

# TOP *of* MIND

## INVESTING IN CLIMATE CHANGE



On the heels of a climate-focused World Economic Forum in Davos, the unveiling of Europe's new Green Deal, and increased attention on climate change by the world's largest asset managers and banks, climate change is undoubtedly Top of Mind. We speak with Michael Greenstone of the University of Chicago, Nathaniel Keohane of the Environmental Defense Fund and GS's own Steve Strongin and Jeff Currie about the climate challenge, and what it will take to address it. We then turn to GS analysts Michele Della Vigna and Alberto Gandolfi to discuss how capital markets and climate policy are driving transformational shifts in the energy industry, and what it means for sector returns. Finally, our GS SUSTAIN team and head of the GS Sustainable

Finance Group, John Goldstein, provide insight and advice on ESG investing and integration, and the growing implications of shareholders and clients increasingly demanding more accountability on climate.



If we end up choosing policies that are expensive, we're going to run out of enthusiasm before we've made substantial progress against climate change... carbon pricing is our best bet to achieve carbon reductions on the cheap.

- Michael Greenstone

Carbon pricing would enable specialization in finding a solution based on who's best at solving the problem... as opposed to who's causing the problem.

- Steve Strongin

The key [to ESG investing] is to clear out preconceptions and treat ESG like any other investing question, which requires forming a clear investment thesis.

- John Goldstein



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...AND MORE

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# Macro news and views

We provide a brief snapshot on the most important economies for the global markets

## US

### Latest GS proprietary datapoints/major changes in views

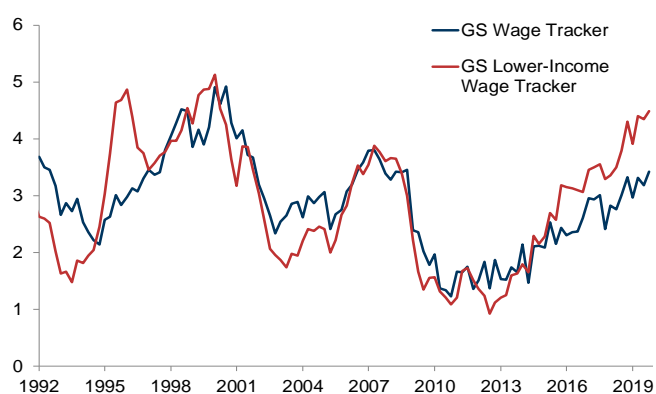
- We think growth should pick up from its current pace of around 2% to the 2.25-2.5% range, in part because of a strong positive impulse from financial conditions.

### Datapoints/trends we're focused on

- The decline of the ISM manuf. survey to a cycle-low; we expect a gradual manuf. recovery on the back of encouraging January surveys, reduced trade risks and firmer global growth.
- The impact of US election uncertainty on sentiment indicators.
- A rise in the GS wage tracker to 3¼ - 3½%, a new cyclical high, despite a decline in average hourly earnings growth.

### Steady wage gains

GS wage tracker, percent change, year ago



Source: Goldman Sachs Global Investment Research.

## Europe

### Latest GS proprietary datapoints/major changes in views

- We expect a gradual reacceleration of growth to an annualized pace of 1.2% in H1 and 1.5% in H2 2020.
- We've raised our expectation for core inflation in the Euro area by 20bp to 1.3% yoy by December 2020.

### Datapoints/trends we're focused on

- A more encouraging Composite PMI, with new orders rising sharply, despite an unchanged overall reading in January.
- Stronger forward-looking indicators, especially for German IP.
- The second phase of Brexit negotiations; we expect a more elastic timeline than the UK government has articulated.

### A sharp rebound

German IP and leading indicators, percent change, year prior



Source: Haver Analytics, Markit, Goldman Sachs Global Investment Research.

## Japan

### Latest GS proprietary datapoints/major changes in views

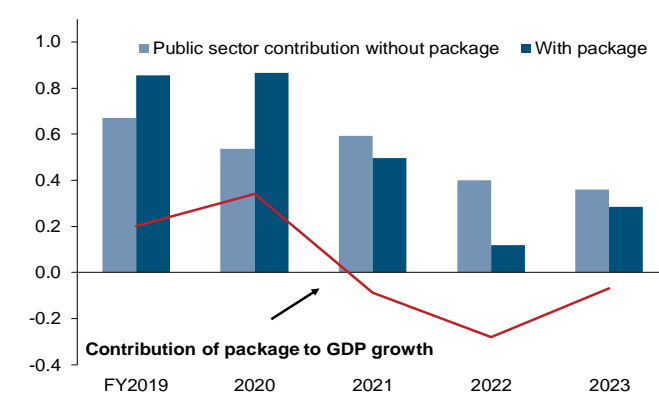
- We expect ¥3tn of the government's recent fiscal package will be spent in FY2020, boosting growth by 0.3pp to 0.4%.
- We lowered our Q4 2019 GDP estimate by 50bp to -3.0 qoq ann. and marginally raised our recession prob. to 38%.

### Datapoints/trends we're focused on

- The domestic macro implications of the coronavirus, which poses downside risks given inbound China tourist consumption is currently 15x larger than during the 2003 SARS outbreak.
- The output gap; we think the BOJ will refrain from further easing as long as it remains positive and ¥/USD is above 100.

### Turning the fiscal corner

Estimated contribution to GDP growth of fiscal package, pp



Source: Goldman Sachs Global Investment Research.

## Emerging Markets (EM)

### Latest GS proprietary datapoints/major changes in views

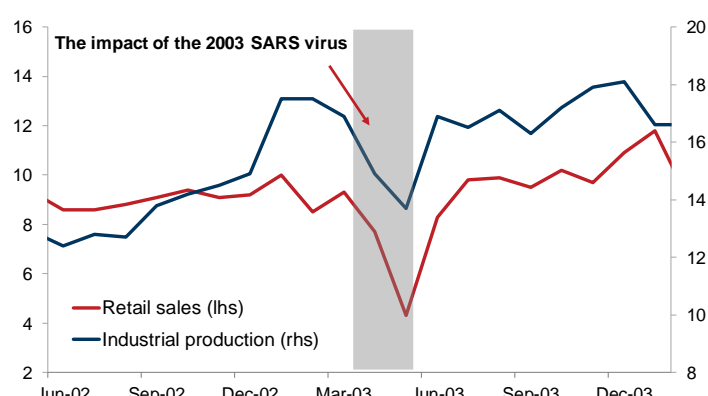
- No major change in views.

### Datapoints/trends we're focused on

- The coronavirus outbreak; past viruses suggests the hit to growth should prove short-lived, though downside risks remain.
- Fiscal stimulus in Asia, with China, Japan, Korea, Taiwan, Australia, and India set to boost spending in 2020.
- Russia's recently announced 0.5% of GDP fiscal package, which presents upside to our above-consensus 2020 GDP forecast of 2.2%.

### History as a guide?

China retail sales (lhs); China industrial production (rhs), percent



Source: NBS, CEIC, Goldman Sachs Global Investment Research.

# Investing in climate change

On the heels of a climate-focused World Economic Forum in Davos, the unveiling of Europe's new Green Deal, and increased attention on climate change by the world's largest asset managers and banks, climate change is undoubtedly Top of Mind. We dig into the climate challenge, what it will take to address it, and the growing investment implications as shareholders and clients increasingly demand more accountability on climate.

We start by speaking with two climate policy experts, Michael Greenstone, Director of the Energy Policy Institute at the University of Chicago, and Nathaniel Keohane, Senior Vice President of the Environmental Defense Fund. They both argue that putting a price on carbon is our best bet to realizing carbon reductions efficiently, which is essential to managing the delicate balance between pursuing cleaner energy and economic growth—the core dilemma underlying the climate challenge. That said, they believe that addressing climate change is not incompatible with growth, but rather essential to it, as the only path to a prosperous future is a low-carbon one (see pg. 22 for GS economists' review of climate change and growth).

But how will carbon pricing actually help achieve an efficient solution to climate change? Steve Strongin, head of GS Global Investment Research, explains that setting a price for carbon would be an important step in incentivizing enough R&D to actually solve the problem. And knowing what removing a ton of carbon from the atmosphere is worth will motivate people to maximize the amount of carbon removed per dollar spent—the definition of an efficient solution.

That said, establishing a price for carbon is easier said than done. In practice, the primary mechanisms for doing so are carbon taxes, which effectively assign a price for carbon, and cap-and-trade programs, which set a limit on emissions—typically for a certain sector or industry—and enable participants to trade emissions allowances under the cap, which gives rise to a carbon price at which the demand and supply for allowances clears.

Greenstone is relatively agnostic between the two options; in his view, any price for carbon materially above zero would be a positive step, and whether we get there via carbon taxes or cap-and-trade programs just depends on whether having certainty on price (via a tax) or on emissions reductions (via cap-and-trade) is more important, because you can't have both. Keohane believes that any approach must put both a price and a limit on emissions to ensure progress towards emissions targets. So he prefers cap-and-trade programs to pure carbon taxes, and points to the success of the 1990 cap-and-trade system for sulfur emissions in eradicating acid rain as evidence that such programs work.

But Jeff Currie, global head of GS Commodities Research argues that the acid rain problem was very different than today's climate challenge; the number and diversity of countries involved was smaller, the source of harmful emissions was more concentrated, and income inequality—which lies at the center of backlash to addressing climate change today—was lower. In his view, that means rich people in rich countries will have to play a larger role in solving (i.e. paying for) this global problem.

Strongin, for his part, agrees that rich countries will have to bear the majority of the initial costs, and makes the larger point that most of today's policy proposals to address climate change—from carbon taxes, to cap-and-trade programs, and beyond—share the problem of assuming that the answer lies with the

## So what exactly is the climate challenge?

It's the rise in the world's average temperatures largely caused by an increase in the level of carbon dioxide in the atmosphere, which [evidence suggests](#) has increased the probability of extreme weather events, raised average sea levels, and had other negative consequences for people and the planet. At the UN Climate Change conference in Paris in 2015 (COP21), 184 countries committed to the [Paris Agreement](#), which pledged to keep the rise of global average temperatures to well below 2 °C above pre-industrial levels, and to attempt to further limit the temperature increase to 1.5 °C.

source of the problem—utilities, cars and energy producers. But, Strongin says, these sectors are not typically considered the most innovative areas of the economy, and others may be better placed to find more efficient solutions. In his view, a carbon price, a funding mechanism from which to pay innovators for each ton of carbon their technologies remove, and a referee to verify those savings will motivate the most efficient answers.

Across the current spectrum of possible solutions, Strongin sees the most hope for batteries and carbon capture and sequestration technologies to be part of the climate solution, given their immense scalability, as does Greenstone. But they point out that we may not yet know which technology will be the best answer. After all, Strongin says, no one could have anticipated that shale would have solved the problem of "peak oil"—but it did.

Michele Della Vigna, head of GS Energy Industry Research, also sees sequestration technologies as a potentially important part of the answer. That's because his [Carbonomics](#) work has found that today's conservation technologies have the potential to abate only about half of current carbon emissions at a carbon price of less than \$200/ton, and would leave a quarter unabated. More broadly, Della Vigna argues that capital markets' focus on decarbonization is paving the way for an energy transition. Tighter financing for hydrocarbon assets is driving consolidation in the oil & gas industry, which he believes is likely to lead to a halt in non-OPEC supply growth, higher energy prices and increased profitability of Big Oils. In his view, these shifts should ultimately enable Big Oils to be part of the solution to climate change.

Alberto Gandolfi, head of GS European Renewables, then takes a close look at Europe's new Green Deal—a plan for Europe to reach net zero carbon emissions by 2050. He sees the plan as a €7tn investment opportunity that will generate strong returns for European "Climate Champions" in the coming decades, and will likely reshape the larger economy in the process.

More broadly, how should investors—and corporates, for that matter—approach green/sustainable investing? Derek Bingham, head of GS Americas SUSTAIN research, answers our clients' most-asked questions about ESG investing. And we then dive deeper with John Goldstein, head of the GS Sustainable Finance Group, who discusses everything from the investment rationale for sustainable investing, to the ESG strategies that hold the most value today, and those on the horizon for tomorrow.

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# Interview with Michael Greenstone

Michael Greenstone is Director of the Energy Policy Institute at the University of Chicago (EPIC) and former Chief Economist of the Council of Economic Advisers under President Obama. He explains the importance of pricing carbon to unleash the power of markets and innovators to find the most cost-effective climate solutions, and how the social cost of carbon can help set pricing policies. He also discusses the promise of batteries and carbon capture and sequestration.

*The views stated herein are those of the interviewee and do not necessarily reflect those of Goldman Sachs.*



**Allison Nathan: How should we think about the tradeoff between promoting economic growth and mitigating the costs of climate change? Isn't there an unsolvable dilemma in that the developing countries that need to reduce future emissions the most also have the greatest need for cheap energy?**

**Michael Greenstone:** That dilemma is what I call the Global Energy Challenge—how societies around the world, but especially developing countries, balance the need for cheap and reliable energy that is so critical for economic growth with the need to manage pollutants that result from that energy consumption and increase the odds of disruptive climate change. Societies are going to reach different conclusions about that delicate balance based on a range of factors, including economics, values, and preferences for redistribution today and across generations. But figuring out the right balance on a global basis is one of the most pressing challenges of our time and one where I think facts and evidence can make a contribution.

**Allison Nathan: Is it realistic to think that the lion's share of energy developing economies need to propel growth is going to come from anything but fossil fuels?**

**Michael Greenstone:** Not given the way that energy markets are constructed currently where pollution, be it local air pollution or greenhouse gases, is not priced. The result is an uneven playing field that favors fossil fuels, and this is especially so in today's developing countries. In the absence of fundamental changes in the construction of these markets or the private costs of fossil fuels versus low-carbon energy sources, we should expect developing countries to continue to prioritize the use of fossil fuels. We don't have many instances of economies achieving high living standards without high energy consumption, and by 2040 energy demand in OECD countries should remain fairly stable while roughly doubling in developing countries. So any solution to the global climate problem will require changes in developing economies' energy markets or technological breakthroughs to address their energy needs.

**Allison Nathan: Is it possible to shift the economics of energy in a way that favors cleaner energy sources?**

**Michael Greenstone:** Yes. Climate change is the result of two market failures. The first is that there is no cost to generating pollution and the damage it inflicts on people and the planet. The simple solution to that failure is to put a price on carbon so that people have to pay to pollute. That would effectively raise the cost of carbon-intensive energy sources. The complication to that solution is that it reduces the purchasing power of consumers.

But that could be mitigated, for example, by governments refunding the revenues from a carbon tax to the public, and in a progressive way that would ensure that the costs of the tax would be borne by higher income households.

The second market failure is that there is too little incentive to invest in R&D for low-carbon technologies because investors are unlikely to reap all of the benefit of this R&D; even if the R&D produces commercial ideas—which is not a given—basic advances will inevitably spillover to others who didn't incur the investment costs. Again, there is a simple solution to this failure, which is government funding/subsidization of basic R&D for low-carbon energy sources or other technological solutions that will make cleaner energy sources cheaper—and competitive with fossil fuels—or carbon-intensive energy sources less polluting. Another possibility is that rich countries could directly subsidize the use of low-carbon energy sources in developing countries. However, I would not want to run for Senator in Massachusetts, Alabama, or really any state on a platform of "let's pay for India and China to have cheaper energy."

