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# *Strategies for competitive nuclear power plants*

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**FOREWORD**

This technical publication on competitive strategies for nuclear power plants (NPPs) is part of an ongoing project on management of NPP operations in a competitive environment. The overall objective of this project is to assist the management of operating organizations and NPPs in identifying and implementing appropriate measures to remain competitive in a rapidly changing business environment.

Other documents that have been written on this topic have focused on how the environment in which NPPs operate is changing. This report instead focuses on strategies and techniques that operating organization and NPP managers can use to succeed in this environment. Of particular note is ongoing OECD/NEA work to describe the environment for nuclear power in competitive electricity markets. The main objective of the OECD/NEA study is to review the impacts of increasing market competition on the nuclear power sectors in OECD Member countries. The OECD/NEA study is identifying various nuclear aspects which have to be considered in relation to the regulatory reform of the electricity sector in OECD Member States. The OECD/NEA work was co-ordinated with the development of this IAEA report; staff members from the two organizations participated in the development and review of the associated documents. Thus, the strategies and techniques identified in this report are consistent with the impacts of increasing market competition identified in the OECD/NEA study.

The IAEA wishes to thank all participants and their Member States for their valuable contributions. The IAEA officers responsible for this publication are T. Mazour of the Division of Nuclear Power and L. Langlois of the Planning and Economic Studies Section of the Department of Nuclear Energy.

*EDITORIAL NOTE*

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# 1. INTRODUCTION

## 1.1. THE CHALLENGE

Electricity markets are experiencing some form of commercialization or competition in virtually all countries that have operating nuclear power plants (NPPs). Can nuclear power compete successfully, survive and prosper in more competitive electricity markets?

- Electric power is now being sold on the Nordic grid, in parts of the USA, in Victoria State, Australia and in South Africa for less than US $0.02/kW·h. Can nuclear generation match these prices? Where not, can it be made to do so?
- Overcapacity and inefficiency can no longer be hidden or ignored in these increasingly competitive markets. Can nuclear power compete without special dispatching or other considerations?
- New NPPs can cost 2–4 times more to build than alternative plants. These costs do not include risks due to non-completion, exchange rate fluctuations or cost over-runs, risks that can affect a power generator's credit rating. 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 the financing of new nuclear plants?

Economic deregulation and restructuring have also raised concerns that NPPs operating under competitive electricity market conditions might fail to honor their liability or safety obligations. This fear is contradicted by experience to date, which shows that safety, operational and economic performance have improved in both privatized NPPs (e.g., UK) and those where electricity markets are being opened to greater competition (e.g., USA). Safe plants can be operated profitably, and profitable plants can be operated safely. Analysis of NPP performance in the USA, for example, has shown that those plants with the best safety ratings also had the highest availability and the lowest operating costs.

This report provides possible strategies and techniques for NPP and generating company managers to succeed in the new environment. In a competitive environment an organization's economic objective is to maximize profitability while minimizing or compensating efficiently for risks. With a focus on continuous improvement it is realistic to expect continued operational improvements and enhanced safety performance, while maintaining costs at their most profitable levels, consistent with a long term perspective that protects the plant investment.

It is also important to note that, in this document, when we refer to risk, we normally refer to commercial and financial risk, and not to the risk of a nuclear accident or other safety risk. Commercial and financial risks include, for example, market risk (loss of expected customers), currency exchange risks, completion and non-performance risks (for construction, repairs or upgrades), and regulatory, legal and liability risks.

The strategies and techniques provided in this report are discussed under three separate categories; those applicable to:

- existing plants (Section 2)
- plants that have been delayed or are under construction (Section 3)
- new plants or projects that are being considered (Section 4).

In practice, however, the distinction among these categories is not always clear. Many strategies and techniques discussed apply to plants in all three categories. These include management techniques used in successful competitive plants, techniques for improving existing plant operations, investment strategies and financial analysis techniques, and ownership strategies that include privatization, mergers and spin-offs.

Other documents on this topic (e.g., Refs [1–3]) focus on how the environment in which NPPs operate is changing. This report instead focuses on strategies and techniques that NPP managers can use to succeed in this environment.

## 1.2. HOW DID WE GET HERE?

Why is the electricity sector changing so rapidly and dramatically? Why, after decades of public service orientation, are competition and privatization now being introduced in the electricity generating sectors of so many countries? Changing technology is an important factor, coupled with growing public sector financial pressures, and the spill-over effect of increased competition in other economic sectors.

In recent decades technological advances in the oil and gas industry — seismic and 3-D exploration, slant, horizontal and "smart" drilling techniques — have made oil and gas available more cheaply and in greater abundance than previously anticipated. Highly efficient innovations in power generation, such as the combined cycle gas turbine (CCGT), have effectively ended the cost advantage that large plants so long enjoyed through economies of scale. Small CCGT plants have shorter lead times, lower capital costs, easier planning horizons, better load following capabilities, and are easier to locate near consumers; they now also have developed higher thermal efficiencies than most larger units. Suddenly, some industries are finding they can generate their own power for less than they can buy it. In some cases these "embedded" plants have a competitive advantage over grid connected plants as they avoid gird connection charges. Improvements in metering and in high voltage transmission have effectively increased the size of the market that a generator can efficiently serve, again giving customers at least potential access (i.e., restricted only by market regulation) to sources of lower priced power. Parallel technological changes in any number of industries are pushing firms to greater levels of competition in their own markets, with a consequent need for streamlining and cost reduction. Energy costs have become a prime target.

At the same time, in countries with growing populations and growing demands on public sector funds, less budgetary support is now available to publicly held generation companies to finance electricity sector expansion (or even sometimes for adequate maintenance). This is particularly true in countries where electricity pricing has reflected more political and social concerns than the long term cost of generation. Where multilateral assistance is sought to bridge this gap, institutions like the World Bank and the International Monetary Fund (IMF) insist on public sector reforms and a commercial approach to electricity generation to protect the loans they make in these areas. In countries where private investment has become the obvious solution to a shortage of government funding as well as a shortage of power, such financing almost inevitably comes hand in hand with at least a modicum of competition.

A third important factor of change has been the large though transient excess generating capacity in some countries, where investment programmes assumed constantly rising instead of falling or static demand. Slower demand growth factors such as changes in population growth, significant efficiency gains in both energy production and consumption, and negative or lower-than-expected GDP growth. Rationalizing the generation industry in these cases means that some surplus generators must be closed, generally those with the highest operating costs. The logical response of those threatened with closure is to cut costs and improve efficiency, reducing their marginal generating costs to be able to sell profitably at market prices. They would also become more willing to sell power at "discount" prices (covering variable though not fixed costs), in order to stay in business. Such distress sales can effectively compete with and undermine traditional long term, fixed price sales contracts.

With cheaper generation more readily available, many customers have become less willing to be tied to traditional monopoly suppliers by means of such long term, fixed price service agreements. For years such agreements have formed the basis for financing growth in the utility sector, just as power purchase agreements now form the basis for financing most independent power producers. However, such contracts may also tie customers to what have become higher cost suppliers, paying rates that reflect the costs of carrying older technologies, idle excess capacity, high financing costs or the costs of some social programmes. Such arrangements impinge on the customers' own ability to compete in global markets. A mismatch in supply and demand, with willing buyers and customers, and a mismatch (or disequilibrium) in prices, are precisely the conditions that create dynamic pressure for competition as suppliers and buyers work to adjust to changing market realities.

Financial, technological and commercial pressures are thus urging traditional public service oriented power markets along a continuum from cost-plus, contract based, sometimes fixed rate power sales to captive markets, toward more competitive markets where producers must be able to sell at a profit at market price. There are no pure market forms along this continuum — changing market structures in the power sector are likely to reflect monopoly transactions; contractual arrangements where producers bid for long term contracts with long term revenues; competitive transactions in open markets where prices fluctuate to reflect seasonal, daily and even hourly changes in supply and demand; and ultimately, in some cases, mergers and acquisitions that may tend to re-concentrate markets. Movement along the continuum will be driven by the experience that electricity prices tend to decline as one moves toward a market driven structure, and by the fact that market pricing stimulates innovation that leads to further efficiency gains.

## 1.3. DIFFERENT INCENTIVES

A key to understanding the importance of market restructuring is to recognize that each type of market structure creates its own different set of incentives for behaviour on the part of producers, consumers, investors and lenders. Investors and lenders should be differentiated. Investors supply equity capital to a project by purchasing an ownership share in the firm. They thus agree to absorb much of the risk of financial success or failure. Lenders make loans to the firm, i. e., they supply debt capital for the project.

The fortunes of the equity-holders rise and fall with the fortunes of the firm — their investment is completely at risk. In return for absorbing such risk, equity owners receive higher rates of return on their capital. Lenders are concerned primarily with the returns of and on their loans, and seek assurances that the borrowing firm is sufficiently viable to secure and repay the loans regardless of the fortunes of the firm. Most lenders moreover in effect have a claim on the assets of the firm, so that even if things go wrong, they have priority recourse for return of the loans made and the interest due. With this higher standing in the hierarchy of claims, their risk is thus lower than that of equity holders, and the expected returns on their capital are consequently lower.

Competition has been found desirable because it creates incentives that encourage and reward efficient and productively creative behaviour on the part of producers, consumers, lenders and investors alike. This effectively gives each party more disposable income or assets to use in their own interest. Monopoly, public sector, and managed utility markets are increasingly being found wanting from a commercial perspective because they give rise to and even reward inefficient behaviour, largely through cost-plus pricing formulas. Society may be politically willing and economically able to tolerate and share the burden of such inefficiencies for a sustained period of time, so long as political satisfaction outweighs the costs imposed on the economy through higher or subsidised electricity prices, misplaced investments, reduced disposable income and investment capital and the costs of inefficiently used resources.

These inefficiencies will ultimately and inevitably create a drain on the economy and the public treasury through subsidies, lost output and tax revenues, and direct budgetary outlays. When such costs are no longer acceptable, change will occur. This change may be hastened by conditions imposed on private sector or multilateral borrowing. It is from such necessity as much as from ideology, that competition, market deregulation, and technology are being introduced into electricity sectors, resulting in electricity market reform.

