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World Nuclear Industry
Renaissance or Decline?

Mycle Schneider and Antony Froggatt[1]

The triple disaster that hit the Fukushima Daiichi Nuclear Power Station on 11 March 2011 has had a profound impact on public opinion and nuclear policy far beyond Japan. In China, the government froze all new nuclear projects. In the Republic of Korea public support for nuclear power plummeted. Belgium and Germany confirmed nuclear phase-out legislation by 2025 and 2022, respectively. The Netherlands and Switzerland have abandoned new reactor construction projects. And governments in many other countries are reviewing their nuclear plans.

The first World Nuclear Industry Status Report, published in 1992 to assess the impact of the Chernobyl disaster on the global nuclear industry, predicted a dramatic slowdown of nuclear expansion and asserted that "the market niche that nuclear power once held has in effect gone". In 2012, reality has confirmed that assessment. Nuclear power's competitors—most notably wind and solar generation—are rapidly gaining market share as long lead times, construction delays, cost overruns, and safety concerns have combined to make nuclear power a risky investment that the markets are increasingly unwilling to make.

As of early 2012, a total of 31 countries were operating nuclear fission reactors for energy purposes—one more than in 2010—with the Islamic Republic of Iran starting up its Bushehr reactor in 2011. Nuclear power plants generated

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1 This briefing paper is based on Mycle Schneider and Anthony Froggatt, "2011–2012 World Nuclear Industry Status Report", *Bulletin of the Atomic Scientists*, vol. 68, no. 5. It summarizes the findings of the World Nuclear Industry Status Report 2012 that can be found at <www.worldnuclearreport.org>.

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2,518 terawatt-hours (or billion kilowatt-hours) of electricity in 2011,[2] the same amount as in 2001 and 5.3% less than the historic maximum in 2006. The maximum share of nuclear power in commercial electricity generation worldwide was reached in 1993 with 17%; it had dropped to 11% by 2011, a level last seen in the early 1980s.

As of 1 July 2012, a total of 429 nuclear reactors were operating in 31 countries, down 15 from the maximum of 444 in 2002. The current world reactor fleet has a total nominal capacity of about 364GW (or thousand megawatts). There are large uncertainties to these figures, mainly stemming from the undefined future of the 50 Japanese nuclear reactors that are officially still operating but were all, save one, shut down as of 10 July 2012.

Currently, 13 countries are building nuclear power plants, which is two less than a year ago. As of July 2012, 59 reactors are under construction. For perspective, the peak of units in progress was 234 in 1979. Over the past year, the most spectacular construction freeze took place in China. No new concrete base was poured in the country after 11 March 2011.

The total capacity of units now under construction in the world is about 56GW, down by about 6GW compared with a year ago. A closer look at currently listed projects illustrates the level of uncertainty associated with reactor building:

- Nine reactors have been listed as under construction for more than 20 years. The US Watts Bar-2 project in Tennessee holds the record; construction started in December 1972, was subsequently frozen, and is now scheduled to be finished in 2015. The Argentinian Atucha-2 reactor comes in second place; it was started 31 years ago.
- Four other reactors—two Taiwanese units at Lungmen and two Indian units at Kudankulam—have been listed as under construction for 10 years or more.
- At least 18 of the units listed by the International Atomic Energy Agency (IAEA) as under construction have encountered construction delays.
- Nearly three quarters of the units under construction are located in just three countries: China, India, and the Russian Federation. None of these countries has historically been very transparent or reliable about information on the status of their construction sites. It is nevertheless known that half of the Russian units listed are experiencing multiyear delays.

Lead times for nuclear plants include not only construction times but also long-term planning, lengthy licensing procedures in most countries, complex financing negotiations, and site preparation.

In the absence of any significant new construction and grid connections over many years, the average age of operating nuclear power plants has been increasing steadily and now stands at about 27 years.[33] Some nuclear utilities envisage average reactor lifetimes of beyond 40 years and even up to 60 years.

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2 Nuclear capacity and electricity generation figures are the authors' estimates based on the IAEA's Power Reactor Information System (PRIS) online database, available at <www.iaea.org/programmes/a2/index.html>.

3 [3] "Startup" is synonymous with grid connection and "shutdown" with withdrawal from the grid.

In the United States, reactors are initially licensed to operate for a period of 40 years. Nuclear operators can request a license renewal for an additional 20 years from the Nuclear Regulatory Commission (NRC). As of March 2012, 72 of the 104 operating US units have received an extension and another 15 applications are under review.

