ECONOMIC COMPETITIVENESS OF NUCLEAR POWER

MOVING TARGETS

BY HANS-HOLGER ROGNER AND LUCILLE LANGLOIS

Most world electricity markets are now moving towards greater competition, driven in part by technology, low fuel prices, and experience that competitive markets are more self-sustaining. Electric power is being sold in a number of markets in member countries of the Organization for Economic Cooperation and Development (OECD) for around US $0.02 per kilowatt-hour (kWh). Can nuclear generation match such prices? If not, can it be made to do so?

Electricity companies are now in the business of selling a commodity (kWh) and commercial services instead of a strategic good. Excess capacity, low demand growth and lower product prices in major industrialized countries have forced power generators and their suppliers to be more concerned with the costs of their operations and profitability of their investments. These companies increasingly need a commercial, profit-oriented approach if they are to survive and prosper. Even more, they will need to make substantial cost reductions over the next few years. The nuclear industry is no exception.

How does nuclear power stack up in this environment? The IAEA Planning and Economic Studies Section is doing a series of studies on precisely these questions, divided into issues affecting the near, medium and long-term future of nuclear power. This corresponds roughly to matters affecting existing plants, upgrades and life extensions, or new plants. In general, the studies find that nuclear power has the potential to be competitive in all three markets. But realizing that potential will require significant changes on the part of the industry and its regulators.

This article focuses on the prevailing market situation in many industrialized countries. Several lessons also are applicable to developing countries, particularly in cases where the financing of electric power projects is expected to come from international capital markets. The overall situation is distinctly different for developing countries. Typically the capacity there for generating electricity remains in short supply, and revenues that cover generating and financing costs pose fundamental problems to future expansion of capacity. As a result, competitive prices have to reflect long-term marginal costs rather than only operating costs.

OPERATING NUCLEAR POWER PLANTS

For existing nuclear power plants that are approaching full depreciation, plant revenues need only cover marginal operating costs in order to be profitable. Many well managed nuclear plants therefore now enjoy a cost advantage. In the USA, for

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Photo: Nuclear power plants generate about one-sixth of the world's electricity.

example, more than two-thirds of the nuclear units are reported as producing power for less than the national average of around US $0.02/kWh.

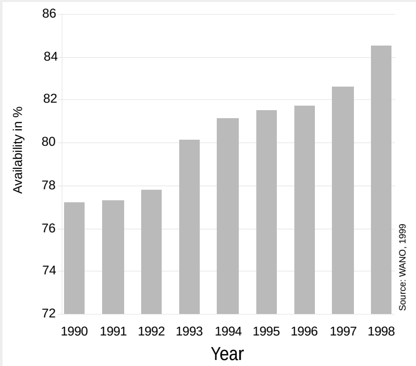
But as the average cost of all generation inches lower, operators of nuclear plants will have less of a cost advantage. As net cash flow margins converge under competition, nuclear operators will need to reduce unit costs and increase net cash flow margins even further to survive.

The difference between success and failure depends on a number of factors including astute decisions about financing and choice of technology, and successful estimates of demand growth, coupled with good plant management that provides cost control and efficiency gains. But in the end, the most important variable for commercial viability is the marginal cost per kWh of generation, compared to the market price and the marginal cost of competing generation.

A nuclear generator must be able to cut unit costs without compromising safety, especially operating and maintenance costs, and to achieve high levels of plant availability. There will be intense management pressure in both areas. Most competitive nuclear plants have already made significant if not dramatic improvements in availability over the last decade and significant if not dramatic reductions in operating and maintenance (O&M) costs. Operating costs have fallen by as much as 40%.

The cost of compliance with safety regulations has had a profound effect on the cost of nuclear power production. At the onset of electricity market liberalization, concerns have been raised that the pressure of competitiveness may adversely affect operating safety. Meanwhile, experience has shown that this need not be the case. Studies in the UK and the USA show a strong correlation between the most successful commercial nuclear plants and the safest ones. In these cases, safety has not been compromised, but rather made an integral part of the plant's commercial requirements.

