Bandwagons and busts

Nuclear plants are getting ever more expensive. But Asian countries may build them more cheaply

IN HAIYANG, ON the northern Chinese coast, and at Sanmen, farther south, an international consortium led by Westinghouse is well into building two AP1000s, with two more in the works; China plans eventually to have 12 split between the two sites. If the plans go ahead, each site will have as much capacity connected to the grid as the whole of Nigeria has today. Yet the two plants represent only a small fraction of China's nuclear ambitions. Its pre-Fukushima plans to increase its nuclear capacity from 10GW to 80GW by 2020 may fall behind schedule, but China still looks certain to build more new nuclear plants than any other country over the decade to come—and possibly more than all others combined.

By nuclear standards, this is a big deal; China will add more nuclear capacity in those ten years than France has in total. But for China itself it is less big; nuclear will go from generating less than 2% of the country's electricity to less than 5%. Ming Sung, who works for the Clean Air Task Force, an American think-tank in Beijing, points out that China is not betting on nuclear; it is betting on everything that offers an alternative to coal. China consumes half the world's annual coal output, and has the supply problems, dirty air and huge death toll (hundreds of thousands a year from respiratory diseases) that go with it. Junda Lin of the China Greentech Initiative points out that the 2020 target for nuclear has to be seen in the context of a 200GW target for wind and an extra 100G w of hydropower. The idea is to try everything and see what works best.

Most of the plants China is currently building are generation lis derived from a French design it bought in the 1980s and now built by Chinese companies, but there are also Russian pW R S in Tianwan and Canadian Candus in Oinshan. In Taishan two EPRs are being built by Areva and the China Guangdong Nuclear Group, which has a long-standing relationship with the French industrial base from which its domestic designs ultimately derive. And then there are the AP1000s. Westinghouse won that contract in large part by promising to transfer the technology in full to local companies, but it hopes that its expertise will allow it to keep a prominent role in the Chinese industry.

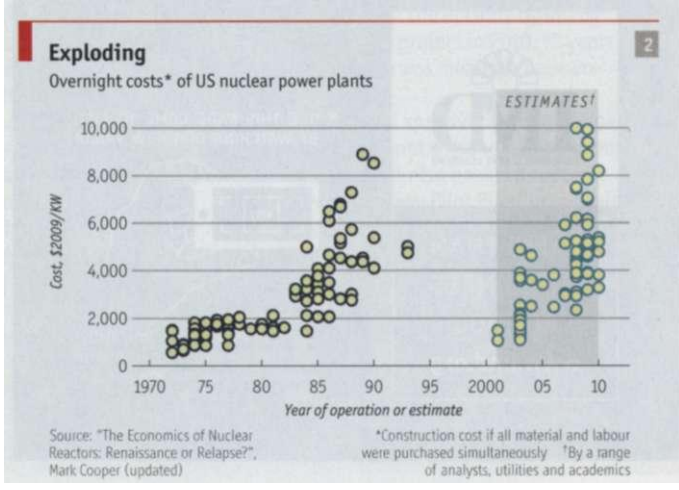
After Fukushima the state council stopped approving new power stations and called for re-evaluations of the seismic and flooding risks faced by those already built and under construction. A new law expected later this year will take nuclear regulation away from the National Development and Reform Commission, the state's industrial planners, and hand it over to the environment ministry, thus splitting the role of cheerleading from that of invigilation. Part of what passes for the Chinese government's legitimacy comes from the perception that it can manage large-scale technology well. The backlash against China's high-speed train programme after last year's accident at Wenzhou, which provoked criticism and anger of a sort that Chinese leaders fear, would be dwarfed by what could be expected from a nuclear accident.

A sincerely self-interested desire to avoid accidents, though, will not necessarily translate into a model regulatory infrastructure. A safety culture of constant questioning will not be easy to instil. And China's nuclear regulatory workforce is already more stretched than that of other big economies in terms of employees per gigawatt under regulation.

Beside the seaside

Another new law will outline future plans for the industry. Some expect China's nuclear boom to slow down in the wake of Fukushima, with new capacity perhaps reaching only 40GW by 2020. And China could get proportionally more AP1000s and fewer of its own home-made designs, the safety of which may be less assured. All China's current plants are by the sea, both because it is convenient for cooling and because that is where the demand is. There have been plans for nuclear plants inland, cooled by rivers, but concerns about the availability of water in drier years to come and the risk of contaminating it may cause these plans to be shelved.