**Allison Nathan: What's the right price for carbon?**

**Michael Greenstone:** Ideally, the price of carbon should reflect the value of the damages associated with the pollution it creates. During my time in the Obama administration, I co-led, with Cass Sunstein, an effort to develop such a "social cost of carbon" for the US government that added up the costs associated with the release of a ton of carbon dioxide into the atmosphere in terms of changes in mortality rates, crop yields, labor supply, flooding, and so forth. The value that we came up with was \$51/ton. So we found that every ton of CO<sub>2</sub> released into the atmosphere caused \$51 worth of damages in present value terms.

This estimate can be used for thinking about the "right" price of carbon, and several proposals for carbon taxes in the US and elsewhere have loosely pegged the tax to it. The estimate also provides a bright line to assess which policies are worth pursuing, and which ones cost more than they're worth. For example, research I conducted on home energy efficiency programs, such as attic insulation, found that the cost per ton of CO<sub>2</sub> abated was several hundred dollars versus only \$51/ton of benefit. Given these practical uses of the social cost of carbon, I think it's the most important number you've never heard of.

**Allison Nathan: How much confidence do you have that this \$51/ton estimate is still accurate today?**

**Michael Greenstone:** At the time that we developed the initial estimate, it was clear that the understanding of the science and economics of climate change was advancing rapidly, and a framework for how to ensure that the estimate remained current was required. The Obama administration tasked the National

Academy of Sciences with developing recommendations on such a framework—which they’ve done—but those have been totally ignored by the current administration. Under President Trump, a series of changes have been made that have reduced the original \$51/ton number to somewhere between \$1 and \$7, but none of the changes are justified by frontier science or economics research—they were political decisions.

Seeing a clear need for robust research that could keep the social cost of carbon current with the latest developments in the field, myself and a few of my colleagues have established something called the [Climate Impact Lab](#), which aims to produce an updated social cost of carbon that reflects the National Academy of Science’s recommendations. This is a work in progress, but I think the \$51/ton estimate will likely change once we follow the recommendations and incorporate the latest evidence. At least in the area of mortality, the most updated evidence suggests that the costs of the release of a ton of CO<sub>2</sub> for mortality alone appear to be 10 or 15 times larger than what was embedded in the Obama-era social cost of carbon.

**Allison Nathan: Are cap-and-trade schemes or carbon taxes more effective in achieving a price for carbon?**

**Michael Greenstone:** Relative to where policy is today, I think the debate about whether a cap-and-trade scheme or a carbon tax is preferable is just a parlor game. The real issue is that the effective price on carbon in most parts of the United States and certainly around the world today is basically zero. So the first and most important step is to raise the price of carbon towards the social cost of carbon; whether we get there through a trading scheme or a carbon tax is less important.

**Allison Nathan: That said, policymakers will ultimately have to decide which approach to take if we’re serious about putting a price on carbon. So how would you advise them?**

**Michael Greenstone:** The primary advantage of a cap-and-trade scheme is you have certainty on emissions, and the primary advantage of a carbon tax is that you have certainty on price. The dilemma is you can’t guarantee both the price and the quantity. So choosing the best approach depends on political and societal judgments about the greater risk. If you think the greater risk lies with the politics—and that big energy price spikes would undermine the entire system—a carbon tax is more appropriate. But if you think the greater risk lies with larger climate damages in the event we end up getting more emissions than expected at a particular carbon price, a cap-and-trade scheme is preferable.

**Allison Nathan: If countries take different approaches to establishing a price for carbon—and we end up with many prices of carbon—what implications would that have?**

**Michael Greenstone:** We already see an exceptionally wide range of prices for carbon around the world; Sweden’s price is about \$125/ton and the EU and California’s prices are in the high-teens or low-20s/ton. But these differences are a second order problem. Right now, the average price for a ton of carbon across the world is roughly \$2.50 because most of the world has a price of zero. So what strikes me as the most urgent problem are all of those zeros. Once all countries are above zero and committed to carbon pricing, I think the issue of different countries having different prices that you’re raising becomes a more important one. Of course, the ultimate solution is a global price for carbon,

but I don’t see that happening in the foreseeable future, given very different fundamentals in India, China, and the US.

**Allison Nathan: Should other policies beyond carbon pricing—like efficiency standards, conservation policies or sector-specific regulations—be part of the policy mix?**

**Michael Greenstone:** The problem is that the primary policy/regulatory alternatives to carbon pricing tend to be more expensive on a per ton basis. This is especially the case for policies that are more opaque in how they would operate and less directly targeted at emissions reductions, such as energy efficiency policies that generally have a diffuse set of goals. My view is that if we end up choosing policies that are expensive, we’re going to run out of enthusiasm before we’ve made substantial progress against climate change. That’s why it’s so critical to ruthlessly search for the cheapest reductions in CO<sub>2</sub>. And, honestly, carbon pricing is our best bet to achieve carbon reductions on the cheap. That said, we should absolutely pursue non-pricing policies where the current or future benefits in terms of carbon reductions are projected to be larger than the costs. The climate problem has arrived and we need to get on with it.

**Allison Nathan: There’s a lot of activity and innovation in low-carbon technologies. Which look the most promising?**

**Michael Greenstone:** I think it’s hard to see a path to a green future that doesn’t run through more efficient batteries. In the power sector, renewables run into the well-known problem that the sun doesn’t shine all the time and the wind doesn’t blow all the time. Right now, we’re largely filling in those gaps with fossil fuels by using natural gas plants. A greener alternative would be to improve batteries so that they can provide the storage to smooth out the production of energy from renewables. And if the power sector becomes low carbon through the use of batteries, they can also be the key to reducing petroleum consumption in the transport sector. This would solve the problem that in some states currently the CO<sub>2</sub> emissions from an electric vehicle exceed the CO<sub>2</sub> emissions from an internal combustion engine car—this is because in these states the EVs are basically plugged into a coal plant. So I see batteries as potentially pivotal.

I also think that making serious progress on carbon capture and sequestration has got to be an important piece of the puzzle. The world is awash in inexpensive fossil fuels, and the idea that we’re just going to leave them in the ground strikes me as very unlikely. So I think it is incumbent on the world to find a way to use them that is consistent with climate goals, and the path to that is through capture and sequestration. I consider it a tragedy of policy that the world is not operating several demonstration coal and natural gas carbon capture and sequestration plants at scale.

All that said, my views that these technologies will be at the center of solving climate change are just guesses. The core problem today is that we have not yet unleashed the power of markets and innovators to come up with the right solutions. The contrast with fossil fuel recovery where there is a clear price incentive and the kind of miraculous technical achievement that hydraulic fracturing for gas and oil requires is striking. Until there’s a price incentive, and markets are allowed to do what they’re so good at—ruthlessly seek out the most economical way to do something—we’ll all be left just guessing as to what the most promising low-carbon technology really is.

# Interview with Nathaniel Keohane

Nathaniel Keohane is Senior Vice President of the Environmental Defense Fund and former Special Assistant to President Obama for Energy and Environment on the National Economic Council. Below, he argues that the only pathway to future prosperity is a low carbon one, and that carbon pricing, preferably via emissions trading programs, is central to achieving global climate goals.

*The views stated herein are those of the interviewee and do not necessarily reflect those of Goldman Sachs.*



**Allison Nathan: The UN climate talks that took place in Madrid last month have been described as a failure. Do you agree?**

**Nathaniel Keohane:** The reality is that the Madrid talks were never expected to be that important. The meeting in Glasgow at the end of this year is more significant, because it will mark

the five-year anniversary of the Paris Agreement, when countries are due to update and ideally strengthen their emission targets. That said, Madrid was deeply disappointing. First, parties were unable to agree on guidance around the use of carbon markets to meet their targets. This issue was already carried over from 2018, and was once again kicked down the road. Second, parties weren't even able to agree on language calling for more ambition in addressing climate change. While such language would have been only rhetorical, the fact that countries couldn't agree to affirm that more ambition is needed was not a good sign. So it's hard to describe Madrid as anything but a failure. It certainly reinforced the sense that we are seeing very little forward progress right now in the UN.

**Allison Nathan: So, where are we today in terms of achieving the Paris climate accord's goal of limiting the increase in global average temperatures to below 2 degrees Celsius above pre-industrial levels?**

**Nathaniel Keohane:** We are very far away, and headed in the wrong direction. Although growth in global carbon and greenhouse gas emissions have begun to slow, emissions are still rising. Even if countries met their current targets, we would still be far off the trajectory needed to meet the two-degree goal. Any chance of meeting it will require global emissions to peak in the next decade—the sooner the better—and then get onto a very steep downward path.

**Allison Nathan: What is the most efficient way to achieve the required emissions reductions—via policy or markets?**

**Nathaniel Keohane:** Successfully addressing climate change requires both policy and markets. Markets are the most powerful force we have to address climate change, but they won't move towards solutions on their own; private actors by themselves generally won't take into account that emitting carbon dioxide, methane and other greenhouse gases has significant implications for the health of the planet and for current and future generations. As an economist would say, we are dealing with a massive negative externality. So we need policies that harness the power of markets to achieve our climate goals, in particular by rewarding private actors that embrace and deploy low-carbon technologies and develop the new and better technologies that we'll need.

**Allison Nathan: What government policies can most effectively achieve this?**

**Nathaniel Keohane:** First, we need policies that put a price on carbon so that the damage to the planet inflicted by carbon emissions can be embedded as an actual cost. This will provide a powerful economic incentive to cut emissions by deploying clean energy, reducing tropical deforestation, decarbonizing industry, and so on. But the price is only a means to an end. We need policies that reflect the end we're trying to achieve: limiting the total amount of pollution that we put into the atmosphere, and ultimately driving it to net zero. It's not enough to just emit less carbon; to stabilize the climate, we have to get to the point where we are taking out as much carbon from the atmosphere as we are putting in. So it's critical that policies establish both pollution limits as well as a price on carbon, which will help steer us towards achieving those limits in the quickest, most cost effective way.

**Allison Nathan: So are cap-and-trade systems or carbon taxes more preferable in addressing climate change?**

**Nathaniel Keohane:** We need both a limit and a price on emissions, and there are multiple ways to do that. The advantage of cap-and-trade programs is that, by design, they integrate both; the cap sets a limit on total emissions, and trading emissions allowances within that cap gives rise to a price. This approach has proven successful in the past. The most effective environmental policy the world has ever seen was the trading system Congress put in place in 1990 to address acid rain, which reduced the sulfur pollution that causes acid rain by 86% between 1995 and 2015. And in the climate arena, current cap-and-trade schemes in the EU and parts of the US are leading to lower emissions.

In contrast, a carbon tax by itself only sets a price on carbon—not a limit on emissions. That makes a pure carbon tax less preferable, in my view. But carbon taxes could be structured to incorporate a limit, for example, by including a provision that sets out a trajectory for emissions reductions over time; if that reduction isn't met, the carbon tax would automatically rise.

**Allison Nathan: Won't a carbon price high enough to materially reduce emissions risk a political backlash to climate change policies? Can such backlash be overcome?**

**Nathaniel Keohane:** The politics cannot be ignored. We learned that the hard way from the experience of the 2009 Waxman-Markey cap-and-trade bill, which passed the House but failed in the Senate. A key lesson from that experience is that those of us who advocated for the bill focused too much on the mechanism of cap-and-trade and not enough on the outcome—that is, the benefits that addressing climate change would bring for the lives of taxpayers and voters, and for their children's lives.

Today, I think people have become increasingly aware of the damage from unchecked climate change because they actually see it. The Australian wildfires are just the latest example of the extreme weather events that climate change makes more likely. But governments also need to clearly articulate to voters, taxpayers, and consumers what they're getting out of policies to reduce emissions.

Addressing climate change is not only compatible with growth and prosperity—it is essential to it. There is no high carbon path to future prosperity because the impacts of climate change will be devastating to people, to economies and to the planet. A prosperous future is a low carbon one. The policies we put in place and the actions we take now and in the coming years will determine whether the transition is one of high prosperity and better, faster growth—or whether we put the brakes on growth because we waited so long to act.

**Allison Nathan: Do we need national climate legislation in the US to really address climate change globally?**

**Nathaniel Keohane:** In my view, the most important and vital step that can be taken to address climate change globally is passing national climate legislation in the US. First, national action drives international action, not the other way around. How far we get under the Paris climate accord will depend entirely on what national and regional governments are willing to do to fight climate change, and this is especially true for the world's largest emitters. Second, while state-level action is important, the US will never be able to reduce its emissions to zero or beyond just by acting at the state level. Finally, American leadership has always been—and remains—vital to this issue given America's historical leadership role in international diplomacy in general, and its place as the largest emitter historically. We've put more carbon into the atmosphere than anyone else. We won't have strong action from China, India and others without acting here at home.

**Allison Nathan: Does US national climate legislation require bipartisan support? Is it naïve to think such bipartisan support is achievable anytime soon?**

**Nathaniel Keohane:** For climate legislation to be effective, it has to be durable. That's true for legislation in general, but it's especially true for climate policy that will influence investors' and businesses' decisions about real assets—power plants, industrial facilities, manufacturing plants, and so on—that will last 30, 40, 50 years. In order for those decisions to be made, there has to be confidence that climate policy will remain in place. And the best way to ensure that is to get bipartisan support. So we have to aim for that. Is that naïve? It's certainly challenging, given the current degree of polarization on a whole range of issues, but I think we need to try.

**Allison Nathan: In that context, is this year's US election as pivotal as it seems?**

**Nathaniel Keohane:** Without speaking to the election specifically, I will say that time is running out. Another four years or five years of inaction on this issue will set us back even further in terms of both America's emissions trajectory, as well as our leadership in the world.

**Allison Nathan: How seriously should we take China's commitment to addressing climate change?**

**Nathaniel Keohane:** Very seriously. China is acting for a set of reasons. First, it needs to solve an air pollution crisis in its cities, which reached a level that threatened the legitimacy of the government. Taking action on climate—for example, by reducing coal-fired power generation—also has clean air benefits. Second, the Chinese government sees an enormous opportunity to lead the world in renewable energy and other clean tech, and climate policy can create a domestic market to help support that. Third, under the Obama administration, China saw leadership on climate as critical to its positioning as a global power. That's less true now, which is one reason to expect that while China will meet the commitments it has already made, it likely won't show much new ambition until we have a US president that's willing to make it a priority.