The fundamentally different incentives created in competitive and monopoly markets translate specifically into business practices and characteristic approaches that vary with market structure. These affect such basic items as pricing, management objectives, market strategy, finance, procedures for business regulation, environmental regulation (compliance without regard to cost vs. cost effective compliance as a cost of doing business), allocation and securing of risks, and management of scare resources or supplies.

A decade ago most power markets were managed monopoly markets, dominated by integrated firms ("utilities") with exclusive licensed franchises. In such markets, pricing is set by the power company together with the economic regulator, for some fixed period of time, and almost invariably on a cost-plus basis. In some cases the operating organization was also the economic regulator. Management objectives in such markets typically focus on technical excellence, social welfare or other goals rather than on efficiency. Market strategy is not a major concern given captive customers and markets guaranteed to a single seller. While regulators require assurances of adequate capitalization to meet long term liabilities and obligations, financial criteria often take second place to technical feasibility as a basis for investment. Financing is often done through the public sector, through public procurement, or is secured by guaranteed markets and revenue streams or through cost-plus pricing.

Typically, such markets are managed by economic regulators who set business and pricing practices. Compliance with other environmental, social and safety regulations has often focused on optimizing technical performance, on a cost-plus rather than a cost effective basis. Since costs can be passed on to captive customers in such markets, there is a reduced incentive to manage costs. Risks and scarce resources are allocated in such markets by regulatory decision or by monopoly preference rather than by price, thus the socially and politically favored can be assigned preferential access or pricing privileges without regard to the economic consequences of doing so. Commercial and financial risk in such markets is generally allocated to captive customers who are unable to either manage or reduce it.

Almost the only form of competition in these managed markets has been a certain degree of inter-fuel competition, often between monopoly gas and electric suppliers with overlapping franchise territories. Though beneficial, such competition has been a limited and regulated form of competition in marginal markets, often at regulated prices, between two regulated monopolies, each operating within its own guaranteed areas.

In contrast, for competitive markets, prices generally are set by market conditions rather than by any individual firm or economic regulator. Management objectives focus on efficient operations as the key to profitability (operating so that revenues cover costs and investment at a profit). Market strategy is essential. Profitability depends on market responsiveness, including such strategies as gaining market share or identifying niche markets. Firms without guaranteed markets have to attract customers by offering best value services, and attract capital market financing by offering profitable services.

In competitive markets, there is little if any need for economic regulation of prices, though in making a transition from managed markets to competitive markets initial access to customers and markets may necessitate special regulatory interventions. In competitive markets, satisfying environmental, safety and other social regulation is treated as a cost of doing business. Thus, there is a strong incentive to achieve these levels of performance in cost-effective ways. Risks and scarce resources (including peak power capacity) are allocated and rationed not by regulatory fiat or monopoly restrictions, but by price. The buying and selling of risk tends to leave the risk with the party that has the best opportunity to reduce it or can best manage risk profitably (the reader is reminded that “risk” here is commercial and financial risk, not nuclear safety risk). The competitive market thus alters the role of government and regulator as arbiters of financial risk. The information in this paragraph applies to an established competitive market

Growing competition will also change the way the firms relate to each other. International collaboration will increasingly be defined in contractual and commercial terms, as joint ventures, mergers and acquisitions and foreign investment. Information sharing among firms on such matters as cost cutting initiatives will be tempered by anti-trust fairness and competitive considerations.

The net result of these market conditions is a drive for competitive firms to be efficient, for management to be accountable for their own economic decisions, for pricing and operations to be transparent, and for operations to be flexible in response to market changes. None of this necessarily conflicts with the ultimate responsibility of nuclear power plant operators to fulfill their license obligations.

Privatization of State owned companies is often a key element in competitive market restructuring. Privatization and competition are two separate and completely distinct concepts. Privatization can be aimed deliberately at creating competition. But, one can also privatize monopolies without increasing competition. Moreover, sometimes State owned firms find themselves operating in competitive markets.

Privatization is defined and characterized by divestiture of State ownership and interests in a company. A State monopoly made into a corporation where a majority of the shares are owned by the government or by government-held companies, is not privatized. Private ownership is a fundamental basis for the hallmark incentives of competitive markets, namely, accountability, efficiency, transparency and flexibility. When one's own money is at stake in the performance of the company, then there is a great incentive to run that company as well and as profitably as is possible.

There are many ways to privatize. Why a government privatizes will affect the process. How it privatizes will set the market structure, the degree of competition achieved, and the success or failure of the privatization process. Governments may privatize to shed money-losing enterprises, to recover their sunk costs in an investment, to earn revenues from asset sales, to deliberately create competitive enterprises, or as part of a larger restructuring. They can privatize enterprises with or without responsibilities for pre-existing debt. They can privatize in one fell swoop or in phases. Governments can privatize by selling or transferring public monopolies to a single private monopolist, by selling to the highest bidder, by breaking up large public firms into smaller ones, by using vouchers, by simply giving State owned companies to their workers or managers, or by selling publicly traded shares in capital markets.

For nuclear plants there will be additional concerns with regard to privatization: will the plant be privatized as a separate entity, which may not be a viable competitor, or as part of a larger portfolio of generators; and how will licensing obligations be dealt with in the transfer of ownership?

Each of these choices will create different incentives for the managers and owners of the new company. Managers of a monopoly company simply transferred from government ownership will have less incentive for efficient operation than managers who are accountable to shareholders for the performance of a firm in a highly competitive market. Nonetheless, the managers of privatized companies will always be accountable to the owners of the firm for the economic consequences of their actions, which inevitably instills some measure of economic discipline into the management process. In addition, in most Member States, managers and operators have legal liabilities for nuclear safety, personnel safety, and environmental protection measures associated with protecting the public.

This accountability holds true even though global competition in the electricity sector has resulted in a growing number of mergers, and hence a growing divergence between the owners and operators of generating plants. Owners increasingly may have other assets and hence other commercial interests besides the generating plant. They may not be familiar with the day-to-day operations, the demands on management or the nuclear aspects of a plant. They may not readily recognize or monitor degradation of management or of assets. Operators, by contrast, are intimately concerned with the operation and core business of the plant. Their goal is the continued safe and efficient operation of the plant. Yet, ultimately, they are accountable for satisfying the goals of the owners or shareholders. Clear communication and understanding between the two sides must be an integral part of decision making.

This discussion on market incentives is not exhaustive and the differences between market types are not always so clear-cut as presented here. However, this discussion does illustrate two things. First, that as market structures vary along the continuum from monopolistic and managed markets to more competitive ones, each level requires its own degree and style of economic regulation. Second, that the incentives created by competition and by deregulation, and the commercial perspective required to compete successfully, have not traditionally been a part of nuclear power plant or electricity sector management models.

## 1.4. COMPETING GENERATORS

Electricity is becoming a commodity, and the business of selling that commodity is becoming increasingly competitive, i.e., market determined. All parties in the power sector, including nuclear power generators, will have to change to adapt to the new and more commercial environment in which cost-plus pricing and guaranteed markets no longer mask a power generator’s inefficiencies.

Such changes affect the management of all generators, whether in developed or developing countries, or economies in transition. The details of particular impacts will vary from country to country, and the degree of change that is required will differ. However, the basic trend of market changes and the tenor of required adjustments by power companies has been remarkably consistent.

Nuclear generation must compete for market favour with other fuels and generating technologies: natural gas, coal, oil, hydro, and renewables. These are all variously placed with regard to costs and risk, the two most critical commercial considerations. How these inter-fuel differences can be managed to advantage will affect how the various generating technologies are equipped to compete.

Cost considerations include both absolute levels of costs and cost structure, the latter being a separation of costs into fixed costs (such as rent, that does not vary with output), and variable (or operating) costs (such as fuel and process ingredients) that vary with output. Fossil fuel plants tend to have lower construction (and fixed) costs, and the potential for low operating costs (which are dominated by fuel costs). In contrast, nuclear and hydro have tended to have higher construction costs, relatively low operating costs, and very low fuel costs.

Risk is economically significant because it carries a cost, sometimes high, that can be reduced or managed more or less efficiently. Commercial and financial risks are related to size of investment and health of the firm; to the length of time before plant construction is completed and the plant is earning revenues; risk of non-completion; currency risks linked to foreign investment and to the import of technology, goods and services; and the risks of innovation. All of these apply more frequently and more heavily to nuclear power plants than to fossil fueled generating units.

The particular characteristics of nuclear power plants may impede their competitive success. They have higher capital costs and thus heavier debt burdens than alternative generation technologies, longer construction times with higher accumulated interest during construction and hence higher commercial and higher non-completion risks. They carry perceived or potential open-ended liabilities associated with plant decommissioning and waste disposal. Furthermore, operating largely in a cost-plus environment, they have not always been motivated to find cost effective ways to achieve safety or operational performance goals. These conditions/problems are common knowledge, but their impact has been sheltered in large measure by the cost-plus environment under which these plants have operated.

The challenge for NPPs then becomes to maintain an uncompromising focus on high levels of nuclear safety, while at the same time earning a profit in competitive markets. A number of NPPs in Member States have already made a successful transition from a monopoly, cost-plus environment to competitive markets. They did this through an integrated approach to managing safety, production and economic goals; through a realization that safety and production are interdependent; and that there is no fundamental conflict between safety and production performance.

How risks and costs are managed in competitive markets will govern which generating technologies will be retained or phased out, dispatched or not, and selected for future plants or not. The crux of the matter for nuclear power is that long term financing for capital intensive investments requires rewards to investors that are commensurate with long term commercial risk. The key to a nuclear future is whether the nuclear industry can afford the required rewards, or can reduce investors' commercial and financial risks to affordable levels.

This report provides strategies and techniques to examine problems and proposed solutions — including those related to safety, licensing or legal matters — from a commercial perspective. In competitive markets, for example, the desired result for NPPs is that nuclear safety be integrated into the business practices of the company, with a focus on finding the most cost-effective ways (in the long term) to achieve safety goals. Commercially oriented remedies are needed specifically to address and mitigate the fact that nuclear power's particular combination of characteristics may potentially result in lower returns for nuclear power than for alternative generating options. This in turn can result in the shutting out of nuclear plants from competitive generating markets.

## 2. EXISTING PLANTS — STRATEGIES AND TECHNIQUES

### 2.1. BACKGROUND

Most nuclear power plants produce power at competitive costs and with a positive cash flow. Others are closed in bankruptcy. In the USA, more than half the nuclear sites are considered competitive in changing markets. More than two-thirds of the US units are reported to be producing power for under US \$0.02/kW·h, about the national average generating cost; some generate for less, yet others have costs of US \$0.06–0.13/kW·h. In the United Kingdom, each of British Energy's eight privatized nuclear stations produces and sells power at a profit at competitive market set prices (an average of around US \$0.03/kW·h), while the Magnox plants assigned to BNFL are still producing at around US \$0.05/kW·h.

What causes these differences? The answer often lies in astute decisions concerning financing, and choices of technology, and successful estimates of demand growth, coupled with good plant management that provides cost control and efficiency gains while maintaining high standards of safety and operational performance. Of these, only good plant management is readily within the control of current NPP managers. Management is thus the focus of this section. Where managers still have choices over investment decisions, such as for new and resumed power plant construction, they also have more options for assuring profitability. These situations are discussed in Sections 3 and 4. The key question is the same though: can the NPP operate profitably? For existing NPPs this translates into whether the plant's incremented revenues can cover marginal operating costs.

Traditional monopoly pricing and franchised power company accounting focused on assuring that all costs were recovered through regulated rates. In competitive markets, this control disappears. Without subsidies, firms must sell at market prices and keep costs below that level to earn a profit. The key variable for commercial viability is thus the marginal cost per kW.h of generation, compared to the market price and the marginal cost of competing generation. Well managed nuclear plants now enjoy a cost advantage over many generators. 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 their costs and increase their margins even further to survive.

A generator's ability to compete thus depends on an ability to cut unit costs, especially operating and maintenance costs, and on increasing plant availability (or for some plants, maintaining already high levels of availability). There will thus be intense management pressure in both areas. It is important also to recognize the high costs of inadequate levels of safety or not maintaining the plant investment.

The importance of good management practices is emphasized for two reasons. First, a commercial and competitive management approach is new to many utility and nuclear industry managers, and so bears some discussion in detail. Second, good management can make a telling difference in the bottom line. Almost all nuclear plants that are now competitive have made significant if not dramatic improvements over the last decade in their availability, and significant if not dramatic reductions in costs. They have achieved these operational improvements, while at the same time maintaining or improving their safety performance. Availability has increased in many cases by some thirty percentage points, approaching (and in some cases, exceeding) 90%. Operating costs have fallen by as much as 40%. Studies in the USA show a strong correlation between the most successful commercial NPPs (those with lowest operating costs and highest availabilities) and the safest ones.

This, then, must be a principal and primary strategy for nuclear plant managers: To achieve all objectives, including high levels of nuclear safety, in a profitable manner. Strategies and techniques will be examined to see if they contribute to profit, sometimes by reducing risk. Cash flow and profitability thus become a basis for operating decisions, providing a dynamic rather than static assessment of a firm's potential fortunes or the advisability of an operating or investment decision. Plants with insufficient cash flow simply cannot finance maintenance, repairs, or needed upgrades, no matter how closely these might be linked to safety concerns. Even a safe plant, if not operating profitably, eventually will not operate at all. Subsidies might be used to keep non-economic plants open for a while, but the political ability and financial resources required to do so are finite.

The remainder of this section provides examples of strategies and related techniques that have been found effective for operating NPPs in making a successful transition to open energy markets.

## 2.2. STRATEGY: DEVELOP A COMMERCIAL CULTURE

Open energy markets bring with them a focus on improved efficiency, market awareness and cost reduction. What is needed is not merely a collection of skills in these areas but the inculcation of a commercial attitude or "culture" in the organization. Managers, owners and workers at all levels must be convinced that plant survival depends on both safety and profitability, and that the two are not conflicting objectives. This will immediately raise fears that the safety culture so carefully nurtured in NPPs will be lost by commercial considerations. Those NPPs and operating organizations that have successfully made this transition from a monopoly, cost-plus environment to competitive markets have placed a great deal of emphasis on maintaining/improving their safety performance and culture. At the same time they have encouraged productive innovation of business practices to improve operational performance and efficiency. They have also taken steps to ensure that at all levels of the organization the interdependence among safety, production and profitability are understood.

#### 2.2.1. Technique: Develop competencies needed in the new environment

The following are some of the areas in which competencies will need to be developed:

- Eliminate "cost-plus" thinking when assessing options. This changes the attitude that fixes problems by spending more money but doing nothing new, to an approach that solves problems by changing behaviour.

  A recognition by everyone in the organization that the "business model" for successful NPPs is built upon strong safety and operational performance, with a long term view toward optimizing profitability.
- A focus on profitability, with an understanding that all personnel share in the effects of profits or losses.
- Encouraging technical and economic initiatives to become more competitive.
- An awareness by people throughout the organization of work and business processes.
- Assessing and making trade-offs among goals and among resources.
- Encouraging and rewarding productive innovation.
- An environment where change becomes the normal state of affairs, and continuous self-assessment not only is encouraged but expected.
- An organization designed to flexibly meet changing demands and to manage change effectively.
- Accountability that reaches as far down and up in the organization as practicable.

Corporate practices and organizational approaches that implement these characteristics include:

- Management teams that are business as well as safety and technology oriented. Ensure that investment and operating decisions or decisions to modify or upgrade the plant are made on the basis of economic considerations by the operations organization, and not by the engineering organization alone. In many nuclear plants this may imply the need for a change in management.
- Clear goals, objectives, and communications between the "owners" and "operators" so the owners understand operational and safety constraints, and the operators understand the owners priorities and objectives. Effective oversight methods are established to ensure that operational, financial and safety, objectives are achieved in an integrated manner.
- Establish an internal environment in which operating, maintenance and technical personnel understand how the plant generates revenue, and respond to those factors that

are important to maintain sufficient revenue (e.g., peak and seasonal loads, power sales and purchase contracts, and the commercial consequences of non-delivery).

- Ensure that personnel from all levels of the organization are responsible for identifying areas for improvement.
- Be prepared for change, including mergers and acquisitions, spin-offs and other structural and institutional reorganizations. Carefully planned assessment and implementation as well as flexibility are key to successful change as well as regulatory acceptance of the change. Of particular interest and consequence here are financial qualifications of licensees and the assurance, disposition and ownership of decommissioning funding, and where applicable funds for final disposal of high level waste and spent fuel.
- Flexibility in the use of financial and physical resources. Because all firms have limited resources compared to their goals, this involves being aware of and informed about trade-offs among resource applications and priority results. A willingness to profitably optimize trade-offs is key to a competitive approach.
- Sharing human resources among a number of plants in an organization can be an effective tool for accomplishing needed work. It can also benefit employees in terms of knowledge gained and career growth.
- Responsibilities: should be clearly defined in and among all organizational units; should be matched appropriately with financial authority; should be clearly and effectively communicated at all levels; and should not conflict. Responsibility should be recognised and accepted by all personnel for the outcome of their assigned tasks.
- An incentive system for employees tied to organizational objectives and associated performance. Maximum achievable rewards should be sufficient to provide such incentives.
- An incentive system for vendors and contractors (both individuals employees and organizations) to encourage them to participate in achieving plant performance goals.
- As a complement to increased employee responsibility, provide developmental assignments.
- Identify all stakeholders in the new environment (e.g., customers, public, interest groups, unions) and maintain a focus on their concerns, so that the overall business climate can be managed effectively.
- Encourage and reward productive innovation.

While these objectives and practices are not unique to nuclear plant operators, they represent important changes in attitude and management culture for many NPPs. This management approach ultimately translates into reducing operational and safety costs while improving operational and safety performance. It would thus permit nuclear power plants to compete on a more equal footing in generating markets.

IAEA-TECDOC-928, *Good Practices for Cost Effective Maintenance of Nuclear Power Plants* [4], IAEA-TECDOC-1052, *Nuclear Power Plant Organization and Staffing for Improved Performance: Lessons Learned* [5] and IAEA-TECDOC-1024, *Selection, Competency Development and Assessment of Nuclear Power Plant Managers* [6], provide specific examples of how NPPs and utilities have developed competencies needed in this new environment.

### 2.2.2. Implement an effective change management system

As was indicated earlier, part of a commercial culture is that change is a normal condition. Achieving new, challenging goals can stimulate productive innovation, and improve performance. However, change can also bring unintended risk. In many companies, managers at the top of the organization are less aware of at least some aspects of this risk exposure than those at the working level. Thus there is a need for a change management system that has the following characteristics:

- core values of the organization are communicated by senior managers in a way that people at all levels understand and accept
- the boundaries of allowable actions are defined, as well as those specific actions that are off-limits
- diagnostic systems are in place to monitor critical performance variables
- interactive information management systems stimulate learning and feedback
- adequate internal controls are maintained (e.g. oversight, internal audits).

## 2.3. STRATEGY: OPTIMIZE OVERALL USE OF ASSETS

### 2.3.1. Technique: Use financial analysis and economic considerations in evaluating plant operations and improvements

The use of financial criteria provide an objective basis for judging the economic benefits of business decisions whether they involve investment, appropriate inventory management, work schedules, or planning maintenance programmes. It flows from the manager's responsibility to maximize profitability (as measured by various financial ratios or criteria) while minimizing or compensating efficiently for risks. Commonly used financial criteria include net present value (NPV) calculations, internal rate of return (IRR), pay-back period assessments, and benefit–cost ratios.

A financial analysis should be used to assist in decision making regarding modifications/improvements. Among the types of improvements that should be subjected to such considerations include:

- safety improvements
- use of standardized equipment
- reliability improvements
- maintenance improvements
- finding appropriate levels of redundancy
- on-line maintenance
- up-grading equipment/systems
- procedure system changes/improvements
- energy conservation
- dose reduction measures.

With respect to safety and environmental issues the financial analysis is not used to establish performance goals or standards, but rather it is used in evaluating alternative ways to achieve these goals.

