

# Nuclear Power Versus Renewable Energy—A Trend Analysis

By ANTONY FROGGATT

MYCLE SCHNEIDER



The year 2013 saw a number of developments that dramatically widen the gap between nuclear power and renewable energy trends. This is particularly important at the current time as Governments around the world are formulating their post-2020 climate change mitigation policy in preparation for the UNFCCC summit in Paris, France, in December 2015. The importance of action on climate change is underlined in the 5th Assessment Report (AR5) of the International Panel on Climate Change (IPCC), which suggests that under current policies, CO<sub>2</sub> emissions from the energy sector could double or triple by 2050.<sup>1</sup> Reducing emissions to a level unlikely to cause dangerous climate change will require a significant drop in the energy intensity of global economies, along with the rapid reduction in the use of fossil fuels. The IPCC report also notes that decarbonizing the power sector is a key component of cost-effective mitigation

strategies. It suggests that the share of low-carbon energy sources, defined in the report as carbon capture and storage, renewable energy, and nuclear power, needs to increase from approximately 30% to 80% of electricity generation by 2050. While the report does not make recommendations of low-carbon power options' relative priority, it does state that many renewable energy technologies have demonstrated substantial performance improvements and cost reductions, and a growing number of renewable energy technologies have achieved a level of maturity to enable deployment at significant scale.

On the other hand, the IPCC notes that nuclear energy is a mature low-greenhouse gas emission source of baseload power, but its share of global electricity generation has been declining for the past twenty years. While nuclear power could make an increasing contribution to low carbon energy supply, a variety of barriers and risks exist including operational risks, and associated concerns like the environmental impact of uranium mining, financial and regulatory risks, unresolved waste management issues, nuclear weapons proliferation concerns, and adverse public opinion.

It is these differences along with significantly larger public support for renewable energy than for nuclear power that are leading to increasingly

<sup>1</sup>IPCC, "AR5, WG III," International Panel on Climate Change, 2014.

widely diverging investment and deployment trends.

There are 31 countries in the world operating nuclear power plants<sup>2</sup> with a total of 388 reactors having a combined installed capacity of 333 GW.<sup>3</sup> The 388 operating reactors are 50 fewer than the peak in 2002, while the total installed capacity peaked in 2010 at 367 GW before declining to the current level, which is comparable to levels last seen two decades ago. Annual nuclear electricity generation reached a maximum of 2660 TWh in 2006 and dropped to 2359 TWh in 2013, which represents however a stabilization (+0.6%) after two consecutive years of significant decline (−4% in 2011, −7% in 2012), corresponding to a level previously seen in 1999.

The nuclear share of the world's power generation declined steadily from a historic peak of 17.6% in 1996 to 10.8% in 2013, while its share of global commercial primary energy production declined from the 2012 low of 4.5%, a level last seen in 1984,<sup>4</sup> to a new low of 4.4%. In the absence of major new-build programs apart from China, the unit-weighted average age of the world operating nuclear reactor fleet continues to increase and by mid-2014 stood at 28.5 years. Furthermore, over 170 units (44% of the total) have operated for 30 years or more; of those units, including 39 that have run for over 40 years.

Fourteen countries are currently building nuclear power plants, almost two-thirds (42) of these are in three countries: China, India and Russia. In 2013, construction started on a reactor in Belarus for the first time, while Taiwan has halted construction work at two units. As of October 1, 2014, 67 reactors were under construction with a total capacity of 65 GW. The average building time of the units under construction stands at seven years.

<sup>2</sup>Unless otherwise noted, the figures indicated are as of July 1, 2014.

<sup>3</sup>All figures are given for nominal net electricity generating capacity. GW stands for gigawatt or thousand megawatt.

<sup>4</sup>According to BP, "Statistical Review of World Energy," June 2014.

However, at least 49 have encountered construction delays, most of them significant (several months to several years). For the first time, major delays—several months to over two years—have been admitted on three quarters (20/27) of the construction projects in China. Twenty-eight years after the Chernobyl disaster, none of the next generation or so-called Generation III or III+ reactors has entered service with construction projects in Finland and France many years behind schedule. In 2013, construction began on ten reactors, including four units on two sites in the United States, a first in 35 years. Until the end of September 2014, a second unit got underway in Belarus and a third one in UAE, while work started on a small 25-MW pilot plant in Argentina.