**Allison Nathan: Setting climate policy aside, what is the most productive way for the private sector to engage in addressing climate change today?**

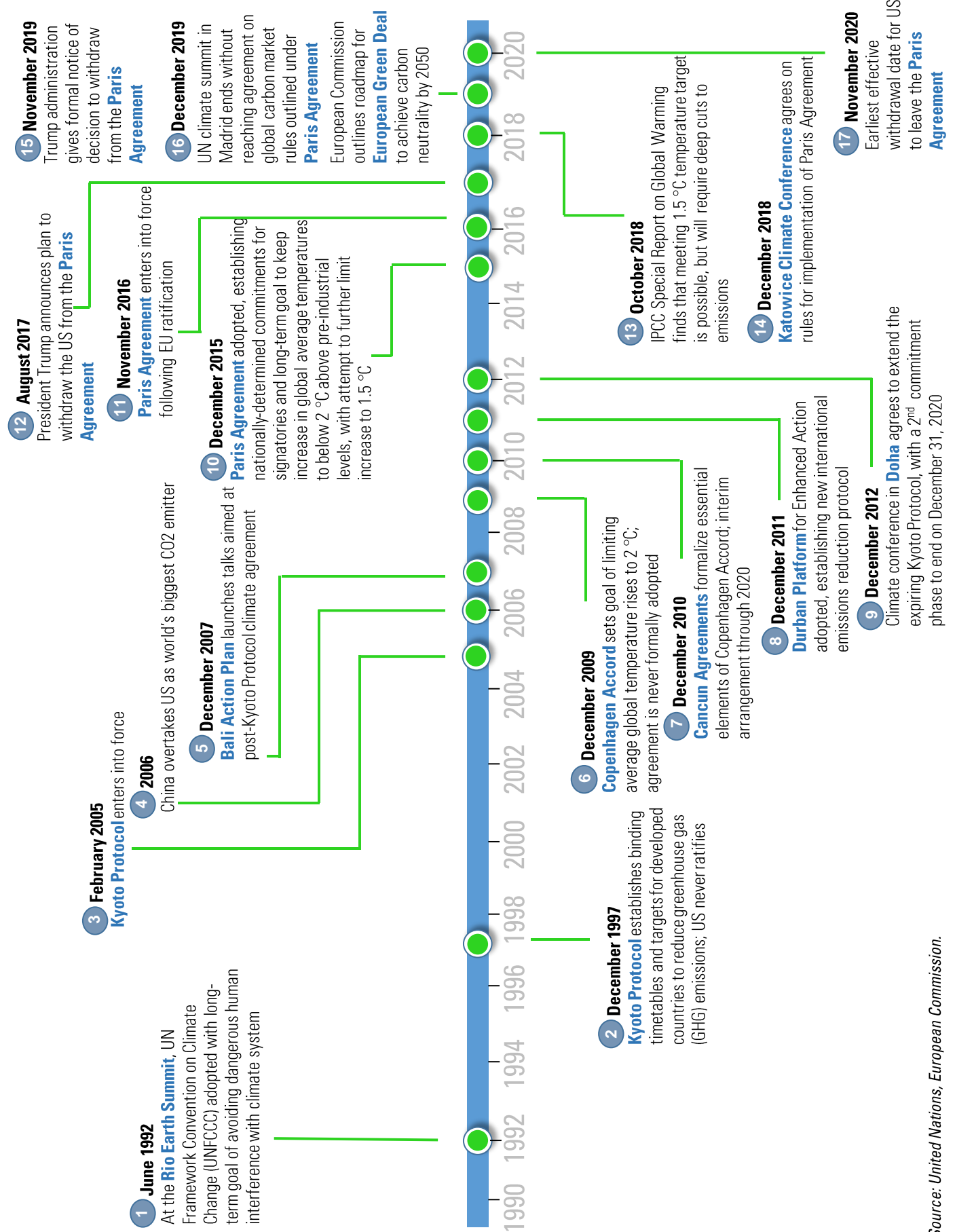
**Nathaniel Keohane:** I've seen a surge in interest from private and institutional investors that want to play a bigger role in addressing climate change. I think about investor engagement in three buckets. First is investing in technologies that could be part of the solution. There's a whole range of potential technology investments, and we need all of them, from more cost-efficient renewable energy, which is already showing signs of scalability, to carbon capture technologies that are in a more nascent stage, but show substantial promise. Second, investors can divest from fossil fuel-intensive technologies. Coal in particular is a no-brainer: the world should not be investing in new coal-fired power plants, full stop. And, third, capital owners and asset managers can take a much more proactive role in pushing companies to do more on climate both in their operations and their advocacy. So investors should be demanding more of the companies they are investing in.

**Allison Nathan: What will you be watching this year?**

**Nathaniel Keohane:** Well, I will be looking to see whether countries bring more ambition to the table when they revise their targets leading up to Glasgow at the end of the year. But I will be even more focused on developments at the national and regional level, which, as I said, will be crucial to driving international action. What will Europe do in the context of its new Green Deal? How will China's roll-out this year of an emissions trading system for its power sector—the world's largest—go? Will Australia respond to the wildfires with new climate policy? At the international level, aside from Glasgow, I'll be following the aviation sector. Starting next year, most international flights will be covered by a cap on carbon emissions at 2020 levels. If that system succeeds, it could be a template for carbon markets globally.

Finally, despite the gridlock at the UN level, there is potential for a coalition of countries to come together outside of the UN process and agree amongst themselves on standards for high-integrity carbon markets. Again, given the importance of establishing a carbon price that will help harness the power of the private sector alongside governments to address the climate challenge, that would be a meaningful step forward.

# The history of climate policy

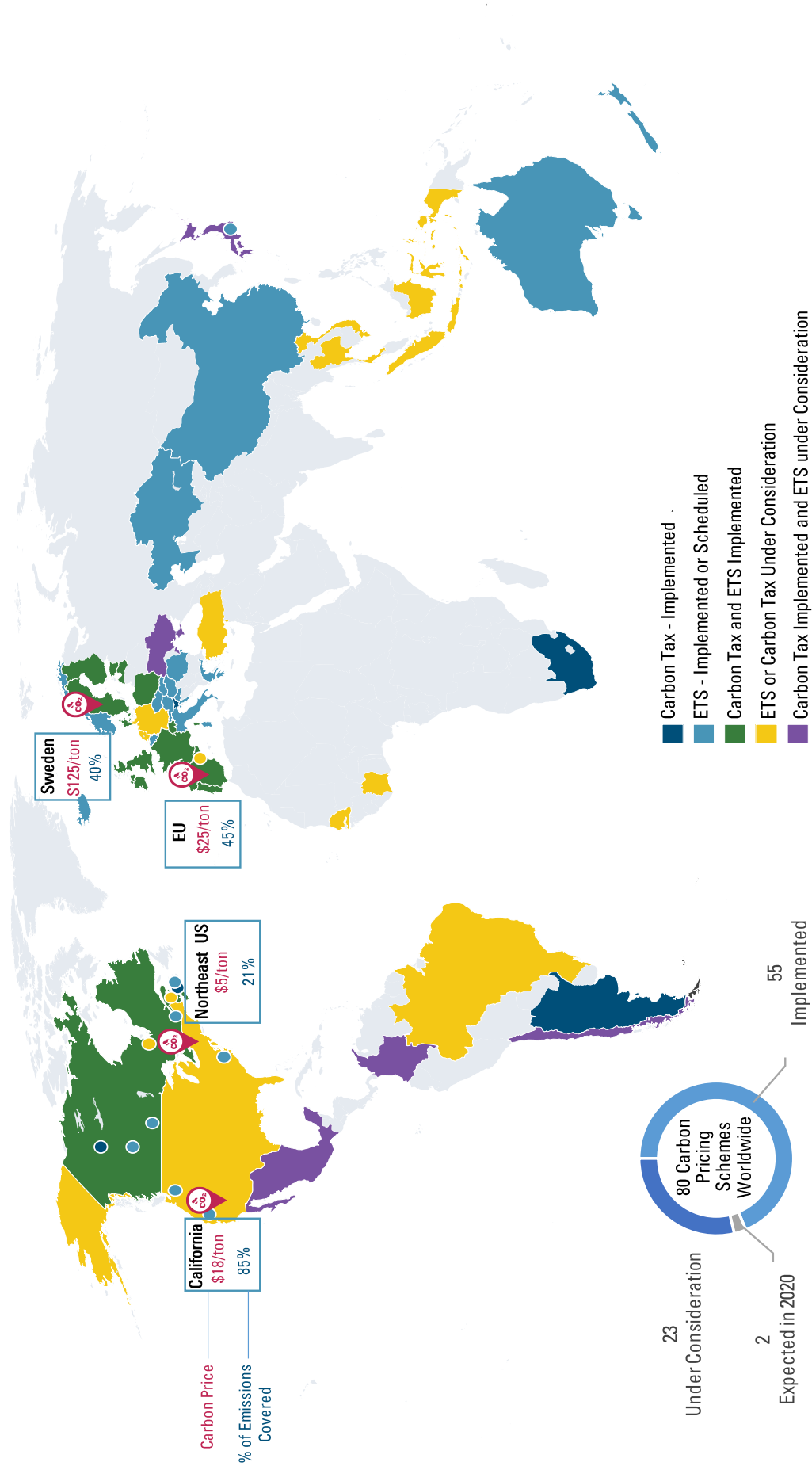


Source: United Nations, European Commission.



# Carbon pricing today: few and varied

20% of global greenhouse gas emissions are covered under carbon pricing initiatives



Note: Carbon prices may not be comparable among countries, due to differences in sectors covered, allowances distributed, and exemptions applied.  
Source: World Bank.

# Interview with Steve Strongin

Steve Strongin is the head of Goldman Sachs Global Investment Research and a member of the Board of Directors of Ocean Conservancy, the Jury of World Resources Institute's Ross Prize for Cities, and the Becker Friedman Institute Advisory Council. Below, he argues that while most policy proposals to address climate change today—such as cap-and-trade schemes and emissions taxes—focus on emitters, it's not clear that's where the most efficient solution will come from.



**Allison Nathan: Several experts tell us that establishing a price for carbon is essential to start to address climate change. What will carbon pricing actually achieve?**

**Steve Strongin:** Carbon prices can help address climate change in three ways. First, the key to solving climate change is maximizing the amount of carbon

removed from the atmosphere per dollar spent. The only way to motivate people to focus on the most efficient solutions is to pay them per ton of carbon removed, and establishing a carbon price per ton would be the first step in that direction. Second, while most of the current policies and regulations focus on the sources of carbon—utilities, cars and energy producers—it's not clear that's where the solution will come from. Carbon pricing would enable specialization in finding a solution based on who's best at solving the problem—whether that be through different agricultural practices, re-forestation or improved batteries for use in the power sector, etc.—as opposed to who's causing the problem. And, third, a carbon price will facilitate R&D because the most basic element of investing is calculating the present value of what the technology/solution might be worth, and that requires a price.

**Allison Nathan: Cap-and-trade programs are often discussed as one of the best ways to establish a carbon price. Do you agree?**

**Steve Strongin:** Perhaps, but not necessarily. The problem with most of the carbon price proposals today is that they essentially assume the answer. The simplest example of that are cap-and-trade schemes. These schemes basically identify a certain set of emissions as the problem, and reducing them as the solution. That may be the answer. But it also may be that those emissions are actually economically efficient, and the solution instead lies in reducing emissions elsewhere or capturing and sequestering carbon. If that's the case, cap-and-trade doesn't necessarily get you the right answer. In general, I think if we continue to try to solve climate change by getting rid of emissions sources one by one—via cap-and-trade schemes, or taxes on emitters, etc.—it's very unlikely to get us the whole way there.

**Allison Nathan: Experts often say that the "unleashing of market forces" once we have a carbon price will lead to the most efficient solution to climate change. Is there too much optimism about the power of markets to solve this?**

**Steve Strongin:** There may be. The key to unleashing market forces is setting up conditions that allow people to make money pursuing creative solutions. Case in point, in the 2000s, we were concerned about the concept of "peak oil" and running out

of energy. At the time, there was a similar debate about what technologies were going to solve this problem. As it turned out, we solved the problem, and a large part of the solution was shale oil, which wasn't on anybody's original list of potential solutions; it was discovered because the oil price was high and people were motivated to find an answer.

“The key to unleashing market forces is setting up conditions that allow people to make money pursuing creative solutions to the problem.”

Today, as I said, most of the policy proposals focus on taxing emitters in the utilities and transportation sectors, rather than solving the problem elsewhere. And it's ironic that the places where we've provided the biggest incentives to come up with technological innovation to solve climate change are electric utilities and car companies, which are not typically considered the most innovative sectors of the global economy. So we need to structure the system so that innovations have a chance to happen across the economy. If we can expand the problem in this way, then I am optimistic that market forces will solve it.

That said, I think the bigger problem may be naivety about how simple it will be to establish the conditions that will unleash market forces. You could declare a carbon price tomorrow, but if you haven't learned how to measure carbon emissions from all possible sources, and you haven't figured out how to provide credits for as-of-yet-undiscovered methods of reducing carbon, you haven't unleashed market forces. For example, you'll need to figure out how to think about providing credit for methane reductions, or for plants whose roots decay at different rates, or whatever else people think of.

**Allison Nathan: So what should we do next to move in the right direction?**

**Steve Strongin:** If you're going to create the flexibility we need to find a solution, then you have to find a way to pay for it. Solutions that focus on emitters, like a gasoline or electricity tax, are, of course, revenue-producing. But solutions like cultivating natural carbon storage or atmospheric capture and sequestration will require that investors be paid a capture fee. People sometimes argue that revenues from emitter taxes can be redirected as capture fees and cover the costs of motivating investment in other, more innovative solutions. But experience so far with emitter taxes suggests these revenues are too low to completely, or even mostly, cover the costs, and the level of taxes required to do so leads to significant voter opposition. And by that I don't just mean that politicians can't get enough votes for the taxes, but that people actually take to the streets in

opposition, which we have already seen even in countries like France.

**Allison Nathan: What could a mechanism that generates enough revenues to finance a solution actually look like?**

**Steve Strongin:** As a practical matter, I think you will end up having to negotiate a funding mechanism at the international level, with the richer countries bearing the majority of the costs initially. You will also need a referee who can certify that a solution is indeed reducing carbon in the atmosphere and is therefore eligible for a subsidy. This would have to be an international organization, probably affiliated with the national laboratories in a number of countries. I think it will be very hard to make real progress without those two things—a funding mechanism and a referee on the international level—so getting those two objectives on the global climate agenda would be a critical step forward.

**Allison Nathan: That seems like a very tall order. What if it doesn't happen?**

**Steve Strongin:** You essentially get a version of what we have today, which is lots of small programs in lots of countries that result in different carbon prices around the world. That isn't necessarily a bad starting point. From the standpoint of motivating innovation to solve the problem, having any price at all that people can invest against will create information. And there are ultimately mechanisms like border adjustment carbon taxes, which tax imports and rebate exports for their carbon content, to attempt to account for the differences in carbon values in different places, although measuring carbon content in this way is easier said than done. But when you look at this solution cumulatively, you still have high carbon emissions. You're not going to get to low global emissions without a global program. Without one you run the risk of motivating a shift in activities to places with no or low carbon prices, which would be deeply counterproductive given the extended supply lines, increased shipping times, etc. this would likely imply.

**Allison Nathan: If we think about the solutions, the experts often say we'll need everything and the kitchen sink to meet our climate goals. But in practice, is there likely to be a lot of little answers, or a handful of big ones? And if it's the latter, what looks most promising today?**

**Steve Strongin:** The answer is, of course, that there will be a mix of solutions. But in reality, this will likely mean a lot of smaller, low-cost solutions that are cheap—so why not do it—but are difficult to scale, and a handful of more expensive, big solutions that scale to absorb all of the smaller projects that don't work.

As I said, only investment in innovation will determine what those scalable solutions are in the end. But at this point the two

most scalable solutions seem to be related to batteries, which can be put almost anywhere and create efficiencies, and atmospheric capture/sequestration, which potentially encompasses everything from catalytic filters, to living bricks that absorb carbon, to new types of plants and re-forestation. In reality, it's hard to see how economies around the world, and developing economies in particular, will give up cheap carbon fuels that are so critical to transportation and growth, or change dietary habits to reduce emissions, etc. So you have to believe that some form of capture/sequestration will be a potentially big part of the solution.

**Allison Nathan: So addressing climate change doesn't necessarily spell doom for the fossil fuel industry?**

**Steve Strongin:** It's easy to assume that addressing climate change means the end of the fossil fuel industry. But two underlying assumptions of that view may not turn out to be true: first, that you'll actually get a global consensus to cap emissions, and second, that that's the right way of solving the climate problem. It may well be that some combination of conservation that reduces emissions and capture/sequestration is the right mix. And if sequestration ends up being a significant part of that mix, then the fossil fuel industry probably exists forever, but not all of it, as different parts of the industry have different carbon intensities. For example, consuming natural gas locally to produce electricity is a relatively low-carbon activity, while transmitting it through home networks that leak releases a significant amount of methane into the atmosphere. Along these same lines, the production of heavy oils is exceptionally carbon-intensive. Having a price of carbon that will draw out these differences will be helpful in guiding where the industry goes from here.

