



CARBON'S FUTURE IN BLACK AND WHITE

THERE ARE REASONS TO BE OPTIMISTIC THAT THE WORLD WILL BREAK ITS ADDICTION TO FOSSIL FUELS. BUT TIME IS RUNNING OUT.

BY JEFF TOLLEFSON

Making sense of recent energy trends can seem like a high-stakes Rorschach test. Some experts see the boom in renewable energy and the shift away from coal in many countries as evidence that the world is beginning to turn a corner on global warming. Others see simply a continuing reliance on low-cost fossil fuels, slow governmental action and a rising risk of planetary meltdown.

The fact is that both sides are right. Renewable energy is indeed undergoing a revolution, as prices for things such as solar panels, wind turbines and lithium-ion batteries continue to plummet. And yet it is also true that the world

remains dependent on fossil fuels — so much so that even small economic shifts can quickly overwhelm the gains made with clean energy.

So it was in 2017, when, after staying relatively flat from 2014 to 2016, carbon emissions grew by about 1.5% (see 'A brief lull'). All it took to create that spike was a small rise in economic growth across the developing world, according to a final estimate released in March by the Global Carbon Project, an international research consortium that monitors carbon emissions and climate trends.

The setback is likely to loom large in December, when countries will meet in Katowice, Poland, to complete the

KEVIN FRAYER/GETTY

A worker walks through a sorting area at a coal mine in Shanxi, China.

first assessment of their progress in implementing the 2015 Paris climate agreement — an ambitious pact that aims to limit global warming to 1.5–2°C above pre-industrial levels. The bottom line

is hardly encouraging: by and large, governments are falling well short of their commitments, both collectively and individually. Many countries are likely to miss the emissions targets that they made in 2015, and the world is on track for more than 3°C of warming by the end of the century.

The spike in 2017 threw the situation into sharp relief. Governments are going to have to face the fact that they need to do more if they are serious about meeting the Paris climate agreement's goals, says Glen Peters, a climate-policy researcher at the Center for International Climate Research in Oslo and co-author of the Global Carbon Project's March report. "A lot of hard truths will have to come out in 2018," he says.

Here, *Nature* examines the forces behind the recent emissions trends and what they signal for the future. The good news is that clean-energy technology is at last making substantial strides. The bad news is that the pace isn't nearly quick enough. Big economic and political hurdles stand in the way of shutting off the fossil-fuel spigot and the cheap energy it provides.

THE PLATEAU AND THE SPIKE

To determine where carbon emissions are heading, researchers must first understand why they flattened out for three years. The most optimistic answer is that the seeds of a clean-energy revolution have been planted and are now growing like weeds (see 'The road ahead').

More than a decade of government mandates and economic incentives have helped the renewable-energy industry to take root. Thanks to a combination of technological advances and economies of scale, prices have fallen dramatically for wind and solar. Meanwhile, improvements in lithium-ion batteries have made electric vehicles the clean technology to beat in the transport sector.

All of this has created a virtuous cycle that is driving prices down and sales up, says Jules Kortenhorst, chief executive of the Rocky Mountain Institute, an environmental think tank based in Basalt, Colorado. "President Trump can easily imagine a world where we all turned back to coal-fired electricity and horses and buggies and kerosene lamps, but the reality is that the world is shifting at an accelerating pace to a completely different reality," Kortenhorst says.

The impact of the renewables boom can be readily seen in the United States and China, the world's two largest greenhouse-gas emitters. In the United States, where annual carbon emissions have decreased more than 13% since 2005, renewable sources have become an increasingly important part of the story, contributing more than half of the energy-generating capacity added in 2017 — the equivalent of about 46 average-sized coal plants. In China, the development of renewable energy sources has helped to scale back coal consumption and rein in the country's skyrocketing emissions. In late 2017, Climate Action Tracker, a research consortium that monitors international climate policies, reduced its projection for China's annual emissions in 2030 by 700 million tonnes of CO₂. That figure, which is more than twice the current annual carbon emissions from France, could double if China's efforts to curb coal use continue apace.

