will affect agriculture and migration patterns in Brazil—and also how cuts in ethanol subsidies might limit deforestation in the Amazon. Currently, climate scientists extract regional results from global climate models and pass them to experts in agriculture or economics to understand effects on human behavior. Now, says Erin Coughlan de Perez, a climate hazard scientist at the Red Cross Red Crescent Climate Centre, modelers are "moving from just forecasting what weather will be, to what the weather will do."

Getting there won't be easy. Exascale supercomputers rely on both traditional computer chips as well as graphical processing units (GPUs), which are efficient at handling intensive calculations. GPUs are good for running model components in parallel and training artificial intelligence algorithms—two techniques Destination Earth will lean on to enhance performance. But old climate modeling code will have to be reworked. ECMWF has a head start: It is adapting its forecast model to a GPU-based environment, and last year tested it at 1-kilometer resolution for four simulated months on Summit, the U.S. supercomputer that was the world's fastest until a Japanese machine recently eclipsed it.

The massive amount of data generated by the model will be a problem of its own. When the Japanese team ran its 1-kilometer-scale experiment, it took half a year to extract something useful from a couple days of data, Doblas-Reyes says. "There's a bottleneck when we try to access the data and do something clever with it." A big part of Destination Earth will be solving this problem, designing ways to analyze model results in real time.

As an operational system, Destination Earth will likely run at several time scales, Bauer says. One will be near daily, perhaps targeting individual extreme weather events weeks or months in the future. Runs in the other mode—long-term predictions—would be less frequent: perhaps a decadelong prediction of the climate made every half-year or so. "If this works, it could be a template for other countries to follow," Bauer says.

The Europeans aren't alone in planning for exascale climate models. "We're heading in that direction as well, but we've yet to reach that level of effort," says Leung, who serves as chief scientist for DOE's earth system model.

Stevens says it's thrilling to be involved in a truly planetary-scale information system that can reveal not just the proverbial butterfly effect in weather and climate, but also how local human actions manifest globally. "That's the story of globalization. That's the story of the Anthropocene. And this is the scientific platform that will allow you to explore those." ■

CLIMATE CHANGE

# China's bold climate pledge earns praise—but is it feasible?

## Plan to achieve carbon neutrality by 2060 would make China a global leader, but abandoning coal will be hard

*By* **Dennis Normile**

China's surprise pledge last week to cut its net carbon emissions to zero within 40 years has reignited hopes of limiting global climate change to tolerable levels. The country is the world's largest producer of carbon dioxide ($CO_2$), accounting for 28% of global emissions, and its move may inspire other countries to follow suit. But observers warn that China faces daunting challenges in reaching its goals. Kicking its coal habit will be particularly hard.

"We aim to have $CO_2$ emissions peak before 2030 and achieve carbon neutrality before 2060," Chinese President Xi Jinping told the United Nations General Assembly via a video link on 22 September. That's "a very significant and encouraging announcement," says Josep Canadell, an earth system scientist at Australia's Commonwealth Scientific and Industrial Research Organisation. He says the new targets "won't likely let us to stop at 1.5° Celsius [of global warming]," the preferred target set in the 2015 Paris agreement. "But below 2° might still be consistent with [Xi's] announcement." China's commitment also "ratchets up pressure on other major emitters" to set more ambitious targets "while further isolating the Trump administration in its climate myopia," Vance Wagner of Energy Foundation China wrote in a piece published online by the nonprofit China Dialogue.

China had previously said its $CO_2$ emissions would peak "around" 2030, a target most analysts considered within reach. But achieving carbon neutrality before 2060 will require drastically reducing the use of fossil fuels in transportation and electricity generation and offsetting any remaining emissions through carbon capture and storage or planting forests.

China has not yet revealed details of how it will do this. But a research group at Tsinghua University presented a $15 trillion, 30-year road map on 27 September that calls for ending the use of coal for electricity generation around 2050, dramatically increasing nuclear and renewable power generation, and relying on electricity for 80% of China's energy consumption by 2060.

Coal is both the biggest challenge and an opportunity. Last year, the carbon-heavy fuel accounted for about 58% of China's total energy consumption and 66% of its electricity generation. In coal-producing regions, coal is also used to heat buildings. Recent advances in renewable energy have made replacing coal easier than cutting oil use in transportation and emissions from farm fields and livestock. "The power sec-

A coal-fired power plant in Jiangsu province. Coal accounted for 58% of China's energy consumption last year.

