

► at Harvard University in Cambridge, Massachusetts.

Cap-and-trade systems set an overall limit on emissions and then distribute allowances to emitters. As total emissions decline, companies can buy permits to emit more — or make money by selling unused allowances. The goal of such a system is to spur innovation and to allow companies to find the cheapest way possible to reduce emissions.

The European Union has been operating the world's largest cap-and-trade system since 2005, and California and a group of northeastern US states run similar systems. China's trading scheme is expected to encompass roughly half of the country's emissions, including those from electricity generation and energy-intensive industries. That would make it the largest such system in the world.

### GLOBAL CONNECTIONS

China's plans come as countries that will participate in the upcoming UN climate talks grapple with whether to allow links between emissions-trading systems in different parts of the world.

Stavins says that a coalition of countries, including Venezuela, Nicaragua and Cuba, is pushing to prevent international trading, which would prevent money from flowing to those regions where it is easiest — and cheapest — to reduce emissions. “That, in my mind, would be a tragedy,” he adds.

Although many economists believe that cap-and-trade systems represent the cheapest way to reduce emissions, their track record in the real world is mixed. The EU carbon market, for instance, crashed early on owing to an oversupply of allowances, and even today prices remain around €8 (US\$9) per tonne of carbon dioxide — too low to spur a major revolution.

**“This is truly significant, and it's going to be extremely important in putting wind at the backs of delegates at the climate summit in Paris.”**

China has been experimenting with carbon trading at the provincial and city level, but implementing a national system could be particularly difficult. Researchers have had a hard time verifying even basic information about energy consumption and emissions, and this could increase the risk of early mistakes, says Glen Peters, a climate-policy researcher at the Center for International Climate and Environmental Research in Oslo. He co-authored a paper published last month suggesting that Chinese emissions may be lower than previously believed (Z. Liu *et al.* *Nature* 524, 335–338; 2015).

“There will be mistakes, no doubt, but lots of learning by starting early,” says Peters. “And when it is really needed to reduce emissions, a functioning framework will be in place.” ■



Wildfires have proliferated during California's ongoing drought.

### HYDROLOGY

# California faces arid future

*El Niño might bring relief, but droughts are likely to return.*

BY ERIKA CHECK HAYDEN

Three brown, withered lawns surround David Behar's home in Marin County, north of San Francisco in California. Behar, who directs the climate programme at the San Francisco Public Utilities Commission, no longer waters his grass — after several years with next to no rainfall, he gave in and brought greenery to his home in the form of drought-resistant plants instead. It is just one of the many adjustments that Californians have had to make as the state enters its fifth year of drought (see 'Dry state').

As of 30 September — the end of the 2015 'water year' — the state's water supplies are desperately low. The spring snowpack is the paltriest ever measured — by April it contained just 5% of a normal year's

water — and by the end of August the major reservoirs held 59% of their historical average. Wildfires have burned through almost three times more land than they do in an average year. And there are myriad ecological impacts, including more patches of dead foliage than usual in the canopies of the state's iconic giant sequoia trees.

Yet despite the severe lack of rainfall, the state's biggest consumer of water has fared remarkably well. Agriculture last year generated revenues that were just 1.4% lower than in 2013, when it took in a record US\$34 billion, according to the Pacific Institute, a think tank in Oakland, California. Agriculture-related employment reached a record high of 417,000, and the amount of land being used for farming had fallen by less than 10% from pre-drought levels.

But that has come at a cost. Farmers have



ZACKARY CANEPARI/NYT/REDUX/EV/INE

sustained production mainly by pumping up huge amounts of groundwater. “The massive overdraft of groundwater to make up for lost surface water has buffered farmers, and that can’t continue forever,” says Pacific Institute president Peter Gleick. In August, NASA reported that the massive increase in pumping has caused parts of the state to sink by 33 centimetres in less than a year. Some households that rely on wells have been left without water to shower or wash dishes.

