Nuclear Renaissance: **What's next after Fukushima?**

The emergency at Japan's Fukushima nuclear power station following the devastating earthquake and tsunami on March 11 has refocused attention on the viability of nuclear power systems. In this edition of Signature Report, **Massimo Bonansinga, Vice-President and Portfolio Manager for Signature Global Advisors**, looks at the state of the world's nuclear energy infrastructure and the outlook for renewal.

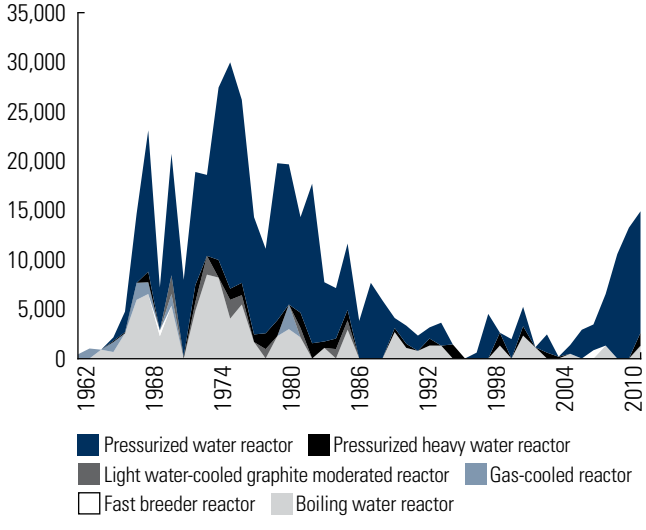
Nuclear renaissance, an overview

Nuclear technology can no longer be considered new – it has been widely employed for over 50 years to generate electricity. In the 1960s and 70s, it was seen as the future provider of unlimited cheap power to satisfy the insatiable electricity demand of modern societies.

More than 160 nuclear power stations were built around the world between 1960 and 1976, accelerating to about 260 between 1976 and 1988, then falling precipitously to less than 50 between 1988 and today. (See Chart 1) Economics pointed to other sources of energy, accidents at Three Mile Island and Chernobyl raised safety concerns, potential new builds in emerging countries highlighted the risks of nuclear proliferation, and the ever-present problem of waste disposal continued unsolved.

The majority of nuclear reactors built in OECD economies came on stream before 1988 (the last built in the U.S. was commissioned in the mid-70s) and are rapidly approaching the end of their lifecycles (around 40 years). Many industrialized countries rely on nuclear for a significant portion of their electricity needs (See Chart 2) and the

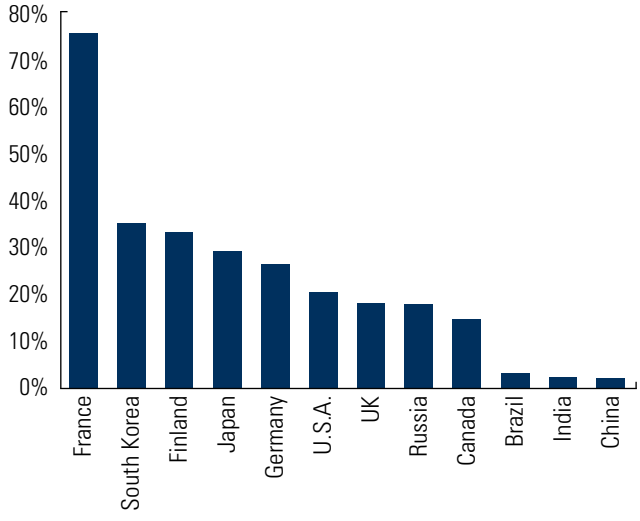
Current capacities built by year (in MW)



Source: IAEA, Signature Global analysis

Chart 1: The vast majority of the world`s nuclear power capacity was in place before 1988. Only recently has construction picked up again.

Nuclear output (%) of total electricity production (2009)



Source: IAEA, WNA, Signature Global analysis

Chart 2: Despite the advancing age of many nuclear power installations, industrialized countries rely on nuclear for a significant portion of their electricity, with France having made the largest commitment to nuclear energy.

general expectation has been that new construction would eventually re-accelerate to replace the aging fleet and expand nuclear power output.

The phrase "nuclear renaissance" emerged at the beginning of the 21st century to describe this expected imminent relaunch of nuclear capacity. The theme was enlisted to market high-profile IPOs such as Electricité de France (EDF) in 2005 and to encourage long-term investment in the industry.

Renewed interest in nuclear was prompted by increasing concerns about the security of the supply of oil and gas security of supply and the mounting importance of low carbon emission energy technologies. Nuclear power plants are expensive to build, but enjoy low operating costs, so that their electricity compares favourably to that generated by coal and natural gas (See Table 1). Despite the strong rationale, the nuclear renaissance has been a rather unimpressive phenomenon in Europe and the Americas. Just a handful of nuclear plants are under construction and a relatively small number are in various planning stages in the U.S., France and the U.K. Overall, activity is far shy of what is necessary to replace the existing fleet, let alone expand nuclear capacity.

The "real" renaissance that has eluded the West is instead tangible in Japan, Korea, China, Russia and India (See Chart 3). These countries, recognizing the long-term necessity of nuclear to meet their energy needs, have created policies that dictate significant new capacity and that cultivate homegrown expertise. The Korean nuclear industry, for example, has successfully exported its expertise abroad, winning a landmark project in the United Arab Emirates and competing in Turkey head-to-head with the French.

Electricity – a global problem with local solutions

Electricity systems have developed in vastly different ways across the globe, driven by fuel availability, policy decisions, consumption patterns and growth rates.

Japan

Japan's lack of an indigenous fuel source has made nuclear a strong choice since the 1970s, especially after the oil shock of 1973. As a result, Japan has one of the largest – and oldest – nuclear fleets. Many plants, including Fukushima, are nearing the end of their lives and private companies, with strong supervision by the government, have a relatively large program to replace them. Japanese companies have excellent nuclear capabilities and the nuclear industry is a source of export.

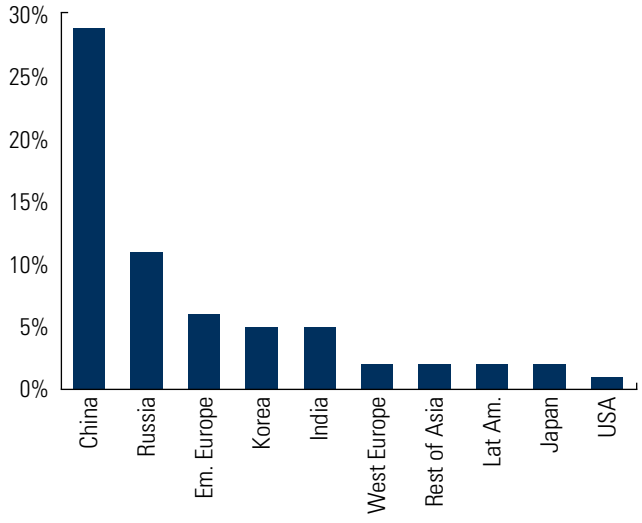
U.S. levelized electricity cost by technology

			Nuclear	IGCC Coal	CCGT Gas	Hydro	Wind Onshore
Construction Cost	a)	USD/KW	4,000	2,600	1,000	2,300	2,000
O&M	b)	USD/KW	90	39	12	14	30
NPV Int while Construction	c)	USD/KW	740	480	100	270	200
TOTAL FIXED COSTS		USD/KW	4,830	3,080	1,100	2,570	2,200
FIXED COSTS		USD/KWh	46	29	20	32	81
Financial Annuity	d)	USD/KWh	42	29	18	36	59
Total Fixed Costs		USD/KWh	88	58	37	68	139
Fuel Price	e)	USD/KWh	4	24	29	–	–
Varible O&M	f)	USD/KWh	4	3	2	2	–
Production Tax Credit	g)	USD/KWh	–	–	–	–	(22)
TOTAL VARIABLE COSTS		USD/KWh	8	27	31	2	(22)
TOTAL GENERATION COST		USD/KWh	**96**	**85**	**68**	**70**	**117**