NUCLEAR POWER PLANT PERFORMANCE IN THE 1990s
(average availability in percent)



There is, in fact, a strong commercial aspect to nuclear operating safety: there is an enormous incentive for managers in privatized markets to protect their shareholders' productive assets. Cutting corners in safety-related matters is costly in commercial terms, as nuclear safety regulators will enforce plant closure (e.g., in 1997 in Ontario), which incurs costs without earning revenues. On the other hand, plants with insufficient cash flow cannot finance maintenance, repairs, or needed upgrades, no matter how closely these might be related to safety. Unprofitable plants, no matter how safe, will be shut down by their owners.

UNFINISHED PLANTS & LIFE EXTENSIONS

The aging of the world's fleet of nuclear power plants and the potential for lifetime extension are matters of considerable interest. Completion of unfinished nuclear power plants, or extending the life of successful ones, can be an economically attractive and practical alternative either to building a new plant or to decommissioning old ones. But the decision should be weighed objectively.

A decision on project completion, relicensing or life extension of an operating nuclear plant hinges on whether or not it is financially beneficial. This financial evaluation in its simplest form is a comparison of only three elements: net present value (NPV) of the cost of completion versus the NPV of the anticipated future revenue stream from the completed project (generating revenue minus costs, discounted commensurate with corporate strategy), versus the cost of plant closure or stopping construction. Once these numbers are computed and compared, the basis for decision is clearer. This holds true even when the project is government financed or when the decision to be made is a "defensive" one: i.e., choosing the option that loses the least money.

Project Completion. It is easy to assume that the current status of a project is a basis for deciding on its completion. A plant that is 90% built is thus seen as a better candidate for completion than a plant that is 60% complete. But there may be little correlation between engineering estimates of completion and the remaining costs, and it is these costs that are key to future investment decisions. A plant that is 90% complete does not necessarily have only 10% of its costs unpaid. The remaining investment cost could be less and very frequently is much more, perhaps even more than the anticipated revenues from the completed plant.

Note that shutting down a construction project is potentially expensive, as most construction contracts have cancellation costs or penalties if a project is terminated. Completing the project at a loss may be cheaper than closing it down. An analogous situation results when asking, on the basis of NPV, whether an operating NPP should be shut down. Shutting down a plant incurs many costs and the firm may be better off operating the plant at a loss.

Lifetime Extension. This offers a real possibility for continued and profitable use of nuclear power in the short to medium term. There are several major benefits to lifetime extensions over the building of new plants.

For one, investment costs for lifetime extension, while not trivial, are lower than for a new plant (nuclear or otherwise) and may be only a fraction thereof, in part because costs such as civil works, land acquisitions, and site preparation are not incurred. Another point is that operating costs already are low or else extension would not be considered. The plant's decommissioning fund also should be fully satisfied, further reducing operating costs. For another, plants considered for lifetime extension usually carry little debt, being largely amortized by the time of renewal, and have a revenue stream attached to assure repayment of financial obligations incurred for lifetime extension. Assuming the economic calculations are sound, financing should therefore be less of a problem.

A lifetime license extension also can result in a power uprating and hence the effective addtion of new capacity. Power upratings of 10% and more have been achieved at many plants. This is attractive because it reduces generating costs.

Nuclear plant life extension also can be attractive for environmental reasons. This is the case where compliance with air pollution standards or commitments to greenhouse gas emission reductions argue against increased generation from fossil fuel plants.

All possible provisions should be made to reduce anticipated completion costs before any investment is decided. Failure to do so could skew the investment decision, would make financing more difficult, and could result in unmarketable generation. Particularly on completion projects, where previous experience with cost control and risk management has probably not been good, investors must be assured of a return with interest, which may involve freeing the project from past debts. Contracts must contain incentives to avoid construction delays, and materials costs managed through inventory control, competitive procurement, a balance of local content and imports, and by ensuring the use of adequate and the most affordable products.

Safety Upgrades. Upgrading a plant for safety reasons may be essential to continued operation, whether to protect assets or to protect the license. Where safety upgrades do not increase output or revenues, owners may be faced with investments they cannot expect to amortize. If continued regulatory approval for operation hinges on the upgrade, such investments must be weighed against both the expected revenues and the cost of closing the plant. A financial NPV analysis would reveal the relative economic benefits of these choices.

NEW NUCLEAR GENERATING STATIONS

New nuclear plants can cost two to four times more to build than fossil-fueled plants. This excludes the cost of risks that affect a project's credit rating, such as non-completion, exchange rate fluctuations or cost over-runs. OECD investment rules already add a 1% risk premium to lending rates on all OECD export credits where nuclear power plants are concerned. Can such risks and costs be reduced or secured sufficiently for nuclear power to compete in capital markets for financing new nuclear plants?

CAPITAL COSTS & CONSTRUCTION TIMES FOR DIFFERENT ELECTRICITY GENERATING OPTIONS

	Cost per kWe installed US $	Total cost for 1000-MW capacity Billion US$	Construction period Years	Typical plant size MW	Typical plant turn key costs Billion US $
Nuclear LWR	2100 – 3100	2.1 – 3.1	6 - 8	600 – 1750	1.5 – 4.2
Nuclear, best practice	1700 – 2100	1.7 – 2.1	4 - 6	800 – 1000	1.3 – 2.1
Coal, pulverized, ESP	1000 – 1300	1.0 –1.3	3 – 5	400 – 1000	0.5 – 1.3
Coal, FGD, ESP, SCR	1300 – 2500	1.3 –2.5	4 - 5	400 – 1000	0.6 – 2.5
Natural gas CCGT	450 – 900	0.45 – 0.9	1.5 - 3	250 – 750	0.2 – 0.6
Wind	900 – 1900	0.9 – 1.9	0.4	20 - 100	0.03 – 0.12

Notes: All costs include interest during construction. Costs per kWe installed are at 10% discount rate.
LWR = Light-water reactor; ESP= Electrostatic precipitator; FGD = Flue gas desulphurization; SCR = Selective catalytic reduction; CCGT = Combined Cycle Gas Turbine.

Source: OECD, 1998.

The target for commercial success has been moving fast as generating costs have tumbled. In 1995, US $0.043 per kWh was considered the goal for a new nuclear power plant to be competitive in the USA. By 1998 estimated costs had to be less than US $0.03 per kWh, absent government intervention, for a plant to be potentially profitable. The average in 2000 has dropped to US $0.02 and, in the absence of substantial increases in electricity demand (the need for new capacity) or fossil fuel price hikes, may even slip further. This decline in generating costs did not just result from competition, but also from low fuel prices and from significant improvements in thermal efficiency in coal and gas fired plants. The thermal efficiency of gas fired plants has risen to well over 50%.

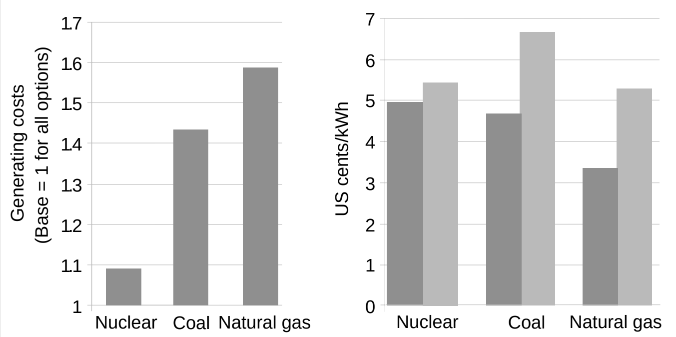
A study on projected costs of generating electricity (OECD, 1998) shows installed capital costs for new nuclear power plants around the world ranging from $1400 to $2800 per kWe (5% discount rate) and $1700 to $3100 per kWe (10% discount rate) including interest during construction. In these cost comparisons, nuclear power is the least costly option in six countries at a 5% discount rate, and least cost in two countries at 10% discount.