But the 2014–16 emissions plateau was shaped by more than just a clean-energy push. One of the biggest factors

in keeping levels in check was an economic slowdown in China, which lowered demand for everything from energy to concrete and steel. In the power sector, the country's aggressive pursuit of renewables and nuclear energy has been accompanied by efforts to boost the efficiency of modern coal plants and retire old ones. Similarly, much of the decline in US emissions comes from a shift from coal to natural gas, which emits less carbon.

The upshot, says David Victor, a climate-policy specialist at the University of California, San Diego, is that two of the biggest factors in reducing emissions from electricity come from the fossil-fuel sector itself: increasing coal-plant efficiency in China and the expansion of shale gas in the United States. Because so much energy comes from coal, slight fluctuations from year to year can wipe out massive gains in renewables. "When coal sneezes, the whole world knows it," Victor says. "When solar has a revolution, almost nobody notices."

And, to a large extent, that is precisely what happened in 2017. Solar continued to grow at a breakneck pace, but coal consumption in China also rose. A lack of rainfall in parts of China reduced hydropower output, and coal made up the difference. The government had also initiated a stimulus programme towards the end of 2016, aimed at boosting the economy ahead of the Communist party congress in October 2017. All told, China's carbon dioxide emissions, driven by coal consumption, increased by 3.5% in the first half of 2017, according to the Global Carbon Project.

That small blip in China's coal emissions might have been a major contributor to the spike, but developments in other countries also played a part. India's emissions rose faster than expected, owing to stronger economic growth. Thanks to changes in fossil-fuel consumption, emissions in the United States and European Union dropped more slowly in 2017 than in years past. Then there is the rest of the world, whose emissions rose by 2% in 2017, according to the Global Carbon Project's analysis. That includes developing countries, where tapping fossil fuels remains a relatively cheap and easy way of making economic progress.

BENDING THE CURVE

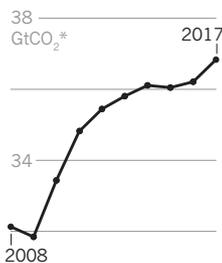
Little time remains for the world to get its emissions under control. The Paris agreement is predicated on a single global carbon budget that countries are collectively using up each year. The longer humanity waits to reduce emissions, the more aggressive future measures will need to be to keep the total under budget.

It is difficult to say exactly how much time is left. Estimates for the maximum amount of carbon that can be emitted if warming is to remain below 1.5°C, for example, vary widely. There could be 10 or even 15 years of leeway remaining. Or, humanity might have already burned through the total allotment six years ago. Either way, the tight margins have led many researchers to suspect that even the 2°C Paris target could be out of reach — at least without developing technologies to pull CO₂ out of the atmosphere or artificially cooling Earth by blocking incoming solar radiation.

The amount by which the world will ultimately warm hinges on a key question: how quickly will the emissions curve bend? An optimist might point to the fact that almost all projections for clean energy have proved to be overly conservative. In 2008, for instance, China set a goal of installing 2 gigawatts of solar photovoltaics by 2020. But it is now likely to achieve more than 200 gigawatts, says Jiang Kejun, a senior researcher at China's Energy Research Institute in Beijing. Kejun says that the pattern is likely to

A BRIEF LULL

Global carbon dioxide emissions plateaued from 2014 to 2016, but rose by 1.5% in 2017.

