The Uranium Institute

Twenty-Third Annual Symposium
10–11 September 1998: London

Electricity Market Competition and Nuclear Power

Caroline Varley & John Paffenbarger

Throughout the world, including OECD member countries, governments are promoting competitive electricity markets. In particular, there is a move away from administrative price setting by government institutions to market price setting through the introduction of competition. Today this is often focused on competition in generation. However, competition among final electricity suppliers and distributors to provide effective consumer choice is a further step that governments are likely to pursue as experience with market reform grows.

The basic objective of all efforts to reform electricity markets is to improve the economic efficiency of a secure electricity supply, and to pass through the benefits to consumers through lower prices. Other objectives, however, remain very important. As electricity markets are changed, some of these policy objectives constrain the range of available choices for the new market structure. The most important examples are the policy objectives to maintain security of fuel supply, system reliability, and environmental performance.

Broad Influences of Competition on Generation Plant

The single most important influence of competition on electricity supply systems will be the greater emphasis on cost efficiency by utilities. This is one of the fundamental benefits competition is intended to promote. Competitive markets provide incentives, in a way that no other approach can, to reduce costs and increase productivity.

Electricity market competition is expected to:

- concentrate efforts by plant owners to reduce expenditure on generation and to maximise returns;
- re-orient decision making to incorporate private rather than public costs and benefits;
- lead to more transparent and effective pricing, to better reflect costs.

Utilities will seek new methods and technologies to ensure that they are able to provide secure and clean electricity at the lowest possible cost in comparison with their competitors. A recent International Energy Agency (IEA) study[1] identifies specific utility strategies to minimise costs in generation. Utilities have always pursued cost-effective operation through "technical" approaches related to improvements in plant investments, operations and maintenance, and fuel efficiency. The ultimate scope for further cost reductions in specific utilities from competition will depend on how successful, or not, regulators and governments were at maximising commercial efficiency under the former monopoly supply conditions.

Utility responses to the introduction of competition are not restricted to improvements in generation plant and operations, although these areas are fundamental. Business practices in general will become more oriented towards profitability. As monopoly supply rights disappear, marketing will grow in importance. Marketing and pricing will increasingly be tailored to user needs in all respects: avoidance or tolerance of supply interruptions, seasonal or daily variations in demand, power quality, related services such as customer system maintenance, green pricing, and other areas.

Competition and Nuclear Power

Nuclear power cannot remain isolated from electricity market competition. Table 1 summarises the status of electricity market reform in OECD countries with nuclear power plants. Both existing and future nuclear power plants will be affected by competition. Ultimately nuclear power, like all power generation technologies, will be increasingly subject to market requirements that may not have been foremost under traditional, monopoly supply arrangements. Nuclear plant operators will increasingly be left to fend for themselves in electricity markets.

Structure of Discussion

The impact of electricity market competition on nuclear power generation is discussed under the following headings:

- energy policy issues,
- operating nuclear power plants,
- nuclear utility business structures,
- new nuclear plants,
- safety and safety regulation,
- plant closure and waste disposal,
- other nuclear activities.

Several key transitional issues for the nuclear industry when moving to competition are also addressed.

Energy Policy Issues

Transparency of Policy Measures

An important change in the framework for nuclear power development under competitive markets will be the clearer separation of commercial and government decision-making. Under non-competitive supply systems, governments had available a number of mechanisms to pursue public policy objectives without any easily identifiable public or private expense. The essential arrangement was to assign the responsibility for executing policies to utilities which, through state ownership, regulation, or in a "co-operative" spirit, bore the costs. These expenses could be passed on quietly and diffusely to electricity ratepayers.

The list of such policy objectives pursued through electricity utilities is long and extends well beyond energy-related policies. Among others, it includes support for domestic coal mining, support for domestic power equipment suppliers, regional development, consumer protection, rural electrification, employment, environmental objectives, and promotion of energy security. Seemingly every type of generation technology / fuel combination has been promoted or discouraged in one country or another in support of various policy objectives. Governments followed this approach because they felt that least-cost development of electricity supply

Table 1. Status of electricity market reform in OECD countries with nuclear power plants (mid 1998).

Country	Current status/ policy orientation*	Year	Comments
Belgium	EU Directive	1999	
Canada	Provincial-level competition	2000	In Ontario, to be first competitive province out of three provinces with nuclear power plants
Czech Republic	Privatisation	1997	
Finland	Competitive market	1997	Member of NordPool market
France	EU Directive	1999	Emphasis on " public service"
Germany	EU Directive**	1998	Negotiated network access model
Hungary	IPP programme	1994	60% privatised since 1995
Japan	IPP programme	1996	
Korea	IPP programme	1993	Privatisation programme starting 1998
Mexico	IPP programme	1997	
Netherlands	Competitive market	1999	Network access model, pool possible
Spain	Competitive market	1997	
Sweden	Competitive market	1996	Member of NordPool market
Switzerland	Under discussion	n.a.	Network access model
United Kingdom	Competitive market	1990	Privatised nuclear plants in 1996
United States	State-level competition	1998	Federal law under development

* " EU Directive" indicates that country has not yet fully defined the legal framework for implementing the EU Electricity Directive, which requires the introduction of some competition in generation, network access, and end-user choice. Independent power producer (IPP) programme defined as procurement of new generating capacity by long-term purchase agreements. This is not a competitive form of electricity market.

** German law transposing EU Directive currently under legal challenge.

Source: IEA

might not have resulted in the same business choices.

In markets where electricity supply becomes open to competition, individual investment and operational decisions will no longer incorporate non-economic requirements unless they are made explicit by government action. Investment decisions will also reflect commercial reality more closely in, for example, projected investment costs or fuel price escalation rates. Policy costs previously borne by monopoly utilities will be made transparent by the arrival of competition. This forces governments to either make their policies and policy instruments transparent or to abandon them. Governments must establish a democratic consensus for policies affecting electricity markets and demonstrate that they are best pursued through the electricity sector rather than through other areas of the economy.

In particular, government support for specific generation sources must become open. The cost of support policies will become apparent and brought to the attention of consumers. For example, in the United Kingdom and Spain, competition in electricity supply has highlighted the cost of policies to support domestic coal mining. In the Netherlands and other countries, support for renewable electricity production has been a particular issue. In Germany, support for combined heat and power systems was extensively debated during their reform of the electricity market.

In every country with nuclear power plants, there has been strong government funding for their development. Research and development of nuclear technology has perhaps been the most visible component of this support. Governments have also built specialised facilities such as enrichment plants, fuel reprocessing facilities, and radioactive waste facilities. In the countries with atomic weapons (United States, United Kingdom, France), military programmes supported the development of civilian nuclear power plants.

The past arrangements for government support of nuclear power perhaps contribute to public mistrust of it. Past government support may contribute today to the sentiment that the choice of nuclear power was not made openly and democratically, but secretly, and with financial support that has not been fully justified or accounted for. In some countries there seems to be a strong public sentiment that the true costs of nuclear power are still unknown because of secretive or unquantified government support. The implication is that nuclear power would not be sustained if left to rational economic choice in open markets.

Competition in electricity markets, and the increased policy transparency it brings, could be an important means to erase this element of mistrust. To the extent government financial support for nuclear power continues, especially for the construction of new plants, it will become more explicit for both market participants and the public. Owners of power plants in competition with nuclear power plants will not hesitate to bring to the attention of the public and competition authorities those support measures that they believe to be unfair or not justified by public benefits. The perception of nuclear power as a fully democratic and market-based choice will be strengthened. Competition could, in this respect, help to strengthen public acceptance of nuclear power.

Accommodating Public Policy Concerns

There is no fundamental incompatibility between competitive markets and the pursuit of government policy objectives of any kind, as the long experience of OECD governments shows. Countless social, economic, defence, and other policies have been implemented through mechanisms that allow markets to function while still taking into account public objectives. The essential requirement is to translate policy decisions into constraints and costs that markets can assimilate. For example, environmental policies can be implemented as technical limits on emissions of pollutants or tradable pollution permits. Owners of industrial and power plants must then pay for pollution control equipment or permits, thus incorporating the cost of the policy measures in their commercial decisions.

There are numerous market-compatible policies and measures that may be used to implement public policy choices. Tonn et al[2] list thirty-one "enabling mechanisms" suitable for use in a restructured electricity industry. For example, governments can require non-competitive parts of the electricity supply system to bear the costs of some policies. Charges on the use of the network can include such a policy-related component. Taxes, investment support, special-purpose markets, and government research and development are potential measures. Nuclear power can be supported, if governments so desire, by these and many other mechanisms.

