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Dozens of Reactors in Quake Zones

Japan, Taiwan Account for Most Sites in High-Activity Areas; 'Large Margins of Safety' Factored In at U.S. Plants

By MAURICE TAMMAN, BEN CASSELMAN and PAUL MOZUR

Dozens of nuclear reactors operate in earthquake-prone regions around the world, including at least 14 in high-hazard areas, a Wall Street Journal analysis shows.

Most of those plants are in just two places: Japan and Taiwan, both islands with limited natural resources that have chosen the risks of nuclear calamity over complete dependence on foreign sources of energy.

Threat by Land and Sea

Dozens of nuclear reactors operate in earthquake-prone regions around the world. Among them, least 14 are in high-hazard areas. See a map and database of all of them.



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Both are now being forced to re-evaluate that calculation amid Japan's unfolding nuclear crisis. A poll in Taiwan taken Monday—four days after a 9.0 magnitude earthquake off the coast of Japan triggered massive devastation and deadly tsunamis—showed that 55% of respondents lacked confidence in the island's nuclear facilities.

The Wall Street Journal looked at the location of more than 400 nuclear reactors across the world—as well as another 100 that are either planned or being built—using data provided by the World Nuclear Association, a London-based industry group. The Journal then used data from the Global Seismic Hazard Program, a 1999 study by the U.S. Geological Survey and the

Swiss Seismological Service, to determine the earthquake risk at each plant.

According to the analysis, 48 of the world's operating nuclear reactors, or 11%, are in areas known to have at least moderate earthquake activity. These include the Fukushima Daiichi reactors at the center of Japan's nuclear crisis. Fourteen, or 3%, are in areas of high activity. Ten

of those are located within a mile of a coastline, making them at risk for both earthquakes and tsunamis.

Japan and Taiwan together account for 10 of the 14 high-activity reactors. But the U.S. has two reactors in such areas and Slovenia and Armenia has one each. Armenia has another planned.

The nuclear industry says reactors world-wide are built to withstand the most powerful quakes thought possible at each location, plus usually an added safety factor in case those projections are wrong. The Fukushima Daiichi plant in Japan apparently survived last week's powerful earthquake intact, only to fall victim to the aftermath.

"There are large margins of safety factored into our plants," said Tom Kauffman, a spokesman for the Nuclear Energy Institute, a U.S. trade group.

Late Friday, the U.S. Nuclear Regulatory Commission issued an information notice that represents its first official attempt to explain the event at Fukushima Daiichi to operators of the 104 commercial reactors licensed in the U.S.

The notice also included a recitation of steps American regulators have taken, over the years, to make sure that reactors are prepared for natural disasters or other extraordinary events—a section intended to reassure the public that U.S. regulators and industry are prepared. Preparation includes the development, the NRC said, for restoring cooling water to reactor vessels and spent fuel pools, both of which have suffered failures in Japan.

Of the more than 100 nuclear reactors in the U.S., only the two at Diablo Canyon Power Plant on the central California coast, are in a high-activity area. The Humboldt Bay plant on California's northern coast, was shut down in 1976 because of earthquake fears but still holds some spent nuclear fuel on the site.

Kory Raftery, a spokesman for Diablo Canyon operator [Pacific Gas & Electric Co.](#), said the plant is designed to withstand a 7.5-magnitude quake from the nearby San Andreas fault. Several other less well-known faults run even closer to the plant, including one less than a mile away that was discovered in 2008, but the reactors have been tested to withstand projected quakes from those as well.

But scientists sometimes have underestimated how powerful quakes can be. The temblor that struck Japan was more than 10 times bigger than the Daiichi plant had been tested to withstand. In 2007, the world's biggest nuclear plant, Japan's Kashiwazaki-Kariwa, was damaged after it was hit by a quake far stronger than its designers anticipated.

Antinuclear activists in Japan have long warned that the country's reactors are more vulnerable to earthquakes than operators and government regulators acknowledge.

"A nuclear disaster which the promoters of nuclear power in Japan said wouldn't happen is in progress," said the Citizens' Nuclear Information Center, an antinuclear group based in Tokyo, in a statement this week.

Nuclear power has also been controversial in Taiwan, where all four of the island's existing reactors are built near major fault lines. Two more reactors are under construction near the densely populated cities of Taipei and New Taipei.

The Atomic Energy Council, Taiwan's nuclear regulator, said all its plants are built to withstand earthquakes of magnitude 7 or above and tsunamis of 12 to 15 meters. Both the regulator and government-owned nuclear operator Taiwan Power Company have pledged to take quick steps to increase safety margins if necessary.

Energy experts say it may be hard for Japan and Taiwan to move away from nuclear power. "Developing nuclear is a way to both diversify and reduce dependence on imported oil gas and coal," said Jone-Lin Wang, managing director of global power for the energy consulting firm IHS CERA and a native of Taiwan.

To be sure, most countries have tried to locate nuclear plants outside of quake zones.

"There are not that many places where reactors are built on these major fault zones," said Ben van der Pluijm, a geologist at the University of Michigan. "Japan is probably the poster child."

—Rebecca Smith and Dionne Searcey contributed to this article.

Write to Maurice Tamman at maurice.tamman@wsj.com and Ben Casselman at ben.casselman@wsj.com

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