Many other countries, however, have no time limitations on operating licenses. In France, where the country's first operating pressurized water reactor started up in 1977, reactors must undergo in-depth inspection and testing every decade. Only two plants—Fessenheim and Tricastin—have so far received a permit to extend operational life from 30 to 40 years. President François Hollande, however, has vowed to close down the two Fessenheim reactors by the end of 2016, before they reach their 40-year lifetime marks in 2017. Even if all of the oldest units were approved to operate for 40 years, 22 of the 58 French operating reactors will reach that age by 2020.

After the Fukushima disaster, it is obvious that the operating age requires a second look. The troubled Fukushima Daiichi units were initially connected to the grid between 1971 and 1974. Four days after the accidents in Japan, the German government ordered the shutdown of seven reactors that had started up before 1981. The exclusive selection criterion was operational age. Other countries did not follow, but it is clear that the Fukushima events had an impact on previously assumed extended lifetimes in other countries, including Belgium, Switzerland, and Taiwan.

Assuming a general lifetime of 40 years for worldwide operating reactors, one scenario for capacity projection indicates that, beyond the 59 units now under construction, 67 additional reactors would have to be finished and started up before 2020 to maintain the status quo. Such an achievement appears unrealistic given existing constraints on the fabrication of key reactor components, the difficult financial situation of the world's main reactor builders and utilities, the international economic crisis, and generally hostile public opinion. As a result, the number of reactors in operation will decline over the coming years unless lifetime extensions beyond 40 years become a widespread standard. The scenario of generalized lifetime extensions is less likely after Fukushima.

To renew the aging world nuclear fleet, nuclear utilities would need to surmount a number of major problems, including a short-term manufacturing bottleneck, a shortage of skilled workers, regulatory uncertainty, a skeptical financial sector, and negative public opinion. The aftermath of the Fukushima disaster, the threat of nuclear terrorism, and the world economic crisis have only exacerbated these problems. A realistic scenario that leads to an increase in nuclear's share of the world's electricity is hard to imagine.

The reaction to the Fukushima accident was markedly different from the response to the earlier major accidents. In 2011 at least 19 reactors were shut down definitively, of which 18 are a direct consequence of Fukushima, and only seven reactors were started up. After Chernobyl, Germany was the first country to start up a new reactor; after Fukushima, that same country shut down eight reactors. Only 14 months after its nuclear disaster, Japan has only a single reactor operating with one more authorized to start up, at least for now.

Safety is not the only issue that the nuclear industry has to deal with. Since the beginning of the nuclear age, there has been a clear global trend: Construction times for nuclear power plants have increased. The reasons for gradually lengthening construction periods

are not fully understood. It is clear that continuously increasing safety requirements and lengthy legal cases have played a role. Growing system complexity is also likely to have had an impact on costs.

After the Three Mile Island accident in 1979, construction times in the United States escalated from an average of six years to almost 12 years. In France, construction times were five to six years between 1970 and 1985. In the second half of the 1980s, they doubled. The eternal Tennessee Valley Authority (TVA) project Watts Bar-2 in Tennessee is an interesting illustration of runaway construction times and costs. The reactor that was ordered in 1970 and was expected to enter operation in 1976, is still under construction and, according to NRC, will not be ready to begin operation until 2015 or 2016.

The Watts Bar-2 project might be extreme, but it is not an isolated case. In 1989, the German reactor builder Siemens and its French counterpart Framatome (now integrated into Areva) formed a consortium for the development and marketing of the European Pressurized Water Reactor, or EPR. The concrete for the first EPR was not poured until August 2005—and that project was not in Germany or France, but in Finland. The Olkiluoto-3 unit was planned to start up in 2009. By early 2012, following a long series of management problems, quality-control issues, component failures, and design difficulties, Olkiluoto-3 was about five years behind schedule and cost estimates had risen to between $7.27 billion and $8 billion (€6 and €6.6 billion)—or 100 to 120% over budget.

