WHEN THE PRICE IS RIGHT

Once touted as too cheap to meter, nuclear power has become too costly to build. But the economics may be shifting, finds Jim Giles.

On the east coast of Britain sits one of the most convincing arguments for ending the age of nuclear power. The Sizewell B reactor is not dangerous: since it opened in 1995 it has never been the subject of a serious security scare. Nor is it unreliable. Quite the reverse: at almost 1,200 megawatts, it is Britain's most powerful single nuclear reactor and is responsible for supplying 3% of the country's electricity needs. But Sizewell B is expensive. So expensive that no private investor would ever touch such a project.

For nuclear experts, the story of Sizewell B is a familiar one. After the longest public inquiry into a construction project that Britain had ever seen, work began in 1987. It took eight years to come online. The budget was revised upwards three times over that period, eventually coming in at more than a third over the £2 billion (US$3.3 billion) quoted in 1987. When the British government reviewed the project in 2002, it estimated that, when the costs of financing, building, running and decommissioning Sizewell B were fully accounted for, the average cost of every kilowatt hour (kWh) of electricity produced over the plant's 40-year life would be six pence — two to three times more expensive than power generated by modern gas-fired stations.

Running down

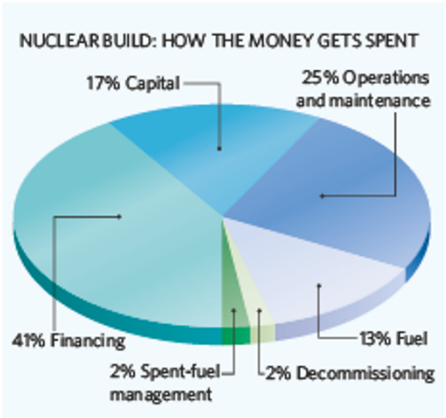
Nuclear power stations account for a fifth of the electricity generated in the United States and a third of that generated in Europe. But they are getting old. Since the 1979 accident at the Three Mile Island plant in Pennsylvania, orders for new reactors in the United States and Europe have reduced to a trickle. Decisions on how to replace the existing plants need to be made within the next ten years. And although renewable sources such as wind are looking increasingly attractive, large central power stations can only realistically be powered by nuclear fission, coal or gas.

Almost all recent studies of nuclear energy have found that gas- or coal-fired replacements would be much cheaper. Given this underlying lack of competitiveness, why bother taking on board the associated risks of terrorism and weapons proliferation that come with the technology, not to mention the displeasure of many citizens? The answer is that when the downsides of fossil fuels — including, but not limited to, their carbon dioxide production — are totted up, nuclear power begins to look more attractive. Some economists are even starting to place bets on a nuclear renaissance.

The current economic picture is persuasively summed up in the 2003 nuclear-economics report from the Massachusetts Institute of Technology (MIT)[1]. After considering the cost of building the plant, buying fuel and operating the reactor, and finally disposing of the waste and decommissioning the facility, the MIT team placed the cost of nuclear electricity at 6.7¢ per kWh. Gas came in at 3.8–5.6¢ per kWh, depending on wholesale gas price, with coal somewhere in the middle of that range. A 2005 report by the UK Royal Academy of Engineering[2] put nuclear costs on a par with coal and gas, but used some unreasonably favourable economic assumptions.

Much of nuclear power's expense comes from construction costs, and the debts that must be incurred to pay them (see chart). A 1,000-megawatt gas-fired plant could, in favourable circumstances, be built in a year or so for $400 million, but a 1,000-megawatt nuclear reactor is likely to take five years to build and to cost between $1.5 billion and $2 billion, depending in part on where it is sited. The long construction time drives the price up by increasing the amount of interest that must be paid on the money borrowed for the project.

And the length of the gestation isn't even predictable; it depends in part on "how slick the lawyers are", notes Donald Jones, an energy economist at RCF Economic and Financial Consulting in Chicago, Illinois. If opponents of nuclear power raise legal challenges, costs mount up quickly. "Halting construction for two years in the middle adds 15% to the final cost of electricity," Jones says. In 2005, hoping to encourage the industry by offsetting this risk, the US Energy Policy Act offered energy companies $500 million of coverage for losses due to construction delays. Yet US investors remain wary of nuclear projects.



SOURCE: BR. NUCL. ENERGY SOC.

