for Peru who is running one of the 40 clinical trials worldwide that are currently testing the drug. "This has been an odyssey."

Ivermectin grabbed attention in April, when researchers in Australia noted that high doses of ivermectin could stop the virus from replicating in cells[1]. Shortly afterwards, a preprint appeared online suggesting the drug could reduce coronavirus-related deaths in people.

That report was later removed from the site by some of its authors because, they told *Nature*, the study was not ready for peer review. The preprint had included an analysis of electronic health records by the US company Surgisphere, which provided COVID-19 data sets that raised red flags for scientists in late May. By June, two other high-profile COVID-19 studies were retracted that contained data from the firm.

But as far as many physicians and patients in Latin America were concerned, ivermectin's reputation was already cemented. Physicians began justifying the drug's use against COVID-19, arguing that even if it didn't work, at least it had a proven safety profile for treating parasites, says César Ugarte Gil, an epidemiologist at Cayetano Heredia who is running the clinical trial with García.

Rapid spread

The eagerness to use the treatment grew as the virus spread aggressively throughout Latin America. Brazil, Argentina, Colombia and Peru have all posted some of the largest case numbers worldwide. "I do not judge a doctor who has a dying patient before him and, desperate, tries anything [to save her]," says Carlos Chaccour, a Venezuelan researcher at the Barcelona Institute of Global Health in Spain. "The problem is when non-evidence-based public policies are made."

The implementation of such policies kicked off on 8 May, when the Peruvian Ministry of Health recommended using ivermectin to treat mild and severe cases of COVID-19. Days later, Bolivia's government added the drug to its guidelines for treating coronavirus infections. The Brazilian state of Natal also promoted it as a preventive — to be taken by people at increased risk of severe illness from the virus, because of "its safe pharmacological profile, clinical experience using it against other diseases, cost and dosage convenience".

Peru and Bolivia have been transparent about how slim the evidence is. "It is a product that does not have scientific validation in the treatment of the coronavirus," acknowledged Bolivian health minister Marcelo Navajas in a press conference on 12 May.

The situation troubles researchers who are trying to run clinical trials. Not only is the drug's popularity making it difficult to recruit people, but physicians are also not documenting possible side effects after they prescribe the drug, meaning valuable data on its safety are being lost, says Ugarte Gil.

Self-medication is on the rise because people can easily buy ivermectin, says pharmacologist Carlos Calderón Ospina at the University of El Rosario in Bogotá. Although most people tolerate ivermectin well, it has been linked to tremors, convulsions, lethargy and disorientation. A 2018 analysis found cases of brain damage and coma in people with a genetic mutation that allows ivermectin to pass from the bloodstream into the brain[2].

But that doesn't mean researchers have given up on collecting the necessary evidence. In late September, Alejandro Krolewiecki, an infectious-disease physician at the National University of Salta in Orán, Argentina, and his colleagues announced the results of a small clinical trial evaluating ivermectin's effectiveness against COVID-19. The researchers recruited 45 people with mild and moderate COVID-19 and gave ivermectin to 30 of them for 5 consecutive days at a daily dose about 3 times as high as that used to treat parasite infections; the rest of the participants received only standard COVID-19 care. Their findings suggest that in people who absorbed a higher concentration of ivermectin, "a clearer, faster and more intense viral elimination occurred", says Krolewiecki.

"The problem is when non-evidence-based public policies are made."

The news is encouraging, says Chaccour. But it's not enough to give ivermectin wonder-drug status, he adds, particularly because Krolewiecki's results have not yet been published, peer reviewed or replicated.

More data are on the way. In the next few weeks, Chaccour plans to submit results from a pilot study for publication. His team recruited 24 people with COVID-19 and administered ivermectin to some of them and a placebo to the others. Chaccour declined to tell *Nature* whether the results look promising, but he's encouraged that trials are yielding data, even if slowly.

"That's what we asked for from the beginning," he says. "There should be some guidance before making public-policy decisions."

Still, researchers might never have sufficient data to justify ivermectin's use if its widespread administration continues in Latin America. The drug's popularity "practically cancels" the possibility of carrying out phase III clinical trials, which require thousands of participants — some of whom would be part of a control group and therefore couldn't receive the drug — to firmly establish safety and efficacy, says Krolewiecki.

1. Caly, L. *et al. Antivir. Res.* **178**, 104787 (2020).
2. Chandler, R. E. *Am. J. Trop. Med. Hyg.* **98**, 382–388 (2018).

HOW CHINA COULD BE CARBON NEUTRAL BY MID-CENTURY

Our special report examines the roles of renewables, nuclear power and carbon capture.

By Smriti Mallapaty

China, the world's largest emitter of carbon dioxide, has promised to become carbon neutral before 2060, and to begin cutting its emissions within the next ten years.

President Xi Jinping made the ambitious pledge to a virtual audience of world leaders at a meeting of the United Nations General Assembly last month. The news came as a surprise to many researchers, even in China, who weren't expecting such a bold target. It's the country's first long-term climate goal, and will require China to rein in CO_2 and probably other greenhouse-gas emissions to net zero, which means offsetting emissions, for example by planting trees or capturing carbon and storing it underground.