The change from monopoly to competitive electricity markets forces governments to adapt policies and subject them to the rigours of public debate, often for the first time. There is no technical reason why policies designed to support nuclear

power cannot be transposed to competitive markets, but this will require governments to clearly spell out the costs and benefits of these policies, and to put them to the test of public debate. If public views on the support of nuclear power have changed since the existing policies were put into place, there is a risk that their transposition to a competitive market will not succeed politically. It is this risk that some governments seem to fear, but it is one that must be taken if nuclear power is to be effectively integrated into competitive markets and if it is to secure a soundly based future.

Energy Security Still a Valid Objective

The goal of preserving energy security has always been one of the primary public policy reasons for supporting nuclear power. Countries with limited domestic fossil fuel resources, notably Japan, Korea and France, have always emphasised energy security in their support for the development of nuclear power. As with other policy objectives, however, the pursuit of energy security is compatible with electricity market competition.

If nuclear power is the most economic alternative in a given market, there is no need for government action to encourage it. If it is not, then the challenge for governments wishing to support it is to find a politically acceptable balance of cost and benefit for supporting energy security through the use of nuclear power, among other potential energy sources. An IEA analysis[3] shows the difficulty of this exercise, especially in quantifying the value of energy security and the contribution that non-fossil energy sources can make to it. Robinson[4] argues forcefully that overriding the market in the case of nuclear power runs the risk of undermining the objective of market reform itself. Since economic efficiency is a primary object of electricity market competition, it would be counterproductive for governments at the same time to supplant the role of the market by substantially altering what would otherwise be the market choice. Still, it is clear from past very strong support for nuclear power, and from the current support for renewables, that political support can be found for specific generating sources when their perceived societal benefits are clear.

Effects on Operating Nuclear Plants

Whereas monopoly supply systems can pass along the cost of operating generation plants to electricity customers regardless of cost, in systems with competitive generation this will no longer be the case. The marginal cost of production (also known as the short term variable cost) of individual power plants is what sets the bulk price of electricity in systems with competition among generators. That is, plant owners will be willing to sell electricity from individual plants as long as the price they receive is greater than their marginal costs of production. Expenses for fuel and operations and maintenance (O&M) are the components of short-term cost.

In the short term, economic viability is ensured if production costs can be kept below the market price. In the medium term, prices must be sufficiently high to pay for debt repayment and capital improvements. In the long term, for investments in new power plants, the market price must provide a sufficient margin to pay both production costs and the full capital costs. For existing nuclear plants, the implications are as follows.

Low-Cost Plants Will Thrive, High Cost Will Shut

Existing nuclear plants with low marginal production expenses will thrive in competitive markets, while those with high marginal costs will either innovate to reduce them, or will cease operation. This is the essence of what changes for existing nuclear power plants under competition. This provides strong incentives to reduce costs and will lead to changes in the way existing nuclear plants are operated and managed. Their output will be maximised and extended in time to maximise revenues. These are well established results in countries with electricity market competition.

Marginal production costs are generally low in nuclear plants, although this can vary considerably. On the basis of marginal production costs, it appears that the majority of existing nuclear plants operating throughout the OECD will be able to compete with their fossil-fuelled rivals.

There is, however, some debate about the size of this majority. This debate has been centred in the United States, which has the largest and most diverse set of nuclear power plants, and where performance varies greatly among operating plants. The best performing nuclear plants have marginal expenses of US$11 to US$15 per MWh, and the average for all US nuclear plants was US$21 per MWh in 1996.[5] In comparison, the average production cost was US$21 per MWh for US fossil-fuelled, steam electricity plants. Although average expenses do not indicate the individual plants that may face economic difficulties, they do suggest that, on the whole, a large group of US nuclear

plants would be able to recover their costs of operation in a competitive electricity market. The best performers would do quite well, since their production costs are well under typical wholesale electricity prices of US$25 per MWh.

On the other hand, two studies, much disputed by the nuclear industry, state that up to 40% of US nuclear capacity could have marginal expenses higher than competitive market prices if the plants remain at their current levels of performance.[6,7] The majority of the potentially uncompetitive plants are located in the Northeast and Midwest. It seems likely that the estimate of 40% is too high. It is clear that some fraction of nuclear plants will face difficulty, as shown by the permanent closure of 8800 MWe of nuclear capacity from 1997 to mid 1998. The owners of the shut plants cited economic reasons, in some cases the need for refurbishment that could not be justified in the light of expected plant revenues. To date, only a few nuclear power plants in several states have been subject to true competition, though all are preparing for it in the expectation that most states will introduce competitive electricity markets in the coming years.

In France, the government-owned utility Electricité de France states[8] that its nuclear power plants are currently competitive with fossil fuelled alternatives on the basis of US$22 per MWh marginal costs (FFr 0.13 per kWh).

Those OECD nuclear power plants already operating in competitive electricity markets are generally faring well. The oldest example is given by British nuclear plants, which have been able to compete on the basis of price in that country's electricity pool since 1990.[9] Nuclear power plants in Finland and Sweden have been operating successfully within the Nordic electricity market, and Spanish nuclear power plants have competed successfully in the competitive market introduced at the beginning of 1998. The single operating nuclear plant in the Netherlands anticipates no problem competing under the new competitive system agreed in 1998. The total capacity of nuclear power plants in the United Kingdom, Finland, Sweden, Spain, and the Netherlands is about 30 GWe and represents over 10% of OECD nuclear capacity.

Although competitive marginal costs of production will allow many nuclear plants to continue operation, this assumes that outstanding plant debt does not pose a cash flow problem. This will be the case if there has been a sufficient period of amortisation or if there were explicit payments for transition costs included in the change to competitive markets; this will be discussed further below.

Performance Improves and Operating Costs Decrease

Nuclear plants will compete not only on the basis of their typical "historical" costs before introduction of competition, but also as a result of lower unit costs obtained through performance improvements and increased plant output. There has been a worldwide trend towards improved nuclear plant technical performance since the late 1980s. Learning must account for a good part of this as the industry has matured. Competition, or the expectation of competition, has also played a role, particularly in the United States. Many indicators of performance and safety are likely to further improve under competition, including:

- corporate and plant-level overheads,
- duration of plant refuelling,
- time between refuelling,
- energy utilisation of nuclear fuel,
- plant utilisation rate (capacity factor),
- staffing,
- unplanned plant shutdowns,
- collective radiation exposure of workers.

The UK nuclear generator British Energy (and its predecessor Nuclear Electric) has operated under a competitive market longer than any other nuclear generator in the OECD and has shown significant cost improvements in its new environment. From 1992 to 1997 staffing decreased from 8200 to 5000, while total plant output increased 64%, from 41 TWh to 67 TWh. The company improved operations as measured by load factor, decreased industrial accident frequency, decreased worker radiation exposure, and improved other technical indicators. Overall, production costs decreased from US$80 to US$33 per MWh (£0.02 / kWh).[10,11] It should be noted that the starting point for technical and economic performance indicators of British nuclear plants was relatively poor among OECD countries in 1990.

The United States has shown substantial improvement in nuclear plant performance in the 1990s. Since 1992, when the Energy Policy Act opened access to wholesale electricity markets, the prospect of electricity market competition has been an important driver of this improvement, though certainly not the only one. From 1990 to 1996, plant thermal efficiency increased by 0.2 percentage points, the volume of low-level wastes generated decreased by almost two thirds,[12] nuclear plant staffing decreased by 7%,[13] and times required for refuelling dropped by over one third. Overall,

nuclear plant production costs decreased from US$23 to US$21 / MWh, according to US Department of Energy data.

Upgrades and Longer Lives Will Provide New Capacity
Increasing the capacity of existing plants and extending their lifetimes are likely under competition[14] because they can provide "new" capacity without incurring the full costs that would be required for a complete facility. In Spain, for example, an extra 4% (220 MWe) nuclear plant capacity was added between 1995 and 1997 from steam generator and turbine upgrades. An additional 7% is expected to be added by 2004. Swedish BWRs using nuclear systems designed by ABB Atom have been upgraded to provide a total additional capacity of 600 MWe.[15] US plants designed by Combustion Engineering have increased their capacities by between 2.5% and 15%. Capacity upgrades are likely to be pursued further under competition.