**Allison Nathan: Does the big investment cycle that finding a solution ultimately requires mean that addressing global climate change could be net positive for growth?**

**Steve Strongin:** If we solve this problem through classic innovation that results in cheaper, cleaner energy sources and/or atmospheric capture technologies that allow us to aggressively use fossil fuels without negative pollution effects, that could be massively positive for growth. But if we continue to address climate change primarily through conservation solutions that target emitters, the growth implications are more likely to be negative, and the less efficient the solution, the more negative the impact on growth. That's why I think motivating the pursuit of innovative solutions is so critical. As countries get richer, they care more about their environments and can also afford more creative solutions. And if we can find an answer that's growth positive, everyone is better off. If we only incentivize answers that are growth negative, this will become a larger and larger political problem over time, and a more and more disruptive one.

# Global problem, local rich solution

Jeff Currie argues that unlike the experience with acid rain in the '90s, the global distribution of carbon emissions and increasing inequality make tackling climate change more difficult

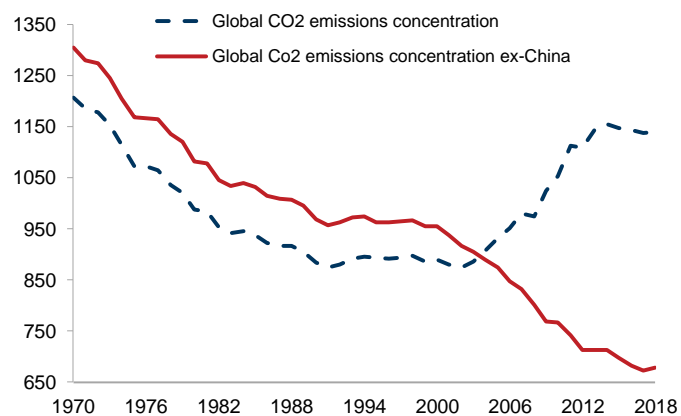
The reduction of acid rain from sulfur emissions in Europe and North America during the 1990s is widely lauded as an environmental policy success. It was the first time market forces were unleashed on a complex, cross border environmental problem that required large-scale investment in new technologies. And it worked; the establishment of a cap-and-trade program for sulfur emissions led to substantial investment in sulfur abatement technologies, and, ultimately a dramatic decline in sulfur emissions that largely eradicated acid rain in the western hemisphere. So, with such a successful blueprint to work with, why has the war on carbon emissions been such a failure?

We believe that the answer lies in the larger and more diverse set of countries involved, increased income inequality and the greater complexity of the problem—the effects of carbon emissions are felt globally long after they are released, they come from a myriad of sources, and are more expensive to abate. Taken together, these three factors have made a market solution difficult to achieve, without which it becomes harder to incentivize the technological innovation that was the basis for success in the war on acid rain.

## Acid rain: a more concentrated problem

In 1979, when the treaty that laid the foundation for the war on acid rain was signed, nearly 80% of all sulfur emissions came from NATO/Warsaw Pact countries. This concentration of emissions allowed for an enforceable treaty (unlike the Paris Agreement) under the military alliances of the US and USSR, who were motivated to take the lead because they were hurt by their own emissions.

## The concentration of ex-China emissions has fallen sharply



Source: IEA, World Bank, Goldman Sachs Global Investment Research.

Today, the problem is more diffuse—encompassing China, India and Latin America—and a solution for it is therefore more difficult to enforce. While China represents 30% of global carbon emissions, the concentration of emissions beyond China drops sharply, with the US emitting 15%. At the same

time, some of the world's biggest emitters are dealing with even more pressing concerns—China is just now dealing with acid rain. In contrast to the diversity of emissions, 83% of global AUM still resides in the US, Europe and Japan, a concentration similar to sulfur in 1979. As a result, western capital sits at the center of the war on climate change, as political solutions remain elusive.

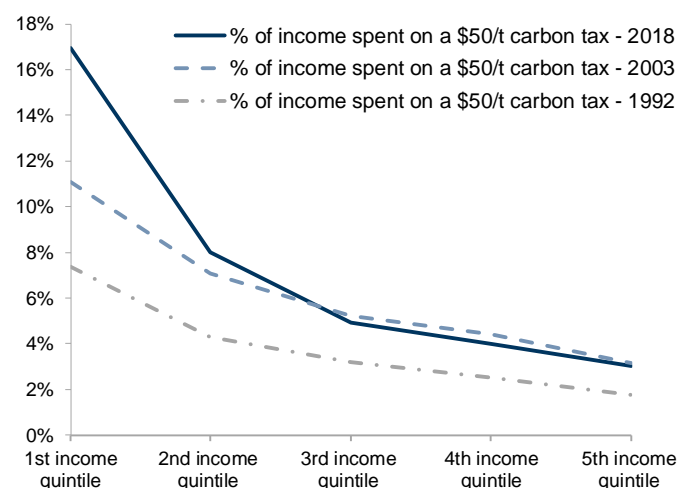
## Rising inequality stands in the way of political solutions

Many of the countries at the center of climate change also face a greater level of populism owing to economic inequality and high living costs—tensions that carbon abatement will only exacerbate. The disappointing conclusion of the recent COP25 climate negotiations held in Madrid underscores the problem this poses. COP25 was originally supposed to be hosted by Brazil, but was moved to Chile after the newly elected president rejected it, and then ultimately to Madrid due largely to populist unrest in Santiago. The event itself failed to yield results due to what Australia, Brazil and China felt was unfair treatment of past abatement efforts and expenditures. That three out of the two-hundred participating countries could stall progress points to the deeper coordination problem in the war on carbon versus the war on sulfur.

While climate change and income inequality are often described as two of the largest challenges facing the world today, the underlying politics of these challenges are largely one and the same. In 1979, not only was the source of the problem contained to fewer countries, but income inequality in these countries was lower, particularly in the rich countries where opposition to climate policy is nearly as strong as it is in poor countries today.

## Carbon inequality has risen since the 1990's

% pre-tax income spent on a \$50/t carbon tax by income quintile in US



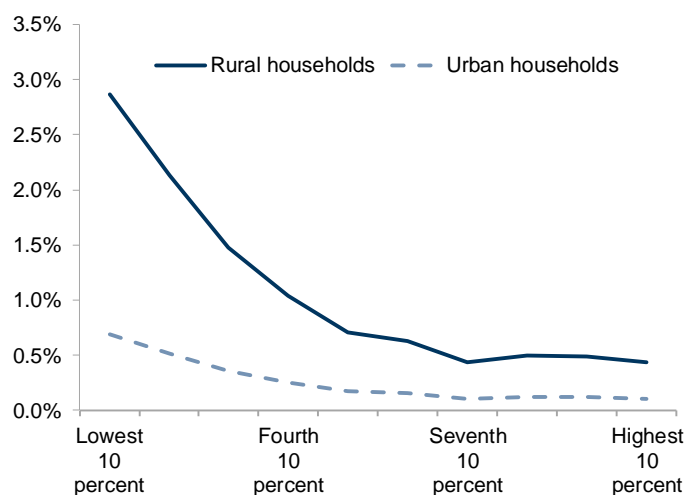
Source: CMU, BLS, CES, Goldman Sachs Global Investment Research.

We estimate that lower-income households in the US will lose two times more income from a \$50/ton carbon tax today than in 1992—while higher-income ones will bear around the same. Further, carbon inequality is more extreme when focusing on the rural and suburban regions where travel by automobile is critical. The share of the US population that resides outside of cities sits at the core of the difference between the US and Europe. In the US, 55% of the population lives in suburbia

while in Europe only 30% do. Like in the US, the rural population in Europe opposes the costs of climate policy. In France, the *gilets jaunes* (yellow vests) protested over a 15% rise in petrol prices, and in the Netherlands Dutch farmers stormed The Hague last October in protest to green policy.

### The rural poor spend the most on heating

US urban and rural household spending on heating oil, % of income



Source: CMU, BLS, CES, Goldman Sachs Global Investment Research.

Putting this together, it is simply too expensive for the world's poor to make the appropriate investments required to reach a net zero carbon world. We estimate that achieving net zero emissions by 2050 will cost each person in the US \$4,000/year—assuming the technology works. By definition, conservation without compensation is a regressive tax to the poor. For this reason, progressive taxation solutions that avoid targeting the world's poor need to be at the center of any solution to carbon emissions.

A carbon dividend to redistribute revenues from a carbon tax can offset the cost of abatement for lower-income households and has become part of the climate discussion in the US. But the carbon dividend program currently under discussion would only cover a fraction of the total cost. In other words, current proposals are asking US citizens in low-income, rural households to drive less—even though they primarily drive to get to work—and reduce their heating and cooling demand, which consume a substantial proportion of their income.

Further, policies aimed at cutting funding to fossil fuel companies will only create energy inflation and act as an additional tax on the world's poor. In contrast, the Acid Rain Program (ARP) was a success because it focused on harnessing market forces to abate sulfur using the best available technology. As a result, a low-cost solution was found, which reduced the implied tax on the poor.

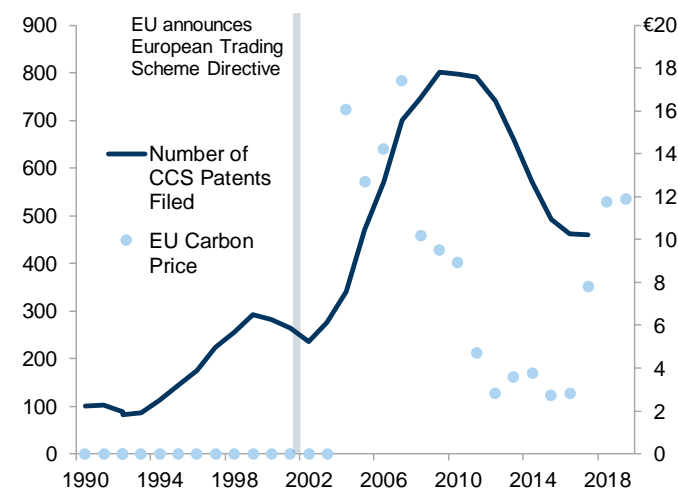
### Market-based solutions stimulate technology

But finding a low-cost solution for climate change won't be easy. Pollutants causing climate change come from many sources and are costly to abate. In contrast, the acid rain problem was far more contained, with sulfur pollutants largely coming from coal-powered generation and vehicle emissions, primarily in rich countries. As a result, a cap-and-trade scheme was able to effectively address the problem, targeting sulfur emitters and establishing a price for sulfur that stimulated

investment in sulfur scrubber R&D. Importantly, this investment took place largely outside of the industry. GE/Alstom—not utilities and oil companies—drove innovation in desulfurization while BASF/Englehard—not automobile companies—drove innovation in catalytic converters.

### Carbon capture/storage patents surged/faded with CO2 prices

Number of CCS patents filed, total; EU carbon price, euros



Source: EPO, USPTO, IEA, Bloomberg, Goldman Sachs GIR.

In tackling climate change, the EU initially proposed a market-based solution in 2002 using the sulfur dioxide market as a blueprint, which successfully stimulated R&D and innovation. In fact, after real carbon prices peaked in 2008, so did the number of CCS patents. However, once it became clear that the EU emissions trading scheme was not the global panacea initially thought, R&D slowed tremendously.

Even so, these schemes can only be effective when dealing with carbon emissions that come from far more sources and involve far more regions. Without a European carbon border tax to contain these issues, the EU carbon price faced stiff headwinds from the rest of the world and so did R&D. Phase 2 of the trade war will likely need to focus on carbon border taxes if the EU wants to make the Green Deal work.

### Carbon capture is progressive, but needs market forces for more R&D

The war on acid rain was successful owing to a combination of a more concentrated and less diverse set of countries involved, less unequal consumption of high-sulfur goods, and the ability to use market forces to address a narrower problem. As the former two are unlikely to be created in the current environment, only progressive solutions where the rich pay for the poor will work in the war on climate change. Solutions that employ carbon capture will also reduce the burden on the world's poor. The technology is still far away, but not too far from where desulfurization technologies were in 1980, which means market-based solutions can still create innovations that help solve the problem, as they did with the war on acid rain. To unleash these forces, rich countries—and especially the rich people in them—will need to come to the realization that if they want to address climate change, they'll have to pay for it.

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Goldman Sachs and Co. LLC

# Carbonomics: the future of energy

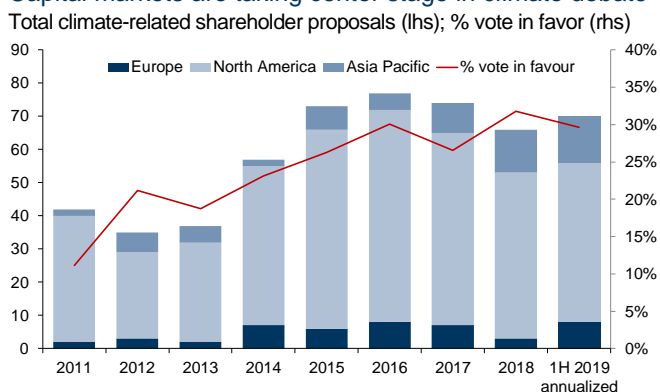
Michele Della Vigna argues that the capital markets' focus on decarbonization is transforming the energy industry

Climate change is re-shaping the energy industry through technological innovation and capital markets pressure. An assessment of the road to decarbonization suggests a substantial need for technological innovation to reach net zero emission goals (see pg.15). Capital markets are taking a leading role in financing this energy transition while tightening financing for hydrocarbon assets. A new Age of Restraint on hydrocarbon developments is driving consolidation in the oil & gas industry, which, in turn, is likely to lead to a halt in non-OPEC supply growth, higher energy prices and increased profitability of Big Oils. These shifts should enable Big Oils to become part of the solution—rather than the problem—of climate change.

### Growing investor demand for decarbonization...

Over the past eight years, investors have taken an increasingly active role in pushing corporate management to incorporate climate change into their business plans and strategy. The number of climate-related shareholder proposals has almost doubled since 2011, and the percent of investors voting in favor of such proposals has tripled over the same period. This investor pressure has a clear bias towards energy producing firms. Data from ProxyInsight shows that 50% of shareholder proposals target energy producers with a further 10% targeting financial institutions that lend to energy producers. As a result, financing conditions have tightened across the hydrocarbon industry, leading to a new age of capital constraint that's driving structural changes in the industry.

### Capital markets are taking center stage in climate debate



Source: ProxyInsight, data compiled by Goldman Sachs GIR.

### ...leading to a new age of capital restraint and underinvestment in oil

The onset of this Age of Restraint marks the end of a period of oil & gas revolutions that saw substantial industry fragmentation, resource expansion and cost inflation, all fueled by cheap financing. Specifically, the period between 2004-16 saw two oil & gas revolutions. The first one (2004-13) was driven by National Oil Companies (NOCs) that deployed their growing balance sheets towards rapid international expansion via a combination of exploration and M&A activities. The second one (2009-16) was led by US exploration & production (E&P) companies, unlocking 100+ billion barrels of US shale oil.