In the wake of the announcement, *Nature* explores several proposals from influential research groups that work closely with the government for how China could reach neutrality before 2060. The plans differ in their details, but agree that China must first begin to generate most of its electricity from zero-emission sources, and then expand the use of this clean power wherever possible — for example, switching from petrol-fuelled cars to electric ones. It will also need technologies that can capture CO_2 released from burning fossil fuels or biomass and store it underground, known as carbon capture and storage (CCS).

The news of China's carbon neutrality target

LI ZONGXIAN/VCG/GETTY

China will have to ramp up solar and wind capacity to become carbon neutral by 2060.

is a "game-changer" for the global climate and could encourage other countries to act faster than they otherwise would have, says Mark Levine, a retired energy-policy researcher at Lawrence Berkeley National Laboratory in Berkeley, California.

For China to achieve its target, electricity production would need to more than double, to 15,034 terawatt hours by 2060, largely from clean sources, according to a proposal developed by Zhang Xiliang, a climate modeller at Tsinghua University in Beijing. This growth would be driven by a massive ramp-up of renewable electricity generation over the next 40 years, including a 16-fold increase in solar and a 9-fold increase in wind. To replace coal-fired power generation, nuclear power would need to increase sixfold, and hydroelectricity to double.

Fossil fuels, including coal, oil and gas, would still account for 16% of energy consumed, so would need to be paired with CCS or offset by new forest growth and technologies that can suck CO_2 directly out of the atmosphere.

Zhang's model, developed with the Massachusetts Institute of Technology in Cambridge, was part of a major national project on China's low-carbon future, led by Tsingua University's Institute of Climate Change and Sustainable Development. The work was presented at a meeting attended by environment officials on 12 October. "Our model is the primary one to support government policymaking," says Zhang.

Under their plan, emissions would continue to rise, from 9.8 gigatonnes of CO_2 in 2020 to around 10.3 gigatonnes in 2025. They will then plateau for 5–10 years before dropping steeply after 2035, to reach net zero by 2060.

But shifting China's economy away from its dependence on fossil fuels in such a short time will be expensive, says Levine. Coal-fired power accounts for almost 65% of the country's electricity generation, with more than 200 new coal-fired power stations planned or under construction. "There will be tremendous opposition" from industries that rely on fossil fuels, he says.

Frank Jotzo, an environmental economist at the Australian National University in Canberra, says that a major cost will be the energy storage required to integrate wind and solar at such scale.

But battery storage has become cheaper over the past decade, and that could bring costs down, says Gang He, an energy-systems modeller at Stony Brook University in New York. If trends in the cost of renewables technology continue, more than 60% of China's electricity could come from non-fossil fuels by 2030, says He. "That is quite encouraging."

Ramp up nuclear

Other teams have also envisaged a carbon-neutral future for China. A scenario led by energy modeller Jiang Kejun, at the Energy Research Institute, National Development and Reform Commission (NDRC) in Beijing, would see emissions peak as soon as 2022, at around 10 gigatonnes of CO_2, followed by a steep drop to net zero by 2050.

To achieve this, electricity production would double to 14,800 terawatt hours by 2050. This output is similar to that in Zhang's model, but would be generated largely by nuclear power (28%), followed by wind (21%), solar (17%), hydropower (14%) and biomass (8%). Coal and gas would make up 12% of electricity production.

This means that China's nuclear capacity — currently 49 gigawatts across some 50 nuclear power plants — would need to increase fivefold, to 554 gigawatts by 2050, through rapid construction of new sites.

According to Jiang's analysis, nuclear power can supply a more consistent base load of power than can solar and wind. He adds that the latest nuclear-plant designs are safe and produce minimal radioactive waste.

But many researchers are sceptical about nuclear's potential. The cost and time required to build the plants has increased significantly, says Zhang. And the 2011 meltdown at the Fukushima Daiichi nuclear power station in Japan has made building plants inland unacceptable to much of the public, he says.

Cut down coal

Jiang's analysis also points to another crucial sticking point among researchers — the role of CCS. The model proposes that some 850 gigawatts of power generated from coal, gas and biofuels could be fitted with technologies that capture and store carbon emissions.

A "stringent climate target requires substantial deployment of CCS", says Hongbo Duan, a climate economist at the University of the Chinese Academy of Sciences in Beijing, who has developed a model that also requires considerable use of the technology.

But this would require significant investment, because China currently has only one large CCS facility in operation, at an oil field. Seven more facilities are being planned or built. CCS would allow China to continue using some coal-fired power in the long term, but some researchers say the technology is still very expensive, which limits its application.

Many researchers think that China should stop building new coal-fired power plants. Existing plants will reach the end of their life before the neutrality deadline in 40 years, says Kaare Sandholt, an energy-systems modeller at the NDRC's China National Renewable Energy Centre, who is based in Copenhagen.

But in making the shift, says He, China also needs to consider the well-being and economic security of some 3.5 million workers in the coal-mining and power industry, as well as the many people who rely on cheap electricity and heating.

The path the country will follow to reach neutral emissions will probably become clearer in the coming months. China, like all nations that have signed the 2015 Paris climate agreement, is obliged to submit increased emissions-reduction targets before the end of the year. Officials are also in the process of drafting the country's latest five-year plan for social and economic development, which will be released in March and is expected to include policies to achieve neutrality.

A detailed breakdown of energy and climate targets will show how serious China is about reaching its carbon-neutrality goal, says Zhang ZhongXiang, an economist at Tianjin University.