The competitive advantage of owning depreciated nuclear plants with low marginal costs, combined with the difficulty in siting and building new plants of any type, is likely to lead many utilities to extend the lives of their nuclear plants. This may entail additional investments to bring plants up to current safety requirements. Two of the earliest reactors built in the United Kingdom applied for and received permission in 1998 to operate for an additional 10 years beyond their initial 40 years of operation, contingent upon further safe operation. The first US plant to seek licence renewal expects to invest more than US$300 million for equipment and safety upgrades.[16] If a twenty-year extension to its licence is granted, the plant will operate for 60 years. With continued investments and refurbishment, current nuclear plants should be able to operate for 60 years, or even longer.[17] As long as the expected value from continued operation exceeds the cost of capital improvements and refurbishment needed to operate safely, individual owners will seek to continue operating their plants. Competitive markets are likely to test the limits of economic lifetimes for the current generation of nuclear plants.

Effects on Nuclear Utility Business Structures
In addition to improvements in plant performance and operation, competition is likely to bring improvements to the management and business arrangements of nuclear utilities. This is already beginning to be seen in the United States, where a diverse group of nuclear utilities is seeking ways to improve the organisation of nuclear generation businesses as competition develops.

Reorganisations and Consolidations
Corporate reorganisations are often legally required when electricity market competition is introduced. Accounting or legal separation of generation, transmission, and distribution activities are typically specified so that there is a sound basis for competition in generation and other segments. Among utilities that own nuclear plants, utility corporate structures may be reorganised to better manage the special requirements of nuclear power generation. Corporate entities may be created to manage special risks or funds related to nuclear power activities.

Consolidation of nuclear power activities is likely. Single-unit nuclear power installations generally have higher fixed operating costs per unit of electrical output because of the specialised infrastructure, staff, and regulatory activities required for nuclear installations, regardless of size. A likely strategy for owners of single-unit nuclear power plants will be to consolidate the business operations of their units with other plants through mergers. Other small or less successful nuclear utilities may decide to hire an operating company to run their nuclear plants. Mergers and operating agreements allow companies to share nuclear-specific expertise and facilities and to spread the fixed costs of some nuclear activities over a larger total output. Consolidation could extend quite far according to some. The head of a major US nuclear utility suggested that the number of nuclear utilities in the United States could drop from around fifty today to ten or fewer.[18]

Utilities may also wish to sell their nuclear plants or shares in nuclear units. The companies that purchase nuclear units or shares in them, as in the case of merging companies, will be able to reduce the per-unit overhead costs of nuclear generation, bring new expertise to the operation of their plants, share specialised staff, and negotiate contracts with suppliers from a stronger position.

International activity of this type is also likely to grow as competition is introduced into other OECD markets. Companies wishing to conclude business transactions with foreign companies are likely to press for the removal of restrictions on foreign ownership of nuclear power plants and other facilities, such as still remain in the United States.

Limits on Consolidation and Special Support
Nuclear generators will lose the exemptions from general competition law they have enjoyed under monopoly supply arrangements. Competition authorities will have an important role in ensuring that utility consolidation (not just among nuclear utilities) does not lead to abuses of market power in competitive markets. They can act to prevent anti-competitive contracts, mergers, or joint ventures between nuclear generators. Competition law will therefore provide some limits to the new business freedom of nuclear utilities in competitive markets.

Competition authorities will also act to eliminate preferential government support for particular generators. Subsidies, transfers, or special privileges such as tax exemptions or procurement set-asides will come under scrutiny. Nuclear utilities that benefit from such support are likely to see it come under pressure.

Contrasting Strategies: Focus on Nuclear or Diversify
Some companies with good records of nuclear plant operation will seek opportunities to expand their activities through operating agreements or acquisitions of nuclear generation and related companies. For these companies, the basic strategy is to develop and take advantage of their strengths in nuclear power. As with consolidation, a benefit to the nuclear industry will be the transfer of superior operating, safety, and management practices from the industry's best performers to others. British Energy has formed a joint venture company AmerGen with an US nuclear utility to explore possibilities to acquire and operate nuclear generating power plants. Entergy is focusing its growth strategy on nuclear operations, and was among the first US utilities to seek contracts for operation of nuclear plants.[19,20]

A contrasting strategy is to diversify activities into other types of generation or entirely new business areas. Utilities who consider that their activities are too highly concentrated in nuclear power generation, or those with poor records of nuclear plant management, may favour this strategy. Some US nuclear utilities have increased their shares in gas-fired power generation outside their service areas through subsidiaries. The nuclear industry is likely to benefit from increased interaction with businesses and industries outside the nuclear area.

The strategies are not mutually exclusive. Electricité de France has been preparing itself for competition in 1999 by, among other actions, investing in non-nuclear generating plant and electricity distribution companies around the world.[21] But it is also pursuing nuclear plant opportunities in China, Turkey, and elsewhere.

Bankruptcy May Contribute to Change
Bankruptcy will be a new potential option that some nuclear utilities may turn to if, ultimately, they are not able to compete successfully. That a nuclear plant could be left abandoned because of the financial failure of its owner is effectively impossible in OECD countries. It is most likely that bankruptcy would facilitate sales of plants to more successful nuclear utilities. It could provide a means to reduce unsustainable debt on nuclear plants if arrangements for the transition to competition do not do so.

Effects on New Nuclear Plants

Current Prospects for New Nuclear Plants
An issue of concern to the nuclear industry and to some governments is the prospect for new nuclear power plant construction when there are competitive electricity markets. Today, this is a largely theoretical concern because, under any electricity market system, monopolistic or competitive, the prospects for nuclear power are very limited in OECD countries. The introduction of competitive electricity markets should not be confused with, or be held responsible for, the pre-existing prospects for nuclear power in the near term.

There are likely to be few, if any, new commitments to build nuclear power plants anywhere in the OECD, except Japan and Korea, in the next 10 to 20 years. This assessment is common, both within the nuclear industry and in the electricity utility industry in general. It assumes that fossil fuel prices do not increase greatly, and that environmental protection regulations do not become significantly more stringent. The reasons why few new plants are expected are well known:

- in many markets, there are power generation alternatives with lower total generation costs;
- there are no fully developed, politically accepted plans and facilities in place today for disposal or re-use of nuclear plant high-level wastes, including used fuel;
- there remain public concerns about what constitutes an acceptable level of operating plant safety in new plants (nuclear plant siting is especially difficult because of this);
- there remain concerns about use of nuclear materials from power plants for atomic bombs

or terrorist actions;
- in some markets, the need for new baseload capacity in the near term is limited because of existing reserves of generating capacity and moderate electricity demand growth rates.

In any type of electricity market, the weak economic position of nuclear power today limits prospects for new plants. Nuclear power is not necessarily more expensive than alternatives in every market, especially in those with high fossil fuel prices and where nuclear plant capital costs can be kept low. However, a joint study by the IEA and OECD Nuclear Energy Agency (NEA)[3] shows that in a majority of countries, and under various financial evaluation conditions, fossil fuelled power generation is less expensive for meeting baseload demand than nuclear power generation. Competitive markets will provide options for meeting demand with plants other than the large, centralised ones common today. In most markets then, competition will merely confirm the humble economics of nuclear power today.

The issue of how to deal with used nuclear fuel has taken on increased importance as temporary storage plans and facilities have been stretched to accommodate delays in developing permanent solutions, but the issue has not been resolved. Only a small fraction of commercial nuclear power plants have permanently ceased commercial operation, so there are few actual examples to confirm cost estimates for final closure. These are elements of uncertainty which compound the tenuous economic case for nuclear power in many markets.

There has been little economic driving force for new nuclear power plants in recent years, so there has been little driving force to resolve some of the non-economic issues which restrain nuclear plant development for the future. The improved policy transparency that competition brings should help to resolve some of these issues and reduce mistrust in nuclear power.

In some countries, there are formal or de-facto prohibitions on the construction of new nuclear power plants. This is the case in Australia, Austria, Denmark, Greece, Ireland, Italy, New Zealand, Sweden, Switzerland, and Portugal, among other OECD countries. Regardless of electricity market arrangements or nuclear power's economic competitiveness, no nuclear power plants will be built in countries or states where there is a political impasse on the use of nuclear power. This political impasse, and the issues that must be resolved before there could be new political decisions in support of nuclear power, are far more important to the future of nuclear power than the introduction of competitive markets.