Nuclear power has been perceived by many financial institutions as a higher-risk investment than conventional or new renewable electricity-generating sources. In the weeks and months following the nuclear meltdowns at Fukushima, many in the financial community made clear their views on the expected impact on global nuclear-sector development. In its April 2011 analysis of the accident, the Swiss banking group UBS noted:

> Before the Fukushima accident, [the Tokyo Electric Power Company] was viewed as a low-risk regulated utility, mainly bought for its stable earnings and dividends. However, the events at Fukushima have led to an 80 percent decline in its share price and discussions about the future viability of the company. Such a quick change in prospects would have been unlikely if Fukushima had been a traditional thermal generation plant. This additional risk linked to nuclear exposure has not, it seems to us, been properly priced in by the market.[4]

Predictions on the possible importance and impact of Fukushima have been borne out over the past 18 months, with little global appetite for construction of new nuclear reactors. There is no single reason for the lack of new orders, but it is clear that in those parts of the world that have more liberalized electricity markets, an important factor is the rising financial costs of nuclear projects. Linked to those costs is increased scrutiny from the financial sector. As the chief executive of E.ON, one of the largest nuclear operators in Europe, put it: "Ultimately the driver for investment [in new reactors] will be the cost of capital, not politics. Definitely, the cost of capital will be higher after Fukushima".[5]

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4 *Q-Series: Global Nuclear Power, Can Nuclear Power Survive Fukushima?,* UBS Investment Research, <www.scribd.com/doc/54263128/Can-Nuclear-Power-Survive-Fukushima-UBS-Q-Series>.

5 Sayeh Tavangar, *"*Europe Will Return to Nuclear Power Some Day, Enel Chief Says", *Nucleonics Week*, 16 June 2011.

Three major rating agencies—Moody's, Standard and Poor's, and Fitch—assess the financial strength of companies and governmental entities and their ability to make payments on their debt. The impact of Fukushima on the nuclear companies is obvious. The Tokyo Electric Power Company, or Tepco, has moved from an AA rating prior to the event to a B+ rating today. The world's largest reactor builder, Areva, started declining long before 11 March 2011 and plunged from an A rating in 2009 to BBB-, only one notch above "junk" status. The decision by the German engineering company Siemens to exit its nuclear business in September 2011 was actually seen by Moody's to be credit positive.

Many major electrical utilities are now fully or partially owned by the private sector. Their stock valuations did poorly before Fukushima but have plunged after the disaster. The share price of the owner and operator of Fukushima Daiichi, Tepco, has not surprisingly lost 96% of its share value since 2007. The shares of the world's largest nuclear operator, EDF, have lost 82% of their value over the same period, while the largest nuclear builder, Areva, has lost 88% of its stock value.

While the loss of Tepco would be expected, the performance of other major nuclear companies is rather surprising. As reflected in the declining credit rating, Areva has done particularly badly over the past year, with a net income of €883 million in 2010[6] shifting to a loss of €2.4 billion in 2011. The Republic of Korea's Kepco has also experienced significant losses in the past few years and has stated that electricity prices are so low that it cannot cover its operating costs. Consequently, its financial prospects are beholden to national policy; the government controls 51% of the firm's shares.

Given the extent to which the financial risks of nuclear investments are now understood by the utilities and the financial sector, it is clear that nuclear plants will not be built without government support. In a revealing presentation, a representative of the French bank BNP-Paribas concluded that "significant government sponsorship will be required in most markets to implement new nuclear".[7]

After Chernobyl, the nuclear industry struggled for 10 years to develop a survival strategy. It was sold to the world as revival. In reality, however, many nuclear companies and utilities were facing great difficulty before the disaster at Fukushima. Eighteen months after 11 March 2011, it is likely that the decline of the industry will only accelerate. It appears increasingly obvious that nuclear systems are not competitive from economic, environmental, and social points of view.

The nuclear establishment has had a long history of failing to deliver on exuberant promises and glossing over glaring problems. Today, installed nuclear capacity is not even one tenth of what the IAEA projected in the 1970s for the turn of the century.

There are now around 400 nuclear power reactors in operation. Because financial and other realities militate strongly against new nuclear construction, the nuclear industry is pushing to keep existing units operating as long as possible. One third of the nuclear countries generated their historic maximum of nuclear electricity in 2011, raising troubling

6 It should be noted that even in pre-Fukushima 2010, Areva registered an operational deficit of €423 million.

7 M. Muldowney, "How Will Financing Be Secured in the Future?", BNP-Paribas, presented at the European Nuclear Forum, Brussels, 19 March 2012.

questions about the depth of the nuclear safety assessments—so-called “stress tests”—carried out around the world after the Fukushima disaster. The future of the nuclear industry increasingly depends on cash-abundant state economies, healthy and wealthy utilities, experienced builders with a large knowledge base, favorable public opinion and generous safety authorities. Which countries would provide these conditions in the future?

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