China's expansion into nuclear power is hardly a market-driven development, but it helps that the plants involved look comparatively cheap. There are two ways of measuring the cost of a nuclear power plant: the "overnight" cost, which counts up the material and labour that goes into a new plant as if it had all been purchased simultaneously, and the "levellised" cost, which is a measure of the total amount of energy a plant provides over its life divided by the total expenditure-construction, operation, maintenance, fuel and, eventually, decommissioning. One is the cost of the capacity to produce electricity, the other the cost of the electricity produced. The 2010 edition of the IEA/NEA Costs of Generating Electricity study puts overnight costs for Chinese generation II plants at $1,700 for every kilowatt of capacity, giving a gigawatt plant a price tag of less than $2 billion. For the AP1000s the estimated costs are higher ($2,300/kw), and by the ••



time the projects are finished they may be higher still; these are the first AP1000s being built anywhere, so its wise to expect surprises. Schedules are being stretched, and the Chinese contractors for key parts of the third and fourth AP1000s are falling behind a bit, according to Westinghouse.

Still, almost anywhere else in the world, these figures would today be a source of envy-or incredulity. When companies were beginning to pitch generation III reactors ten years ago, they claimed that better, standardised designs and improved construction techniques would make them both safer and cheaper. In Western countries that second claim has gone by the board. British studies in 2004,2006 and 2008 put the overnight cost of new PWRS at $2,233/kw, then $2,644, then $3,000. Estimates from the Massachusetts Institute of Technology (MIT) rose from $2,208/kw to $4,000 over roughly the same time. The NEA quotes costs for an EPR in Belgium (now cancelled) at $5,400 per kw. Capacity fired by gas turbines, for comparison, can cost less than a fifth of that.

Real construction costs, which include the cost of borrowing the money needed, are even higher than overnight costs. Construction costs for the two AP1000S that Progress Energy has planned for its Levy site in Florida have recently been reported at about $20 billion, which works out at about $9,000 per kw and strongly suggests that the reactors will not be built.

Cost escalation has been the rule throughout the industry's history. In the late 1960s what is now called the "great bandwagon market" took off in America. Companies selling plants they had no real experience of building offered fixed prices to make them attractive. Utilities keen to reduce their reliance on coal in an age of clean-air standards took the bait. As orders flooded in, costs started to climb. Projects meant to be completed in years dragged on for more than a decade, in part because of new environmental concerns, in part because designs were revised as lessons were learned. At the Vogtle plant, in Georgia, a pair of reactors originally priced at $660m in 1971 came in at $8.87 billion 16 years later. Half the projects ended up cancelled.

The French experience is often quoted as a positive counter-history to the American mess. France had long been keen on energy security. When it made PWRS based on a Westinghouse design a national priority in the early 1970s, it brought a thorough-minded discipline to the matter, building its capacity region by region, improving the designs as it went along and increasing the size of its plants to reap economies of scale. Having the same contractor and customer for so many plants allowed the system to learn from mistakes and to refit older plants to newer standards. Even so, according to calculations by Arnulf Grübler of IIASA, a think-tank near Vienna, each of the six designs France has fielded has cost more per kilowatt than the previous one had. He estimates that the four reactors built in the 1990s cost between $2,267 and $3,252/kw in 2010 dollars, more than twice the real cost of capacity built in the 1970s and early 1980s. The first two EPRS to be built in Europe, in France and Finland, have both gone extravagantly over schedule and budget.

A decade ago the nuclear industry hoped that the combination of safe, low-cost generation III reactors and governments eager to encourage lower carbon-dioxide emissions would lead to a "nuclear renaissance". In the West those low costs have failed to materialise, so the renaissance is largely stalled. Whereas a few years ago Britain was talking of building eight new reactors to replace its ageing fleet, only two are likely to make it in the near term. Steve Thomas, an economist at the University of Greenwich, argues that even with a fixed carbon price of €36/tonne and a guaranteed price for the electricity (both features of a currently planned re-regulation of Britain's energy market; today's EU carbon price is under €10), those plans remain vulnerable.

In a capital-intensive industry such as the nuclear one, the cost of capital is always crucial, and higher overnight costs magnify the problem. Calculations of the levellised costs of energy by UBS, a bank, show clearly that the cost of capital dominates the picture. For a plant costing $5,500 per kw, capital makes up 75% of total costs in Europe and America, UBS reckons the levellised cost of such a plant in Europe is 11% higher than the cost of a gas plant. It would take a quintupling of the carbon price to wipe out that differential. And those calculations assume that it is as easy to borrow to finance a nuclear plant, with all its uncertainties and regulatory risk, as it is to finance a gas plant, which is probably unrealistic.

