Nuclear Power in Competitive Electricity Markets

NUCLEAR ENERGY AGENCY
ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT

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- to contribute to sound economic expansion in Member as well as non-member countries in the process of economic development; and
- to contribute to the expansion of world trade on a multilateral, non-discriminatory basis in accordance with international obligations.

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NUCLEAR ENERGY AGENCY

The OECD Nuclear Energy Agency (NEA) was established on 1st February 1958 under the name of the OEEC European Nuclear Energy Agency. It received its present designation on 20th April 1972, when Japan became its first non-European full Member. NEA membership today consists of 27 OECD Member countries: Australia, Austria, Belgium, Canada, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Luxembourg, Mexico, the Netherlands, Norway, Portugal, Republic of Korea, Spain, Sweden, Switzerland, Turkey, the United Kingdom and the United States. The Commission of the European Communities also takes part in the work of the Agency.

The mission of the NEA is:

- to assist its Member countries in maintaining and further developing, through international co-operation, the scientific, technological and legal bases required for a safe, environmentally friendly and economical use of nuclear energy for peaceful purposes, as well as
- to provide authoritative assessments and to forge common understandings on key issues, as input to government decisions on nuclear energy policy and to broader OECD policy analyses in areas such as energy and sustainable development.

Specific areas of competence of the NEA include safety and regulation of nuclear activities, radioactive waste management, radiological protection, nuclear science, economic and technical analyses of the nuclear fuel cycle, nuclear law and liability, and public information. The NEA Data Bank provides nuclear data and computer program services for participating countries.

In these and related tasks, the NEA works in close collaboration with the International Atomic Energy Agency in Vienna, with which it has a Co-operation Agreement, as well as with other international organisations in the nuclear field.

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FOREWORD

Most OECD countries have undertaken or are planning to initiate a reform of the electricity market. In particular, governments are placing emphasis on market mechanisms to improve economic performance in the power sector. The shift from an economically regulated environment to open competition will likely have specific impacts on the nuclear industry owing to the important role that governments have traditionally played in this field.

In this context, the NEA Committee for Technical and Economic Studies on Nuclear Energy Development and the Fuel Cycle (NDC) initiated a study on nuclear power in competitive electricity markets. This study, focusing on relevant policy issues raised by economic deregulation for various stakeholders in the nuclear power field, complements the activities of the Committee on various economic aspects of nuclear energy.

The study was conducted by a group of experts from twelve Member countries and three international organisations. It covers aspects that are relevant for existing and future nuclear power plants, and highlights key issues for the consideration of analysts and policy makers in governmental bodies and the industry.

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EXECUTIVE SUMMARY

Electricity has traditionally been supplied in OECD countries by state-owned facilities, or state-protected monopolies with regulated pricing. More recently, however, several countries have deregulated their electricity markets, thus opening the door to competitive supply and pricing. Deregulation of electricity markets is a trend that is expected to be followed by many countries. This can have a significant impact on the future of nuclear power programmes, particularly since these have been to some extent subsidised programmes, or have been carried out by utilities that were either state-owned or had a monopoly on electricity supply, in most OECD countries.

Recognising the importance of deregulation in the electricity sector for nuclear power, the NEA Committee for Technical and Economic Studies on Nuclear Energy Development and the Fuel Cycle (NDC) conducted a study that reviews and analyses its potential impact on existing and future nuclear power plants. While this report does not contain recommendations or solutions that the nuclear power community can adopt in order to deal effectively with electricity market deregulation, it is expected to be useful for policy makers and nuclear generators in identifying potential impacts on their particular situations and in planning for the future.

The report provides an overview of the status of electricity market deregulation, briefly reviews related aspects of privatisation of electricity supply, and examines generic and specific issues concerning nuclear power in a deregulated market. In a deregulated, economically competitive market, power generators want to invest in profitable options that have relatively well-known technical, economic and political risks. In such a market, nuclear power might be at a disadvantage, since it may be considered to be encumbered with political risks (such as those arising from public opposition), technical risks related to waste disposal issues, and economic risks associated with liabilities for eventual decommissioning and dismantling of nuclear power plants. On the other hand, nuclear does have environmental advantages, in particular practically zero emissions of greenhouse gases, particulate and other atmospheric pollutants. All of these nuclear-specific characteristics, both positive and negative, may be important in assessing the competitiveness of nuclear power in a deregulated

electricity market. High capital cost, long construction time and need for operation at high capacity factors are relevant to nuclear power, but they apply to other power technologies as well.

Impacts on current nuclear power plants

For existing nuclear power plants, the determining costs in a competitive market are the marginal costs of operation, i.e. operating and maintenance costs, including applicable repair and refurbishment expenses. Plant investment costs are important to the company and stockholders, but they have already been paid and, therefore, can be considered as sunk costs in economic decisions on the continued operation of a nuclear power plant. However, low electricity prices in a competitive market could pose a problem for nuclear power generators, since they might, in some cases, not be high enough to cover both the marginal costs of operation and the investment costs of nuclear power plants.

The impact of electricity market deregulation on the performance of existing nuclear power plants is expected to be positive. Increased competition brings about staff reductions, productivity increases, and availability improvements for nuclear power plants, the sum of which improves economic performance. In some OECD countries, nuclear power plants are already operating well in competitive electricity markets.

Capacity factors for US nuclear power plants have increased and the average nuclear generation cost has fallen in recent years, thus making nuclear power more competitive. US nuclear power plants are on average competitive in terms of production costs. In the United Kingdom, nuclear power plants have performed well under deregulation. Availability has improved and output has increased by improving refuelling operations, reducing outage times and increasing power levels. Nuclear power plants in Finland and Sweden have been operating successfully within the Nordic electricity market, and Spanish, German and Dutch nuclear power plants have successfully competed in the competitive markets that were introduced at the beginning of 1998.

The cost of extending the life of a nuclear power plant is expected to be less than that of building a new power plant of any kind for base-load electricity supply. It is expected, therefore, that competition will increase the chances of life extension of well-operated nuclear power plants.

Nuclear facilities are generally well run, not only because of regulatory requirements but also because of economic incentives to be competitive with other energy sources. Some concerns have been expressed that too much

emphasis on economic competitiveness might impede funding for nuclear safety. However, there are strong indications that economic competitiveness and safe operation are fully compatible, and that nuclear safety will not be affected negatively by electricity market deregulation.

Impacts on nuclear liabilities and insurance

Competition will put pressure on power generators to clearly identify and quantify future economic liabilities of nuclear power plants, and to include them in electricity prices. In competitive electricity markets, changes in regulatory requirements may also have to be considered. However, current liabilities of nuclear power and associated insurance schemes, whose costs are rather well established, are not likely to change in a deregulated market.

Decommissioning and waste management liabilities may be the most important of the various economic risks of nuclear power in competitive electricity markets. The associated concerns include accuracy of the estimated future costs, adequacy and availability of funding provisions to meet those costs, and stability of regulatory requirements that impact on the costs.

There is a risk of shortfalls in funds for decommissioning and waste disposal in a competitive environment due to early plant closures, or not having a guaranteed volume of electricity for sale. Approaches for making up these shortfalls, if they arise, could include a surcharge on electricity consumption, nuclear plant owners bearing the costs, or funding the shortfalls through public revenues.

Intensity of competition in the nuclear decommissioning and waste management market will increase and likely lead to reduced prices. Complete privatisation of waste management and decommissioning might be an outcome. Some governments already have assigned full responsibility for waste management and decommissioning to nuclear power plant owners, with the government retaining an overview and safety regulation role.

Impacts on the structure of the nuclear power sector

Competition is likely to have an impact on the structure of the nuclear power industry, including nuclear research activities. Ownership consolidation or cost-sharing partnerships of nuclear generators are expected in competitive markets in order to obtain the benefits of economies of scale and to be more

competitive in providing base-load electricity to customers. Nuclear vendors, equipment suppliers and engineering companies will consider alliances and joint ventures with a global market approach in order to share the risks in the new market environment and to obtain the benefits of synergy.

Restructuring of the nuclear fuel cycle industry is expected, including: vertical integration of the front-end fuel cycle industries; vertical integration between front-end and back-end fuel cycles; and horizontal integration within each fuel cycle stage. In the back-end of the fuel cycle, traditionally ran by state-owned companies, the emergence of private suppliers is expected. Renewed interest in international solutions for radioactive waste disposal can also be expected if cost pressure on the back-end fuel cycle increases.

Government funding of R&D for nuclear power has declined and this trend is expected to continue as electricity market deregulation increases. Utilities may tend to reduce R&D expenses in order to reduce costs and their efforts will likely focus on applied research aimed at performance enhancement. Although support from utilities to fundamental nuclear research activities will decrease, competition is likely to stimulate and reward initiative and innovation. The benefits of competition can include relief from some regulatory requirements that are not cost-effective, and a certain freedom to be innovative in ways to lower cost. Competition is also creating new market opportunities for innovations in generating technology aimed at improving efficiency and reliability of power plants.

Impacts on new nuclear power plants and other factors affecting the competitiveness of nuclear power

The competitiveness of new nuclear power plants has decreased substantially in recent years, particularly when compared to gas-fired plants. A recently published NEA/IEA joint study on projected costs of generating electricity concludes that nuclear power is seldom the cheapest option for plants to be commissioned by 2005-2010.

In a competitive market, it will be more difficult to predict electricity prices over a long period. Therefore, nuclear power plants that require relatively longer construction times and higher investment costs may have greater investment risks than other power plants. On the other hand, nuclear power has advantages of low fuel prices and lower risks of fuel price escalation.

Investment decisions for new nuclear power plants will depend upon their profitability. The prospects for building new nuclear power plants in competitive markets are not clear. Although sound arguments can be made that

justify building new nuclear power plants in these markets, decisions in many countries are likely to be influenced by public opinion, political will, and the pace of implementation of spent fuel and other high-level waste disposal facilities.

Other factors, such as the environmental benefits of nuclear power, could help in promoting its development. The competitiveness of nuclear power could improve if external environmental costs, e.g. related to greenhouse gas and other pollutant emissions, were taken into account in market prices. In the longer term, stabilising the emission of greenhouse gases world-wide probably will require the use of nuclear power, since it is one of the least costly alternatives among non-carbon energy sources.

Safety regulations and the ways in which they are implemented can have a significant impact on nuclear generation costs and the competitiveness of nuclear power. Investors require stable trading, regulatory and political environments. The uncertainties of nuclear power regulation can be a major factor in investment decisions.

1. INTRODUCTION

Background

Over the past two decades, owners of nuclear power plants in OECD countries have been increasingly concerned with questions about whether to close plants at the end of their present operating licenses, close them earlier, or extend plant life beyond their currently planned endpoints. Governments are reducing their roles in the nuclear power industry by selling state-owned nuclear power plants and curtailing nuclear power programme subsidies. There are, at present, few plans to construct additional nuclear power plants in the foreseeable future.

The nuclear power industry is faced with financial, technical, and regulatory uncertainties. Decommissioning and high-level waste disposal are prime examples of areas where these uncertainties exist. The public attitude toward nuclear power in general ranges from ambivalent to negative which, in turn, is reflected by its political leadership. There is, however, a growing public awareness and concern about potential global warming as well as other environmental and health effects caused by burning fossil fuels. Nuclear power offers some clear advantages in this regard. Although the connection between a cleaner environment and nuclear power is not yet imbedded in the public psyche, it could result in a stimulus for increased use of nuclear power in the future.

Electricity traditionally has been supplied in OECD countries by state-owned facilities, or state-protected monopolies with regulated pricing. There is now, however, a growing trend toward opening electricity markets to competition, coupled with privatisation of state-owned power generation. The question is how and to what extent this trend will influence the evolutionary course of nuclear power programmes.

Objectives and scope

The Committee for Technical and Economic Studies on Nuclear Energy Development and the Fuel Cycle (NDC) in the NEA recognised the importance of a global trend to open electricity markets to competition and launched a study to review its effects on the nuclear power sector. Representatives of twelve Member countries and three international organisations formed the Expert Group for the study in February 1998. The first Expert Group Meeting was held in March 1998.

The main objectives of the study are to review the effects of increasing market competition on nuclear power programmes in Member countries. The study identifies the issues that require careful consideration during review of deregulation of the electricity sector.

The Group agreed that the scope of the study should include:

Impact of electricity market deregulation on current nuclear power plants

- Changes in plant operating parameters, e.g. staffing, productivity, availability, safety, radiation exposure.
- Competitiveness of nuclear power.

Impact of electricity market deregulation on nuclear liability and insurance

- Future financial liabilities for decommissioning and nuclear waste management.
- Third party liability and insurance.

Impact of electricity market deregulation on the structure of the nuclear power sector

- Restructuring of utilities, equipment and service suppliers, fuel cycle industries and nuclear research activities.

Impact of electricity market deregulation on new nuclear power plants

- Costs and competitiveness of new nuclear power plants.
- Prospects for building new nuclear power plants.

Other factors affecting the competitiveness of nuclear power

- Policies aiming at sustainable development and climate change mitigation.
- Security and diversity of energy supply.
- Regulatory and political issues.

Working methods

The study was conducted by an Ad Hoc Expert Group in a manner typical of NEA studies. Its membership consisted of representatives from governments, utilities, research institutes, and international organisations. Expert Group meetings included members from Belgium, Czech Republic, France, Germany, Hungary, Japan, the Netherlands, Spain, Sweden, