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Nuclear plants such as Tricastin will need to build fail-safe systems that operate even after an accident.

NUCLEAR POWER

France 'imagines the unimaginable'

Regulator demands safety upgrades for nuclear plants to guard against a Fukushima-like disaster.

BY DECLAN BUTLER

Nowhere did the alarm bells sounded by the Fukushima nuclear disaster ring more loudly than in France, which leads the world in nuclear energy. About three-quarters of its electricity comes from nuclear power stations, and it is one of the main exporters of reactors and related technology.

Now it is leading the way in setting radical

safety standards for the industry, in an effort to ensure that the disaster in Japan on 11 March 2011 could never be replayed on French soil.

Last week, the country's nuclear regulator imposed what are perhaps the toughest safety measures so far in response to the Fukushima accident. In a novel approach, it will require all power plants to build a set of safety systems of last resort, contained in bunkers that will be hardened to withstand more extreme

earthquakes, floods and other threats than plants themselves are designed to cope with.

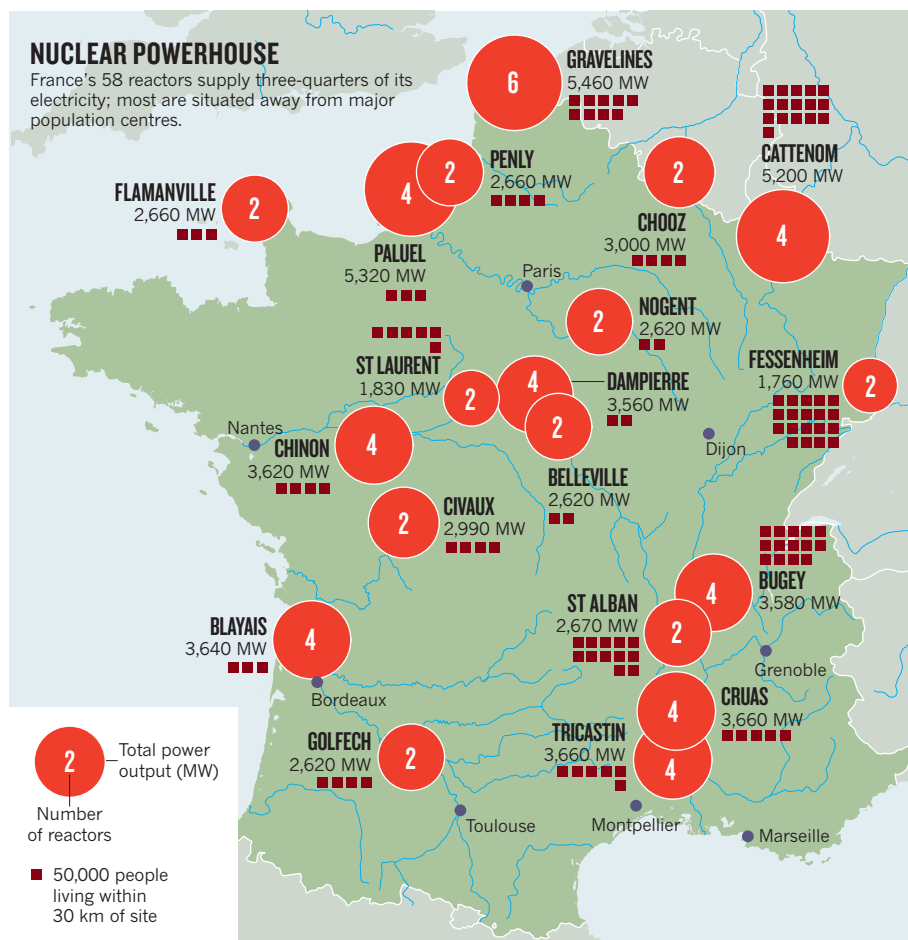
It will also adopt a proposal by Électricité de France (EDF), France's sole nuclear power plant operator, to create an elite force that is specifically trained to tackle nuclear accidents and could be deployed to any site within hours. Both moves respond to the main lessons of Fukushima: that the magnitude of external threats can far exceed those anticipated; that these threats can knock out multiple safety measures; and that to prevent a serious accident degenerating into a catastrophe, it is vital to ensure that key safety capacities — such as a control room, emergency generator and coolant system — remain in working order.