A clear argument for nuclear power

Step on the gas

In eastern Europe, where Russian dominance of gas markets is a political issue and electricity markets are still quite regulated, governments may consider such a differential acceptable. The Czech Republic is about to tender for new generation III PWRS, and Poland has plans along those lines too. But in America things look very different. Asked if Fukushima put America's nuclear renaissance on ice, Ernest Moniz of MIT replies succinctly: "No. Shale gas did." For all the production incentives, loan guarantees and indemnity for costs due to regulatory change offered by government, the sharp drop in gas prices caused by new

• sources of supply ruled out new nuclear plants in any market where the two energy sources compete freely. According to **UBS**, the advantage of gas over nuclear in America is roughly twice what it is in Europe.

John Rowe, **CEO** of Exelon, an energy company that has ten nuclear power plants in its portfolio, says that companies like his no longer have any reason to build nuclear plants. All plans to build nuclear plants in parts of America where the electricity market has been deregulated are coming to naught. Some American plants will still be built, but only in the south-east, where regulators allow the cost of increasing a utility's asset base to be passed on directly-indeed pre-emptively-to its captive customers. Thus electricity consumers in Georgia are already paying for two new **AP1000S** which in February got clearance from the **NRC** to complement the two reactors at Vogtle. In Sumner, South Carolina, two more **AP1000S** are under contract. Those four will probably be all the renaissance America sees for some time.

If the West could build new reactors as cheaply as China can, things would look different. That it cannot is in part due to labour costs. But the Chinese must have other advantages too. The levellised costs of modern Chinese coal-fired power stations are lower than the competition's even when the power stations are not built in China. The same is true for cement works; Chinese companies operating outside China cannot build them as cheaply as they do at home, but they still easily beat the international competition.

Further evidence that a different industrial approach can cut costs comes from South Korea. Like Japan, the country has little by way of indigenous energy supplies, and it too decided on nuclear power to solve that problem and bring new technological skills to its industrial base. It gets some 30% of its electricity from nuclear plants, much the same as Japan did before Fukushima, and more than any large economy other than France. In 2010 **KEPCO**, the South Korean power company, sold its reactors overseas for the first time, beating the French to a contract in the United Arab Emirates; at home its overnight costs for such generation II reactors are calculated at just over $1,500/kw.

The true costs in South Korean business can be hard to make out. It would not be at all surprising if, working abroad for the first time and having been keenly competitive in its bidding, **KEPCO** failed to deliver the **UAE** reactors on budget. And given that nuclear prices have gone up everywhere else, it is fair to expect that they will do so to some extent in Asia, too. But if China and South Korea can build reactors abroad at prices not much higher than those at home, nuclear may see its fortunes tick up elsewhere, argues David Victor, of the University of California. Both Westinghouse and **EDF** have plans for new reactors in the export market that would be designed and sold in collaboration with Chinese partners. Russia is keen to export **PWRS** too, but its costs are not clear.

Inviting the Chinese to come in and build a nuclear plant is an unlikely step for a Western government (though the South Koreans are bidding on a Finnish contract). Some developing countries, though, may be interested. This is a matter of concern for backers of the American nuclear industry with an eye to national security issues, such as Pete Domenici, a former senator. If America is not engaged in the market, how can it use its influence to deter proliferation?

And it will indeed have less scope for such influence. But even at Chinese prices, nuclear energy is expensive compared with coal, and if other countries gain easier access to gas, as America did, that will reduce demand too. Vietnam is enthusiastic about nuclear reactors; other Asian countries, especially those in tectonically active places-such as the Philippines and Indonesia-may be less keen than they were before the great tsunami. South Africa is talking of buying nuclear reactors. India has big plans on paper, but a law that makes the designers (rather than the operators) of power stations liable in case of accidents gets in the way (and buying Chinese reactors might be anathema anyway). There is interest in the Middle East, but as Charles Ebinger of the Brookings Institution, a think-tank, points out, the countries talking about buying nuclear power in response to runaway electricity demand might do better to curb their handsome consumer subsidies. They might also do well to invest in alternative energy. The sun's nuclear reactor has been going for 4.5 billion years, and extracting power from it is getting cheaper every year.

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