The cost structures of these different generating options differ in sensitivities. Because of high capital costs and long lead times, nuclear power costs are highly sensitive to interest rate. Coal plant capital costs vary greatly with the pollution abatement required. Gas generation costs are highly sensitive to gas prices, a relatively high proportion of total costs. *(See graphs.)* In considering a doubling of fuel prices for the case of nuclear power, costs increase by less than 10% while natural gas generation faces a hike of almost 60%. Having nuclear power in the generating mix hedges against fuel price and exchange rate volatility.

Under changing market circumstances, will new nuclear plants be built? Nuclear power could well be priced out of future markets unless the industry takes dramatic action to reduce capital costs and financial risks for new nuclear plants. Nuclear power does have clear advantages including low fuel costs, supply security, minimal environmental impacts, low external costs, and a significant potential for greenhouse gas mitigation in the context of the Kyoto Protocol. Where governments still choose technologies, they may choose nuclear because of such advantages, but only so long as these are not swamped by high capital and generating costs and their associated high risks.

Capital Costs & Risks. New nuclear plants are sometimes divided into evolutionary and revolutionary designs. The former involve modifications of existing designs for improved safety and better economics. In essence, evolutionary design improvements are the result of learning by doing based on past experience. Still, evolutionary designs bear a certain burden of proof that modifications made will result in commercially competitive reactors (e.g., the design may not be attractive if lower specific capital costs are the result of larger plant sizes and hence higher total investment costs which may well exceed the thresholds of shareholder risk).

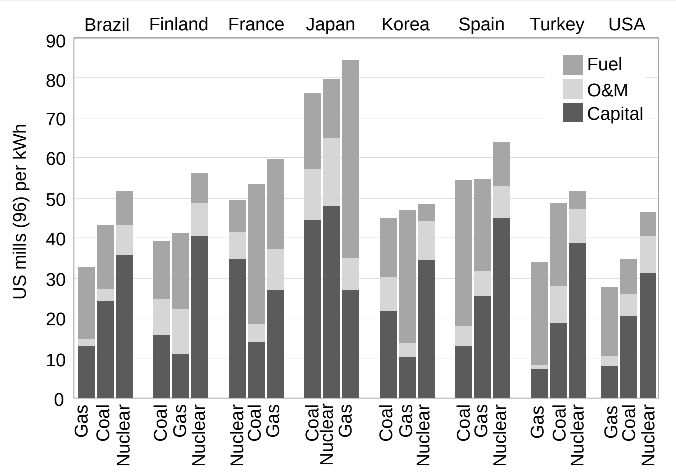
THE IMPACT OF DOUBLING FUEL PRICES ON GENERATING COSTS



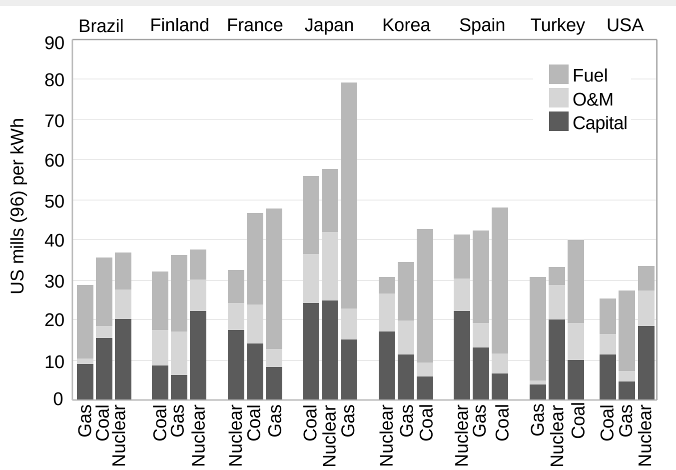
Note: At 10% discount rate & 25 year planning horizon.