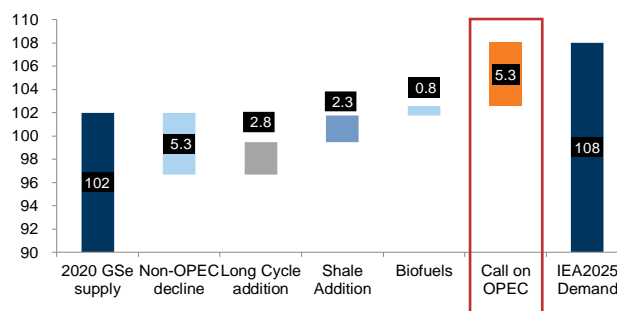
Since 2014, however, tighter financial conditions have raised barriers to entry while increasing the equity risk premium on new long-cycle developments, leading to a more concentrated industry with higher returns and lower volume growth. A small group of companies (the "Seven Sisters") emerged as the structural winners, continuing to invest in new projects consistently through 2014-19. As a result, Big Oils doubled their market share in long-cycle projects and US shale oil over this five-year period and re-established the attractive returns that were lost during the oil & gas revolutions of the 2000s.

### The end of non-OPEC growth is near

At the same time, under-investment in the oil sector resulting from the higher financing costs and industry consolidation is now set to end a decade of credit-fueled shale oil hyper-growth, with higher decline rates/slowing productivity improvements in shale oil reinforcing the slowdown. This, combined with a thinner pipeline of mega long-cycle projects, leads us to expect that non-OPEC oil production will stop growing from 2021, providing upside risk to energy prices.

### Underinvestment means end of non-OPEC growth by 2021

Key drivers of oil supply growth over 2020-25E, million blpd



Source: IEA WEO 2018, Goldman Sachs Global Investment Research.

### From Big Oil to Big Energy

The restoration of profitability to Big Oils is leading them to a position where they can leverage the higher returns from their traditional oil & gas businesses to foster innovation and investment in their transition towards Big Energy. Indeed, Big Oils have shown a tremendous ability to adapt to technological change in their 100+ years of history, and have many tools to drive a low-carbon transition toward cleaner energy providers, including a deeper presence in the global gas and power chains through retail, EV charging and renewables; biofuels; petrochemicals; improved upstream and industrial operations; nature-based solutions and carbon capture.

In these ways, we believe that Big Oils can transition to Big Energy while improving corporate returns and renewing value via greater scale and integration. We estimate that this transition has the potential to lead to a 20%+ reduction in Big Oils' greenhouse gas emissions (GHG) by 2030—consistent with the global ambition to contain global warming within 2 °C—and to Big Oils becoming part of the solution, rather than the problem, of climate change in the coming decades.

### Michele Della Vigna, Head of Energy Industry Research

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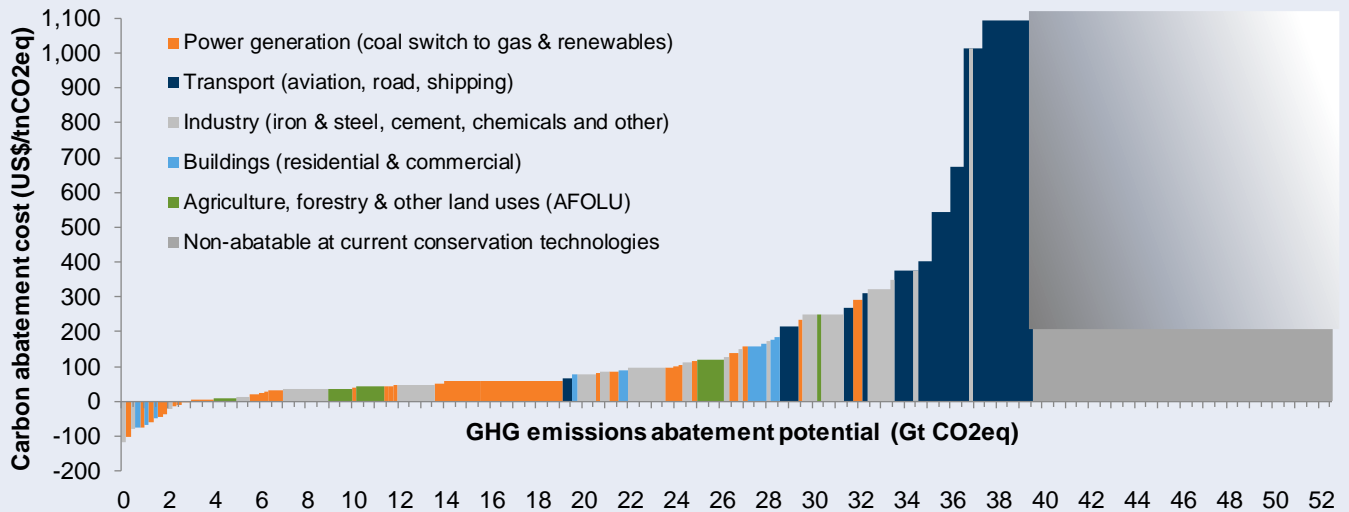
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# Carbonomics: the cost of decarbonization

In our recent [Carbonomics](#) report, we constructed a carbon abatement cost curve for conservation technologies that are currently available at commercial scale across key industries globally: power generation, industry, transport, buildings and agriculture.

The cost curve is steep, with large investment opportunities in low-cost areas, particularly in power generation, but rapidly rising costs at higher levels of decarbonization. At the current costs of commercially available CO<sub>2</sub>-abatement technologies, we estimate that around half of current anthropogenic greenhouse gas (GHG) emissions can be abated at an implied CO<sub>2</sub> price of less than \$200/tnCO<sub>2</sub>eq (ton of carbon dioxide equivalent). Carbon prices of less than US\$100/tnCO<sub>2</sub>eq would transform the power generation industry from carbon-intensive fuels (coal and oil) to cleaner alternatives (gas, solar, wind), but would have little impact on mobility, industry or buildings, excluding technology-specific incentives. Most notably, we estimate that roughly a quarter of total current GHG emissions are not abatable under currently available large-scale commercial technologies.

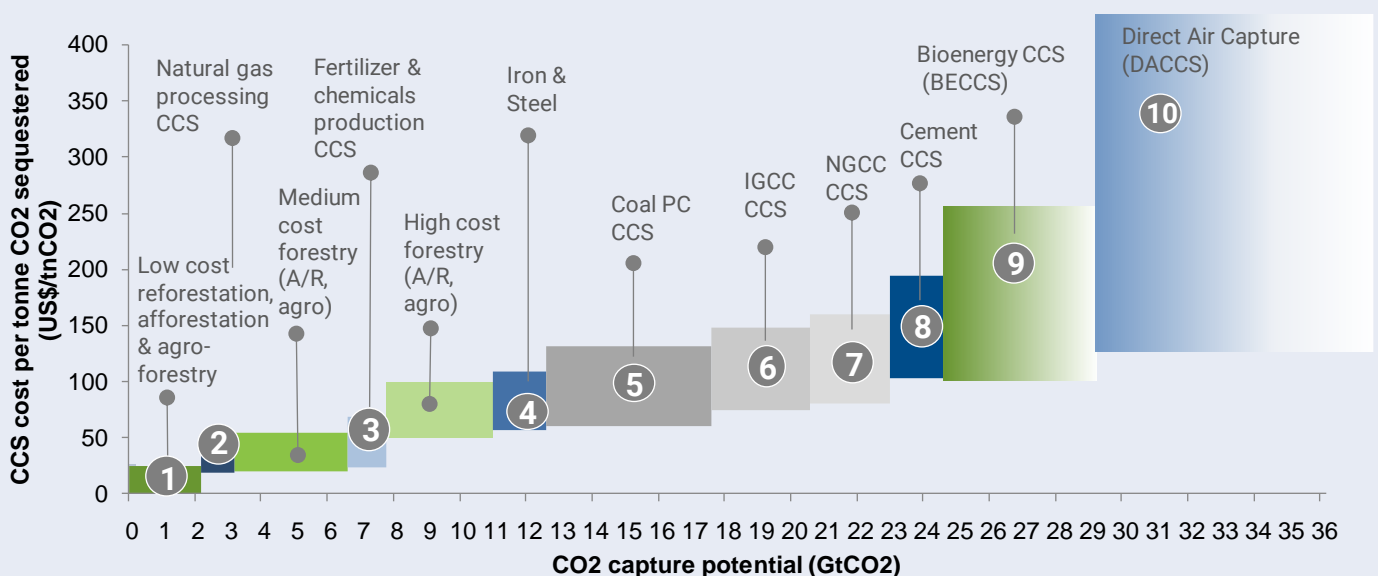
## Plenty of low-cost emissions reduction opportunities, but steepening beyond the 50% mark



Source: Goldman Sachs Global Investment Research.

Further technological innovation and greater investment in sequestration technologies will therefore be required to achieve net zero carbon emissions. Carbon sequestration technologies, which capture or reduce CO<sub>2</sub> emissions that are already in the atmosphere, have seen a revival in recent years, but they have not yet reached the large-scale adoption and economies of scale that traditionally lead to a breakthrough in cost competitiveness, especially when compared with other CO<sub>2</sub>-reducing technologies such as renewables. Part of the challenge is that direct air carbon capture and storage (DACCS) technologies have highly uncertain economics, with estimates ranging between \$40-400/ton (at scale), and only small pilot plants currently in operation. Investments in carbon capture, utilization and storage (CCUS) plants over the past decade have therefore been less than 1% of those in renewable power. The importance of DACCS lies in its potential to be almost infinitely scalable and standardizable, which could ultimately position it as a carbon price setter in a net zero emission scenario.

## Carbon sequestration: a silver bullet?



Source: Global CCS Institute, Goldman Sachs Global Investment Research.

Michele Della Vigna, GS Head of Energy Industry Research

# The European Green Deal: a €7tn plan

## Alberto Gandolfi argues the Green Deal could reshape Europe's power sector and economy

In December 2019, the European Commission outlined a roadmap for the "European Green Deal," committing to publish a comprehensive set of policies to reach net zero carbon emissions by 2050. We estimate that this plan—which is unprecedented in size and ambition—could amount to €7tn of cumulative spending split between investments and subsidies over that time period. The Green Deal is likely to reshape the entire European economy, changing the way we generate electricity, heat our homes, travel, and could even go as far as impacting diets and spending habits.

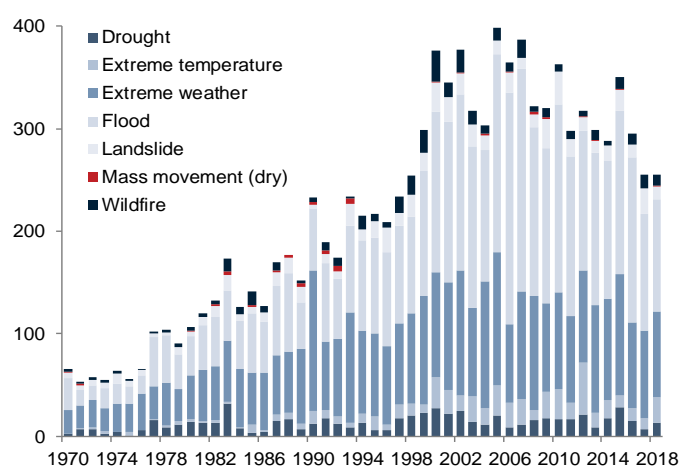
European Utilities will be at the forefront of this monumental transformation, likely undertaking most of the Green Deal investments, which account for about half of the plan's expected spending. This is set to kick off an era of earnings growth and regulatory stability [for Utilities], thanks to a combination of secular growth in infrastructure activities (renewables and networks), higher power demand and lower-for-longer funding costs (e.g. through green bonds). We believe the resulting strong visibility on capital allocation and returns will support a sustained re-rating for the companies most exposed to these trends—"Climate Champions."

### Why a Green Deal?

During 2019, public awareness about climate change increased substantially, in large part fueled by a spike in weather-related natural disasters such as the wildfires in California, the Amazon and Australia. Indeed, these events are symptomatic of a broader trend of a rise in the incidence of weather-related natural disasters by roughly 350% since 1970.

### Extreme weather now more common

Global number of reported weather-related natural disasters



Source: International Disaster Database, ourworldindata.org, GS GIR.

To address increased political focus on environmental issues, the new European Commission, which took office in November 2019, made climate policy central to its agenda. It has committed to a comprehensive set of measures that will culminate in a tightening of 2030 emission reduction targets and the adoption of a climate neutrality ("net zero carbon emissions") target by 2050 through a European directive currently planned for the first half of 2020. Thereafter, the Commission plans to adopt further sector-specific measures to

address the need to reduce emissions in non-energy sectors, including transport, heating and farming.

### A €7 trillion investment opportunity

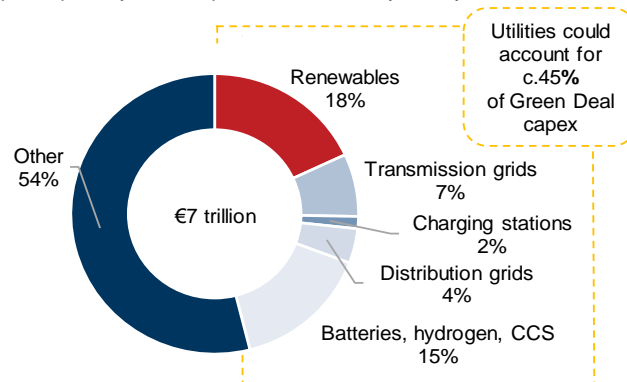
We estimate that the Green Deal will stimulate around €7 trillion in investments—or roughly €230bn per year for thirty years—with major repercussions across the entire economy. Specifically, we identify the following key areas of investment:

- **The electricity system: €2.4tn.** We estimate that €1.3tn will be needed to fully decarbonize the power mix through substantial deployment of wind and solar. To integrate the more volatile output profile of renewables compared to existing technologies, as well as to accommodate higher demand from electrification, €500bn and €300bn will have to be invested in high voltage (transmission) and low voltage (distribution) grids, respectively. A further c.€300bn will be needed to build a sufficient charging network to enable a shift to electric mobility.
- **Heating: €1.8tn.** We estimate that over €1.6tn will be needed for insulation and energy efficiency improvements to buildings while over €100bn will be required to incentivize the substitution of gas boilers with heat pumps.
- **Electric mobility: €1.7tn.** We estimate that roughly €1.2tn and €500bn of incentives will be required to finance the full decarbonization personal cars and public/commercial road transport (buses & trucks), respectively.
- **New technologies: €1.2tn.** This will include the development of hydrogen (power-to-gas) infrastructure for seasonal energy storage, the widespread adoption of lithium-ion grid-level batteries to modulate renewable output and stabilize short-term S&D imbalances, and the installation of carbon-capture facilities (CCS) in industries where emissions cannot be fully avoided.

We estimate that Utilities could account for nearly 45% of Green Deal-related capex, or around €3tn through 2050. Investments would span from developing renewables, to upgrading power networks, to deploying batteries and building fuel cells (hydrogen-based power plants) and fitting gas plants with CCS technologies.

### A boon for utilities investment

Capex implied by the European Green Deal, by activity



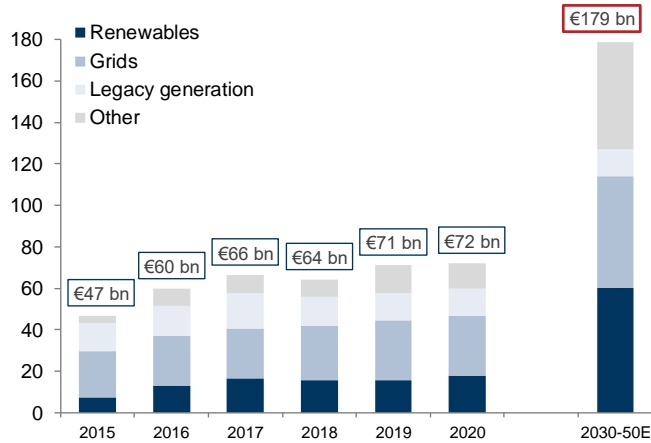
Source: Goldman Sachs Global Investment Research.

