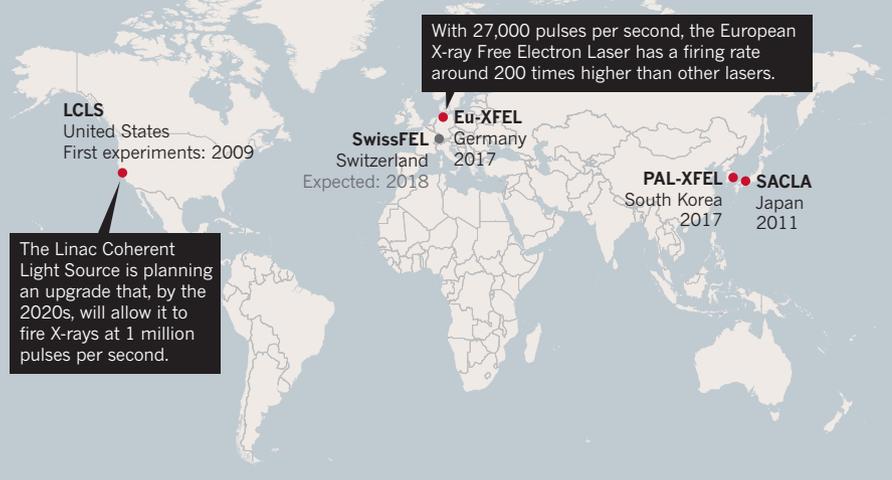


X-RAY LASER GUNS

Four operational facilities worldwide fire bright, X-ray laser light that can determine structures at atomic resolution. Each X-ray flash lasts around 100 femtoseconds — short enough to capture molecular motions.



SOURCE: EUROPEAN XFEL

▶ At the Hamburg XFEL, bunches of electrons are first accelerated down a 1.7-kilometre-long tunnel. Magnets then bend the electrons' path into wiggling slalom tracks, causing them to emit bunches of high-energy X-rays as they curve. The bright X-ray pulses are so intense that they destroy the samples they hit — but not before enough photons have been scattered to reveal the sample's atomic structure.

X-RAY MOVIES

In structure-determination experiments using conventional X-ray sources, molecules must be packed into crystals to scatter enough photons to deduce their structure. But the X-rays from XFELs are so bright that researchers can gather diffraction patterns from

crystals just a few nanometres in size, or even from non-crystalline clusters of molecules. This means that XFELs can study proteins that are hard to crystallize. And researchers can create movies of enzymes, viruses or catalysts in action by building up thousands of different snapshots of the same system taken at different timepoints — often by passing a jet of molecules in solution past an X-ray beam.

In 2015, for example, scientists using the LCLS reported eight snapshots of myoglobin, a muscle protein that binds oxygen, at a resolution of 0.18 nanometres. The images were taken a few picoseconds after a flash of light dislodged a molecule of carbon monoxide from its binding position on the protein (T. R. M. Barends *et al. Science* **350**, 445–450; 2015). On 14 August,

Ourmazd and his colleagues reported using X-ray scattering from single viruses at the LCLS to create a 3D movie at 9-nm resolution. It shows the motions of a virus as it reorganizes its genome so that the genetic material can squeeze through a tubular molecular structure — a process that occurs when the virus infects a cell (A. Hosseinizadeh *et al. Nature Methods* <http://dx.doi.org/10.1038/nmeth.4395>; 2017).

Work such as this depends on gathering many snapshots of identical particles in different conformational states to build up a composite picture of a particle's range of motion, explains physicist John Spence at Arizona State University in Tempe. He says that the European XFEL's high pulse rate will make this process much quicker — so structural data could be accumulated for much smaller individual particles. One of the European facility's most important milestones will be proving that diffraction patterns can indeed be collected from single particles at very high rates, says Mancuso. Because an intense X-ray burst obliterates each particle it hits in a passing spray or jet, it can be a challenge to ensure that the destroyed sample does not impede capture of the next shot. "We won't know that until we try," he says.

Hamburg's facility also has a larger capacity than its competitors: unlike other XFELs, it has three separate undulators to create simultaneous X-ray beams, with the 27,000 pulses per second distributed among them. But the European XFEL will reign for only a limited time: SLAC this year began construction of a \$1-billion project to create an even brighter laser beam that, by the early 2020s, will fire up to 1 million pulses each second. ■

Additional reporting by Mark Zastrow

GLOBAL WARMING

Legal threat raises stakes on climate forecasts

Australian lawsuit shows the difficulty of turning global-warming data into useful advice.

BY NICKY PHILLIPS

In a world-first case, an Australian court will next month begin hearing from shareholders who have sued a bank for failing to disclose its vulnerability to climate change.

The case highlights the fact that financial institutions around the world have been slow to acknowledge the risk that climate change poses to investments in infrastructure, agriculture and property. But researchers say the

lawsuit also shows that Australia and many other countries are currently unable to forecast the financial risks of climate change.

Shareholders Guy and Kim Abrahams filed the lawsuit on 8 August against the Commonwealth Bank of Australia, saying that the institution's 2016 directors' report did not adequately inform investors of climate-change risks. Their suit also seeks an injunction to stop the bank from making the same omissions in future annual reports.

Climate scientist Andy Pitman at the Centre of Excellence for Climate System Science in Sydney, Australia, says that researchers have been warning companies and governments for years about the need to invest in climate modelling and the related field of climate services, which provides forecasts and other information to public and private users. He says that it would take substantial investment and five to ten years of work for his team to provide banks with the climate information they need.

SCIENCE DIPLOMACY

US science envoy resigns

Energy researcher faults US president's positions on climate change and racism.

BY JEFF TOLLEFSON

An energy researcher at the University of California, Berkeley, resigned his post as a science envoy for the US Department of State on 21 August, citing President Donald Trump's "attacks on the core values of the United States".

In a resignation letter addressed to Trump, Daniel Kammen criticized Trump's equivocal response to violent protests by white supremacists in Charlottesville, Virginia, on 12 August. Kammen also condemned the Trump administration's "destructive" policies on energy and the environment, which he said have affected his work as a science envoy. They include Trump's decision to pull the United States out of the 2015 Paris climate pact.

"Your presence in the White House harms the United States domestically and abroad and threatens life on this planet," wrote Kammen, whose term was set to end next month. The first letters of each paragraph in his message spell out the word "impeach".

Former president Barack Obama created the science-envoy programme in 2010 to boost outreach and partnerships with predominantly Muslim countries. The effort, which is run by the state department, has since expanded to cover the globe. Kammen is one of 18 scientists who have participated in the envoy programme; his work in Africa and the Middle East has focused on national security, jobs and sustainable energy.

The White House did not immediately respond to requests for comment. A state-department official confirmed that Kammen was one of three active science envoys and said that the department is in the process of appointing more. The department declined to comment on Kammen's resignation letter.

Andrew Rosenberg, who heads the Center for Science and Democracy at the Union of Concerned Scientists in Cambridge, Massachusetts, says that Kammen's letter illustrates the moral and ethical quandaries that Trump's policies have created for scientists who serve the US government.

"For the science envoys like Dan, where you are going and representing the United States, it's particularly difficult," Rosenberg says. "It's a personal struggle that everyone has to go through." ■

DANIEL MUNOZ/REUTERS



Climate forecasts indicate that Australia will face an increased risk of severe droughts and bush fires.

To be useful, he says, the forecasts would need to be on a time scale that is specific to a business or government's climate vulnerabilities, such as a period of months to years, or on small spatial scales, such as the size of a farmer's field. "That's hugely challenging," he says. "It's the difference between building a car that travels around Sydney and building one that wins a Formula One Grand Prix."

In theory, it should be possible to make such forecasts, but "it's a huge undertaking to actually do it", says Pitman; and it would require high-performance supercomputers generating massive amounts of data.

A QUESTION OF SCALE

No country can yet produce climate forecasts on the scales and with the accuracy needed for detailed planning, says Simon Mason, a climate scientist at Columbia University's International Research Institute for Climate and Society in Palisades, New York. Even the best forecasts are highly uncertain, which makes it difficult to use them for planning, he says.

For instance, if a farmer's bank wants to know the probability that the farm might experience drought, a 10-year projection might suggest a 60% chance of more frequent droughts, says Mason. But that doesn't indicate how severe the droughts might be or whether they will lead to crop failures, he says. "These are exactly the types of questions that need a lot of research."

But Jacqueline Peel, who specializes in climate-change law at the University of Melbourne, Australia, says that companies are likely to face more lawsuits like the Australian one, meaning that they won't have time to wait for fine-scale, tailored models. She says that there is already sufficient information on

future warming scenarios for a business to disclose its vulnerabilities.

In Australia, researchers say that budget cuts haven't helped. A report released earlier this month by the Australian Academy of Science identified major gaps in climate research and climate services. The report found that Australia needs an additional 77 climate scientists, including 33 in modelling and 12 in climate services. The academy commissioned the report after the Australian

"These are exactly the types of questions that need a lot of research."

national science agency, the Commonwealth Scientific and Industrial Research Organisation (CSIRO), axed about 30 climate-science positions in 2016. CSIRO says it later added back 31 posts.

"There is a pressing need to improve projections of extreme-weather events to meet the demand for adaptation planning and disaster risk management," the report said.

The situation is better in Germany, the Netherlands and the United Kingdom, which have well-established, government-funded systems that provide climate information. But in the United States, researchers say that climate services are fragmented and struggle to meet the needs of governments or private-sector decision-makers. The Obama administration tried to launch a climate services division, but the US Congress blocked that effort.

"We haven't invested as much in climate services in time scales from several weeks to decades in the US," says John Furlow, who works on climate change and development at Columbia. ■