weaker while Europe would be more self-sufficient through renewable energy sources, so the invasion was urgent. Clearly, the costs greatly exceeded what Russia expected, but the outcome so far looks like the beachfront hotel. Oil prices are high, and supply is restricted. The ultimate outcome appears unsuccessful and surely has created massive human suffering and destruction.

Finally, one more example of termination risk must be discussed. The human species itself faces termination risk. There is a risk that we will make our planet uninhabitable for humans. Faced with this risk, our managers cannot simply reduce investment or diversify our economy. Rather, we must reduce the probability that this outcome will occur. How can we do this?

Conclusion

The Paris Agreement has a roadmap. Each country must meet its targets for decarbonization. We all must work together on this essential task. To succeed, we must solve the problem of countries that are free riders. The theory behind free riders is that from a self-interested point of view, each country is better off if it does not meet its targets while others do. This solution, however, is not the only solution. There are cooperative games in which by working together a better outcome can be achieved than from competition. Clearly this is such a case.

There is no global body that can force cooperation, so we must do it with policy. The starting point, in my view, is cooperation between the United States and China. The world's biggest emitter, China is also the world's biggest producer of electric vehicles, solar panels, wind turbines, and lots of other green technology. It has a young cap-and-trade system to tax carbon emissions. The United States must also strengthen its efforts to achieve its Paris targets. If these two nations can collaborate, they can be a model for the rest of the world. In this way, we can be confident that the worst outcomes will not occur and that we will peacefully reach a cleaner and greener world.

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