In the long term, there is every reason to expect that nuclear power's economic competitiveness could improve, depending on a host of factors. A penury of fossil fuels could finally arrive in the next century, driving up their prices and improving the relative position of nuclear power. Removal of production subsidies from domestic fossil fuels could increase their prices in some countries. Stricter regulations on emissions of pollutants from non-nuclear power plants could have the same effect by increasing the cost of pollution control. Nuclear power proponents today pin great hope on the commitment to reduce emissions of greenhouse gases as the decisive factor in nuclear power's future. Since nuclear power produces no carbon dioxide, it could enjoy an economic advantage if there is a value to not producing the gas.[22] On the other hand, lower limits on radioactive releases permitted by nuclear plants or nuclear fuel cycle facilities, more stringent or different safety regulations on the disposal of nuclear wastes, or other changes in the regulation of nuclear material could equally have negative effects on the economics of nuclear power.

Such changes in the economics of nuclear generation are unrelated to competitive electricity markets. The examples merely suggest that today's economics situation for nuclear power is not necessarily tomorrow's.

Competition Is Compatible With New Nuclear Plants

Some in the nuclear industry and some governments suggest that competitive electricity markets are inherently incompatible with decisions to build new nuclear power plants. They argue that competitive markets favour investments with low capital costs, short construction periods, and short payback periods, none of which nuclear plants have. According to this line of reasoning, high discount rates that do not reflect the "societal benefits" of a long-term supply of electricity will lead utilities in competitive markets to select only gas-fired combined-cycles and other plants with low capital cost: new nuclear plants will never be built. A parallel argument is also made by some worried about the fate of coal-fired power plants in competitive markets.

The argument reflects a misunderstanding of how competitive markets function. Companies do not make decisions on investments based upon initial cost alone. Rather, they weigh the cost of investment against the prospect of a stream of

revenue extending into the future. If an investment, even a heavy one, offers the prospect of steady profits because its ongoing costs are low compared to alternatives, there will be an adequate incentive to make the investment.

Considering a specific case for baseload power production makes the point clearer. If a gas-fired combined cycle is less expensive to build, but has much higher operating costs than a nuclear plant, its electricity will be too expensive to compete with that from the nuclear plant. Over time the nuclear plant would be able to sell its power on the electricity market while the combined-cycle sat idle, or earned a smaller amount due to its higher running costs. The "advantage" of lower capital cost would be of no use without an adequate revenue stream to repay that lower investment. There will be a strong incentive to invest in the plant with the lowest total cost of generation. In summary, if the balance of capital, operating and fuel costs gives a lower total cost of generation to a nuclear plant, or any capital-intensive plant, there should be no economic impediment, and every economic advantage, to investing in that plant in a competitive market.

Some governments have taken a cautious approach when introducing competitive electricity markets by providing a mechanism to pay power plant owners for capacity separately from electricity. This was the case in the United Kingdom, though these capacity payments are to be eliminated. The markets in Spain, Portugal, and Argentina also provide capacity payments to generators. The payments are designed to provide a steady incentive for investment as prices and demand vary. Capacity payments could help to smooth the transition to competitive markets and reduce investment uncertainty. The need for them in the long term is, however, much debated. Other industries, such as the petrochemicals or the liquefied natural gas industries, demonstrate that markets can mobilise heavy investments, even without such a "structural" market guarantee.

The most important factor determining the balance of capital, O&M, and fuel costs is the discount rate, or opportunity cost of capital. It implicitly sets the relative importance of many factors involved in an evaluation of total power generation cost and profitability, including initial capital cost, construction time, operating lifetime, fuel costs, O&M costs, plant salvage value at the end of its lifetime, plant closure costs, and future revenues.

The argument that discount rates will be "too high" in competitive markets reflects a misunderstanding of the role of markets in allocating capital to productive enterprises. The discount rate used by privately owned companies in any industry reflects a broad societal weighting of the relative importance of saving money (investing) for creating future income versus spending money now. Private investors have a choice of what to do with their money, and by providing equity or lending to a company that invests in power generation, automobile manufacturing, or any other commercial venture, holders of private capital, as a whole, allocate money efficiently to activities society deems valuable. The allocation takes into account the potential value to society (that is, the productive output of the enterprise that society wishes to buy), as well as the cost of producing that value and the possibility that the investment may fall below expectations (that is, the risk).

The possibility that discount rates used by generating companies may change in competitive markets does not mean that the use of capital in power production will be worse than under monopoly markets. Rather, it will simply mean that there will be a better allocation of capital between electricity generation and other productive activities. In many electricity markets, the discount rate may increase when competition is introduced because uncertainty for utilities will increase. After a transition period, perhaps lasting up to a decade, the cost of capital will decline again and reach a stable value.

If the final average discount rate used by generating companies increases in a specific electricity market as compared to the former monopoly regime, this would suggest that capital was previously used less efficiently. Like many other products and services in modern society, such as telecommunications, automotive fuels, or industrial-scale food production and distribution, electricity generation is an essential part of the fabric of daily life. Modern society could not be organised as it is without electricity. However, like other essential products and services, there is no compelling reason to reserve a special allocation of societal capital to electricity generation compared to other activities. In fact, the move to competitive electricity markets reflects the broader recognition of the idea that electricity generation is not such a unique commercial activity after all.

An IEA analysis[1] confirms that investment in generating capacity can be efficiently governed by competitive markets. There is little to suggest that inadequate investment or systematically

incorrect plant choices will be made by utilities in competitive markets.

Competition Will Improve Economic Prospects

The same forces that shape the operation of existing nuclear power plants will inevitably improve the economic performance of new nuclear power plants. Improvements in operating practices, plant technical performance, administration, and many other areas at existing plants should be largely applicable to new plants. The costs of operating and maintaining a new nuclear plant, like existing plants, are likely to decrease as a result of the efficiency improvements from electricity market competition.

The capital costs of building new nuclear plants are likely to decrease as well. As utilities seek ways to gain competitive advantage, there is no economic reason why they should exclude considering improved nuclear plants. Power plant owners seriously evaluating new nuclear plants will identify improvements that plant manufacturers and designers may have missed in the absence of specific market applications for their designs. Furthermore, if the economic promise of improved nuclear plant designs can be demonstrated in the markets where they are economically feasible (though seemingly quite limited today), competitive markets are more likely to risk a new plant design as long as it has prospects for substantial benefits. The nuclear industry itself is beginning to recognise the potential of competitive markets to improve upon and move beyond the first generation of nuclear plant designs.[23,24]

At least four major new nuclear plant designs have been developed in recent years: the Advanced Boiling Water Reactor (ABWR), the AP600, the System 80+, and the European Pressurised Water Reactor. Competitive generation markets will establish how competitive these plants are, particularly in relation to plant size. But the designs exist, and the first three have already passed many regulatory hurdles in the United States. Two ABWR units went into operation in Japan in 1996 and 1997. These updated designs, among others, will thus provide reference points for further improvements in plant economics.

Finance Can Be Found for Economic Plants

Bankers and financial markets in general have sometimes been blamed for stifling investment in capital intensive power projects. They are often said to be hostile to nuclear power, and financing is assumed to be an obstacle to nuclear power development. If there is some unwillingness to finance nuclear projects, past experience would certainly explain some of it. Surely only foolhardy financial managers would knowingly provide money to projects, in any industrial sector, whose technical characteristics were not fully determined at the outset, whose times to completion could be doubled or tripled, whose costs were subject to substantial increases, and whose output might never be sold. These were the characteristics of some nuclear projects in the 1970s and 1980s (though certainly not in all countries).

In fact private capital markets have financed a large proportion of nuclear power plants in the OECD, just as they have financed a large proportion of conventional power plants. They are not hostile to capital-intensive projects, just capital-intensive projects that lose money. They evaluate projects, typically with the support of independent technical evaluators, to ensure that:

- project design constraints and technological choices are well known and fixed;
- the project cost estimate is not likely to be exceeded;
- there are no large, unforeseen future liabilities;
- there are no external legal or regulatory factors which could jeopardise the investment;
- the investment is competitive with others in the same sector;
- the investment will provide an adequate return.

Given these conditions, money can be found for any project. The fundamental condition for a nuclear plant investment, as for any project, is that the plant provide a profit on the money invested. Large investments are often handled by involving many institutions.

Under monopoly supply conditions, financial markets did not need to pay as much attention to the fundamental economics or competitiveness, because the utility had a guaranteed market to absorb any cost overruns. In competitive electricity markets, however, minimising financial risk by ensuring both cost control and revenue potential are fundamental to attracting investors.

