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MRS Bulletin

Nuclear power and nuclear safety

Recently, I was involved in a four-year-long National Academy of Sciences study of lessons learned from Fukushima. One scenario we studied was an accident that almost happened at Fukushima—a spent-fuel fire after a spent-fuel pool boiled dry. Five years ago, the release of 2% of cesium-137 (30-year half-life) from the three Fukushima core meltdowns caused the long-term relocation of about 100,000 people. A spent-fuel pool fire could have caused a hydrogen explosion, resulting in the release of cesium-137 directly to the atmosphere and necessitating the relocation of millions to possibly tens of millions. The losses would be comparable to the cumulative investment in all the world's nuclear power plants. The hydrogen would be generated by the reaction of steam with the hot zirconium alloy cladding of the uncooled spent fuel above a temperature of about 1000°C. The obvious question is whether an alternative cladding could be developed that does not have this unfortunate property—for example silicon carbide?

In 1974, when I first became involved with nuclear issues, the US Atomic Energy Commission projected a US nuclear capacity of 3000 GWe in the year 2016, with growth at a rate of 100 GWe/year between 2010 and 2016. Today, US total nuclear capacity is about 100 GWe, the same as 25 years ago. Global nuclear capacity has been flat as well. The accidents in 1979 at Three Mile Island and in 1986 at Chernobyl were only one cause of this truncation of the growth of nuclear power.

A second is that the growth of US electricity consumption slowed dramatically in the 1970s. It had doubled every decade between 1920 and 1970, but in the four decades between 1975 and 2015, it doubled only once more. As a result, it would take only 500 GWe of nuclear capacity to generate as many kilowatt-hours as all US power plants generate today.

A third reason why there has been no net increase in global nuclear capacity since 1990 is economics. Paying off the investment in a nuclear power plant accounts for most of the cost of nuclear power, and for plants completed in 1990, this cost was four times the cost of plants completed in 1975. Part of this increase may be attributable to more stringent regulations after the Three Mile Island accident; a part also is attributable to a lack of economies of scale in the number of plants being built. In China, where on average, four nuclear power reactors have been brought online each year since 2010, nuclear capital costs are less than half of US costs.

Even after the capital cost is paid off, as is the case for most current nuclear power plants in the United States, the operating cost is still comparable to the cost of natural gas-fired and wind plants. The fuel cost of nuclear power is remarkably low, about half a cent per kilowatt-hour, but labor costs are high. Here safety is again a factor. If it wasn't, it would be hard to explain why it takes about 1000 people to operate a nuclear power plant that is refueled only once every 18 months to two years.

The future of nuclear power is uncertain, in large part, because there has not been a definitive solution to the safety problem.

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