Balancing act

Once a nuclear plant is running, operational costs are relatively low. But there are two important exceptions: storage of radioactive waste and, at the end of the reactor's life, decommissioning costs. In Britain, estimates of the funds required to clean up the country's 20 civil nuclear sites have frequently been revised upwards. Just last month, for example, officials increased the total predicted bill from £56 billion to £70 billion. Some schemes to deal with waste costs are in place — the United States has a levy on nuclear electricity that will fund the country's planned waste-storage facility at Yucca Mountain in Nevada (see page 987). But uncertainty about these costs continues to worry investors.

The economic picture hasn't stopped all construction of nuclear power plants. India, China and Russia are building a handful of reactors, for example, but all are government-funded projects. It is in Europe and the United States, with their largely deregulated energy markets, that the economic arguments have bitten deepest. Finland is the only Western nation to have a new nuclear reactor under construction, but its Olkiluoto station, due for completion in 2009, makes economic sense only because of an unusual funding mechanism: local industries are paying for the plant in return for a contract from the operator that guarantees them low-cost electricity. This is not a model that can easily be exported.

France may also decide to order a new reactor, possibly this year. But again the situation is different from that in most countries. France's experience with the technology means that investors will loan money for projects at a

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Core product: Britain has built no nuclear power stations since Sizewell B, in part because of the expense.

cheaper rate than elsewhere. A French 2003 study, for example, put the price of future nuclear electricity at 3.5¢ per kWh — the lowest figure in any of the recent reviews, with the exception of estimates for Olkiluoto.

When cost comparisons are extended beyond current prices and business practice, however, nuclear looks like a feasible option even beyond the borders of France. For a start, although the nuclear industry faces some unique challenges, the finances of its two major competitors are also looking a little troubled. Take gas: wholesale prices have increased fourfold over the past six years. That pushes the price of electricity from gas-fired stations to around 15% below nuclear.

That gap will shrink further if industry forecasts about the efficiency of modern plants are accurate. Nuclear lobby groups claim new plants could probably be built in four years, not five. Independent experts are aware that the industry has a record of what is euphemistically known as 'appraisal optimism'. But the MIT study, which worked with costs larger than those the industry usually uses, acknowledges that improvements are "plausible". If this were so, the cost of nuclear electricity would come down to 4.2¢ per kWh, making it competitive with gas and coal.

Fair exchange

Factor in the cost of greenhouse-gas emissions, and things look even better for nuclear. In Europe, where emissions from industry are already regulated and traded on a carbon market, prices are currently around $30 per tonne of carbon dioxide. At that price, says Paul Joskow, an economist and participant in the MIT study, nuclear is competitive with coal and gas, at least if the price of the latter remains high. This remains the case even when the cost of the carbon burned while the plants are built and their fuel mined and processed is taken into account.

This broader analysis, which the nuclear industry is understandably keen to promote, boosts its standing. But where should the process of extending the cost comparisons end? Environmental groups say that going as far as carbon prices and no further means taking into account all the costs of other generators while leaving out costs specific to nuclear, such as lowering the barriers to nuclear proliferation. Assessing that argument takes the calculations on to less certain ground, although a smattering of studies have attempted to quantify some of the issues. Inasmuch as anything can be said for sure, however, it seems that the more inclusive approach may improve the case for nuclear.

Take disaster liability. In Britain, the amount that reactor owners have to pay out in the

event of an accident is limited to £140 million ($250 million). US industry contributes to a pool of money that ensures that up to $10 billion is available. Neither figure would be anything like sufficient should a disaster on the scale of Chernobyl occur (see page 982). The extra cost would have to be picked up by the taxpayer, so "in essence this is government-subsidized insurance", says Matthew Bunn, a nuclear expert at Harvard University. If nuclear were forced to insure itself on the open market, it would find it impossible.

Government crutch?

But how big a subsidy this actually is remains unclear, because the real risk of catastrophic accidents is unknown. Estimates can be generated by looking at the frequency of previous accidents and how the associated costs compare with events for which the insurance industry is prepared to provide cover. The MIT study suggests that the subsidy amounts to just $3 million per plant per year — a tiny figure when reactors produce $500 million of electricity annually. "In terms of the impact on the cost of electricity it's lost in the noise," says Richard Lester, an author on the MIT study.