Construction costs are a key determinant of the final nuclear electricity generating costs and many projects are significantly over budget. Investment cost estimates have increased in the past decade or so from US\$1000 to almost US\$12 000 per installed kilowatt. The latter, record figure is for the two proposed European Pressurized Water Reactors (EPRs) at Hinkley Point in the U.K. Construction cost estimates increased in virtually all countries, including China, Finland, France, and the United Arab Emirates. In the United States, the builder of two units at the VC Summer site in South Carolina has asked for the seventh price increase since 2009 to meet rising costs. The analogous Vogtle project in Georgia has reported modest cost increases but the project's independent construction monitor has expressed concern these may be understated. Both projects are also significantly behind the original schedule, although they only started construction in 2013.

In some countries (including France, Germany, the United States, and Sweden), operating costs have escalated so rapidly that the average reactor's operating cost is barely below, or even exceeds, the normal band of wholesale power prices. The largest nuclear operator in the world, the

French state-controlled utility Électricité de France (EDF) experienced an income deficit of about euro 1.5 billion (US\$2 billion) in 2012, because tariffs did not cover the running costs. According to the French Court of Accounts, the cost of generating nuclear power increased by 21% between 2010 and 2013, from 49.6 euro/MWh to 59.8 euro/MWh (US\$67.8–81.7/MWh), an increase of 16% in real terms.<sup>5</sup> In Germany, operator E.ON decided to close one of its reactors seven months earlier than required by law because of projected income does not cover the costs. However, it is not just in Europe where operating costs are rising. In the United States, utilities decided to retire at least five reactors that no longer generate electricity at competitive cost, including two units with operating licenses valid beyond 2030. One study identifies up to 38 United States units threatened by the same fate.<sup>6</sup>

While the recent history of nuclear power is one of decline, the renewable industry remains buoyant with global investments reaching US\$214 billion in 2013, despite decreasing for the second year in a row, down from a record US\$300 billion in 2011, the investment was still four times the 2004 amount.<sup>7</sup> The decrease, however, was four-fifth due to lower costs and only one-fifth due to lower sales. As in 2012, with US\$54.2 billion spent, China has been the largest investor in 2013. Some countries showed sharp declines in expenditures over the previous year, like Italy (−76%), Germany (−57%) and the United States (−23%). While, some countries increased investments sig-

<sup>5</sup>Cour des comptes, "Le coût de production de l'électricité nucléaire—Actualisation 2014," Communication à la Commission d'Enquête de l'Assemblée Nationale, May 2014.

<sup>6</sup>Mark Cooper, "Renaissance in reverse: Competition pushes aging U.S. nuclear reactors to the brink of economic abandonment," July 18, 2013, see <http://will.illinois.edu/nfs/RenaissanceinReverse7.18.2013.pdf>, accessed May 22, 2014.

<sup>7</sup>UNEP-BNEF, "Global Trends in Renewable Energy Investment 2014," Frankfurt School and United Nations Environment Programme Collaborating Centre and Bloomberg New Energy Finance, April 2014.

nificantly with Japan (+75%), the United Kingdom (+46%) and Australia entering the Top Ten for the first time. According to an assessment by the OECD's International Energy Agency, during 2000–2013 global investment in power plants was split between renewables (57%), fossil fuels (40%) and nuclear power (3%).<sup>8</sup>

Globally, since 2000 the annual growth rates for wind power have averaged 25% and for solar photovoltaics 43%. This has resulted in 32 GW of wind and 37 GW of solar being added. This compares to a decline in nuclear generating capacity of 19 GW between 2013–2000 in 2013 alone. In the European Union, in the same time frame, wind increased by 105 GW outpacing natural gas plants with 103 GW and solar with 80 GW, while nuclear decreased by 13 GW. In 2013, wind and solar added 11 GW each to the European grids, while all fossil fuels decreased and nuclear remained stable.<sup>9</sup> China, by the end of 2013, had a total of 91 GW of operating wind power capacity, 18 GW of installed solar capacity, and 16 GW of nuclear power. In 2013, China added a new world record of at least 12 GW of solar in just one year (versus 3 GW of nuclear), overtaking Germany's previous 7.6 GW record and exceeding cumulative additions of the United States, since it invented photovoltaics in the 1950s. China now aims at 40 GW solar and will probably exceed the 100 GW wind power target for 2015.