Sources: Annual Energy Outlook 2011 (AEO2011), Section 48 ITC (2010), California Energy Commission (2010), National Renewable Energy Lab (2010), UBS (2011), Ontario Power Authority (2007), Uranium.info, Environmental Energy Technologies and Division (2009) and EIA.org (2011), Signature Global analysis. a)"Overnight cost" is an estimate of the cost at which a plant could be constructed assuming that the entire process from planning through completion could be accomplished in a single day. Interest charges are excluded. b) Fixed operating and maintenance (O&M) costs are not uniformly defined by all interested parties but generally include staffing, overhead and equipment (including leasing), regulatory filings, and miscellaneous direct costs c) NPV of capitalized interest incurred during the construction phase d) Based on construction cost, capitalized interest and 7% weighted cost of capital e) Coal USD68/Tonne, Natural Gas USD4.25MMBtu and Uranium (U308) USD65/pound f) Variable O&M includes yearly maintenance and overhauls, repairs for forced outages, consumables (non-fuel products), water supply, and annual environmental costs. g) PTC for Wind is $22/MWh till Dec 2012

Will Japan give up nuclear after the Fukushima disaster? It's doubtful, at least in the medium term. Conservation may reduce electricity consumption, but even in a scenario of reduced electricity needs, the alternatives to nuclear present their own challenges. Coal is detrimental to the environment, and Japan's hydroelectric capacity is fully exploited. The only viable alternative to nuclear seems to be liquefied natural gas (LNG). Dependency on LNG is unpalatable partly for its cost, but also for the geopolitical implications of making Japan dependent on the producing countries and shipping lanes. In response to the Fukushima tragedy, the currrent Japanese government, whose credibility is quite poor in the eyes of the Japanese public opinion, is actively pushing for more conservation and renewable resources. The recent stoppage of Chubu Eletric's Kamaoka plant is just precautionary, and maybe, a way to show the public that the government is doing something. In the meanwhile, facts speak loud and the two nuclear plants under construction are quietly progressing towards completion.

Reactors under construction



Source: IAEA, Signature Global analysis

Chart 3: Emerging countries such as China, Russia, India and Korea are investing in new nuclear power plants to meet their growing electricity needs, while the "Nuclear Renaissance" appears to be stalled in the developed nations.

United States

About 20% of the electricity in the U.S. is produced by 104 privately operated nuclear plants scattered across the country, loosely supervised by federal agencies and, for the regulated part of the system, governed directly by state power utility commissions. The average age of these facilities is high and plants will soon start to retire in numbers while just a handful of regulated utilities launch greenfield nuclear power developments. The U.S. nuclear program was expected to grow with the renaissance, but it instead became bogged down by red tape, the unresolved waste disposal issue, a lack of private investments and limited government support.

Nuclear plants going out of commission for old age would tighten supply and push base load electricity prices higher if it wasn't for shale gas. Both cheap and abundant, shale is widely regarded the panacea for environmental, security of supply, dependency on foreign energy and cost concerns. Gas dependency is bound to rise due to the progressive demise of coal-fired power generation, which is much more polluting than gas given its large CO2 emissions. Tighter Environmental Protection Agency standards are making many coal plants uneconomic. Too high a dependency on gas, however, could make the entire U.S. system more volatile and vulnerable to supply shocks. At industry conferences I routinely attend, most participants now see gas as the dominant technology. The shift towards gas looks great right now, but in the medium to long term, cheap gas-fired power forever will likely prove to be an illusion.

United Kingdom

The electrical system in the U.K. is run by private companies with national regulatory oversight. The British nuclear fleet is one the oldest on the planet, displaying a bewildering array of technologies and one-off experiments that make it one of the most complex to run and, hence, least reliable in the world. The country is late in its replacement program and may need rolling blackouts if the nuclear program is called off or further delayed, and will likely need to bridge the time needed to commission new nuclear with a temporary gas solution. It is doubtful the U.K. can abandon its nuclear program unless it accepts being fully dependent on gas imports and/or on electricity imports from the French nuclear infrastructure.

Germany

Germany is another advanced country with a 20% nuclear mix, with ownership divided among private companies and local government-owned utilities. Germany's nuclear fleet is also aging, and the country depends almost entirely on imports from Russia for its gas needs.

Germany's anti-nuclear movement is strong and the government seems to be giving up on nuclear power under pressure from fierce protests and a string of local election debacles. The country is promoting relentless energy conservation, pushing renewable sources to the limit (building wind, solar and, soon, offshore wind) while cutting back on nuclear and, after 2013, possibly shutting down large numbers of coal-fired power plants. The dream of green energy, however, could become a nightmare of high prices and Russian control of gas supplies. We expect Germany to proceed with its utopian vision despite the risks, eventually importing power from its neighbours, particularly France.

France

France relies on nuclear facilities for more than 70% of its needs and is home to a strong nuclear industry. The French electricity grid is nominally run by private companies but EDF (the largest company in the country) is strictly controlled by government with an 80% interest. France's electricity system is long base load and short peak supply, which is often imported from Germany and Italy.

Given its political commitment to the resource, France will continue to be a nuclear powerhouse well into the future. The country continues to upgrade its fleet with new generation plants like Flamaville, currently under construction. France could quickly become the base load provider for Central Europe as Germany proceeds with large cuts in nuclear and coal-powered plants. Furthermore, France could also provide base load supply to the U.K. to compensate for the slowness of capacity investments on the island. In that sense, France is the insurance policy against the imbalances of the European electricity system that could otherwise lead to a widespread crisis.

Russia

Russia has a large legacy nuclear fleet and the country is home to a strong nuclear industry. The Russians need to replace aging nuclear and fossil fuels capacity and are in the process of entirely rebuilding their infrastructure. Nuclear power is tightly controlled by a government agency while the non-nuclear electricity industry has been privatized. Russia's incentive to use nuclear is to free up natural gas for export. Russia wants to export its latest nuclear technology and is unlikely to reduce its commitment to nuclear.

China

China has been growing its power generation capacity at breakneck speed to service an economy doubling its size every six to seven years. Coal is cheap and abundant, and coal power stations have been built in vast numbers. But the country's environment has suffered, leading to a change in direction with the government's new five-year plan. To respond to the environmental crisis and diversify its sources, China is building several nuclear power stations and an unprecedented quantity of renewable sources (mostly wind). In response to the Japanese crisis, China's construction program is currently frozen pending an assessment of the safety of its existing plants and those under construction, but the consensus within the country is that it will resume as early as next fall.

China needs to strike a difficult balance between sustaining electricity consumption, environmental impact, conservation and security of supply. In fact, China imports most of its natural gas and the government is concerned by increased dependency on foreign sources. China is building nuclear plants at half the cost of other countries, partly because of lower labor costs but also because it is building in bulk. Overall, we believe that China will not give up nuclear but, instead, will build increasing numbers of nuclear plants.

Investment implications

Since Fukushima, markets have punished utilities investing in greenfield nuclear capacity, as well as the suppliers and construction firms that support the industry. The announcement of starting a new project is now enough to shave significant value from any utility share price, while companies rethinking nuclear projects are being rewarded with multiples re-ratings.

For a while at least, financial markets will demand a premium on nuclear project returns and/or rock-solid government guarantees to shield investors from cost overruns and delays. Meanwhile, life extension licenses for existing plants will become more expensive and less likely to be approved, thus depriving utilities of a relatively inexpensive way to acquire base load capacity while diluting their carbon footprint.

At Signature, we have avoided utilities that are too keen on greenfield nuclear for some time, mostly because of the repeated costs overruns and delays of recent projects. Governments have added their own burdens to the sector, beginning with Germany's nuclear taxes and the never-ending saga of life extension. Less uncertain programs are generally state-owned, as in China, and can be played only via the equipment producers.