Efforts to regulate water use are being hampered by a lack of data on groundwater withdrawals, Gleick says. “We don’t know who’s using how much,” he says. “There are really big gaps in the data.”

**CLOUDS ON THE HORIZON**

The weather looks set to change, although only in the short term. The US National Oceanic and Atmospheric Administration predicts that this winter will see a strong El Niño, a

storm pattern that has delivered extremely wet winters to California in the past. But plentiful rains are by no means certain, especially for regions outside southern California. “It remains to be seen whether an El Niño will provide relief this year,” Behar says.

But the rains are unlikely to last for long. A team led by climatologist Noah Diffenbaugh of Stanford University in California has used historical data and climate models to show that global warming is increasing the odds of the state seeing warm, dry conditions similar to those that spawned the current drought (N. S. Diffenbaugh *et al. Proc. Natl Acad. Sci. USA* **112**, 3931–3936; 2015).

The droughts could even last for many decades. By incorporating palaeoclimate data into climate models, Benjamin Cook of the NASA Goddard Institute for Space Studies in New York City and two co-authors are predicting droughts that could last as long as 35 years (B. I. Cook *et al. Sci. Adv.* **1**, e1400082; 2015).

“We’re in a new climate, and it’s a climate in which the probability of severe drought conditions is elevated,” Diffenbaugh says. “That recognition is really critical.”

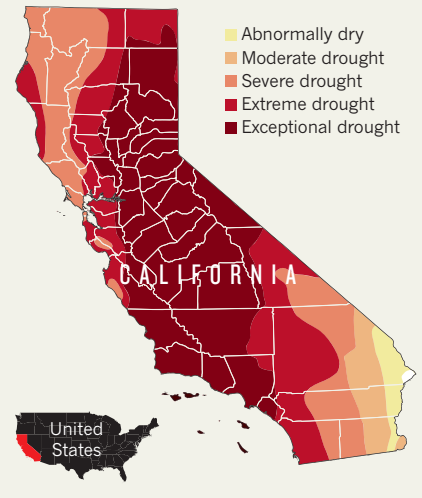
The state is working hard to respond to the dire warnings. In April, governor Jerry Brown called for a 25% reduction in municipal water consumption. Californians managed to save even more than that in both June and July, even though that is when irrigation needs tend to be highest. Last September, Brown signed legislation that takes the first steps towards regulating groundwater use by asking localities to make plans to ensure the sustainability of their groundwater supplies. However, some complain that he has not been tough enough. The path to sustainability does not need to be in place until 2040 — that is hardly an aggressive timeline, says Gleick.

And in June, the state’s water board ordered some of the most-senior water-rights holders — the farmers and irrigation districts entitled to draw first in times of shortage — not to take water from rivers and streams. Some irrigators have responded with lawsuits that are still working their way through the courts.

The state’s water-rights system is said to discourage conservation, because rights holders with priority may see their water allotments cut if they do not use their allocations in a given year.

**DRY STATE**

On 22 September, almost half of California was seeing exceptional drought conditions, and 25% was in extreme drought.



SOURCE: US DROUGHT MONITOR

**PUSH TO RECYCLE**

Meanwhile, Behar and other planners around the state are pushing technological fixes that range from less-water-intensive agriculture and more-efficient home appliances to treating wastewater for reuse. Orange County already pumps treated wastewater into its groundwater; San Diego is developing a similar system and, on 8 September, the San Francisco Public Utilities Commission approved a plan to recycle wastewater to irrigate Golden Gate Park.

Steven Ritchie, the commission’s assistant general manager for water, says that some regions are even looking into the long-discussed idea of desalination — a perennial option that is seldom used because it is energy intensive and therefore expensive. Ritchie says that one idea on the table for the region would be to cut the cost by desalinating brackish water from the San Francisco Bay Delta, rather than ocean water. Water produced in that way would cost about as much as that pumped from wells, Ritchie says, but would still be more costly than surface water. “The choice might be: expensive water, or no water,” Ritchie says. “We have to continue to plan for the future and diversify our supply; we cannot take anything for granted.” ■

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