Today the nuclear industry states that nuclear plant technology is mature and proven, the safety regulatory framework is well established and stable, and therefore total costs are known with certainty. However, if past experience with nuclear plant construction costs provides a lesson, it is that changes in political attitudes towards nuclear power, and the corresponding approach to safety regulation, can have huge effects on nuclear project costs. The value of future liabilities could be affected similarly by changes in public attitudes towards

plant safety or radioactive waste. Therefore, financing of nuclear projects will depend on prospects for a stable political climate for nuclear power, and a stable, consistent regulatory environment.

Effects on Safety and Safety Regulation

Governments of OECD countries have historically attached an absolute priority to the safe operation of nuclear power plants. For example, the "Shared Goals of the International Energy Agency" notes the desire of countries to use nuclear power "at the highest available safety standards". Energy ministers from the G-8 countries, at their meeting in April 1998, committed themselves to "keeping safety as [their] absolute priority in the use of nuclear energy" while at the same time recognising that competitive pressures in the electricity sector are growing. Given the long-standing commitment to safety within the OECD at the highest levels of government, competition should not weaken the ability of nuclear safety authorities to monitor and ensure the safe operation of nuclear power plants. Rather, its most likely effect will be to create new challenges for nuclear safety regulators and to alter the way in which safety regulation is developed and applied.

Monitoring and Incentives for Safe Operation Remain

The argument that competition will lead to lower levels of nuclear plant safety has been advanced by, among others, nuclear plant worker trade unions.[25,26] In OECD countries, nuclear plant safety is assured by independent authorities who are, in principle, outside the control of nuclear plant operators and independent of short-term political influence. Nuclear safety regulators are required to ensure compliance with regulations regardless of the business consequences on the companies affected by their actions. In short, if a plant is not safe, it will not operate. Environmental regulations, airline safety, food processing hygiene, and a host of other regulations are enforced in a similar way throughout the OECD.

Furthermore, nuclear safety regulations themselves are largely independent of the organisation of the electricity sector since they concern individual plants and the procedures in place in individual companies for ensuring that safe plant operation is maintained. The introduction of competitive electricity markets should therefore have little impact on the application of existing nuclear safety regulations by safety authorities.

Competition should not lead individual companies to give a lower priority to plant safety either. In fact, many in the nuclear industry argue that it is likely to have the opposite effect. Competition will magnify the cost implications of failing to comply with nuclear safety regulations. Plants which cannot operate due to safety problems represent an enormous loss of revenue. The cost of bringing plant equipment or procedures to acceptable safety levels after a period of neglect can also be very large. Although the ongoing costs of ensuring safety can be large, there are also potentially huge costs of not complying with regulations and a high likelihood that deficiencies will be noted by safety regulators. One potential benefit of nuclear industry consolidation is that the best safety practices of successful companies will be made available to all their operating units. As long as nuclear safety regulations are applied consistently to all nuclear operators, their cost is simply a normal cost of doing business.

This reasoning is confirmed by recent experience in the United States. The US Nuclear Regulatory Commission (NRC) "has not found a consistent relationship between a licensee's financial health and general indicators of safety such as the NRC's Systematic Assessment of Licensee Performance (SALP)".[27] The US nuclear industry emphatically states that competition is likely to improve plant safety rather than the opposite.[23] The Nuclear Energy Institute, a US trade association, has noted a positive correlation between good plant economic performance and good plant safety performance.[28] That is, plants with the lowest O&M expenses, and those with the highest utilisation rates, are also the plants with the best scores on the SALP. The safety of US nuclear plants, as evaluated by the NRC, has increased since the early 1990s, at the same time as nuclear utilities have begun to prepare for electricity market competition.

The example of British and Nordic electricity market liberalisation also confirms the view that competition does not compromise nuclear plant safety. The UK Health and Safety Commission, when giving evidence to the team responsible for the 1995 Nuclear Review, stated[29] "the system of nuclear regulation in the UK ... is essentially sound, and there is no reason to change it in any fundamental way to deal with whatever [electricity market] structure emerges". No special changes were thought necessary to Swedish or Finnish safety regulation as competition has been introduced in those countries.

Independence of Safety Regulators is Crucial

Business priorities may change for companies operating nuclear power plants, but it should not affect their systematic compliance with nuclear safety regulations. This is not to deny the likelihood that some companies in financial difficulties or with poor management will inappropriately reduce spending on safety, just as they have in monopoly supply systems. As has always been the case, governments must make sure that nuclear safety regulators ensure safety at the level of individual nuclear plants, and not rely simply on the good faith and past performance of plant operators as a whole. Whether utilities are operating in monopoly or competitive environments, there will always be, unfortunately, some whose operations slip towards minimally acceptable levels of plant safety. Adequate regulatory strength and vigilance is a pre-requisite under any electricity market system.

Governments must also make absolutely certain that nuclear safety authorities are able to act independently of short-term influence by both nuclear utilities and political authorities. There is a real danger that safety regulators too sensitive to either could let safety levels drop in a newly competitive market. Adequate regulatory independence is also a pre-requisite under any electricity market system, but even more so in a competitive one.

Because of the financial impact of the decisions of regulatory authorities, competitors to nuclear power generators may put pressure on governments to ensure the functional independence of nuclear regulatory authorities, to the extent that this independence is not already fully established. If safety authorities are subject to influence or informal control by the government, competitors may see them as providing a means to support nuclear power through unfairly favourable treatment. In this respect, competition will help to improve the transparency of safety regulation, just as it does for energy policy.

Safety Regulators Face New Challenges

The advent of competition does bring many new challenges to safety regulators. A comprehensive review of future challenges, including those related to electricity market liberalisation, is given in a report by the OECD Nuclear Energy Agency.[30] They include:

- changes in plant technical operation made in response to the desire for improved economic performance (e.g. extension of plant operating lifetimes, greater operational flexibility, higher energy utilisation of nuclear fuel, longer periods between refuelling, etc.);
- resolving differences in point of view with plant operators regarding the need for and cost of improved safety;
- developing ways to monitor the adequacy for safety of new working arrangements;
- maintaining access to research results while guarding regulatory independence;
- moving towards risk-informed, performance-based regulation.

The latter is perhaps the most important when considering the economic future of nuclear power. Competition will reinforce the existing trend towards more careful analysis of the cost-effectiveness of safety regulation. In non-competitive electricity markets, safety requirements could be implemented without regard to cost because costs could be passed on to consumers. In competitive markets, there is a much stronger incentive for utilities to critically evaluate the potential benefits of safety requirements to make sure that the costs of implementing them are warranted. In other words, plant operators are more likely to openly question the need for some safety actions. Regulators will be asked to pay ever greater attention to the cost implications of their actions. The risk to plant owners from abrupt changes in plant safety regulations is likely to go down, because of the greater incentives for owners to resist and protest against such changes unless they are clearly beneficial.

As in other areas of nuclear plant operation, it is likely that the cost of complying with safety regulations will decrease due to competition's spur to innovation, assuming a stable political environment. Owners are likely to be more insistent that safety authorities consider changes to plant and operation that do not fit within pre-established regulatory guidelines, as long as the changes maintain or improve plant safety. Outdated or procedural regulations may be dropped in favour of performance-based rules.

Inefficient regulatory practices may be exposed as international competition reveals differences between neighbouring countries. An example is given by a study comparing maintenance costs of a German and a Swedish utility.[31] The German utility was found to have higher costs due primarily to differences in safety regulation, including requirements on testing, the use of outside technical experts, working methods, and inspections. The safety levels of Swedish and German plants,

however, appear to be the same. The study concluded that German regulatory requirements should "give greater credit to the utilities' own sense of responsibility for the safety of their plants".

In another similar study,[32] O&M costs of German utilities were found to be about three times greater than for the French utility Electricité de France. If the cost of reserves for waste management and decommissioning are included, the total cost of German nuclear generation is twice that of Electricité de France. The study concluded that "politically imposed burdens" account for much of the difference. In general, competition will put pressure on nuclear safety authorities to set framework and performance conditions, while allowing utilities themselves decide how to apply the safety requirements.

Other Safety Issues

All plans for introducing competition into electricity supply have involved, at the least, the separation of generation from transmission and distribution. Typically an independent operator of the network becomes responsible for plant dispatch and ensuring network stability. Political considerations as well dictate that grid reliability not degrade significantly with the arrival of competition. Ultimately, the quality of institutional arrangements for the independent operator will be one of the most important factors in ensuring a high level of network reliability. Although it has not been seen in practice, it is possible that network reliability could be lowered. The period of transition to competitive arrangements is likely to be the period of greatest uncertainty in ensuring stable network operation.