Over the operating lifetime of the plant, financial analysis and profitability criteria should also aid in operational decisions such as whether or when to:

- shop around for suppliers to meet specifications and standards at least cost;
- consider consolidating services such as spare parts inventory;
- engineer a slight rise in enrichment to improve final burnup by extending operating cycles;
- do a design review for a feasible increase of nominal power which could reduce unit generating costs;
- do a design review for improving thermal cycle efficiencies (thermal insulation, heat exchangers, heat recovery systems, loops, etc.);
- regulate frequency and electrical load cycles to avoid grid penalties.

### 2.3.2. Technique: Establish and maintain appropriate plant procedure systems

Too many procedures (or procedures that are unnecessarily detailed) will unnecessarily restrict workers, discourage responsible initiative and increase administrative costs. A re-engineered procedures system may result in both cost savings and in improved safety and availability. Conversely, inadequate procedures systems may contribute to errors or inconsistent performance. A proper balance of procedures should be systematically devised using objective and appropriate bases for determining whether procedures are needed, the appropriate level of detail, how they are to be used, and how they are to be reviewed. IAEA-TECDOC-1058, *Good Practices with Respect to the Development and Use of Nuclear Power Plant Procedures* [7] provides one method used for doing this.

### 2.3.3. Technique: Eliminate obsolete or unnecessary work

Many work activities continue even after the need for them has gone. There is gain in a "zero based" evaluation of all activities to assess the continuing need for the activity, whether it can be re-designed or integrated with other activities in order to increase its efficiency. IAEA-TECDOC-1052, *Nuclear Power Plant Organization and Staffing for Improved Performance: Lessons Learned* [5], provides techniques for improving the organization of plant activities.

### 2.3.4. Technique: Increase on-line maintenance

On-line maintenance reduces the length and the costs of planned outages. Some of the advantages of on-line maintenance include:

*during outages*:

– easier outage planning
– better overview due to reduced work load
– better work control by plant staff
– availability of full fuel element cooling capabilities.

*during normal operation:*

– better control by plant staff due to reduced work load
– use of the most appropriate plant or vendor staff for each task
– easier planning
– reduced probability of tagging errors.

The main arguments against on-line maintenance are that either reduced system availability or the maintenance work itself may increase safety or availability risk. To address these issues, increased use of on-line maintenance may require compensatory measures including the temporary or permanent additions of mitigating features or methods (e.g., additional power supplies). IAEA-TECDOC-928, *Good Practices for Cost Effective Maintenance of Nuclear Power Plants* [4], provides additional information concerning on-line maintenance. The impact of on-line maintenance activities can be quantified through the use of probabilistic safety assessment (PSA).

### 2.3.5. Technique: Make cost effective improvements in operational performance

Eliminate or reduce sources of unplanned plant trips and outages whose implementation costs are less than the net present value of the additional revenues to be gained from greater availability or profitability. This is one consequence of applying financial criteria as a consistent basis for such decision making. It should be noted that reducing unplanned trips also improves safety performance through reducing challenge to safety systems.

### 2.3.6. Technique: Improve outage planning and execution

Reducing the length and frequency of planned outages increases plant availability. Improving the quality of work done during planned outages will be reflected in a low frequency of forced outages. IAEA-TECDOC-928, *Good practices for cost effective maintenance of nuclear power plants* [4], provides specific examples of outage planning and execution improvements. The characteristics of these improvements include:

- Management commitment and daily participation.
- Adapting the outage organization to the company's goals and objectives.
- Spare parts management based on modular replacement.
- Computerized information management systems.
- Scheduling based on cost, risk assessment and outage length optimization (including the use of reliability centered maintenance to avoid unnecessary work).
- Daily reporting about the outage situation to every outage team member.
- Reporting of outage experiences including human errors and lessons learned.
- Integrating good safety, engineering, environmental and cost management, especially with contractors.

### 2.3.7. Technique: Use benchmarking to identify priorities for improvement

**Benchmarking** means learning lessons from best practices of other companies or groups. The specific procedures of benchmarking include:

- Comparing work performance, processes and outcomes with the best performing company in that field.
- Identifying practices which will bring about the best performance.
- Analysing causes of the gap between best practices and existing practice.
- Working out a plan to reach the highest cost effective levels of existing performance and then improve upon it.
- Taking actions to continuously, cost effectively improve performance.

IAEA-TECDOC-928, *Good Practices for Cost Effective Maintenance of Nuclear Power Plants* [4] and IAEA-TECDOC-1052, *Nuclear Power Plant Organization and Staffing for Improved Performance: Lessons Learned* [5] provide examples of benchmarking methods.

### 2.3.8. Technique: Focus on core competencies

In some countries power plants provide housing, education and other social services for plant personnel. In other countries electricity prices subsidize employment and environmental programmes. This is the result of government and social policies. These programmes incur costs not related to the process of generating and selling electricity, but they are nonetheless funded with the revenues thereof. In more competitive markets sustaining these indirect subsidies becomes increasingly difficult. Market pressures ultimately push for such services to be provided separately from the business of power generation. This discussion is not about the need for such social services, but rather about how they are funded.

### 2.3.9. Technique: Make appropriate use of contractors

Staff reduction is often one of the biggest consequences of industrial restructuring. Manning and employment questions become paramount in the course of re-organization. One technique for balancing personal requirements and efficient operations is the increased use of contractors. However, such contracting is not always or necessarily a cost saving and desirable approach, especially for core activities. Nuclear power plant licensees must always retain responsibility for their licensing obligations. In some countries, these license obligations mean that safety duties are not allowed to be contracted at all. Nevertheless, some goods and services that are directly related to plant business may indeed be provided more cost effectively from outside contractors. Examples of such goods and services can include:

- specialized maintenance, in-service inspection and outage support
- waste management
- security, janitorial and administrative services.

Where contractors are being considered as a cost effective measure, either to supplement or replace plant staff, it is good to consider the following:

- Maintain competition among contract bidders. Look for more than one supplier for different items, avoiding expensive intermediaries.
- Having several direct contracts can be a good alternative to having one contractor and many subcontractors.
- Integrate environmental, safety and other performance requirements into specifications for outsourced work so that bidders include the cost of compliance with these requirements in their offers.
- Long term and spot contracts each have different advantages. A mixed contract portfolio is useful for supply contracts, for example for uranium, for enrichment, conversion and fabrication services for fuel elements. A mixture of suppliers might also mitigate the business risks of procurement associated with suppliers going out of business or being excluded from the market for political reasons.
- Avoid cost-plus thinking — the idea that cost control does not matter — when negotiating contracts. Remember that contract costs and risks are important to profitability.

- Contracts with main contractors should provide for bonded performance, penalties for delay and non-performance, and incentives such as quality bonuses given directly to the people doing the work.
- Specify in inquiry documents the experience, training and qualifications for contractor personnel.
- Treat contract and plant personnel as members in multi-disciplinary teams, starting with preplanning of activities.
- Always have a contingency plan should a contractor fail to deliver on its commitments.

IAEA-TECDOC-928, *Good Practices for Cost Effective Maintenance of Nuclear Power Plants* [4] and IAEA-TECDOC-1052, *Nuclear Power Plant Organization and Staffing for Improved Performance: Lessons Learned* [5] provide examples of appropriate use of contractors.

### 2.3.10. Technique: Promote effective human performance throughout the organization

The most successful organizations in open markets are those that engage all members in achieving the organization's goals and objectives. Three main points in this regard are:

- clear and open communication in all directions (up, down and horizontal)
- authority and accountability delegated to the lowest appropriate level
- productive innovation encouraged and rewarded.

### 2.3.11. Technique: Implement and maintain an effective corrective action programme

Ensure that there is an effective corrective action programme through which all employees can report any event, near miss or visual observation that could help improve safety, reliability, schedule adherence or costs. Ensure that this programme is fully supported by management as the basis for continuous learning/improvement.

### 2.3.12. Technique: Ensure that the business model is clearly understood by both the owner and operator

In competitive markets it is quite likely that the "owner" of the plant and the "operator" of the plant are different organizations with different business practices and cultures. The further the owner organization is removed from the operating organization, the more important it is that both organizations have the same understanding of the business model including management processes, particularly those related to setting and monitoring of performance targets. The operating organization needs to focus on plant operations and not be distracted by confusion about the business model. Clear goals, objectives, and communications between the "owners" and "operators" ensure that the owners understand operational and safety constraints, and the operator understands the owner's priorities and objectives, and accepts them as being achievable. Effective oversight methods need to be established to ensure that integrated and interdependent operational, safety and financial objectives are achieved.

## 2.4. STRATEGY: FOCUS ON COST EFFECTIVE SAFETY AND REGULATION

The IAEA has published a comprehensive Safety Series that addresses nuclear safety fundamentals, requirements and guides as well as Safety Reports that give examples and methods in implementing Safety Standards and Safety Guides. The nuclear safety area has been and is expected to continue to be a major part of IAEA activities. There is no need for, or value added in repeating here the information contained in IAEA Safety Series documents. Rather, one of the main messages in this report is the need to integrate safety, operational and profitability considerations in order to succeed in a commercial environment.

In 1998, IAEA Safety Reports Series No. 11, *Developing Safety Culture in Nuclear Activities, Practical Suggestions to Assist Progress* [8] was published. This report identified attributes needed in an organization's culture, including its safety culture, in order to achieve continuous improvement. Those attributes identified in this report that are most relevant for long term success in a commercial, competitive environment, include:

- Safety and production are seen as interdependent. There is no goal conflict between safety and production performance.
- People are aware of work or business processes in the organization and help managers to manage them.
- Decisions are made in the full knowledge of their safety impact on work or business processes as well as on departments and functions.
- Management's role is seen as coaching people to improve business performance.
- Learning from others both inside and outside the organization is valued.
- Collaborative relationships are developed between the organization and regulators, suppliers, customers and contractors.

The following techniques are provided in the context of integrating safety within the business performance and practices of the organization.

### 2.4.1. Technique: Improve cost consciousness in achieving nuclear safety goals: encourage innovation and flexibility

There were no strong incentives to find the most cost effective means to achieve safety goals in the cost-plus environment where many NPPs have been sheltered from price competition. If new safety goals or requirements were established, whatever costs were associated with their implementation were transferred to customers. During the past 20 years, in many Member States, there have been a large number of new safety goals and requirements established for NPPs, sometimes without a clear focus on the cost–benefit of the requirements, or on finding the most cost effective way to achieve safety goals and requirements. Moreover, safety goals have not always been defined in such a way that a clear determination can be made as to when they have been achieved.