PHOTO: XU CONGJUN/AP PHOTO

tor is the part of the energy system where zero emission technologies are the most mature and economically competitive," says Lauri Myllyvirta, an air pollution analyst at the Centre for Research on Energy and Clean Air in Helsinki. Zero-carbon electricity could make charging electric vehicles cleaner and supplant coal for heating.

But it will require a U-turn. A recent study by Myllyvirta and colleagues found that China's coal-fired generating capacity grew by about 40 gigawatts (GW) in 2019, to about 1050 GW. Another 100 GW is under construction and coal interests are lobbying for even more plants. "This is all despite significant overcapacity in the sector," with plants running at less than 50% of capacity and many coal-power companies losing money, the study said. Canadell says the building boom is the result of misplaced incentives to build coal plants and create construction jobs. He predicts many of the new plants will barely be used or become stranded assets that have to be written off.

A related challenge will be reforming the electricity market. Renewable energy is increasingly cost competitive with coal, says Li Shuo, a climate policy adviser to Greenpeace China. But regulators allocate operational time among electricity plants to match generation to demand, with little consideration of economic or environmental implications, Li says. The system overwhelmingly favors coal-fired generation, partly because it doesn't suffer from the variability of wind and solar power. The uncertain market access has already slowed investment in renewables, Li says. Given the power of coal and construction interests, the needed reforms will take considerable political will.

Expanding nuclear power presents challenges as well. The 2011 Fukushima Daiichi nuclear disaster in Japan sent ripples of concern through China, which mandated additional safety measures that made new plants more expensive. Public opposition is also growing. China has 48 nuclear power reactors in operation and 12 under construction, according to the World Nuclear Association. The government had aimed for 58 GW of nuclear capacity by this year but did not get beyond 52 GW.

China's Five-Year Plan for 2021–25, now being drafted, may contain concrete measures to help realize Xi's ambitious target. "China's interest in climate change has waned in recent years, due to the slowing down of economic growth and the U.S. withdrawal from the Paris agreement," says Zhang Junjie, an environmental economist at Duke Kunshan University. "The commitment on carbon neutrality reignited hopes for China's climate action." ■

Many koalas were killed by Australia's record wildfires, jeopardizing the survival of some populations.

CONSERVATION BIOLOGY

# Record U.S. and Australian fires raise fears for many species

## Scientists say fires likely wiped out some rare Australian organisms, and worry U.S. blazes now threaten more

*By* **John Pickrell** *and* **Elizabeth Pennisi**

For the past 3 months, arachnologist Jess Marsh has been searching for the Kangaroo Island assassin spider. Early this year, during the worst fire season ever recorded in Australia, a wildfire charred the spider's only known home on an island off the nation's south coast. Now, Marsh fears the tiny, rusty brown arachnid is another of the many Australian species that the blazes have put on a path to extinction: Countless hours of scouting haven't revealed a single survivor. "Its habitat is completely incinerated," says Marsh, who is affiliated with Charles Darwin University.

She isn't the only field biologist worried that the record wildfires around the globe are inflicting lasting damage on species and ecosystems. Even as Australia tallies the damage from its blazes, the worst fires in more than 70 years are burning in California, Oregon, and Washington; so far, they have consumed some 2 million hectares, killing at least 35 people. As in Australia, scientists fear the loss of habitat has threatened species with small populations or restricted ranges, and could potentially lead to permanent ecological changes if burned landscapes fail to rebound in a warming climate. "We are in uncharted territory here," says ecologist S. Mažeika Patricio Sullivan of Ohio State University, Columbus. "We just don't know how resilient species and ecosystems will be to wildfires of the magnitude, frequency, and intensity that we are currently experiencing in the U.S. West."

Australia's postfire experience offers cause for anxiety, researchers say. From September 2019 to March, more than 11 million hectares burned, mostly in the continent's southeastern forests, killing at least 34 people. More than 20% of the nation's total forest cover was lost, researchers at Western Sydney University reported in February. Even normally fire-proof rainforests and wetlands were scorched (*Science*, 20 December 2019, p. 1427). By one estimate, released early this year by the Australian government, 114 threatened plant and animal species lost 50% to 80% of their habitats; 327 species saw more than 10% of their ranges burn.

Those estimates, however, were based on satellite data, says John Woinarski, also at Charles Darwin University. To get better assessments, researchers have been trying to visit burned sites, an effort complicated by the COVID-19 pandemic.

In some cases, they've reported good news. There was grave concern for the en-



PHOTO: PETER PARKS/AFP/GETTY IMAGES

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