Nuclear safety authorities have an interest in ensuring that potential decreases in network reliability do not affect the safety of nuclear plants. More frequent network blackouts could increase the estimated danger from plant accidents if on-site backup generators failed during a plant malfunction. Another potential concern is that the independent network operator might not adequately take into account operational constraints of nuclear power plants, such as rates of increase or decrease in plant output.

If there is a transitional risk of lower reliability, nuclear safety regulators can play a role in helping network operators and electricity regulators to understand the safe interaction of nuclear plants and the electricity grid. No amount of nuclear regulatory action is likely to reduce the transitional risk of lower grid reliability. (Otherwise, the nuclear regulatory authority would be in the unusual position of begin able to ensure network reliability better than the operator itself.) Furthermore, the network operator would generally not place costly constraints on the network for one specific plant type, either for reliability or plant dispatching, unless they were part of the commercial arrangements for purchasing electricity from those plants. Therefore, the actions taken by nuclear safety authorities to adapt to new network conditions, should they arise, will be focused primarily on nuclear plants themselves.

Safety regulation is likely to become confined more strictly to safety and not to business matters. As nuclear utilities participate in the competitive market, they will seek to minimise the influence of nuclear safety authorities on matters which are not directly related to plant safety. These include, for example, general financial requirements, restrictions on ownership, or restrictions on asset sales. In the United States, sales of nuclear plants are a particular issue because of the financial reviews required for approval of the licence transfer by the safety authority.[33]

Plant Closure and Waste Disposal Expenses

An important issue regarding nuclear plants operating in competitive markets is how to ensure that they will accumulate enough money over their operating lifetimes to pay for plant closure and waste disposal expenses. Ensuring adequate reserves under any electricity market system has two important components:

- Establishing the technical requirements for plant closure and the corresponding sum of money needed to meet those requirements.
- Setting the financial arrangements for accumulating that money over the lifetime of plant operation. This includes managing any funds held in trust.

The first component is one that must be done by nuclear regulatory authorities. They must define exactly the standards, methods, and timing of plant closure. From these definitions they and the plant owner can estimate the amount of money needed to close the plant. The nuclear industry believes that, with clear definitions, costs are reasonably well known, despite variability among different plants in different countries of up to a factor of six in estimated plant closure costs.

Reports by expert groups convened by the NEA and UNIPEDE both address the question of why plant closure costs are so variable.[34,35] They confirm that waste disposal requirements account for much of the difference, apart from plant technical factors

such as type and size of reactor, and apart from differences in the scope of cost estimates. Today the closure requirements and sums of money needed seem quite uncertain because few plants have actually been fully decommissioned. There is little actual experience to go by. Furthermore, there is a risk that closure requirements may become more stringent due to changes in political views or the availability of new technical or scientific information. This makes it difficult to fix the cost of plant closure or waste disposal with great confidence.

The second component is primarily a financial oversight function. There must be an agreed way to collect and manage money over an extended period of plant operation. An NEA report[36] summarises current requirements in OECD countries for meeting future liabilities. The financial management of money collected is a key question, since excessive risks must not be taken with the funds, but a return must be earned on them to minimise cash requirements. The latter is especially important when regulations allow for a long period for radioactive decay before final plant closure actions, and plant owners wish to take advantage of this period. The principles behind financial regulation of plant closure funds are little different than regulation of pension or insurance funds.

Competition will affect both the technical and financial aspects of plant closure funding. It should put pressure on governments and regulators to establish plant closure requirements that limit open-ended risk in the future. Utilities will strongly resist requests to bear the cost of any stricter closure standards applied retroactively. Regulators may tend to increase the total money collected for plant closure since they cannot rely on automatic pass-through of the costs to electricity consumers. They may also consider faster accumulation of funds. Owners of nuclear plants may wish to proceed more quickly with plant closure than required by regulation in order to limit future liabilities and cost uncertainty.

To the extent that nuclear safety regulators are responsible for financial oversight of decommissioning funds, that role is likely to come under pressure. Utilities will seek changes to the financial management of plant closure funds to reduce their total cash outlays, and may see safety regulators as overly conservative, since they are not specialised in financial matters. Competition could tend to shift oversight of decommissioning funds to specialised financial regulators.

The introduction of competition requires some consideration by regulators (energy and financial, not just nuclear) of how to make up any shortfalls in plant closure and waste disposal funds once a plant has been closed. Assuming the owner is still in business, this does not pose a special problem, since the operator will normally be held responsible for the full cost. However, if the plant operator goes out of business, regulators will need to decide who should fund the shortfall. As in the past, they may ask electricity consumers to pay via a surcharge on electricity consumption or electricity supply services. Or they may ask the general taxpayer to pay, as typically has been the case for unfunded environmental cleanup projects.

Shortfalls of plant closure funding can be precipitated by the introduction of competition. Nuclear plants in a newly competitive environment may shut due to economic reasons before they have accumulated enough money to pay for proper plant closure. This would create unfunded liabilities which cannot simply be written off. The transition mechanisms used to pay for stranded assets can be used for these unfunded plant closure costs as well, according to political choice.

Effects on Other Nuclear Activities

As nuclear plant operators face competition, they will turn to their suppliers and business associates to seek sources of cost reduction. The effects of electricity market competition will thus extend beyond nuclear utilities to:

- suppliers of nuclear fuel and nuclear fuel services;
- suppliers of equipment and plant services;
- co-operative organisations for plant operations;
- research and development organisations.

The pressures on nuclear suppliers have already developed due to the stagnation of nuclear power growth and consequent overcapacity among suppliers. Competition among nuclear generators is therefore unlikely to drastically affect nuclear suppliers, but it could accentuate the pre-existing tendencies.

Nuclear Fuel Suppliers

Nuclear fuel is a major component in the marginal cost of operating nuclear plants, so fuel suppliers will be pressured to increase their efficiency and reduce prices. Utilities may be more willing to seek fuel fabrication services from companies other than those responsible for the plant design, and to seek foreign fuel supply services. As with other aspects of market competition, this will probably put pressure on governments to liberalise the supporting nuclear sectors as well, some of

which have strong administrative restrictions or are government owned.

Services for handling, processing, and storing used nuclear fuel should be pressured to improve efficiency and cost. Historically the arrangements for dealing with used fuel have been driven by political, administrative and regulatory considerations. Cost is likely to become a more important consideration. Regulators may be pressured to consider alternative means of dealing with waste, and governments pressed to complete administrative planning for waste disposal. Electricity market competition will tend to accelerate the process already underway towards establishing more complete plans for high-level nuclear waste disposal.

Suppliers of Equipment and Plant Services

Among nuclear equipment suppliers and plant architect-engineers, the reduced level of nuclear construction long ago increased their attentiveness to prices. The days of contracts based on cost-plus-profit disappeared in the 1980s for most companies. Unless competition forces the early closure of a large fraction of plants (as noted earlier, this seems unlikely), pressures on nuclear plant suppliers and designers should not unduly increase. However, utilities may enter into new types of business relationships with them, for example, to take advantage of technical innovations developed within utility companies. Another example might be more creative use of consortia to pursue improvements to specific classes of power plant. Strong national links to domestic suppliers may weaken as utilities seek the lowest prices anywhere in the global nuclear engineering market.

Co-operative Organisations

Nuclear plant owners participate in co-operative organisations for sharing information and experience on nuclear plant operations. The Institute of Nuclear Power Operations in the United States and the World Association of Nuclear Operators are two of the key organisations facilitating this co-operation. There are also owners' groups for the plants designed by the main nuclear plant vendors. These organisations have played an important role in improving practices for ensuring nuclear plant safety and improving economic performance.

Competition is not likely to harm their role in improving safety practices. Although some of the information shared may be commercially sensitive, there is a strong commercial incentive to maintain high standards of plant safety. National safety authorities are also likely to support continued, strong participation in the groups.

There is the potential that co-operative sharing of operating information for primarily economic improvements could be reduced as companies seek to maintain competitive advantages. Another possibility is that, if nuclear operating companies grow in size through consolidation, sharing of information within these larger companies will fulfil some of the role formerly played by co-operative organisations. The outcome is today difficult to predict, but it seems unlikely that these organisations will be much weakened by the arrival of competition in national markets.