It is important to note the different characteristics of electricity generation. Those critical of renewable energy highlight the variable output of some technologies (wind power and photovoltaics—but not all solar power, since solar–thermal–electric plants typically have built-in heat storage so they can provide power into or through the night). A consequence of

variability is the lower output per installed kilowatt over the year than that of traditional fossil-fueled or nuclear power stations, which more often than not try to operate as base-load plants operating, under normal conditions, continually. However, obviously no power plant operates continually and most nuclear plants have experienced extended unplanned shutdown periods, many exceeding a year. Despite their variable output, which can generally be forecasted at least as accurately as electricity demand, wind and solar photovoltaic power are now becoming significant. Fig. 1, therefore, presents the actual electricity produced by solar photovoltaics, wind and nuclear power and highlights the changing levels of production since 1997. As can be seen during this period, there has been an additional 616 TWh per year of wind power produced in 2013 compared to 1997, 124 TWh of solar photovoltaics overtaking nuclear with just 114 TWh.

In 2013, growth rates for generation from wind power above 20% were seen in North America, Europe and Eurasia and Asia Pacific, with the two largest markets, the United States (19.4%) and China (37.8%) both continuing to deploy at scale. In the world of photovoltaics, North America saw a more than doubling of power generation, Asia Pacific a 75% increase, while Europe and Eurasia experienced a more modest 17.6% growth. Other important milestones for renewable energy are masked by the global figures, but are worth noting. In Denmark wind power covered one third of electricity demand, in Spain it provided just over one fifth making it the largest power source in the country, while in Italy solar photovoltaics provided 7.8%<sup>10</sup>—ten times its contribution in 2010 and two and half times higher than the maximum annual contribution ever made by nuclear power. India's 12% growth in wind power in 2013 mean that it overtook

nuclear power in terms of electricity production. As in China, this had already occurred in 2012. There are now six countries—one in five nuclear states—generating more power from renewables than from nuclear energy. Besides Brazil, India, and Spain, these include three of the four largest economies in the world: China, Germany, and Japan.

The reference date in Fig. 1 is 1997, as this was the date of the signing of the Kyoto Protocol. Despite attempts to restrict greenhouse gas emissions growth, worldwide emissions, primarily from the energy sector, have continued to grow and have risen from 32 billion tons per year in 1997 to 34.5 billion tons of CO<sub>2</sub>-equivalent in 2012. Consequently, additional efforts are needed to rapidly accelerate the use of low carbon energy sources. The current deployment and energy production trends reflect the level of public and political support as well as the views of the investment community in the different technologies.

Considering the low level of nuclear development over the past 15 years, it is surprising that agencies such as the IEA continue to assume in their decarbonization scenarios that there will be a significant increase in the deployment of nuclear power. While on the one hand they recognize the low level of nuclear investment since 2000, which the IEA calculate to be US\$8 billion per year, they still assume that during 2014–2035 the annual investment in their 450 Scenario would average US\$78 billion, a near tenfold increase.<sup>11</sup> This seems sharply divergent from current market sentiment and choices, so speeding up the decarbonization of the energy sector seems unlikely if not simply impossible to be achieved by relying on the rapid deployment of nuclear power.