Nuclear plant safety and environmental protection are fundamental to the commercial operation of a power plant. If a plant cannot be operated safely at a profit it will ultimately be shut down. Having the flexibility to find cost effective ways to achieve business goals is highly desirable in a commercial setting. So too is the flexibility to minimize uncertainty. Achieving such flexibility with regard to safety regulation will require some degree of re-orientation by both regulators and plant managers in many Member States. Past behaviour has often discouraged flexibility and innovation. It will also require greater clarity in defining measurable safety goals.

Overly prescriptive regulation will block the kind of innovations that are needed to design and implement cost effective safety measures. Moreover, extensive regulatory intervention has two further drawbacks. One, it has proven to be inefficient and expensive. Second, it can imply that the regulator, rather than the licensee, has primary responsibility for safe NPP operation.

Strong safety oversight and enforcement will always be key. However, focus on ends rather than means, on targets vs. command-and-control, will generally be more effective in competitive markets. This is already happening in other regulatory arenas. In the realm of environmental regulation, for example, the need for standards that permit cost effective compliance has been recognised. A focus on flexible approaches to achieving a given target level of environmental protection provides a basis for owner and operator awareness of environmental liabilities and pollution abatement possibilities.

### 2.4.2. Technique: Use safety risk management tools to streamline safety regulations

One approach for achieving regulatory flexibility in the field of safety has been to use safety-risk-based screening for setting regulatory priorities. Use of risk based regulatory approaches in the field of safety, for example:

- Focuses on those activities that have the greatest safety significance, using probabilistic safety assessment to determine high risk and low risk activities.
- Uses risk insights, deterministic analysis and performance history to establish objective parameters and criteria to monitor and assess performance.
- Assesses regulatory processes to determine which are most amenable to risk based, less prescriptive approaches.

This approach ensures that both regulators and licensees are focused on those activities that have the greatest impact on reducing safety risk. Having determined the areas where the greatest risk reduction or benefit can be achieved, it still remains important that the means to achieve these benefits be evaluated using cost–benefit considerations, rather than arbitrarily specifying such means. While originally conceived for safety analysis, such risk based techniques might also be applied to investment decisions such as life extension.

### 2.4.3. Technique: Re-allocating liabilities and risk

Competition tends to result in economic risks and liabilities being bought and sold for their profit potential, with these risks and liabilities being ultimately assumed by the parties that can manage them most efficiently. Some commercial liabilities attached to nuclear plants will therefore almost certainly be re-allocated under more competitive market structures. Because a commercial liability represents a profit or potential profit for some party, risk is not a completely negative item. Moreover, the size of the potential liability is not necessarily so important as the management of the liability and actual cost of managing it (hedging, streamlining, sharing risk, etc.). Good and efficient liabilities management is a profitable and sought-after business that results in lower costs for liabilities over time.

The management of financial liabilities attached to a nuclear plant can be largely divorced from plant operation without jeopardising the legal obligations of a nuclear licensee, or relieving licensees from ultimate legal accountability. Thus, while some legal obligations on the part of licensees may not be contracted out or passed on to others, a large part of the commercial and financial risk associated with these obligations can and should be effectively and efficiently re-allocated, often through the capital markets.

Concern has also been raised that owners of nuclear plants in competitive markets might fail to assure the adequacy of decommissioning funding. Other parties contend that, where funds have existed for a long time, more money has been collected than will ever be needed for decommissioning. The adequacy and collection of such funding, like compliance with environmental and safety regulations, is established by law. Compliance constitutes a cost of doing business for the licensee. Experience has shown that no generating company can offer an iron clad guarantee that a plant, nuclear or otherwise, will run for the full term of its license/contract or earn anticipated revenues. Under present conditions, the legal liability of the operating organization remains intact, even if fund collection is insufficient. If the funds prove to be in surplus under current conditions, then a case could be made for reducing industry fund contributions and thereby lowering plant operating costs

# 3. PROJECTS UNDER WAY

## 3.1. BACKGROUND

This section deals with cases where:

- work on an NPP project has been suspended prior to completion;
- where existing NPPs require retrofits and upgrading to remedy inefficient or unsafe conditions or avert early closure; or
- where existing NPPs are considering plant life extensions or upgrades that necessitate additional investment.

In all of these cases the generating company, whether government owned or private, faces the decision whether to invest further in completing the plan, or to terminate the project. What guides such decisions? More specifically, how does the basis for such decision making change as one moves to more competitive or deregulated power markets? In such market situations, an objective financial analysis of continued or incremental investment in construction, license extensions, major modifications, upgrades, or power uprating is needed to evaluate whether the investment is justified in a business sense. This should be accomplished by comparing costs and revenues with due consideration given to uncertainties.

## 3.2. STRATEGY: MINIMIZE ANTICIPATED COSTS OF INVESTMENT ALTERNATIVES

It is important to make all possible provisions for cost reductions in anticipated costs before making any investment decision. If a decision is made to complete a plant or project, continued cost vigilance will always be necessary, but failure to minimize anticipated costs in the planning phase could skew the result of the decision. Project managers have considerable control over the costs that go into the investment.

### 3.2.1. Costs of completion (or upgrade/power uprate)

*Finance costs*

Capital costs typically constitute around 60% of the cost of construction of a nuclear power plant. They are therefore a prime target for cost reduction. Capital costs are a function of the investor's willingness to lend money to a project, based the anticipated cash flow from the investment and the degree of risk that this cash flow will not be recovered. Matching expectations, risk and returns is a matter for financial negotiation. Capital costs will ultimately be a function of the source and structure of the investment and financing package negotiated, the amount of equity financing available, the currency in which the financing is provided, construction time, the terms and conditions, pay back period, price of financing, the degree of risk involved, and where and how it is all secured. Each of these factors is subject to negotiation and hence to cost management and reduction techniques, including adjusting repayment and down payment arrangements. How well financing costs are managed can be measured using a number of financial ratios including internal rate of return (IRR), pay back period, net present value (NPV), debt/equity ratios, and benefit cost analysis.

Most of the basic considerations requisite for any decision on continued investment in a project revolve around giving comfort to investors that they will get their money back from the investment with interest. Such comfort can come from a government providing sovereign guarantees of the debt, or from assurances that the anticipated revenue stream will be adequate not only to pay off the debt but also sufficient to operate and maintain the plant adequately. For plants where construction has been suspended for long interludes, repayment of the debt on construction and loans to date often represents a heavy financial commitment that must be met regardless of current income. Additional investment is not likely to be forthcoming if payment on existing debt absorbs all revenues, if the company has defaulted on its debt, or if revenues collected from electricity sales do not cover operating and finance costs or costs for maintenance and repairs.

*Construction time*

Time is money is an old cliché but very true for power companies that are paying financing costs during construction, paying interest on interest, and earning no revenues from the investment. Such costs can rise rapidly with delays and longer construction times. Shortening the construction time can be achieved by such measures as:

- Limiting design changes during construction, except minimally as required for licensing.
- Including wherever appropriate in construction contracts, penalties for delays in completion of specified tasks. Incentives for early completion can also be appropriate.

*Cost of further delays*

Assuming that financing for project completion can be obtained, some estimate should be made of the cost of further delays that might occur during project completion. There is no guarantee that the renewed construction phase will go as planned. Investors, lenders and managers should have an idea of the risk of delay and the cost of such delays. Both can be mitigated to some extent. The cost of delay can also be allocated by contract to provide monetary incentives for on-time completion.

*Cost of materials*

The cost of construction materials is affected by their quantity, quality, source and procurement method and by management actions. Each of these characteristics is susceptible to cost control.

**Quantity** of material needed depends in part on the design of the plant and on inventory management. One can reduce the quantity of material required simply by adhering to more modest construction plans for outside the power block (exhibition center, simulator, administration building, training center, etc.). The carrying costs of inventory and spare parts can be reduced by rationalizing inventory holding requirements and making common use of installation tools. Efficient project management is needed.

**Quality** of material needs to be guided by cost effective considerations. In a cost-plus environment, "gold plating" can be tolerated. There is a temptation to use "top of the line" equipment, both for safety related and non-safety materials, even when not necessary. In more competitive circumstances, quality of material needs to be adequate, affordable and appropriate.

**Source and procurement considerations** are closely linked. The international market for nuclear components, related goods and services is very much a buyer's market, making it worthwhile to shop for supplies and suppliers. There may be pressure or temptation to procure a certain percentage of the project's supplies and labor from local markets. However, using power company procurement to protect or encourage local industry can impose a costly surcharge on construction costs. The perceived social benefits of this option need to be weighed objectively in the context of cost, timing and quality, compared with other options.

Competitive procurement can often result in lower contract costs (though not necessarily lower procurement costs) than using sole-source contracts. Project managers need to be willing to select suppliers and contractors to secure or take advantage of cost savings in overall operations. Procurement plans should include shopping around, and should consider potential savings and costs to be had from purchase of generic or standardized materials and components.

## 3.3. CRITICAL CRITERIA FOR CONTINUED INVESTMENT

A partially completed plant is not evaluated financially on the basis of how much money has already been spent on the plant; nor on the basis of interest payment considerations resulting from past decisions; nor on construction completed. These are what are called "sunk costs" that have already been incurred. The repayment of debt represents a real cost and continuing obligation for the borrower, and may affect his future ability to attract capital, but it does not enter into the calculation of whether or not to continue construction. Efforts to include sunk costs distort the decision making process. A financial decision on completion or termination will focus exclusively on future costs and revenues. It will ignore past costs and costs that are already committed, and which cannot be reversed.

This financial evaluation in its simplest form is a comparison of only three elements: net present value (NPV) of the cost of completion vs. the NPV of the anticipated future revenue stream from the completed project (generating revenue minus costs, discounted over the expected life of the plant), vs. the cost of plant closure or stopping construction. Once these numbers are computed and compared, the basis for decision is more clear. This holds true even when the project is government financed or when the decision to be made is a "defensive" one: i.e., which option loses the least money.