These and a raft of other measures are outlined in a 336-page report published by France's independent Nuclear Safety Authority (ASN), based in Paris, on 3 January (see go.nature.com/ytkvto). The report has been submitted to the European Commission as part of ongoing European Union (EU) 'stress tests' of all its member countries' reactors. The ASN report bluntly states that despite existing safety measures, a loss of power or cooling systems at some French plants could result in a "core meltdown within a few hours in the most unfavourable cases".

Keeping systems running in the crucial hours after an accident will be a core doctrine of French nuclear safety in the future. "If you can get the water flowing, you can buy time" and thus avoid the meltdown that made the Fukushima accident so serious, says Martial Jorel, director of reactor safety at the Institute of Radioprotection and Nuclear Safety (IRSN) in Fontenay-aux-Roses near Paris, which gives scientific advice to the ASN. The ASN report incorporates many IRSN recommendations made in November 2011 (see go.nature.com/b3tjru). "In France, we're saying, 'imagine the unimaginable'," says Jorel. The current basis of nuclear safety is 'defence-in-depth', in which multiple levels of protection and redundancy are intended to guard against a serious accident, he adds. "But at Fukushima, all of those lines of defence collapsed. The accident has thrown into question all of our safety rules, our ways of thinking."

NATURE.COM
Nature's interactive graphic of the world's nuclear plants:
go.nature.com/hgicgt

Like nuclear regulators in other countries, which are also taking stock of safety, the ASN intends to review and reinforce ►



► conventional measures such as flood-protection barriers. It has also ordered better safety and emergency-response training of plant staff, and a complete review of reactor cooling systems.

The bunker concept is different, however, because it short-circuits the traditional approach to safeguarding against estimated levels of risk. Irrespective of their perceived vulnerability to external threats, plants will need to be equipped with this 'hard core' of protected control rooms, generators and pumps, as well as hardened reservoirs of coolant.

This circumvents the delays and compromises inherent in setting new estimates of seismic, flood or other risks, which requires years of discussions between the regulator, industry and expert advisers, says Jorel. Predicting risk is an imperfect art, and the

bunker concept should protect against any other unforeseen, low-probability event. "It's far easier to design and build a system of last resort than to try to address every potential problem," he says.

The new measures are part of a shift in the emphasis of nuclear safety in the wake of Fukushima, from preventing a nuclear accident to stopping one from spiralling out of control — and mitigating the damage should the worst occur, says nuclear engineer Laurent Stricker, chairman of the World Association of Nuclear Operators (WANO) and a senior adviser to EDF. WANO, which was created as an international forum on nuclear safety in the aftermath of the 1986 Chernobyl accident, announced in November that it would increase its staff from 140 to 415 to address this broader mandate.

France's strategy is also likely to influence the global debate on nuclear safety, with the

bunker safety system and rapid-response team possibly gaining traction internationally, say experts. Stricker endorses both concepts, and adds that WANO will encourage its members to consider creating such specialist response teams in key regions around the world.

Many of the national reports for the EU stress test have been published only in the past few weeks, to meet the commission's deadline of 31 December 2011. But it already seems clear that France's proposals are the most comprehensive. They contrast sharply with those from the United Kingdom, for example, which were released last week and concluded that no major changes were immediately needed at the country's ten plants.

This may reflect differences in the reactors used by each nation, says Andrew Sherry, director of the Dalton Nuclear Institute at the University of Manchester, UK. France uses pressurized water reactors (see 'Nuclear powerhouse'), whereas almost all of Britain's are advanced gas-cooled reactors, which progress to meltdown more slowly in the event of an accident, buying more time to mount an emergency response. "What might be appropriate in France might not be appropriate in the United Kingdom," Sherry says. Experts from EU member states will now peer-review each other's reports and carry out site inspections of nuclear plants, to assess the safety of nuclear reactors across the EU. That exercise is scheduled to be completed in June.

Meanwhile, EDF has said that it fully backs the new rules, but its initial estimate is that adopting them will cost €13 billion (US\$16.6 billion). It must submit initial designs for its new safety features to the ASN by 30 June. The big question, says Jorel, is how fully the planned measures will be implemented.

Yves Marignac, a Paris-based consultant on nuclear and energy issues, says that the French report is a "thorough analysis", particularly in its assessment of the existing safety shortcomings at plants. But he says that the concepts of a protected bunker and rapid-response force will take time to flesh out, and are not likely to be a quick solution. "It's technically wrong to sell politically the idea that billions of euros could fix the problem in the coming months," he says.

Sherry is convinced, however, that the Fukushima accident has been a wake-up call for the nuclear industry. "What's quite clear to me is that they are taking things very seriously." ■



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