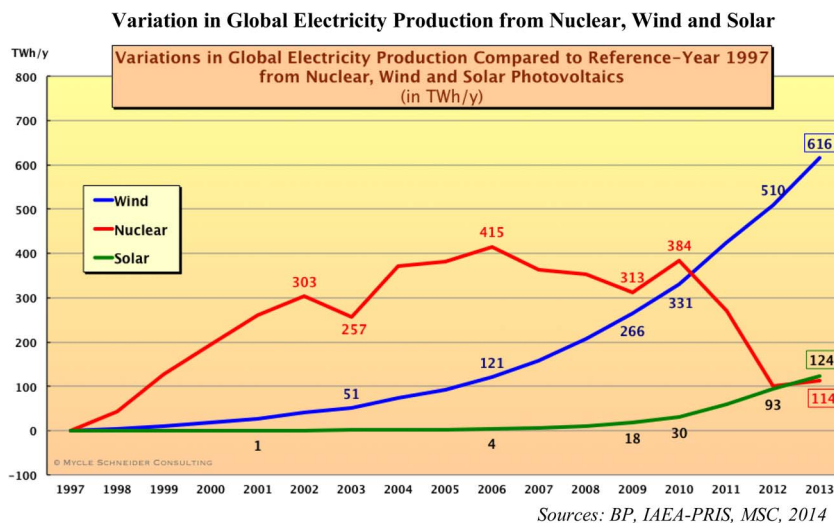
The traditional concept of base-load electricity generation is likely to become obsolete with increasing re-

<sup>8</sup>IEA, "World Energy Investment Outlook," June 2014

<sup>9</sup>EWEA, "Wind in Power, 2013 European Statistics," European Wind Energy Association, February 2014.

<sup>10</sup>REN21, "Renewables 2014 Global Status Report," Renewable Energy Policy Network for the 21st Century, 2014.

<sup>11</sup>IEA, "Special Report, World Energy Investment Outlook," International Energy Agency, June 2014.



**Fig. 1. Variation in Global Electricity Production from Nuclear, Wind and Solar.**

newable energy penetration in national grid systems. Several countries now experience periods of very low or even negative electricity prices on the spot market. Electricity generators literally pay to produce because shutdown and restart would cost them even more. In 2013, the German system generated 152 TWh from renewables, 56% more than from nuclear plants. In just the two past years, the number of hours with negative prices more than quadrupled, from 15 to 64. The hours with prices below euro 15/MWh (US\$20.5/MWh) increased from 161 to 727 (8% of the time). From 2011 to the first quarter of 2014, average baseload prices decreased by an astonishing 40%. Consequently, in 2013, Germany exported a record 34 TWh *net* to neighboring countries, while nuclear France—otherwise also a net power exporter—remains a net power *importer* from Germany.

It is clear that greater penetrations of renewables on the grid will need changes to the way in which electricity is transmitted, used and stored. However, as fast as these issues come to light they are being solved, with rapidly falling costs of batteries and the increased investment of IT companies, like Google, into the power sector. These are other developments have led many banks (Barclays, Deutsche Bank Research, CitiBank, UBS), financial institutions (Nomura, Moody's), and consultancies (Deloitte, Ernst and Young) to question the future of large centralized electricity utilities. Nuclear power, with its large upfront costs and inflexibility of generation, is clearly the most unsuited generator to the new vision for the power sector. Current trends show nuclear power is unlikely to be implemented in many countries in the future and therefore globally will be-

come less and less significant. A recent assessment by UBS, the largest Swiss financial institution and a major international investment bank, puts it this way: "Large-scale power generation, however, will be the dinosaur of the future energy system: Too big, too inflexible, not even relevant for backup power in the long run."<sup>12</sup> This is having a material effect on the industry and on November 20, 2014, the credit-rating agency Standard and Poor's downgraded the French state-owned AREVA, largest nuclear builder in the world, to speculative grade BB+ or "junk".<sup>13</sup> ■

<sup>12</sup>UBS, "Global Utilities, Autos & Chemicals—Will solar, batteries and electric cars re-shape the electricity system?" August 20, 2014.

<sup>13</sup>Digital Look, "AREVA downgraded by S&P," November 20, 2014, <http://www.digital-look.com/news/international-companies/areva-624619.html>, Accessed December 28, 2014

#### ABOUT THE AUTHORS

**Antony Froggatt** is an independent European energy consultant and Senior Research Fellow at Chatham House, London, U.K. He is a Lead Author of the World Nuclear Industry Status Reports.

**Mykle Schneider** is an independent international consultant on energy and nuclear policy, Paris, France. He is the Convening Lead Author of the World Nuclear Industry Status Reports.