## 3.4. STRATEGY: USE FINANCIAL CRITERIA FOR EVALUATING PLANNED INVESTMENTS

### 3.4.1. NPV calculation

The purpose of a NPV calculation is to determine whether the anticipated revenues from an investment are greater than the anticipated costs from the same project. A NPV calculation is based entirely on future costs and revenues alone, even if sunk costs have created an emotional attachment or antipathy to a particular project.

Revenues and costs that should be included in NPV analyses include virtually all future cash inflows and outflows related to the project, but should exclude costs that are not directly necessary for the project. If NPV is used to compare fuel choices, it is important that the competing fuels be compared on the basis of the power supply that is required, including the pattern of power supply requirements, and not on the basis of the megawatt capacity of the plant, because different types of power plants often have different potential availability.

In the case of a power project, revenues for the most part arise from the sale of electricity though there are also possible incomes from sales of heat, desalinization, or other income sources including government subsidies. Costs can be divided into capital costs that arise prior to the operation of the plant, and costs incurred while operating the plant. Because both revenues and expenditures occur over time, an interest rate, often called the discount rate, is used to measure the effects of time on how one values future incomes and costs. Generally, a project is considered worth investing in if the NPV of the project is greater than zero.

While it is popular to speak of "the discount rate", the appropriate interest rate to use in evaluating a project is a complex issue. The discount rate that prevails is not set by the utility, by the power sector or by any individual, but by financial markets and by the risks a particular firm faces. Hence for the most part it is useful to calculate NPV at several discount rates if for no other reason than to determine the sensitivity of an investment to changes in the cost of money over time. This also allows for a measure of the financial risk involved in the project.

### 3.4.2. Cost of stopping

It is commonly accepted that the current status of a project is a sufficient basis for determining whether a plant should be completed. Thus if an NPP is said to be 90% physically completed it is, in this view, a better candidate for completion than a plant that is 60% complete. These measures of completion are in fact engineering measures while the financial concern is the NPV of the future cash flow of the plant. It is important to realize that a power plant that is physically 90% complete does not necessarily have only 10% of its investment costs left to be spent. The investment cost could be less and very frequently are more. It may even be more than the anticipated revenues from the completed plant. The revenue side of the NPV equation is independent of the per cent completion of the NPP except in the very important issue of the timing of revenue receipts.

One curious outcome of evaluating a project that has already been started is that in some cases one might wish to continue investing in a project with a negative NPV. This occurs because shutting down a construction project is potentially expensive. Most construction contracts have cancellation costs or penalties if a project is terminated. If completing the project results in lower losses (measured in NPV) than shutting down the project, then the investment should continue.

An analogous situation arises in asking, on the basis of NPV, whether an operating NPP should be shut down. Shutting down a plant incurs many costs and sometime the firm is better off operating the plant at a loss, because that loss is less than the losses incurred in shutting it down. This is also one reason why several nuclear power plant sales have recently been described as being “at no cost to the buyer”.

Generating companies operating in managed markets may be able to pass on to captive customers the costs of cancellation. In a competitive electricity market this may not be possible, and at least a partial write-off of sunk costs will be inevitable. It is also possible that plants terminated while still under construction can be mined for salvage and the sale of components. The salvage value of the plant mitigates the costs of stopping and in practice is subtracted from sunk costs to derive the net cost of terminating the investment.

### 3.5. RELICENSING AND PLANT LIFE EXTENSION — A SPECIAL CASE

The aging of the world’s nuclear power plant and the potential for lifetime extension are matters of considerable current interest that need to be viewed in a dispassionate manner. Like project completion, relicenzing or life extension of an operating NPP is, in a competitive market, based on whether or not the relicenzing or life extension is financially beneficial. It would be considered financially beneficial if the discounted cash flow anticipated over the remaining (extended) life of the plant exceeds the discounted capital and operating costs incurred by the plant over its remaining life time.

Extended operation of such plants can be very profitable. One assumes that operating costs are already low or else extension would not be considered. Capital costs, while not trivial, may well be lower than for a new plant, because the plant’s debt is usually largely paid off by the time of renewal, and many significant costs such as land acquisition and site preparation are not incurred. A plant’s decommissioning fund obligations should also be fully satisfied, further reducing operating costs. Life extension of nuclear power plants can also be attractive for environmental reasons in regions where compliance with air pollution standards or commitments to greenhouse gas emissions reductions argue against increased use of fossil fuel fired generation.

Lower capital costs are just one way in which relicensing or life extension of plants differ from completion of an unfinished plant. Such plants also already have a revenue stream attached to assure at least some repayment of any financial obligations incurred for the relicensing or life extension. Assuming the financial calculations are sound, financing is therefore less of a problem.

Another category of relicensing is power uprating. Power upratings of 10–20% have been achieved at many plants. Such power upratings are often very attractive financially because they further reduce unit costs. The investments needed to achieve power upratings are not trivial, involving new or modified generators and other plant modifications as well as engineering, analysis and licensing expenses. But, nevertheless, they are often less expensive than building new capacity (nuclear or otherwise).

# 4. NEW PLANTS

## 4.1. BACKGROUND

This section focuses on issues specifically related to new plants. The key difference between investment in new plants and investment in existing plants or projects underway, is that with a new plant there are no sunk costs or choices. One has more freedom of choice at the outset, the most basic being fuel choice and technology, but also siting, plant design, financing, operations, and risk allocation. One can choose efficient options. The corollary responsibility in a competitive market is that the project planner and investor need to be profit- and market-oriented to assure the viability of the investment.

Developing countries and countries in transition are already experiencing at least some degree of competition in their power sectors, if only from the introduction of foreign investors and private or independent generators. Budget limitations in many of these countries are forcing increased reliance on private sector financing for power sector (and other) expansion. This will impose a degree of market discipline on investment decisions. Construction of nuclear power plants is being considered in such countries for a variety of reasons, including energy security, fuel availability, national security and environmental protection, but at a time when electricity markets are becoming increasingly competitive and commercial. The need for a commercial and competitive orientation is great in these circumstances. Below are some strategies and techniques for power sector managers and investors who are contemplating commercial nuclear power in competitive markets.

## 4.2. STRATEGY: MAKE EFFICIENT DESIGN CHOICES

### 4.2.1. Technique: Make the most profitable choice among fuels and technologies that is possible

One of the first decisions that a power generation investor must make is which fuel and which technology to use, as well as plant location. Usually these choices are linked because fuel availability, and therefore fuel costs, will vary from one location to another. Nuclear power is just one of many fuel choices a potential power plant investor might consider. While nuclear power may offer great environmental advantages over other technologies, in the end, it must compete on the basis of costs and revenues.

It is worth noting that some governments or investors might have dual interests when choosing generation technologies. They may select a technology on the basis of profits and for satisfying public interests in safety, energy security, job creation or environmental protection. Nuclear power should only be considered in these cases if it has the potential to best meet both profitability and public policy objectives. Some nuclear plants have been used successfully to achieve multiple government goals such as power generation plus energy security, or environmental protection. But if nuclear power fails to meet these joint goals, then another technology will be chosen that does.

One common example of such dual-purpose plants is the construction in many cities of garbage fired power plants. These seldom pay for themselves by producing thermally based power alone but they do achieve the objective of efficient solid waste disposal while producing saleable electricity as well. At least part of the difference between the cost of such plants and their most economical alternative, between market price for capacity and society's willingness to pay, can be used to establish preliminary values for the non-power related products of the plant, such as environmental protection or energy security. But the combined socio-economic efficiency and profitability of the undertaking must be positive, otherwise governments will not sustain such undertakings.

Exactly the same principle applies in the case of the Clean Development Mechanisms (CDMs) created under the Kyoto Protocol. These CDMs are designed to encourage the construction and use of facilities that reduce greenhouse gas emissions over alternative choices, but that, absent a value assigned to such reductions, would not be the most economical investment. One of the goals of the Kyoto Protocol is to set a price on carbon emissions that can later be used to establish trading.

#### 4.2.2. Technique: Recognise that plant design can affect profitability under different market conditions

Because reactor designs differ, the suitability of reactor designs for a specific market will vary. Also individual vendors might provide particular features that meet differing requirements. Several types of reactors are being designed for large unit capacities to capture economies of scale, while other designs are intentionally of smaller size to appeal to developing countries or other smaller grid capacity situations. The characteristics that are of importance to a particular project should be clearly specified at the outset so that both the technical and economic benefits of the alternative plant designs can be assessed. Among these considerations include: grid characteristics, load following capability, load rejection, frequency control, generation locations relative to market demand, standardization of designs and equipment, operating cycle/availability, and proven performance.

### 4.3. STRATEGY: SECURE ALL ECONOMIC RISKS AND LIABILITIES EFFICIENTLY

Economic risks are usually considered in a financial context as any action or condition that might result in unexpected or uncontrolled consequences to investment profitability. No party in a free and competitive transaction will willingly accept an open-ended risk or liability without sufficient compensation. All risks in some fashion must be secured: i.e., someone must accept accountability for averting, minimizing or making good on potential or actual losses if things go wrong. Such security can take the form of performance bonds on construction contracts, insurance policies, collateral for loans, a government guarantee of markets or an indemnity, to cite but a few examples.

Competitive markets tend to allocate risk efficiently for at least two reasons. First, they make parties holding the risk accountable for the loss of any assets at risk. This provides a strong incentive to reduce the risks involved and the costs associated with them. They permit risk to be bought and sold for profit among those who manage risk and those who are risk averse. This permits risk to be assumed and traded by parties as a matter of economic choice, so that if one party becomes more or less able to manage risk efficiently, it can be assumed by another more appropriate party.

As noted earlier, risk mitigation and allocation of risk management efforts do not alter the licensing obligations of a nuclear plant operator or exonerate him from his ultimate responsibilities, any more than buying an insurance policy would do so. In fact insurance is one of the most common forms of risk management and mitigation.

### 4.3.1. Technique: Allocate the risks of plant construction and operation efficiently, and reward the party that is accepting risk

Most large investments, including those in the power industry, involve more than one party. Even if only one firm owns an NPP, governments that encourage NPP investment are usually involved in providing guarantees that are part of the investment process. So are insurance companies. It is an established business rule that the party that can best control a form of risk, should be responsible for its management. For example, if one party in a nuclear power plant investment has greater experience in managing nuclear fuels, that is usually the best party to handle nuclear fuel issues. If there is political or policy risk in a nuclear power plant investment, the government is usually viewed as the party that can best manage such risk.

Taken as a whole, such allocation of risks normally reduces investment and operating costs more frugally than a more random or arbitrary allocation. Consideration of capacity to manage risk forces investors to specify what risks are involved in each investment. This clarifies investment planning.

Managing risk entails costs and efforts on the part of the project manager. No party would be willing to undertake risk management without compensation. An individual's exact allocation of revenues from an investment is generally subject to negotiation, but it would normally be affected by the risks he accepts and his risk management costs, as well as by his level of capital investment. Most contracts associated with power plant investment, operation and maintenance, are also risk allocation contracts.

### 4.3.2. Technique: Specify the allocation of plant completion risks, including allocation of and terms for risks due to policy change

Completion risk relates to the fact that once investment is made in a power plant, the plant might not be completed or finished, and thus might never generate revenues to repay the investment. The nuclear power industry historically has a high completion risk relative to most other generation choices, equaled only in some cases by large hydropower projects. The sources of completion risk in nuclear power are many. They include a high capital investment that is sensitive to inflation; a regulatory inclination to impose retrofits to reflect changing safety requirements and in reaction to accidents such as Chernobyl or Three Mile Island; and, increasingly, changes in popular and political assessments of the desirability of nuclear power.

Money expended on a power plant that is never built is a total loss because revenues that would fund the plant's expenses are never received. The high completion risk for nuclear power generally means that investors will require protection against losses of significant amounts of money in the case of policy related non-completion, before investing in any nuclear plant.

### 4.3.3. Technique: Establish liability for political and policy based risks during operations

Government involvement at some level is needed for the construction of any nuclear power plant. Investors will seek assurances about the reliability of this aspect of the project, as for any other aspect. This need for assurance is especially high in the case of NPPs that are built in direct response to public (government) policy, and whose viability depends on continuation of government commitment. If the government were to change its policies toward nuclear power or the power industry in general, investors would wish to have losses, based on the new policy, recouped.

Sweden and more recently Germany have promoted nuclear power phase-out policies. These have had a sobering effect on any potential investors in nuclear power. Investors in phased-out plants are limited to seeking after-the-fact compensation for the cancellation of the revenue stream on which repayment of investment funds was predicated. Potential new investors will certainly seek assurances and specific arrangements in advance, that they will be compensated if nuclear power operation policies change. Otherwise potential investors would bear the full financial risk of political and policy changes, over which they have no control. Few investors would be to take this risk.

### 4.3.4. Technique: Allocate safety risks among operations and plant design areas; establish patterns of liability for safety risks

Safety risks have potential financial consequences. Safety risk management imposes certain costs, as does the meeting of safety standards. For the plant manager, safety and financial risks are separate though related items. Each must be managed in its own sphere, with the goal of risk optimization and efficient allocation of liability, though the exact techniques in each case may differ.

### 4.3.5. Technique: Potential domestic and foreign liabilities from plant operations and failures must be specified and allocated among plant managers, governments, and appropriate agencies

Liability is a sub-category of risk. Risk is the probability of some negative event multiplied by its consequences, while liability is the amount of potential damages one might have to pay if that something did in fact go wrong. For nuclear power plants, liability generally encompasses any debt or claim that might arise from the construction or operation of the plant. A major complication and impediment to NPP investment is that worst case potential liability scenarios can be exceedingly high, even though the actual risk of incurring such major liabilities is very small.

Most nations where nuclear power plants are operated or contemplated have found it difficult or even impossible to start plant construction without simultaneously arranging a legal basis for the allocation and compensation of major potential liabilities. More recently it has been recognized that liabilities can cross borders. Claims from the Chernobyl accident certainly contributed to this realization. The Nuclear Safety Convention focuses on providing solutions to these issues.

### 4.3.6. Technique: Responsibilities and funding for waste fuel management, retired plant disposal, and other perceived open-ended liabilities after plant closure must be clearly allocated

Among the largest operating expenses of a nuclear power plant are funding the disposal of spent fuel and the costs of dismantling the plant at the end of its operating life. In some countries spent fuel disposal costs are included in the cost of the fuel itself; other countries have established spent fuel disposal funds similar to decommissioning funds. In any event, some method of allocating responsibilities for spent fuel disposal expenses must be determined at the outset. Plant retirement and site restoration costs, which can be at least several hundred million dollars and might be more, must be estimated and collected or otherwise provided for during the life of the plant. Arrangements for funding of post-plant-closure work need to be made at the start of the project, and clearly allocated to appropriate parties before operations and financial arrangements are initiated. This is usually done through the licensing process, and should include financial or economic considerations that permit efficient allocation of liability.

Financial planning for the plant will in fact require the allocation of all such responsibilities. However, despite the best planning, costs and risks are likely to change over time, and difficulties might still arise if anticipated costs do not match actual costs. Contingency liability provisions must be made at the outset: This is an aspect of risk management. If, for example, public opinion requires site restoration at a level not initially envisioned in the establishment of the funds, or requires plant closure before the appropriate funding is amassed, who will fund the difference?

Conversely, and perhaps more interestingly, what happens if the cost of retiring a plant is less than was anticipated? Do the owners of the plant receive the surplus funds or would they be returned to rate payers? The answer depends a good deal on market structure. Under a franchised monopoly (utility style) power system, plant owners would normally be required to pass surplus returns on to rate payers. A market or contract system would often permit the plant owners to retain any surplus. Because of such uncertainties and because of the large sums involved, management of plant retirement funds are an issue where NPPs are privatized or shift to competitive market environments. Investors in new NPPs will want some certainty about access to such funds before committing money to a project.

Waste disposal and the allocation of liabilities associated with it, are becoming increasingly contentious issues as older facilities are retired. While many governments have in principle assumed responsibility for waste disposal, few if any have succeeded in providing for high level waste disposal on a long term and definite basis. Consequently, uncertainties about spent fuel storage and nuclear waste costs contribute to difficulties with acceptance of nuclear power, and to uncertainty about its future. The potential liabilities associated with waste storage, transport and permanent disposal create financial uncertainties and thus also greater financial risks and costs for nuclear power plants. Investors will want a clear understanding at the outset of who bears the responsibility and the liability for these activities. Governments can clarify their own role in waste disposal matters and the role of taxes to fund it.

## 4.4. STRATEGY: FOCUS ON PROFITABILITY

### 4.4.1. Technique: Meet financial criteria for net returns and for risks in order to assure the availability of funding

Commercial funding will not be available for investment in an NPP if the plant does not meet established financial criteria for anticipating commercial viability. Lenders intend to get their money back, with interest of course. Financial criteria indicate whether this is possible. The most popular methodology for determining financial viability is called "net present value" (NPV), which was discussed earlier. There are several other financial ratios that normally yield the same results about whether an investment should be undertaken; these include "internal rate of return" and "benefit–cost" analysis," and calculation of the "pay back period".

Each is useful for providing information about specific financing aspects, but normally none of them meets as many selected financial or mathematical requirements as NPV.

Net present value allows for the comparison of alternative investment projects. One advantage of internal rate of return is that it can be used to show what cost of funds (interest rate) a particular investment would be able to cover. Yet another measure, pay back period, does not determine if an investment is advisable but is a measure of project risk because it will tell the investor how long he would have to wait before revenues from his investment would cover his cost.

#### 4.4.2. Technique: Design construction plans to minimize the net financial effects of interest during construction and delays

A competitive disadvantage for nuclear plants is their long construction period. The cost of this time results mainly from accumulated interest charges on funds expended during construction, and might amount to 40 percent or more of total construction costs if the plant takes seven or eight years to build, depending on the discount rate that is applied. Much of the cost savings posited for newer power plant designs would occur due to shortened construction schedules rather than to profit oriented design improvements. Construction contracts can be written to include penalties for delays and incentives for early completion.

However, the rather lengthy construction period for a nuclear power plant is partly related to meeting engineering and design requirements perceived to have a safety impact. Decisions must then be made on how to achieve safety in a cost effective manner while improving the efficiency of construction. In some cases standardization of plant design might improve productivity, shorten construction schedules and reduce costs, but this is not always compatible with commercial investment choices in competitive markets.

#### 4.4.3. Technique: Design the plant to reduce the net costs of down time from operational failures

Given a need to fund heavy debt requirements, one of the greatest financial risks for a nuclear power plant is posed by lengthy, unplanned shut down. A shut down plant does not pay off its debts. Nuclear plants in a number of Member States have suffered extended shut downs, either for operational failings, or because of an accident, incident, or other nuclear safety concerns. This history contributes to the high perceived risk of nuclear investments.

Some reduction in likely down times might be achieved even before construction, through design plans and through predetermined operating procedures. There is, of course, a trade-off. Excessive design to prevent down time would be expensive as well. A balance must be struck between achieving a decrease in the probability of future down time, and the certainty of related increased construction costs.

#### 4.4.4. Technique: Reduce capital costs

Capital costs during construction comprise perhaps 60% of the total investment costs of nuclear power plants. Reducing capital costs is therefore an important variable in making nuclear power competitive. A report by OECD/NEA on “reduction of capital cost of nuclear power plants” identifies several possible specific measures for doing so. Those that are compatible with competitive markets include:

1. Improve construction methods (open top access, modularization, slip-forming technique, parallel construction, reducing pipe welding points).

2. Reduce construction schedule through up-front engineering and licensing, prefabrication, modularization, use of large cranes, improving construction interface, streamlining and reduction of documentation, strong industrial relationships, etc.

3. Improved design, including plant arrangement, accessibility, simplification of design, and use of modeling.

4. Improve procurement and procurement scheduling, organization and contracting.

5. Efficient project management, including control of costs, scheduling and quality.

Work cooperatively with regulators to optimize regulation, policy measures and licensing in the light of competitive market requirements.

## 4.5. STRATEGY: KNOW AND SERVE YOUR MARKETS

### 4.5.1. Technique: Design the plant to meet the capabilities and interests of the electricity grid and potential market structures

The appropriate scale and operating schedule for a power plant is often determined by characteristics of the power grid to which it is attached. Grid size and demand patterns, for example, can determine the appropriate size and architecture of a plant. At a time when decentralization, niche markets and delivery of tailor made energy services are becoming the hallmark of the electricity sector, nuclear power especially might have difficulty adapting to changing grid requirements. Many nuclear plants designs have become larger and larger to take advantage of engineering economies of scale. Some grids are too small to reliably accommodate these larger size NPPs. Additional designs are needed to suit small grids and flexible grid conditions, and to overcome a nuclear plant's limited load following capabilities.