Climate spending could more than double annual investments for European Utilities compared to the current run rate of just under €80bn to about €180bn per year. We expect broadly two-



thirds of this capex to be directed at infrastructure activities, such as the construction of renewables and power networks.

**Utilities capex could more than double to €180bn a year**  
Aggregate annual sector capex by activity, €bn



Source: Company data, Goldman Sachs Global Investment Research.

**Favor the "Climate Champions"**

The upgrade in capex and growth would be particularly relevant for a subset of companies—"Climate Champions"—that enjoy vast exposure to renewables and power networks.

Given the growth visibility that Green Deal policies will provide, and in light of the growing importance of scale to safeguard returns, we expect the relatively fragmented global renewables market—where the top 10 firms account

for only about 15% of market capitalization—to start consolidating. In Europe, this trend should be particularly pronounced due to the European Commission's stated intention to relax antitrust laws to support the leadership of European companies on the global stage.

**Net zero feasibility: a difficult "last mile"**

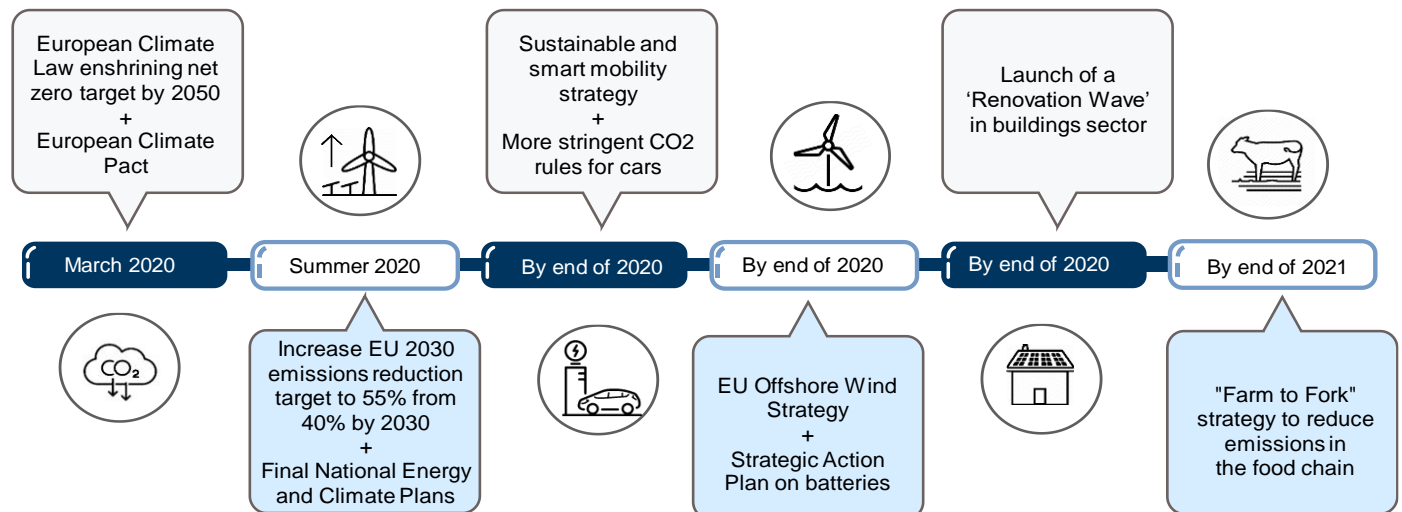
While an 80% reduction in emissions by 2050 should be feasible (largely through electrification and a complete decarbonization of the power mix), and 90% could be achievable (e.g. through an extensive adoption of hydrogen as feedstock in industrial processes), achieving the last 10%-20% might prove difficult, for three reasons: (1) this "last mile" would be more expensive as it would have to rely on less mature technologies such as carbon capture sequestration or hydrogen/fuel cells, while yielding a lower marginal gain in terms of emissions avoided; (2) for global exporting industries, the costs related to emissions reductions (e.g. carbon levies, carbon capture equipment) might lower competitiveness, hurt profitability and have negative implications for employment; and (3) cost inflation on carbon-intensive habits, such as car usage and red meat consumption, could disproportionately affect the spending power of the lower income brackets of society, creating possible political and social hurdles to additional emissions reductions.

**Alberto Gandolfi, Head of European Renewables Research**

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Tel: +44 20 7552-2539

Goldman Sachs and Co. LLC

**The EU's path to "net zero"**



Source: Goldman Sachs Global Investment Research.

# Interview with John Goldstein

John Goldstein is head of the Goldman Sachs Sustainable Finance Group. He shares his observations and advice about ESG integration strategies for investors and corporates.

*The views stated herein are those of the interviewee and do not necessarily reflect those of Goldman Sachs Research.*



**Allison Nathan: How have you seen growth in ESG investing evolve?**

**John Goldstein:** I think my own story is a good illustration of the magnitude of growth in ESG investing. I co-founded a small, dedicated ESG and impact investing firm—Imprint Capital—in 2007, which went from being a very small firm to a somewhat small firm over the course

of about eight years, initially working with large US foundations and then with financial institutions. In 2015, one of those institutions—Goldman Sachs—endeavored to buy us rather than become one of our clients. And so our \$550 million asset manager became a part of Goldman Sachs Asset Management, and, over about four years, what was initially a combined \$3 billion in ESG assets grew to north of \$60 billion today.

Alongside this growth in ESG strategies has been substantial evolution of them. In general, they have become both broader and deeper; strategies that were once centered in active equities moved into passive equities, then fixed income, and, most recently, private equity. And what started as simplistic negative screening of companies you don't want to own has transitioned into the creation of highly thoughtful portfolios across a range of public and private assets to manage climate risk. Finally, as the sophistication of these strategies has grown, so has engagement across different types of investors. Case in point: hedge funds used to be on the periphery of ESG investing, but interest from the hedge fund community has surged in the last 6-12 months.

**Allison Nathan: Why now for a surge in interest in ESG investing?**

**John Goldstein:** As Goldman Sachs CEO David Solomon put it, it's largely the confluence of urgency and economics. Events like the wildfires in Australia have provided a sense of urgency to the issue because they're visible in a fundamentally different way than they've been historically. That alone arguably wouldn't be enough to drive the growth in interest we're seeing. But on top of that, we've seen the economics evolve in a way that has strengthened the business case for ESG investing. For example, renewables are now the lowest cost form of new energy in many parts of the world, and comprised more than 70% of new power generation capacity last year. That is a seismic shift from where we were even 10 years ago.

We've also seen a new breed of practitioners and firms focusing resources on ESG integration. And as more and better products and services enter the market, and investors can implement those strategies with greater degrees of sophistication, success begets success; so we've seen somewhat of a virtuous cycle take hold.

**Allison Nathan: That said, the original grounding of ESG investing in ideology has tended to make investors skeptical of these strategies. What's your response to critics who argue that ESG investing is just a passing fad? Is there a durable investment rationale for it?**

**John Goldstein:** There is often a preconception that these strategies are an ideological pursuit, which I find typically leads to two groups of investors—those that are too apt to love them, and those that are too apt to hate them. But the key is to clear out these preconceptions and treat ESG like any other investing question, which requires forming a clear investment thesis. In my view, this thesis revolves around the recognition that the world is changing, which is leading to new drivers of returns, risk and efficiency. Take renewable power; for some companies, it drives growth—which is really about revenues. For other companies, it reduces risk—which is really about minimizing losses or drawdowns. And for still others, it lowers energy expenses—which is really about margins. Any one of these levers can provide a clear investment thesis for ESG integration. So today, the business case is fundamentally different and stronger. That, along with more sophisticated products that enable crisper execution, substantially bolsters the investment rationale for ESG investing.

**Allison Nathan: Where should investors that are just beginning to think about ESG integration start? How should they think about some of the resources available, like third party ratings, and what are best practices in terms of organizing a team around ESG integration?**

**John Goldstein:** In terms of where to start, again, number one is to approach the ESG discussion as an investment discussion and have an investment thesis. There's no one magical thesis, but have a thesis that makes sense relative to your broader strategies. As investors are finding their footing, data like external ratings can be a useful starting point. But I think it's important to see them as an input, not as an answer—similar to a credit agency rating. Investors should have a clear understanding of what these ratings are and where they come from; generally, they are the result of scraping lots of data, some of which is about performance, but much of which is about whether companies have policies and make disclosures, which are weighted in various ways. So use these ratings to begin your process, not end your process, and consider them in the context of sector and industry specific views and data, some of which may already exist in your organization.

To that end, while there is no one right answer in terms of team organization and staffing, we've generally seen that hybrid approaches that have both PMs/analysts with deep sector expertise/portfolio construction know-how as well as a dedicated ESG resource that can provide extra support to the investment process strike a useful balance; this type of approach avoids putting ESG expertise in a silo but is also realistic about what it takes to add new knowledge and capabilities to an organization.

**Allison Nathan: It's tempting for new investors to focus on ESG funds, but many well-known ESG companies look very highly valued today. Is there an ESG bubble today?**

**John Goldstein:** I think that's probably too strong of a phrase. Like any investment story, as ESG becomes better understood and more widely practiced, the bar for adding value rises. That's

how it should be, and ESG is no different. But as the conviction in their stories rises, valuations can continue to rise. So some of the companies with seemingly high premiums today could continue to skyrocket. That said, investors will likely be rewarded for having differentiated insight on which names really have an exciting trajectory, and which ones don't.

#### **Allison Nathan: So where can investors find value today?**

**John Goldstein:** That answer is constantly changing; what's interesting at one point can quickly become less interesting. But, generally speaking, in both public and private markets, the key is finding stories that have graduated from being nascent, high risk and capital intensive, but are not yet flooded with capital, either because the market hasn't yet realized that they've reached this stage, or hasn't yet figured out how to access them. One strategy we've seen to tap into this space is buying mediocre ESG companies that want to be great. Other strategies target companies whose sectors are in significant flux, but have the potential to transition into successful businesses amid these shifts. And, in some cases, we've seen investors, such as hedge fund activists, looking to partner with companies who want to go through that transition. These all take work, but the market usually ultimately rewards such efforts. Sweat and complexity are often ways to make money.

“The key is finding stories that have graduated from being nascent, high risk and capital intensive, but are not yet flooded with capital, either because the market hasn't yet realized that they've reached this stage, or hasn't yet figured out how to access them.”

#### **Allison Nathan: What about credit strategies, and green bonds in particular?**

**John Goldstein:** Green bonds are a useful tool for both investors and companies in signaling a commitment to green priorities. For investors, this is a relatively straightforward proposition; for basically the same return, investors can reflect a green agenda in their portfolios. For companies, a bit more work is required in terms of having to actually issue green bonds, segregate the use of proceeds and provide accounting for them. And this work does not generally materially benefit their risk profile. But companies derive the benefit of diversifying their investor base in a constructive way and signaling to employees, shareholders and customers a green direction for their firm.

That said, a new green bond framework that Goldman Sachs helped Italian utility Enel implement serves as an intriguing example of the even deeper economic proposition of making companies accountable for results. The bond is structured without segregated proceeds—so that the company can spend the revenues in any way it wants—but with covenants that require the company to reach 55% installed renewable capacity by the end of 2021, or face a 25bps per annum increase in the interest rate it pays on the bond. In my view, that structure provides an interesting proposition for everyone involved. For Enel, it sends a

very clear signal to the market about the seriousness of its commitment to green objectives, which ultimately helped it save a material amount of money on the well-subscribed issuance. And for investors, the structure provides clarity on the company's green agenda, allows investors to pay the company for performance and to get paid themselves if the company fails to deliver. I think we'll see more of this type of innovation that enhances the value proposition of some of these instruments going forward.

#### **Allison Nathan: What regulatory changes do you see coming down the pipe that investors should be aware of?**

**John Goldstein:** The first change to be aware of is a fairly extensive set of regulations coming from the European Union on sustainable finance taxonomy. This was initially designed to help avoid greenwashing, and is set to include regulations about what counts as sustainable finance, which will apply to products from asset managers, as well some products from banks and insurance companies. Although it's tempting to dismiss these regulations because they will only take effect in Europe, of course, US companies have a substantial amount of investors that are based in Europe, and many US asset managers market products in Europe. And I think other countries are watching Europe to see what they can learn, and potentially emulate.

The second change is a softer form of regulation that may become less soft over time. The Task Force on Climate-Related Financial Disclosures (TCFD), which is a network of central banks around the world, is coalescing around a disclosure standard for a wide variety of companies and financial market participants to better document, understand and manage climate risk.

And the third change is a broader push for companies to have better data on fewer things that matter more. Some of that is embedded in the sustainability accounting standards board (SASB). Although none of these changes are imminent, market participants are already beginning to focus on them, and trying to get ahead of them, which will likely bring forward the timing of their impact.

#### **Allison Nathan: You speak to a lot of corporates in addition to investors. What are you hearing from them, and what's your advice for them?**

**John Goldstein:** Corporates are feeling the pressure for more ESG engagement on all sides. The demand for ESG data points has exploded; one CFO recently told me she had been asked for 2,000 different ESG data points in the last year. But even beyond these data requests, shareholders, employees and business partners are all clearly signaling to corporates the growing importance of these issues, which is coming through to them loud and clear.

My advice to corporates is, understand the scrutiny you're under and be sensible about that; know your ratings and be thoughtful about them, but also don't chase your tail. Focus on having a strong core business strategy, a compelling story behind it, and metrics that reinforce it. In short, when thinking about ESG integration do what you strive to do every day: run a good business, have a good strategy, execute well and communicate thoughtfully.

# Q&A with Derek Bingham

Derek Bingham, Americas head of GS SUSTAIN, answers key questions about ESG investing

## Q: How is ESG investing defined?

**A:** ESG investing can mean a lot of different things. The exclusion of firms from portfolios is probably the oldest and best known variety, but the greater trend in recent years has been toward a broader definition of “ESG integration,” including using ESG as a risk management tool across sectors, as well as recognizing opportunities inherent in sustainable business practices and products.

## Q: What’s driving demand for ESG investing?

**A:** The demand is primarily coming from clients that are increasingly requiring asset managers to demonstrate ESG credentials and principles in order to win mandates. Status as a signatory to the Principles of Responsible Investment (PRI) is generally well regarded, as is a program of corporate engagement. Beyond client demand, other catalysts for the increasing adoption of ESG include capital markets regulation, corporate sponsorship, and asset managers’ search for differentiation and alpha through emerging ESG strategies/data.

## Q: Are investors more focused on the E, S, or G today?

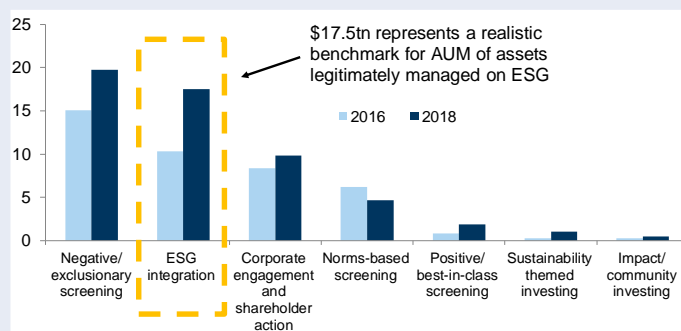
**A:** There are always focal issues in each category at any given time, and the emphasis will vary by sector and by company. However, environmental considerations seem to be receiving the greatest attention from both asset owners and managers today. This includes a search for companies with smaller emissions footprints, mitigation solutions, and an active dialog about the ‘investability’ of the traditional Energy sector.