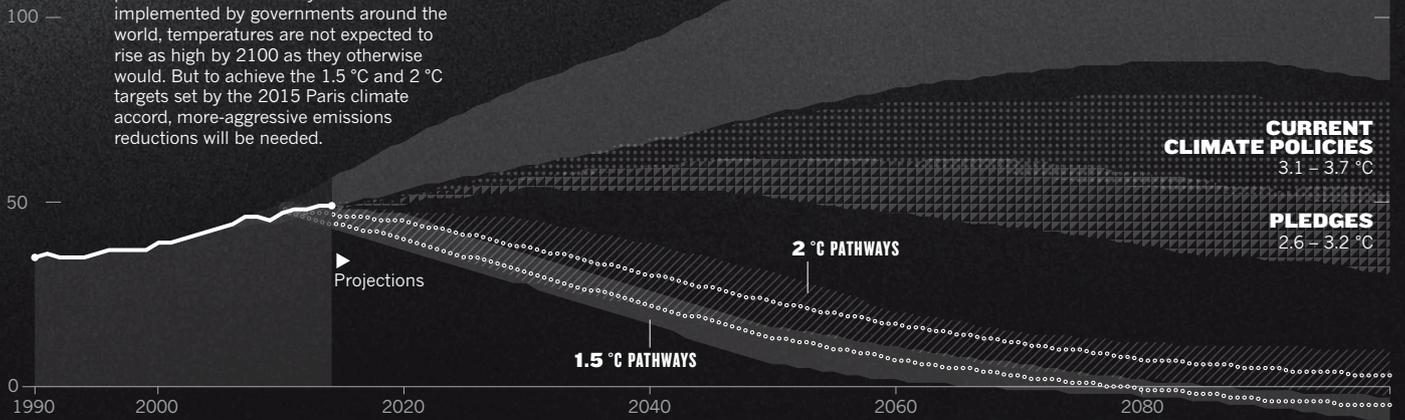


* Gigatonnes of carbon dioxide

150
GtCO₂*
equivalent

PLOTTING THE FUTURE

Greenhouse-gas emissions could take many paths in the coming years, resulting in differing levels of warming relative to pre-industrial levels. Thanks to policies that have already been implemented by governments around the world, temperatures are not expected to rise as high by 2100 as they otherwise would. But to achieve the 1.5 °C and 2 °C targets set by the 2015 Paris climate accord, more-aggressive emissions reductions will be needed.



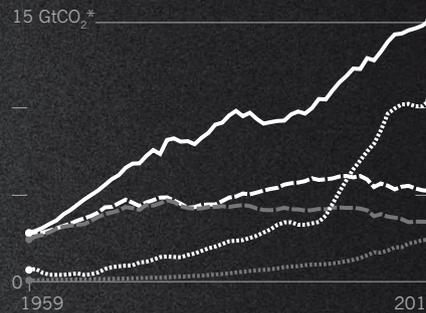
THE ROAD AHEAD

Massive reductions in global greenhouse-gas emissions — of which carbon dioxide is the largest component — will be needed to limit warming to 1.5 or 2 °C. With prices plummeting, clean-energy technologies such as solar, wind and electric vehicles could make a significant dent. But the sheer scale of global fossil-fuel consumption raises questions about the feasibility of that goal.

THE BIG CONTRIBUTORS

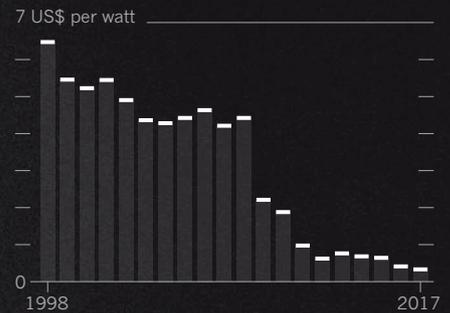
A fairly small number of countries are responsible for the bulk of CO₂ released annually. But emissions from the rest of the world are on the rise.

India — European Union
United States — China — All others



SEEDS OF A REVOLUTION

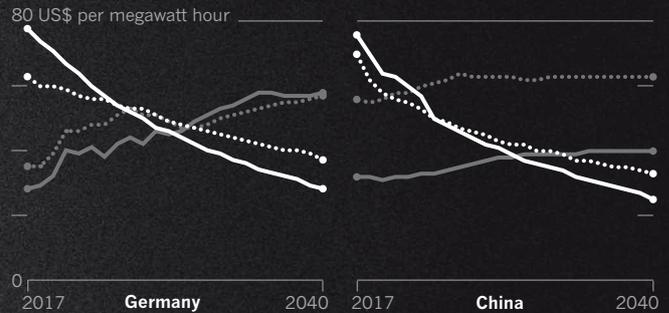
The cost of electricity generated by solar modules has declined significantly in the past 20 years.



SOLAR TIPPING POINT

In the coming decade or so, the cost of building a solar plant is expected to fall below the cost of operating an existing coal plant in Germany, China and other countries.