Another problem for nuclear power is that voltage fluctuation on a power grid can lead to unplanned plant shut downs and can damage power plant machinery. In this regard, grid size relative to the plant capacity is an important factor.

### 4.5.2. Technique: Identify and develop market niches for the power plant

With the privatization of the power industry, power producers are increasingly looking for "niche markets". This can include selling all or part of a plant's electricity (or steam) output to customers under secured contract (power purchase agreements) or specializing in delivery to specific limited markets. Some non-fossil fuel generators, for example, specialize in selling "green" power even at above market prices to environmentally conscious customers. In the Russian Far East, small reactors designed initially for nuclear submarines have been used to provide local or emergency power services to some communities.

Nuclear power generates minimal air pollution, making it an attractive alternative for those seeking to reduce particularities, acid rain precursors or greenhouse gas emissions. Possible niche markets could be defined for nuclear plants within the context of the Kyoto Protocol, for example, if nuclear power were considered as qualifying under the Protocol's flexible mechanisms provisions. Signatory States would have to act deliberately to include nuclear power on the qualifying list for undertakings such as the Clean Development Mechanisms (CDMs), but if this were done, nuclear power would be recognized as an economic alternative to carbon technologies, thus at least assuring its ability to compete in certain niche markets.

Another form of market specialization is designing a power plant to meet either peak or base load power demand. Nuclear power is generally preferred for base load power because of its relatively low operating costs, and because its heavy debt service burden requires a constant revenue stream. NPP profitability thus often depends on the ability to achieve and maintain high availability factors. Nuclear plants are less satisfactory as a source of peaking power — largely because it is difficult to start up and shut down most nuclear facilities during the course of an hour, a day or even in a period of a few days.

### 4.5.3. Technique: Consider revenue sources other than power generation (cogeneration, desalination, etc.)

The capacity to earn revenues from sources other than electricity production is increasingly recognised by the power industry. The clearest example of this would be irrigation, recreation, water supply and flood control in the hydroelectric industry. Nuclear is more limited in its capacity to obtain non-electricity revenues partly due to its technology and partly due to the distance that is usually sought between nuclear power plants and population and industrial centers. Nonetheless, cogeneration (steam production), district heating and desalination are additional uses for a nuclear power plant. These uses are of course not restricted to nuclear power and can be performed by most thermal energy sources. They are however potential revenue sources that at times might make the difference between the commercial operation of a nuclear power plant and the closure of the plant.

Another aspect in this regard is diversification outside a power generation, such as engineering services or through acquisition of foreign power generation capacity. While such diversification can have benefits in reducing cash flow risks, it is important to ensure that the activities do not deter the operating organization from its responsibilities for safe, reliable and profitable operation of its plants.

## 5. SUMMARY

Nuclear power has clear advantages including low fuel costs and minimal environmental impacts. However, there are certain characteristics of nuclear power that make it especially vulnerable to exposure in competitive markets. These make reform strategies both more important and more difficult to achieve. NPPs have higher capital costs and heavier debt than alternative generation technologies, longer construction times and higher commercial risks; some inflexibility in load following and other grid management characteristics, demanding safety requirements and a current lack of final solutions for disposal of wastes.

How high are nuclear plant capital costs? Estimates vary with size, location and technology of plant, estimated construction time, and many other variables, but a generally accepted range is about US \$1.8–2.0 million/MW, assuming a construction period of 7–8 years. New designs may cut these costs further through simplified design and construction, and shorter construction times.

There is also a considerable range of estimates for other generating technologies. An average estimate for a modern coal plant with only limited pollution control (i.e., no flue gas desulfurization [FGD]), would be about US $1 million/MW. FGD would add another 10–15% to this cost. Estimates for a gas plant where a delivery infrastructure is in place (i.e., pipelines in place with excess capacity) would be about US $0.5 million/MW and occasionally less. The cost of building a nuclear power plant is thus 100–400% higher than the cost of building another equivalent power plant. To be comparable to coal or gas plants respectively, the construction cost of a nuclear plant would have to fall between 40–75%.

High construction costs mean the nuclear plants carry a commensurately heavy debt load. The inexorable need for repayment creates its own set of pressures and engenders its own set of additional costs whenever repayment is delayed or put at risk. This is one reason why delays are so costly in nuclear construction projects. High construction costs are also one reason (besides technological limitations) why nuclear plants, once in operation, run as base load plants. Moreover, the size of the debt for a nuclear plant, for many countries, implies foreign borrowing, which poses potentially devastating currency risks for debt repayment, as illustrated by recent Asian experience.

For nuclear generating costs to be competitive, the gap in capital costs must be made up in fuel and operational and maintenance (O&M) costs. Whether this is possible is unclear. Certainly nuclear fuel costs are low where natural or slightly enriched uranium is available, but the difference between even the cheapest nuclear fuel and the highest historical fossil fuel prices has not necessarily been sufficient to overcome the construction cost disadvantage of nuclear plants. The O&M advantage of nuclear is even less clear. Improvements in plant availability and cost reduction made over the last decade allow many nuclear plants to compete effectively in today’s markets. But the demands of more sophisticated technology and high safety concerns limit the flexibility of nuclear plant managers to respond further. As other technologies also improve their efficiencies, nuclear power may lose some of its competitive edge.

Moreover, nuclear plants carry with them several and potentially severe commercial risks beyond those of a non-nuclear generating station. These include a higher risk of non-completion once construction begins, the risk of early shutdown for political reasons, and the risk of retroactive safety related regulations or mandated plant shutdowns. Each carries with it the possibility that revenues will be insufficient to pay a return of and on the investment. Each of these risks can indeed be accepted and secured, but only at some cost. Anyone willingly assuming such risks will expect a suitable financial reward for doing so. For nuclear plants the relevant question is whether this risk can be absorbed and compensated at a cost that still permits nuclear power to compete in the generation market.

Will nuclear power be able to compete in tomorrow’s generating markets? In the end, the market and government policy will decide. Much will depend on the nuclear technology being offered by the industry. Even if nuclear power offers clear environmental advantages, . investment decisions ultimately will be made on the basis of relative costs, not perceived environmental benefits. Innovative technological and market responsive improvements will be needed to bring nuclear power plants into the generating world of the next millennium. These are possible, but will require flexibility and innovation on the part of industry and regulators alike. Innovative commercial and financial arrangements may also be used to give nuclear power an economic edge in electricity markets.

Government policy (including international commitments, energy and environmental policies) is the domain of each Member State, but increasingly competitive power markets and financial markets will establish their own values for nuclear power and for nuclear power plants, based on the relative costs and risks associated with nuclear power compared to other generating alternatives. What can we learn from experience to date?

In the USA, where nuclear plants are being auctioned off as part of the electricity sector restructuring, the sales prices for nuclear power plants provide some indication of the value the market places on nuclear power. The two plant sales negotiated during 1998–1999 were well managed and had good operating records. Each sale included approximately US $23 million for the facilities themselves plus some US $70 million for the fuel (included as working capital), and with a 3–6 year power purchase agreement. Each sale amounted to less than US $200 000/MW, about 10% of the estimated cost of a new MW of nuclear power, and less than half of the cost of a MW of gas fired combined cycle capacity.

In large part the lower sales price reflects the perceived risks and liabilities associated with nuclear power plants, risks of mandated early closures, risk of potential liabilities, unknown risks and liabilities associated with decommissioning and site restoration. The lower sales prices reflects the cost of compensating new owners for assuming and managing potentially profitable risk. It may also be that these plants have been undervalued. Clearly several other nuclear plants were not put on the market at these prices.

The nature of such sales and the ultimate ownership patterns may vary. In the USA they are more likely to be sales of a single plant to a single buyer or consortium, or they may be cooperative arrangements or a pooling of plants into a nuclear operating company. In the UK, the privatization of British Energy took the form of a public stock offering for shares in a generating company that comprises the more modern nuclear plants in the country. International transactions and cooperative ventures are not impossible.

All of these sales are in fact one response to competition. Change in ownership can often provide greater flexibility to all parties involved, for example:

- Sales may reflect a desire to change corporate focus or to reduce corporate risks. There may also be a defensive element in some sales. As noted earlier, plant retirement costs may make shutting down a plant more expensive than operating it, even at a loss. Selling the plant would permit its owners to minimize losses and/or to recover at least partly their investment costs at one time. The low prices recently realized for some recent US nuclear plants might reflect this approach.
- Purchases on the other hand reflect the view that greater profits can be made through further efficiency gains in already well run plants. Purchases may also be used to gain entry into a new market, or as a relatively inexpensive way to add generating capacity. Regardless of motive, the purchase of existing ("used") plants is an economic decision, judged on the basis of factors that include anticipated market for plant output (i.e., anticipated revenues), the level of O&M costs vs. anticipated market prices, whether there is room for improvement in costs and efficiency, future costs including maintenance and refurbishment, remaining economic life, locational advantages, the commercial, regulatory

and financial risks attached to the purchase, outstanding liabilities including regulatory and political uncertainties. Grouping buyers into a consortium is one way to pool both the costs of and whatever risks attach to, the purchase and operation of the plant. This reduces both the costs and the risks for individual investors.

Finally, it is worth noting that — also in response to market conditions — a full spectrum of waste disposal services is now being offered on a commercial basis, for and at a profit. This is being done under contract to nuclear plants and facilities that may retain ultimate accountability for waste disposal under their licensing arrangements, but who may want to transfer or re-allocate the risk and uncertainties thereof. The fact that such firms have contracts throughout the world for their services indicates that commercialization and competition in waste disposal services is a viable alternative to existing, often stagnating corporate or government programmes. There is every reason to anticipate that privatization and competition in the areas of waste disposal and other nuclear services such as outage support would engender the same results as in the generating sector, namely, lower costs and more flexible performance, and efficient compliance with established standards. This would benefit commercial nuclear power generators by reducing costs of these needed services.

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