ELECTRICITY GENERATION COSTS FOR SELECTED COUNTRIES

At 5% Discount Rate



At 10% Discount Rate



Source: OECD

Revolutionary designs -- that is, radically new designs without a previous commercial history -- offer perhaps a greater potential for competitive advances, primarily because they can be designed explicitly for particular market conditions. In addition, they often also offer significantly improved safety features.

Yet with the exception of the development of the Pebble Bed Modular Reactor (PBMR) in South Africa, and the Advanced Light Water Reactor (ALWR) in the USA, no advanced reactor development has identified as its primary goal a commercially competitive reactor that will meet and beat prevailing market prices, with increased efficiency, profitability and performance.

The development of most other advanced reactor designs, prompted by the Three Mile Island accident in 1979, focus on enhanced safety, but with a cost premium. For the Sizewell-B reactor in the UK, one of the most expensive reactors built to date, up to 20% of the capital cost has been estimated as attributable to "enhanced" safety for an "enhanced" reactor.

High capital costs are the largest single barrier to financing and building new nuclear plants, accounting for some 70% of their total estimated generating costs. Under current estimates these costs would need to be reduced by some 35% before new nuclear plants can compete with new coal and gas plants. Achieving such cost savings would require a number of strategies, including reducing the cost of compliance with safety-related regulation, and reducing the regulatory uncertainties associated with post-operational liabilities.

Uncertainties, risks and liabilities are economically significant because they carry a cost, sometimes high, that can be reduced or managed. They must all be estimated and accounted for and are just as important to investors as the estimated cost of generation Therefore, reducing financial uncertainties will be as important as reducing nominal costs.

New nuclear plants have high financial risks not necessarily unique to nuclear power. These include completion risks, regulatory and political risk, and commercial risks associated with changing markets. Investors will require high return on investment to compensate for such risks. The big question for nuclear power is whether market prices will permit them to afford such premiums and still turn a profit.

Cost Effective Safety. Enhanced safety is a major focus in the design of new nuclear power plants, and its costs will be a significant factor in any decision to invest or not in nuclear power. Improving the cost-effectiveness of these safety-related investments can therefore contribute to the financing of new plants. While the share of safety costs as a percent of total costs for a new nuclear power plants cannot be determined with any precision, it is significant; some estimates range up to 40% to 60%.

There are a number of approaches being explored to reduce the costs of enhanced safety in new reactor designs, many of which include making a standard of no significant off-site consequences even under worst case accident scenarios (instead of specifying a number of individual performance requirements and regulations). These include among others:

- the use of passive safety designs;
- the reduction of the number of components and materials subject to “nuclear grade” quality requirements, which for some components can add 200% to the cost of procurement;
- a move to more risk informed safety regulation; and
- regulatory prescription of goals rather than means, permitting greater flexibility in compliance.

In the past 20 years, certain new safety goals and requirements have been established for nuclear power plants with little consideration of economic costs and benefits, or of alternative and perhaps more cost effective ways of achieving the desired safety goals. This approach was encouraged by the fact that most nuclear plants operated in monopoly markets where costs could be rolled into rates and so were not necessarily a primary concern. But times and markets have changed, and regulatory approaches must also change, to permit a clearer definition of when a plant is safe and, at the same time, to provide for flexibility in achieving this goal.

The safety risks associated with current nuclear plants have already been reduced to very low levels, while the financial risks associated with building new nuclear power plants are large and growing. Investors will scrutinize new plant and new plant designs on the basis of cost/benefit and net present value analyses. These can be used to identify improvements for which the lowest achievable cost may still be very high, may be disproportionate to the consequent safety gains or to the costs associated with the risks to be reduced, and may threaten the economic and financial viability of the plant. For a company selling power in increasingly cost conscious and competitive markets, the net cost of safety measures - like all generating costs - is a crucial concern. It is also significant in choosing nuclear versus non-nuclear technologies for electricity generation.