What's more, nuclear is not the only industry that benefits from subsidized insurance. A major explosion at a depot handling liquid natural gas could produce a bill well beyond the scope of the owner's cover. So would the wall of water let loose from a hydroelectric dam destroyed by an earthquake. "There is an implicit assumption that the government would step in," says Lester. "Everything has an insurance limit."

Some other costs are simply unquantifiable. The European Union's ExternE study[3], which has been running since 1991, provides perhaps the fullest accounting of what economists call 'externalities' — costs that the people directly involved don't end up paying. ExterneE's audit assigns nuclear extra environmental costs of 0.2–0.8¢ per kWh, mostly derived from air pollution attendant on the plants' construction, mining and transport of fuel, and decommissioning. The figures for fossil fuels, which include damage to the climate as well as air quality, are much higher — up to 18¢ per kWh for coal. Yet even when ExternE's comprehensive analysis is considered, some things are still unaccounted for. "We can't include terrorism issues," says Anil Markandya, an economist at the University of Bath who works on ExternE. "We don't have a handle on how to quantify that." There is also the cost that would be incurred were an unstable nation to develop nuclear weapons by buying nuclear-reactor technology. "The contribution of the civil nuclear system to proliferation is impossible to monetize," says Bunn. "But that would be the biggest externality."

"We can't include the cost of terrorism issues. We don't have a handle on how to quantify that."
— Anil Markandya

Buried costs: uranium is a small part of a power plant's expenses, but mining it generates carbon dioxide.

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Unstable fuel

Such costs, even if they cannot be quantified, do not apply only to nuclear. "If you're concerned about nuclear safeguard costs you have to look at the costs of other sources," says William Nuttall, a nuclear expert at the University of Cambridge, UK. Putting a figure on the Western military spending associated with maintaining fossil-fuel supplies from the Middle East is a politically contentious task. But various estimates, from tens of billions of dollars a year to more than a hundred billion, suggest there is a hidden subsidy for oil prices that might top 10%.

These arguments, although vital for policymakers wondering what to encourage, will not on their own influence investors' decisions. But a final point in favour of nuclear comes from a source that the money men are used to listening to. Portfolio theory is an established way of generating a mix of investments that creates maximum return for a given level of risk. This, says Shimon Awerbuch, an economist at the University of Sussex, UK, is exactly how governments should approach energy decisions. "Talking about generating cost without also talking about financial risk is like watching a movie with the sound turned off," he says. "You miss a big part of the story."

In the case of electricity generation, 'risk' concerns the chance that fuel prices, be they uranium or gas, will go up. Hikes in oil prices have a similar knock-on effect to those of energy prices more generally — they reduce gross domestic product. The real cost of a fuel source, says Awerbuch, needs to take such risks into account. That is bad news for sources whose price fluctuates, such as gas, and good news for nuclear, as uranium costs are reasonably steady, and likely to remain so unless there is an unparalleled boom in plant building.

Awerbuch's approach is to analyse the current mix of fuel sources in the economy to see what levels of risk governments are implicitly willing to accept. He then searches for other mixes that deliver the same risk at less cost. When trying out new combinations, something surprising can happen: adding an expensive non-fossil-fuel source such as nuclear or wind can actually decrease the overall cost. Nuclear lowers exposure to price hikes, and that lets planners simultaneously invest in riskier but cheaper sources such as gas. That additional gas more than compensates for the more expensive nuclear power, so overall prices fall. Although most of Awerbuch's work focuses on wind[4], his analysis also suggests that the steady price of uranium means nuclear should be retained as part of a healthy mix of generation sources.

When Awerbuch's way of looking at energy is combined with the recent rises in gas prices and, more significantly, the new carbon markets in Europe and the United States, another round of nuclear build seems a realistic possibility. A straw poll of nuclear experts shows they are starting to be convinced. Bunn used to offer straight bets against new nuclear construction starting in the coming decade. But put all these changes together, he says, and he might need to start offering odds. "Over 15 years," he adds, "I might switch my money to the other side." ■

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See Editorial on page 969.

1. *The Future of Nuclear Power: An Interdisciplinary MIT Study* (Mass. Inst. Technol., 2003); published online http://web.mit.edu/nuclearpower
2. *The Costs of Generating Electricity* (R. Acad. Eng., London, 2004); published online http://213.130.42.236/wna_pdfs/rae-report.pdf
3. *ExternE: Externalities of Energy* (European Commission, 1995).
4. Awerbuch, S. *Mitigation Adapt. Strateg. Glob. Change* (in the press).