## Q: How big is the ESG investment market today, and how fast is it growing?

**A:** Growth in sustainable assets, a broad category of investments that consider ESG factors in portfolio selection and management, increased by 34% between 2016-18 to \$30.7tn globally in 2018—up from a 25% increase between 2014-16—according to GSIA. From that total, negative/exclusionary screening accounted for \$19.8tn AUM, up from \$15.1tn in 2016. However, ESG integration has delivered the largest absolute increase in assets, growing \$7.2tn (a 30% CAGR) since 2016. Sustainability-themed investing has seen the fastest levels of growth from a smaller base, rising to \$1tn in 2018 from just \$276bn in 2016, a CAGR in excess of 90%.

## ESG AUM has risen substantially in recent years

Total assets incorporating ESG by type, including double counting; \$tn

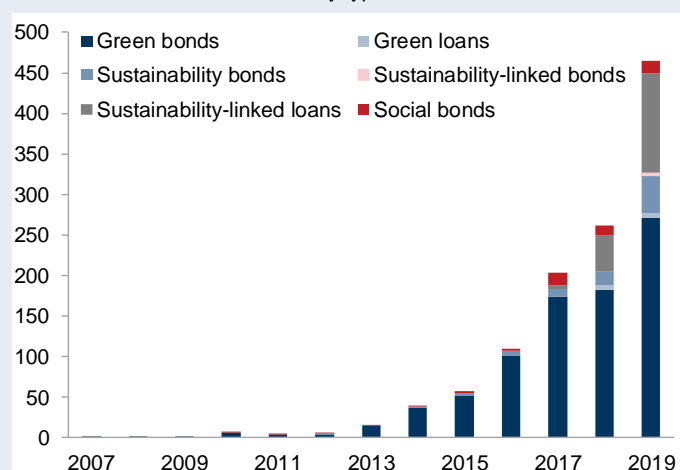


Source: Global Sustainable Investment Alliance, Goldman Sachs GIR.

The market for “green finance”—bonds earmarked for specific ESG-related purposes—is also expanding. Green bonds, first issued in 2007, have seen accelerating issuance, with over 18x growth from 2013-2018. Europe has largely led the increase, although North America and Asia have been closing the gap more recently. Liquidity appears to be slightly worse for green bonds than for comparable conventional bonds, potentially a result of the larger buy-and-hold investor-base for these securities. A host of related products (green loans, sustainability bonds, social bonds) have also begun to see rising issuance in recent years.

## The market for “green finance” is expanding rapidly

Total sustainable debt issuance by type, \$bn



Source: Bloomberg New Energy Finance, Goldman Sachs GIR.

## Q: Are data/metrics sufficient to support ESG investing?

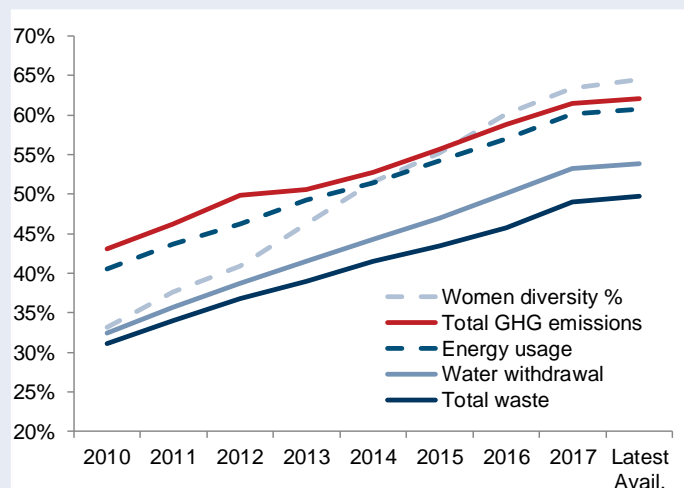
**A:** Generally speaking, yes. On the environmental side, data related to waste and emissions are available (e.g. metric tons of waste generation and scope 1 & 2 GHG emissions), and disclosures on companies’ resource usage, such as power and water, is relatively robust. On the social side, data relating to human capital, including employee health & safety (e.g., injuries and fatalities) as well as talent attraction & retention (e.g., compensation, turnover, diversity, training, etc.) is plentiful. Relevant ESG topics will vary by sector, and so will the available data, which is commonly disclosed in companies’ annual reports, sustainability reports and on corporate websites. Most of the best-known financial data providers are also now collecting and offering ESG indicators.

In terms of corporate disclosures specifically, significant data challenges remain, but disclosures for global (MSCI ACWI) constituents have climbed steadily from the 30-40% disclosure range 8 years ago to the 50-60% range today across many of the most widely cited metrics mentioned above. Focusing on metrics that are most material by sector, the disclosure picture looks even better. For example, latest GHG emissions disclosure among global Chemicals firms in the ACWI is 83%. For global Airlines it’s 86%. Disclosure of energy usage in the Steel sector is 75%, as is disclosure of water withdrawal by global Miners.

In cases where material ESG exposure is hard to measure, disclosures are insufficient, or good metrics are not available or only tell part of the story, there are other useful data sources, including regulatory sources, conventional or social media feeds, and specialized third-party databases, etc., which could increasingly complement the ESG mosaic.

### ESG disclosure is marching higher

Average disclosure rate for MSCI ACWI constituents, %



Source: Bloomberg, Thomson Reuters, Goldman Sachs GIR.

### Q: How should I think about third-party ratings, and which are most useful?

**A:** Third party ratings, such as those from MSCI and Sustainalytics, often serve as a starting place for investors beginning to integrate ESG considerations into their investment processes. These raters offer aggregated scores combining a large set of company-reported metrics and policies, as well as some estimates. Generally, as active investors become more comfortable with analyzing ESG data, they move towards developing their own methodologies based on a more focused subset of metrics identified as financially material. This evolution offers a pathway for ESG-integration to serve as a differentiating factor for active investors.

### Q: Won't incorporating ESG considerations hurt investment performance?

**A:** Not necessarily. Our work [has indicated](#) that using a sector-relative approach, companies with better metrics on material, environmental and social factors have tended to outperform. This makes sense intuitively. Companies better positioned to take advantage of ESG-related demand trends will see it on their top line, while companies that operate more efficiently, effectively and with better regulatory relations should see cost benefits. Setting aside whole sectors introduces benchmark risk, but alternate or custom benchmarks can be substituted (carbon-free benchmarks, for example) for those wishing to express particular ESG-related views into their portfolios.

### Q: How can I spot "greenwashing" by corporates?

**A:** Greenwashing comes in many forms and is not always black and white. Generally speaking, companies touting environmental and sustainability (E&S) accomplishments that are materially removed from the operational or product impacts

of their business could be scrutinized for this practice. Reporting that heavily favors disclosure of policies rather than measurable performance metrics or quantitative targets is another red flag. As investors gain conviction in what they feel are material E&S factors for a given business, they will more easily be able to identify greenwashing.

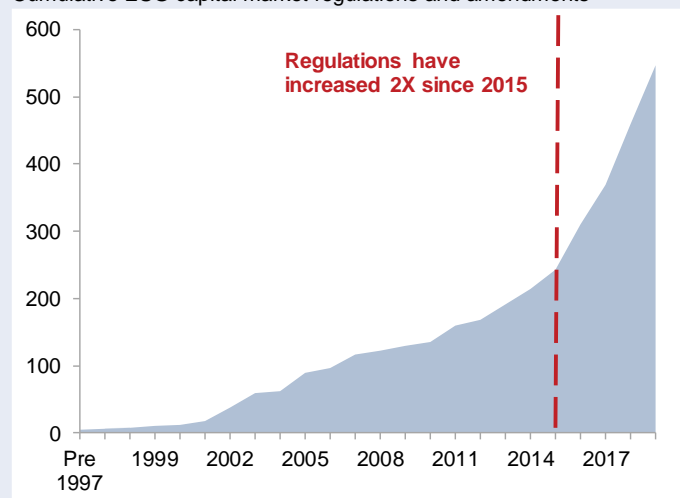
### Q: What other pitfalls should investors be aware of?

**A:** Somewhat related to the topic of greenwashing, a common pitfall is giving too much credit for ESG disclosure alone, or penalizing companies for non-disclosure. Our research [has found](#) that this tends to favor larger, lower-growth companies with more resources and more mature reporting efforts. This approach can also introduce geographic biases given significant differences in disclosure rates by region. Related to this is a failure to narrow one's focus to issues that are the most relevant to a given industry. For example, putting a significant weight on the environmental impact of a packaged software company is unlikely to lead to a useful investment conclusion.

### Q: How might future capital markets regulation affect ESG investing?

**A:** Future regulation has the potential to significantly alter how ESG data is reported and consumed. At present, the vast majority of ESG data is reported voluntarily by corporates outside of their annual reports and regulatory filings. The voluntary nature of disclosure contributes to many of the issues ESG data currently faces around quality, standardization, and timeliness. As regulation around corporate disclosure of ESG data grows, it is possible this data could increasingly migrate into regulatory filings, diminishing today's data challenges. On the investor side, regulation could impact how these groups measure, structure and communicate their use of ESG data in their investment processes, as well as how asset managers market their offerings.

### Capital market regulations based on ESG have accelerated



Source: PRI, Data compiled by Goldman Sachs GIR.

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# Climate change and growth

Climate change has increasingly drawn the attention of economists. Recently, over 3,500 economists—including 27 Nobel Laureates and 4 former Fed Chairs—signed a statement supporting a carbon tax in the US, and research on the economics of climate change has grown markedly.

## Assessing the welfare effect of climate change

One key challenge economists face is assessing the welfare effects of climate change. Welfare effects include not only output losses and monetary damages, but effects such as increased mortality, species loss, and environmental degradation. While there is no clear-cut way to quantify such losses, economists have constructed methods for estimating monetized equivalents.<sup>1</sup>

Recent academic studies have identified a wide range of channels for a welfare impact of climate change at the micro level, such as increased frequency of storms, lower crop yields in agriculture, lower productivity in manufacturing, and higher crime and mortality through which climate change can lower welfare. Researchers have also looked at the relationship between climate change and growth at the country and region level, with an influential [study](#) finding that higher temperatures have likely already weighed on aggregate growth in poor countries.

**Empirical evidence on the welfare effects from climate change by sector**

Sector/Channel	Study	Key Finding/Description of Channel	Direct Output effect?
Agriculture	Moore, Baldos, Hertel & Diaz (2017)	A 2°C increase in the global temperature vs. 1995-2005 baseline lowers major crop yields by 10-30%.	Yes (negative)
Manufacturing (productivity)	Zhang, Deschenes, Meng, Zhang (2018)	A day with temperature above 90°F (26°C) decreases China plants' output and TFP by around 0.5%, relative to a day with temperature between 50-60°F (i.e. 21-26°C).	Yes (negative)
Energy	Aufhammer (2018)	Rising temperature increases electricity consumption (e.g. summer AC) but lowers natural gas demand (e.g. winter heating) in California.	Yes (ambiguous)
Storms	Hsiang and Jina (2014)	Tropical cyclones persistently depress growth rates for 15 years with a 7% cumulative decline in per capita income after 20 years.	Yes (negative, at least in study)
Sea-level rise	NA	Houses, offices, plants and infrastructure could be chronically inundated.	Yes (ambiguous)
Mortality	Deschenes and Greenstone (2011)	Under a "business as usual" scenario, climate change will increase the US annual mortality rate by about 1% by 2100 (and boost annual residential energy consumption by 20-25%, corresponding to 0.1% of GDP.)	Mostly no
Migration	Bohra-Mishra, Oppenheimer, Hsiang (2014)	Above 25 °C, a rise in temperature is related to an increase in outmigration in India.	No
Crime and conflict	Burke, Hsiang, Miguel (2015)	A 1σ increase in temperature increases the frequency of interpersonal conflict (e.g. domestic violence, murder, road rage) by 2.4% and of intergroup conflict (e.g. riots, land invasions, civil war, coups) by 11.3%.	No
Temperament/ happiness	Baylis (2015)	An increase in the temperature from 70°F to 80°F (i.e. 21°C to 26°C) lowers happiness as much as a switch from Sunday to Monday does.	No
Species and forestry loss	NA	Climate change leads to a loss of species and forests.	No

Source: compiled by Goldman Sachs Global Investment Research.

An even harder challenge for researchers is estimating the impacts of future climate change. There is considerable uncertainty about how much temperatures will rise, and even more uncertainty about how that will affect natural systems and how humans will adapt. Scientists are particularly worried about potential nonlinear effects, such as "tipping points" that lead to sudden and large changes in physical systems, but these are inherently hard to predict.

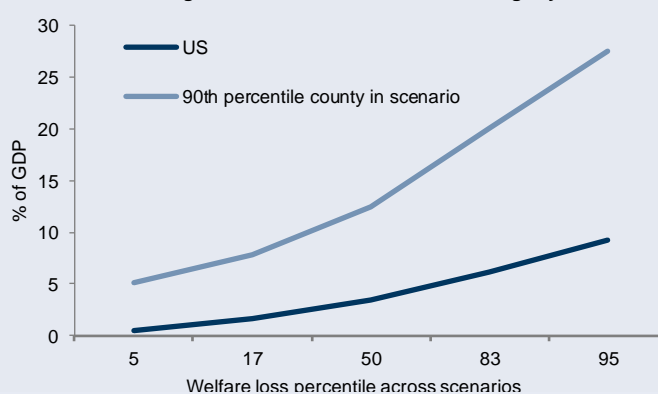
The large uncertainty and different assumptions made by researchers have led to a wide range of estimates of the welfare effects of long-run climate change. A recent study by Hsiang et al. that estimates future economic damages from climate change in the US finds a large right tail in the distribution of potential welfare losses and large heterogeneity in estimated welfare losses by region, underscoring the risk of potentially very large long-run welfare effects.<sup>2</sup>

## Assessing the growth effect of climate change

While assessing the welfare effect of climate change is difficult, the potential effects of decarbonization policies on economy-wide activity is also ambiguous, for three reasons. First, abatement in the polluting industries also requires both capital investment and the hiring of additional workers. Second, workers and firms typically shift to other often cleaner production or innovation activities (or less regulated areas). Third, the policy details and fiscal picture also matter.

We note once again, however, that short-term growth is not equivalent to welfare. Overall, our survey of the literature suggests that policies aimed at curbing emissions could trigger significant shifts in the economy and have the potential to raise welfare of current and especially future generations.

**Annual long-run welfare loss from climate change by scenario\***



\*From the Hsiang et al (2017) meta-study which simulates welfare losses in 2080-2099 under the Representation Concentration Pathway 8.5 ("Minimal Change in Policy/Technology")  
Source: Hsiang et al (2017), Goldman Sachs Global Investment Research.

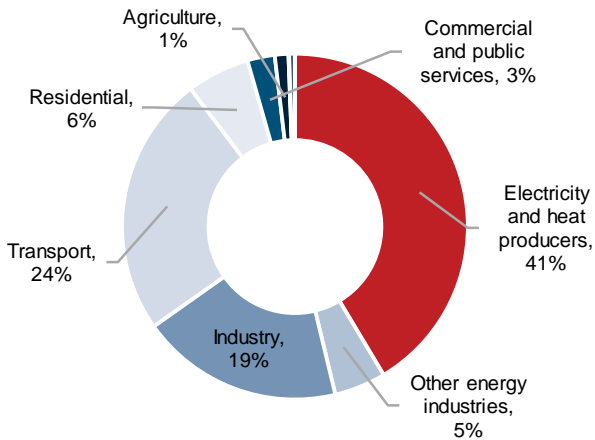
David Choi and Daan Struyven, GS US Economics Research

<sup>1</sup> For instance, economists have relied on estimates on the value of a statistical life and estimates of the economic cost of crime.