This question of diminishing returns is not unique to nuclear safety, but in fact governs most environmental and health protection standards. In air pollution control, for example, the cost of 90% to 98% removal may be tolerable, but removing the last 2% is exorbitant in relation to the benefits gained. It must be unequivocally stated that the level of safety-related expenditures are not a measure of a plant’s safety level. What has to be accomplished is to reduce safety costs while at the same time not compromising but rather improving safety.

This approach does not make judgments about what safety level is appropriate, but it does require consideration of economic consequences, financial analysis of proposed safety requirements, and background analysis of costs and benefits in the safety field.

Managing Liabilities for Decommissioning & Waste Disposal. The second most important impediment to investing in new nuclear plants is post-operational liabilities, namely, the costs and risks associated with decommissioning and waste disposal. Here there is a need to extend analyses from engineering cost estimates and their funding to the practice of liability management.

The engineering and technology are available to handle these tasks. Engineering plans and cost estimates for decommissioning and waste disposal have been thoroughly researched and are regularly updated, primarily as a basis for assuring that sufficient funds are set aside to cover the eventual cost of decommissioning and waste disposal. Moreover, the standards established for these activities are good.

Nevertheless, present cost estimates will surely differ from the costs ultimately incurred, because the circumstances on which these costs are predicated will surely change. Examples include: availability of waste disposal facilities and policies governing their use, early plant closings; changes in allowed radiation standards for release of materials and sites; regulatory policies that affect the economics of plant operations, decommissioning and waste disposal; changes in tax and accounting rules; restructuring, privatization or increased competition.

Given the long lead times involved in decommissioning and waste disposal, companies will usually have time to adapt to changing circumstances, assuming risk management techniques and provisions are in place, and there is flexibility to change strategies appropriately. There is no doubt at all that decommissioning and waste disposal can be and will be accomplished. The only questions are those of timing, priorities, efficiencies and hence costs, most of which lie outside the control of nuclear plant managers. The choice of how expensive and how efficient decommissioning and waste disposal is largely political. The major choice for nuclear plant owners and operators is how best to incorporate and minimize the uncertainties involved.

What matters, then, is how companies are prepared to deal with unanticipated change. The nuclear industry generally is not well equipped in this respect. Nor do they regularly review the economic implications of regulatory changes. As a result, significant economic costs and inefficiencies are likely to be incurred by the industry and by society, and the financial risks associated with these post-closing operations can grow rapidly unchecked. The focus should be on efficient cost management, and on appreciating the costs of uncertainty and of political and regulatory change.

Prudence is needed rather than foresight: strategic and financial provisions need to be made for political uncertainties affecting post-operating obligations. Continual risk assessment that is tied to the company's bottom line, and prudent financial provisions for scenarios that can affect the company's assets or revenues, are all standard corporate risk management strategies. Yet with few exceptions, such techniques are not standard among nuclear plant owners and holders of operating licenses.

How risks and costs are managed will govern over time which generating technologies are retained or phased out, dispatched or not, and selected for future plants or not. High cost, high-risk projects will require high returns. Can the nuclear industry afford the required rewards in competitive markets, or can it reduce investors' commercial and financial risks to affordable levels? These are moving targets.

PREPARING THE WAY

So what is the future of nuclear power? Existing plants, where efficient, can be expected to thrive. New plants won't be built without a clear and strong nuclear industry initiative to change its design requirements, commercial orientation, and regulatory context.

It is true that nuclear power offers many environmental benefits, particularly in reducing air pollution and greenhouse gas emissions, but these are insufficient by themselves to assure a nuclear future. Those who pin their hopes for nuclear growth on the Kyoto Protocol — and ignore reform — will be doomed to disappointment. Finally, policy makers must address the question of waste disposal, and be willing to let the industry demonstrate the availability of technology to manage nuclear waste. This is essential to informing public perceptions about the safety of nuclear waste disposal as an industrial process. ❑