Research and Development

The fate of research and development in competitive markets is a much debated subject.[37] The main debate is whether or not competitive markets will provide an "adequate" level of money to ensure a reliable, long-term supply of electricity. It is often said that competitive markets will lead to short-sightedness in research and a drop in long-term research projects. The question in the nuclear field is particularly difficult to analyse since governments historically have spent enormous amounts of money that were never borne directly by electricity ratepayers. Nuclear research institutes already face many challenges, even without changing electricity markets.[38] Many involved in nuclear research apparently fear that the difficult environment caused by decreases in government research and development funds will be compounded by "inadequate" money from utilities.

There is quite a bit of confusion regarding the link, if any, between less government support of nuclear research and the introduction of competition. Although the two may be related by the increasing acceptance of governments to rely on markets to produce efficiency and innovation, competition itself is not responsible for decreasing government support for research and development.

Regardless of the "adequacy" debate, it is clear that competition leads companies to re-orient their research and enhance its effectiveness.[39,40] Utilities will tend to reduce research into generation technologies and instead focus on improvements to plant operations and in-plant technologies. "Public good" research projects with no commercial benefits will be dropped. It is likely that nuclear utilities will participate in collaborative research programmes more than in the past.

There remains a strong incentive for power generators to continue industrial research programmes. There also remains a role for government funding of research programmes that provide an element of "public good". Some public funding may be warranted for pilot projects of unproved technologies, but most agree that governments should not try to "pick the winners". Co-operative arrangements between industry and government, such as those developed in the IEA Technology Implementing Agreements, can help to combine private and public research efforts. International co-ordination of nuclear research through organisations such as the NEA will take on added value from the introduction of competition.

Issues in the Transition to Competitive Markets

Stranded Assets

Stranded assets often confuse discussions of nuclear power economics. They are essentially irrelevant to the question of operating expenses at existing nuclear power plants. They relate only to the transition from monopoly to competitive electricity generation markets.

Stranded assets may be defined as those unamortised costs of prior investments that would be recovered by monopoly supply utilities but which would not be recovered under competition due to lower electricity prices. The main source of stranded nuclear assets is high investment costs, typically due to cost overruns on plant construction, cancellation of partially finished nuclear plant projects, or prohibitions on the operation of functional plants. The existence of nuclear plant stranded assets indicates that some investments made in the past are uneconomic or even non-productive today. The debt incurred for these investments would be recovered only over a longer period than originally expected (if at all). However, stranded assets relate to past investments or commitments. They do not correlate with ongoing costs of operation, nor do they necessarily indicate future investment costs of nuclear power plants. Table 2 summarises estimates of stranded nuclear assets in four OECD countries.

The treatment of stranded assets is important to the operation of individual utilities. Plant owners may face cash flow problems if they must continue to pay interest on investments which do not generate adequate revenue. Stranded assets can be, therefore, very important to the financial situation of individual utilities, who might be unable to continue in business, even if individual plants could continue to operate economically based on marginal costs.

Governments may choose to compensate utilities explicitly for stranded assets when the electricity market is reformed to avoid placing individual utilities in difficult financial situations. Allowing recovery of stranded assets also removes an incentive for an incumbent utility to abuse its market position in order to improve the chances of recovering its stranded assets on its own. As an issue of fairness, it is often argued that governments must take responsibility for ensuring recovery of stranded assets because it is governments who create them by changing the electricity market framework. In the United States, the Federal Energy Regulatory Commission has accepted the general principle of stranded cost recovery in the transition to competitive markets. The European Union Electricity Directive also recognises the importance of transitional costs. The Spanish electricity restructuring law made arrangements for stranded assets.

For government-owned utilities, the state may accept a lower value for the assets than their book value. For example, the 1996 privatisation of British

Table 2. Estimates of stranded nuclear plant assets.

Country	Estimated stranded nuclear assets (local currency)	Stranded assets per unit of total nuclear capacity (US$/kWe)	Source
United States	US$24 to 56 billion	240 to 550	Reference 41, assuming 1/3 of total stranded costs from nuclear
Spain	Pts 0.730 billion	700	Reference 42; base value of nuclear moratorium payments
Italy	Lira 3 trillion	1400	Reference 43
Switzerland	SFr 2.6 billion	580	Reference 44

Notes: All figures are rounded.
Estimates of stranded investment vary considerably among national sources.
Italian nuclear capacity taken to be 1.3 GWe, none of which is in service.

Energy brought in £1.4 billion, even though the company's newest generating station, Sizewell B, was completed in 1995 at a total cost of over £3 billion. Prior to its privatisation, British Energy's nuclear plant capital accounts were strengthened through a levy on electricity sales, known as the Non-Fossil Fuel Levy.

The transition to competitive markets both creates and exposes the value of stranded assets. However, not all markets making a transition from monopoly to competitive generation will reveal stranded costs. This has been shown already in Finland, the Netherlands and Sweden. Based on the evaluations of Electricité de France, France would not have stranded nuclear assets.

Last-Minute Utility Decisions

Nuclear plant owners expecting electricity market competition have incentives to recover as much capital investment as possible under monopoly supply arrangements before they disappear. In order to improve their competitive position, they may be tempted to make plant investments to improve safety or increase capacity before competition arrives. Authorities responsible for overseeing the transition to competitive markets will therefore need to be attentive that investment decisions made by incumbent utilities are sound and that they do not thwart or unduly delay the onset of competition.

Some owners might be tempted to opt for the path of least resistance and uncertainty by closing nuclear plants even though the plants might be economically viable. This might allow the owners to recover their plant investment through a transition cost arrangement while avoiding the struggle to adapt in a new competitive environment. Here again, competition authorities and electricity regulators will need to make sure that stranded costs are truly stranded, and not just inconvenient.

Transitional Uncertainty

As competition is introduced in an electricity market, there will be a period of considerable business and regulatory uncertainty. All the individuals and organisations involved will require a period of learning and adaptation stretching over many years. Sellers and buyers in the electricity market will need time to understand how electricity prices vary in response to demand and competitive pressures. Utilities will require time to enter into new commercial structures. Safety regulatory authorities will need time to adapt their methods of monitoring and ensuring nuclear plant safety. Other government institutions must adapt to the new market structure.

During the period of transition, the final outcome of many developments will be unknown for a period. This introduces uncertainty that could affect decisions on new investments or new undertakings in the electricity industry as a whole. New nuclear power undertakings, such as power plants or fuel cycle facilities, should face the same array of uncertainties as other types of power generation facilities.

If special transitional issues related to nuclear power are resolved as quickly as issues for other forms of generation, there should be no effect on nuclear power investments compared to others, except that nuclear power would be disadvantaged relative to less capital-intensive options. During transition, the pace of plant building may slow and those plants that are built are likely to be smaller and less expensive. As noted earlier, however, the limited near-term prospects for new nuclear power plants in the OECD, and a number of important non-economic roadblocks to nuclear power development, make this a largely theoretical issue.

However, if the transitional issues specific to nuclear power take longer to resolve than those of electricity market in general, these could delay investments in nuclear power if it would otherwise be chosen in a competitive environment. If any nuclear-specific transitional issues do take longer to resolve in specific markets, they will probably relate to the adaptation of:

- nuclear safety regulations,
- nuclear safety institutions,
- regulations on ensuring adequate provisions for decommissioning and waste disposal expenses.

Experience in countries with nuclear power where the transition to competitive markets has already taken place suggests that adaptation in these areas need not be lengthy at all. However, if there is any question as to ensuring the safety of nuclear plants during the transition period to competitive markets, clearly this will take precedence. The United States' nuclear regulatory system presents a special case because of its sheer size, complexity, and federal versus state structure.

Governments have every interest in making the transition period as short as possible. Transitional uncertainty can also be reduced when governments provide clear statements of their ultimate objectives and the likely features of the market in the long term.

Conclusions

Competition provides an opportunity to re-invigorate nuclear power. Nuclear plants with low operating and fuel costs will thrive in competitive markets. All nuclear plants will improve their technical and economic performance beyond what has been seen in recent years. The strong economic performance of nuclear plants will result in many of them lasting longer than originally expected. Plants with high operating costs that cannot be reduced to competitive levels are likely to be a small fraction of the total, but they will be shut sooner than in non-competitive markets.

Competitive markets will improve the transparency of energy policy making and the policy framework for nuclear power. It will provide a clearer separation between commercial and government decision-making and help to reveal the true costs of nuclear. These changes will help to dispel the notion of nuclear power as an energy choice made secretly or undemocratically. Competition could very well help to reduce public mistrust of nuclear power and clarify what the real issues of public concern are.

New nuclear power plants face a difficult near-term future in the OECD with or without competition, because of high total generating cost, the lack of waste disposal plans and facilities, and other impediments. A political impasse on the use of nuclear power exists in many OECD countries. But competition's spur to innovation in existing plants will help prospects for new plants as well.

Safety has always been given the highest priority in nuclear power development in OECD countries. This will not change under competition. Safety regulators will continue to have the authority and ability to ensure safety, though they will face new challenges to adapt to the changing commercial environment. Safety regulators must make an effort to adapt to competitive markets, just as plant operators must. Competition is likely to improve the regulatory process.

Stranded nuclear assets reflect some of the past difficulties of building nuclear power plants, and are embarrassing to the nuclear industry as it makes its case for continued development. They arise because of the transition to competitive markets. But stranded nuclear assets do not reflect the economics of running existing plants or, necessarily, of building new ones. There are other transitional challenges in moving to competitive markets that take time to resolve.

Governments which wish to "keep the nuclear option open" should make sure that the government institutions involved in nuclear power, especially and foremost nuclear safety institutions, adapt to competitive markets as quickly as nuclear utilities. Competition will reveal if the economic outlook for new nuclear plants is really as difficult as it appears to many today. Regardless of current evaluations of nuclear power's economics, competition will provide a strong impetus for cost reduction and innovation, perhaps laying the economic foundation for a stronger nuclear power industry in the future.

References and Footnote

1. *Electricity Reform: Power Generation Costs and Investment*. International Energy Agency, Paris, 1998.
2. Tonn B, Hirst E & Bauer D, *Public-Policy Responsibilities in a Restructured Electricity Industry*. ORNL / CON-420, Oak Ridge National Laboratory, Tennessee, 1995, p22-25.
3. *Projected Costs of Generating Electricity - 1998 Update*. OECD, Paris, 1998.
4. Robinson C, *Privatising Nuclear Power: Evidence for the Review of Future Prospects for Nuclear Power*. Surrey Energy Economics Discussion Paper Series No 79, University of Surrey, Guildford, UK, 1994.
5. *Financial Statistics of Major US Investor-Owned Electric Utilities*. US Department of Energy, Energy Information Administration, Washington DC, 1997 (Table 14).
6. *Need for Natural Gas Increases with More Nuclear Plant Shutdowns*. Washington International Energy Group, Washington DC, May 1998.
7. *Consultant says 40% of US plants can't compete for baseload market*, Nucleonics Week, 11 December 1997, p6.
8. *EDF official says nuclear is competitive, can stay that way*, Nucleonics Week, 19 December 1996, p3.
9. British nuclear generators received, effectively, lump-sum payments through the Non-Fossil Fuel Levy from 1990 to 1996. This was to enable them to meet unavoidable long-term liabilities that were not matched by assets. These liabilities included costs for plant closure, waste management, and reprocessing of fuel already used. According to the UK Department of Trade and Industry, the payments were specifically designed to avoid giving the generators incentives to increase output beyond the level indicated by their marginal costs of production and the market prices of electricity, including the Pool price. In practice, nuclear generating marginal costs at existing stations have been below pool prices. Upon privatisation of the modern nuclear plants in 1996, payments to nuclear generators from the Levy were stopped, except for those accrued in earlier years but not yet made.
10. *NE says nuclear kWh costs cut by 40% in five years 'operation*, Nucleonics Week, 1 December 1994, p3.
11. *BE reports pre-tax profits tripled as it became UK's top generator*, Nucleonics Week, 21 May 1998, p8-9.
12. *Continued progress for the US nuclear industry*, Nuclear News, May 1997, p40-43.
13. *More competition, less staff*, Nuclear Engineering International, July 1996, p29-30.
14. *Restructuring will encourage nuclear life extension, study says*, Nucleonics Week, 21 May 1998, p19-20.

15. Olsson S & Haukeland S, *Light Water Reactors for the Next Century*. Uranium and Nuclear Energy 1997, Proceedings of the Twenty-Second Annual Symposium of the Uranium Institute, London, 3-5 September 1997, p36-46.
16. *BG&E becomes the front runner in seeking NRC license renewal*, Nucleonics Week, 12 March 1998, p1 ff.
17. *Extended lives, reduced outages to keep Japan's nuclear economic*, Nucleonics Week, 8 May 1997, p1 ff.
18. *One-unit plants must consolidate or be shut down, says PECO's Smith*, Nucleonics Week, 2 April 1998, p1 ff.
19. *Entergy, NYPA announce precedent-setting nuclear pact*, The Energy Daily, 1 August 1996, p1-2.
20. *Joint statement by the New York Power Authority and Entergy Corporation*, Press Release, Entergy Corporation, New Orleans, 29 October 1996.
21. Blanc H-C, *Analysing EdF's Aims and Strategies Within an Increasingly Competitive European Market*. Electricity in Europe '97, Berlin, 24-25 June 1997.
22. Bourdaire J-M & Paffenbarger J, *Climate Concerns and Nuclear Power's Future*. Proceedings of the 41st Annual General Conference of the International Atomic Energy Agency, Vienna, 30 September 1997.
23. Lacy BA, *Competition: The Essential Element for Future Nuclear Success*. Uranium and Nuclear Energy 1997, Proceedings of the Twenty-Second Annual Symposium of the Uranium Institute, London, 3-5 September 1997, p154-162.
24. Timbers WH, *The Future of Nuclear Power: Not 'Why?' but 'When?'*. Proceedings of the National Association of Regulatory Utility Commissioners Annual Convention, Boston, 11 November 1997.
25. *Britain's nuclear engineers said on Wednesday they were worried that safety could suffer if the government goes ahead with a plan to privatise the industry*, Reuter's News Service, 22 November 1995. (Note: The article summarises the concerns of the Electricity Supply Trade Union Council.)
26. *Alerte sur l'avenir de la sûreté nucléaire*, Libération, 14 October 1996.
27. *Final Policy Statement on the Restructuring and Economic Deregulation of the Electric Utility Industry*. US Nuclear Regulatory Commission, Washington DC, 20 October 1997.
28. *Nuclear power in a competitive environment: myths and facts*, Nuclear News, March 1997, p33-35.
29. *The prospects for nuclear power in the UK - White Paper published*, Press Release P / 95 / 310, 9 May 1995, Department of Trade and Industry, London.
30. *Future Nuclear Regulatory Challenges*. OECD Nuclear Energy Agency, Paris, 1998.
31. *Maintenance costs: PreussenElectra and Sydkraft compared*, Nuclear Engineering International, July 1996, p30-31.
32. *German O&M costs three times higher than EDF's, VDEW says*, Nucleonics Week, 31 July 1998, p1 ff.
33. *Selling off your nuclear? - Here's what the NRC has in store*, Public Utilities Fortnightly, 15 June 1997, p34-38.
34. *Decommissioning of Nuclear Facilities - An Analysis of the Variability of Decommissioning Cost Estimates*. OECD Nuclear Energy Agency, Paris, 1991.
35. *Cost Estimates for Decommissioning Nuclear Reactors - Why Do They Differ So Much?*. UNIPEDE, Brussels, March 1998.
36. *Future Financial Liabilities of Nuclear Activities*. OECD Nuclear Energy Agency, Paris, 1996.
37. *Competition and New Technology in the Electric Power Sector*. International Energy Agency, Paris, 1996.
38. *Trends in Nuclear Research Institutes*. OECD Nuclear Energy Agency, Paris, 1996.
39. *Competitive concerns are reshaping utility R&D programs*, The Energy Daily, 10 April 1996, p3.
40. *Trends in R&D reflect strategies for deregulation*, Power, November / December 1996, p43-44.
41. *The Changing Structure of the Electric Power Industry: An Update*. DOE / EIA-0562(96), US Department of Energy, Energy Information Administration, Washington DC, December 1996.
42. *Spanish Electrical Power Act - First Draft* (unofficial translation). Comisión del Sistema Eléctrico Nacional, Madrid, November 1997, p67 ff.
43. *A long half-life*, The Economist, 11 July 1998, p68.
44. *Production cost comparison reveals nuclear investments are vulnerable*, European Energy Report, 16 January 1998, p10.