<sup>2</sup> Solomon Hsiang, Robert Kopp, Amir Jina et al., "Estimating economic damage from climate change in the United States," *Science*, 2017.

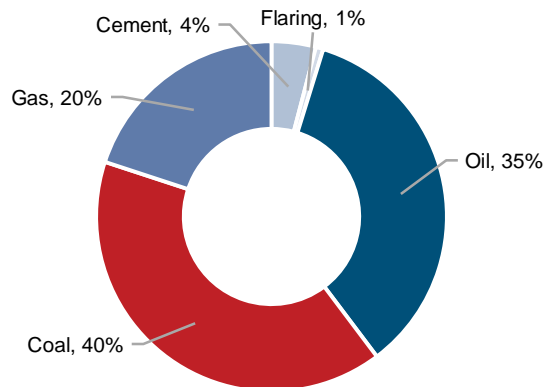
# The global state of climate

Three sectors account for 85% of global emissions...  
Carbon dioxide emissions by sector, %



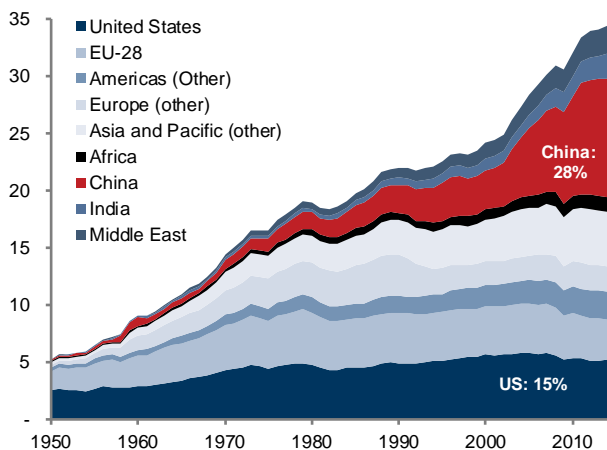
Source: International Energy Agency, Goldman Sachs GIR.

...and three fuel sources account for 95%  
Carbon dioxide emissions by fuel type, %



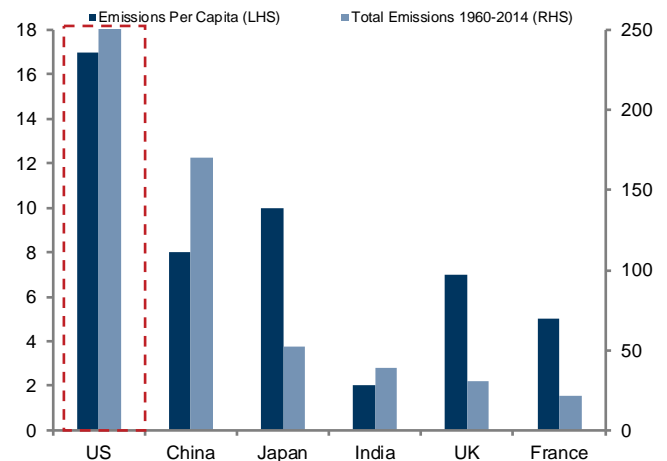
Source: Global Carbon Project, Goldman Sachs GIR.

China is now the biggest polluter on an absolute basis...  
Annual carbon dioxide emissions, billions of tons



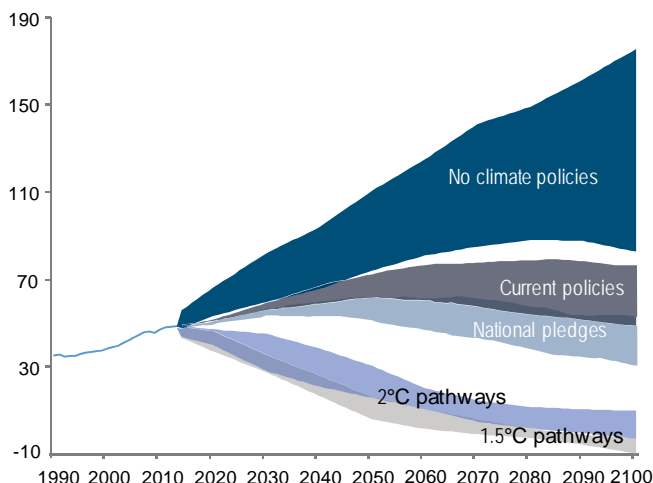
Source: World Bank, Goldman Sachs GIR.

...but the US has emitted more historically and per capita  
Carbon dioxide emissions, tons (LHS), billions of tons (RHS)



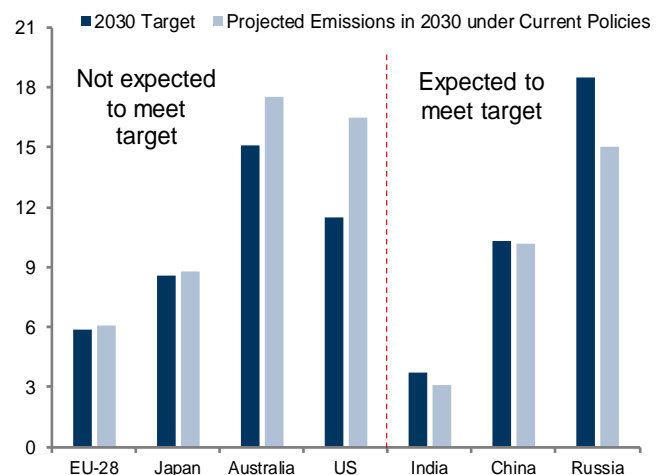
Source: World Bank, Goldman Sachs GIR.

Paris Agreement aims to limit global temperature rise to 1.5 °C  
Global greenhouse gas emissions, billions of tons



Note: Each band represents a range between high and low estimates.  
Source: CAT, IPCC, Goldman Sachs GIR.

Tracking progress towards Paris emission targets  
Annual carbon dioxide emissions per capita, tons



Note: US pledge to 2025; EU doesn't include Green Deal as hasn't been formalized.  
Source: United Nations, Goldman Sachs GIR.

# Summary of our key forecasts

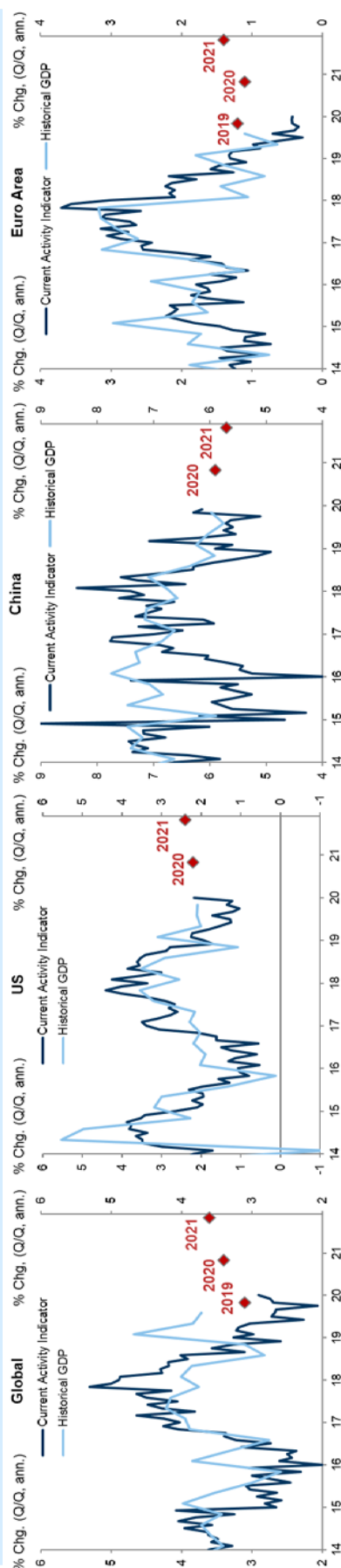
## GS GIR: Macro at a glance

### Watching

- **Globally**, we expect growth to pick up to 3.4% in 2020 from 3.1% in 2019, in response to easier financial conditions and friendlier trade policy. We're most confident that sequential growth will improve in the US and UK, owing to easier financial conditions and a decline in Brexit uncertainty, respectively, and also expect a gradual improvement in the Euro area and Japan.
- **In the US**, we expect growth to rise from the current pace of around 2.0% to the 2.25 – 2.50% range in 2020, owing to easier financial conditions, an end to trade escalation, and a reduced drag from inventory adjustment. We estimate the probability of recession in the next 12 months is around 15%. We expect core PCE inflation to rise from current levels to just shy of 2.0% by Q4 2020.
- **We expect the Fed to remain on hold through 2020** given our forecast of slightly above-trend growth and inflation near 2%; we see the bar for the policy rate to move in either direction as high.
- **In the Euro area**, we expect a gradual pickup in annualized growth from its current pace of around 0.5% to a slightly-above trend 1.1% in 2020, driven by an expected improvement in manufacturing, a modest fiscal impulse, and receding risks around Brexit and the global trade war. The EU Withdrawal Agreement is now UK law, with the UK embarking on a post-Brexit status quo transition phase on January 31; we believe the timescale for the second phase of Brexit talks will be more elastic than the government has articulated.
- **We think the ECB** will leave interest rates on hold but will maintain its EUR 20bn/month QE program until Q4 2021 in light of subdued inflation.
- **In China**, we expect a notable, if temporary, hit to growth from the coronavirus outbreak over the next couple of months and see downside risk to our full-year GDP growth forecast of 5.9% for 2020, although we believe the impact is likely to be confined mainly to the first quarter.

Goldman Sachs Global Investment Research.

### Growth



Source: Haver Analytics and Goldman Sachs Global Investment Research.

Note: GS CAI is a measure of current growth. For more information on the methodology of the CAI please see "Trackin' All Over the World - Our New Global CAI," Global Economics Analyst, February 25, 2017.

### Forecasts

Economics		Markets				Equities												
GDP growth (%)	2020	Interest rates 10Yr (%)		Last	E2020	E2021	Returns (%)		12m	YTD	E2020 P/E							
	GS	Cons.	GS	Cons.			GS	Cons.										
Global	3.4	3.1	3.6	3.3	US	1.60	2.25	2.30	EUR/\$	1.10	1.11	1.15	P/E	4.0	1.4	18.8x		
US	2.2	1.8	2.4	1.9	Germany	-0.41	0.00	0.20	GBP/\$	1.30	1.35	1.37	EPS	\$183	\$196	13.9x		
China	5.9	5.9	5.7	5.8	Japan	-0.04	0.10	0.15	\$/JPY	109	110	105	Growth	6%	9%	11%		
Euro area	1.1	1.0	1.4	1.3	UK	0.45	1.20	1.40	\$/CNY	6.92	6.85	6.90	STOXX 600	5.0	-1.1	15.2x		
Policy rates (%)	2020	Commodities		Last	E2020	E2021	Consumer		Wage Tracker 2019 (%)									
	GS	Mkt.	GS	Mkt.			CPI	Unemp. Rate	Q1	Q2	Q3	Q4						
US	1.63	1.40	2.13	1.26	Nat Gas (\$/mmBtu)	1.9	2.5	2.5	USD	IG	99	115	--	US	3.0	3.1	3.1	
Euro area	-0.50	-0.53	-0.50	-0.52	Crude Oil, Brent (\$/bbl)	60	63	63	HY	371	425	--	Euro area	1.1	7.5	1.3	7.3	
China	2.50	2.50	2.25	2.59	Copper (\$/mt)	5,613	6,300	7,000	EUR	IG	104	112	--	China	3.6	--	1.6	--
Japan	-0.10	-0.04	-0.10	-0.07	Gold (\$/troy oz)	1,573	1,600	1,600	HY	328	380	--	Japan	7.0	7.0	7.0	7.0	

Source: Bloomberg, Goldman Sachs Global Investment Research. For important disclosures, see the Disclosure Appendix or go to [www.gs.com/research/hedge.html](http://www.gs.com/research/hedge.html).

As of Jan. 30, 2020.



# Glossary of GS proprietary indices

## Current Activity Indicator (CAI)

GS CAIs measure the growth signal in a broad range of weekly and monthly indicators, offering an alternative to Gross Domestic Product (GDP). GDP is an imperfect guide to current activity: In most countries, it is only available quarterly and is released with a substantial delay, and its initial estimates are often heavily revised. GDP also ignores important measures of real activity, such as employment and the purchasing managers' indexes (PMIs). All of these problems reduce the effectiveness of GDP for investment and policy decisions. Our CAIs aim to address GDP's shortcomings and provide a timelier read on the pace of growth.

*For more, see our CAI page and Global Economics Analyst: Trackin' All Over the World – Our New Global CAI, 25 February 2017.*

## Dynamic Equilibrium Exchange Rates (DEER)

The GSDEER framework establishes an equilibrium (or "fair") value of the real exchange rate based on relative productivity and terms-of-trade differentials.

*For more, see our GSDEER page, Global Economics Paper No. 227: Finding Fair Value in EM FX, 26 January 2016, and Global Markets Analyst: A Look at Valuation Across G10 FX, 29 June 2017.*

## Financial Conditions Index (FCI)

GS FCIs gauge the "looseness" or "tightness" of financial conditions across the world's major economies, incorporating variables that directly affect spending on domestically produced goods and services. FCIs can provide valuable information about the economic growth outlook and the direct and indirect effects of monetary policy on real economic activity.

FCIs for the G10 economies are calculated as a weighted average of a policy rate, a long-term risk-free bond yield, a corporate credit spread, an equity price variable, and a trade-weighted exchange rate; the Euro area FCI also includes a sovereign credit spread. The weights mirror the effects of the financial variables on real GDP growth in our models over a one-year horizon. FCIs for emerging markets are calculated as a weighted average of a short-term interest rate, a long-term swap rate, a CDS spread, an equity price variable, a trade-weighted exchange rate, and—in economies with large foreign-currency-denominated debt stocks—a debt-weighted exchange rate index.

*For more, see our FCI page, Global Economics Analyst: Our New G10 Financial Conditions Indices, 20 April 2017, and Global Economics Analyst: Tracking EM Financial Conditions – Our New FCIs, 6 October 2017.*

## Goldman Sachs Analyst Index (GSAI)

The US GSAI is based on a monthly survey of GS equity analysts to obtain their assessments of business conditions in the industries they follow. The results provide timely "bottom-up" information about US economic activity to supplement and cross-check our analysis of "top-down" data. Based on analysts' responses, we create a diffusion index for economic activity comparable to the ISM's indexes for activity in the manufacturing and nonmanufacturing sectors.

## Macro-Data Assessment Platform (MAP)

GS MAP scores facilitate rapid interpretation of new data releases for economic indicators worldwide. MAP summarizes the importance of a specific data release (i.e., its historical correlation with GDP) and the degree of surprise relative to the consensus forecast. The sign on the degree of surprise characterizes underperformance with a negative number and outperformance with a positive number. Each of these two components is ranked on a scale from 0 to 5, with the MAP score being the product of the two, i.e., from -25 to +25. For example, a MAP score of +20 (5;+4) would indicate that the data has a very high correlation to GDP (5) and that it came out well above consensus expectations (+4), for a total MAP value of +20.

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