However, the accelerated shutdown of nuclear stations in Western Europe is presenting opportunities as tighter supply results in higher electricity prices and better profitability for gas-fired generators in a low gas price environment. German electricity prices have jumped from 52.50 euros to more than 60 euros per kilowatt, and our investments in Central European generators should eventually benefit from this trend. Our long-term investment in Calpine, a Texas-based merchant gas-fired generator, has also benefited from this theme in the U.S., as a combination of nuclear concerns and EPA activity against coal plants has helped to boost the share price about 25% year-to-date.

Nuclear power's role in an electricity system

Because of its characteristics, nuclear is a quintessential base load technology. Electricity grids need a combination of base load power and peak power to successfully manage fluctuating demand during the day and across the seasons. Grids must be constantly balanced and supply must modulate to meet the ever-changing demand. Base load power to provide a constant electricity supply for a given grid is usually supplied by nuclear and coal-powered plants, partly because both are cheap to run but also because they are expensive and slow to shut down and restart.

Sudden consumption peaks are generally covered by sources of supply that are easy and inexpensive to switch on or off (usually gas, oil and/or hydro). The cost of gas, oil and diesel has generally confined them to peak plants, but if natural gas prices remain relatively cheap in North America, it could be more widely used in base load applications.

Although they are becoming more cost effective, the most popular renewable sources of energy can be unreliable, with wind being intermittent and solar depending on sunlight. Both options require a robust backup in the form of gas-fired generation ready to keep the grid in balance.

Conservation, widely promoted around the globe, is the most untapped resource and could dramatically reduce the need for new electricity plants, especially in developed, post-industrial economies.

Nuclear power stations are expensive to build but cheap to run, making them an excellent choice for underpinning the basic needs of a given grid. Nuclear does not emit pollutants such as carbon dioxide (CO2) or heavy metals and plant reliability is superb, with the U.S. fleet consistently operating 95% of the time.

Nuclear, however, carries the enormous human and economic risk of radiation accidents. The need for abundant amounts of water to cool down the reactor dictates that nuclear plants must be close to large bodies of water, exposing seaside power stations to the risk of tsunamis. The treatment of spent fuel remains an unresolved issue, with solutions ranging from reprocessing to the Japanese and U.S. non-solution of leaving spent fuel in purpose-built pools by the nuclear plants.

The cost of building nuclear plants, the length of the construction phase and the likelihood of delays and cost overruns make greenfield nuclear projects difficult to fund in an unregulated power market. Utilities that want to build new plants require government support in the form of credit guarantees and power purchasing agreements. The Chinese government is tackling the cost/time issue by standardizing their projects, but not all countries have the same level of control or the number of plants under construction to make it relevant.

Conclusion

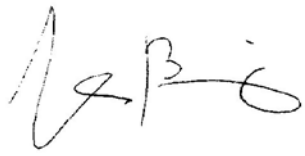
Nuclear power is an established source of electricity in which technology and safety measures are constantly evolving. The issue is not the frequency of accidents (which in actual fact are rare), but their intensity. Modern plants are relatively safe, and the likelihood of an accident with devastating impact is very low, even when all that can go wrong, does go wrong, as it did in Chernobyl.

The lessons learned from Fukushima will result in additional safety redundancies and the cost of new nuclear plants will increase accordingly. Life extension licenses will become more difficult to obtain and more expensive, some projects will become unprofitable and older plants will close.

Security of supply, fuel diversification, environmental impact and cost are all considerations in any nuclear power decision. There is no globally accepted solution, just local policy decisions. We believe that the size and uncertainty surrounding nuclear projects (especially greenfield) is a government policy decision, regardless of whether the construction and ownership is public or private.

Governments must lead the decision making because, unlike less controversial fuel choices, in building a nuclear plant both companies and financial markets alike require guarantees, financing and political involvement to manage the different sensitivities and tolerances to the risk/benefit balance.

Ultimately, nuclear will continue to be part of the energy mix in many countries and will be part of the solution to the world's energy needs.



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