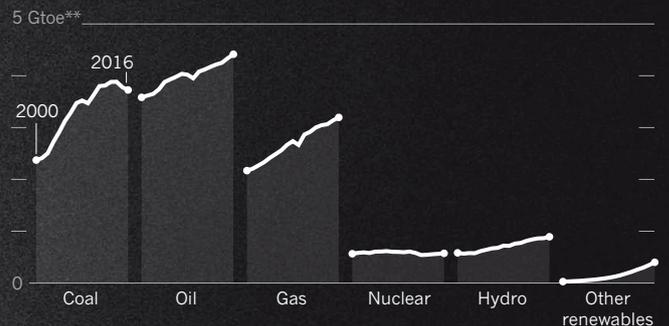
Coal — Gas
Wind — Solar



THE SCALE OF THINGS

Global energy consumption is still dominated by fossil fuels. A small fluctuation in coal use from one year to the next can wipe out a seemingly dramatic expansion in renewable energy.

* Gigatonnes of carbon dioxide
** Gigatonnes oil equivalent



DESIGN BY JASIEK KRZYWOSTOJA/WATUPE. GRAPHIC SOURCES: CLIMATE ACTION TRACKER, CARBON DIOXIDE INFORMATION ANALYSIS CENTER/GLOBAL CARBON PROJECT, BLOOMBERG NEW ENERGY FINANCE, BP



be repeated in the future. “Modellers are underestimating the potential of renewable energy,” he says.

Some analysts think that solar energy, in particular, is poised to hit a tipping point that could change the face of the energy market. Watt for watt, solar energy already costs as little as coal in some places. And intriguingly, the London-based energy consultancy Bloomberg New Energy Finance (BNEF) has calculated that solar could become so cheap that, by 2030, it would be more cost-effective in many regions to build a solar plant than to continue supplying fuel to an existing coal plant. Similarly, beginning in the mid-2020s, the consultancy projects that falling battery prices will make electric cars cheaper to buy and run than their conventional counterparts — without the government subsidies that have fuelled the market so far.

“These are very important tipping points, but nobody quite knows what will happen and how policymakers will respond,” says Angus McCrone, chief editor at BNEF. “Politics is a bottleneck, particularly when there’s a powerful incumbency in an industry that is going to be affected by these new technologies.”

But politics can also help to bring about rapid change. While Trump is fighting on behalf of the fossil-fuel industry, leaders of other countries are moving in the opposite direction. The United Kingdom and France have both announced plans to ban the sale of petrol- and diesel-powered vehicles by 2040. And more than two dozen countries have committed to phasing out coal by as early as 2030.

These types of mandate are a sign that energy politics might be shifting towards more brute-force methods, says Michael Mehling, an energy and environmental-policy researcher at the Massachusetts Institute of Technology in Cambridge. Economists tend to favour market-based programmes, such as the EU’s Emissions Trading System, but Mehling says there is little evidence that such arrangements will drive the kind of rapid transformational change needed to meet global climate goals. Old-school government mandates might be the last resort, Mehling says.

“If the decisions are made at a sufficiently high level,” he says, “they can change the landscape pretty much overnight”.

Kejun’s calculations suggest that, driven both by policy and economics, China’s carbon emissions are still on track to peak as early as 2020, and its coal consumption could drop by as much as 40–50% by 2030. “The transition has already started,” says Kejun.

A similar movement seems to be under way in India, which is racing to provide reliable power — and cleaner air — to more than 1.3 billion people. If India can chart a path to sustainable development, it would set an example for other developing countries and avoid a repeat of China’s coal-fuelled ascension.

Today, the solar-power industry is booming in India, thanks to government incentives and falling prices, and the Indian government aims to install 100 gigawatts of solar capacity by 2022 — nearly double the current solar-generation capacity in the United States. Meeting that goal could be challenging, because solar power will increasingly need to compete with existing coal-fired power plants for limited space on the electricity grid, says Rahul Tongia, an energy researcher at the non-profit public-policy organization the Brookings Institution in New Delhi. Still, he says, the trends are impressive. “Maybe it takes a bit longer to hit the targets. Who cares?” Tongia says. “The progress is still remarkable, measurable, dramatic and meaningful.”

But can such progress realistically rein in warming? For Peters, the boom in renewable energy is necessary and welcome, but still insufficient. Ultimately, the only thing that matters to the climate is the quantity of greenhouse gases emitted — and so the question is when humanity will begin to close the spigot and shut down fossil-fuel infrastructure. When that happens, he says, “you can start to feel a little bit better”. ■

Jeff Tollefson writes for *Nature* from New York City.

Work is done on a rooftop solar panel installation in Wuhan, China.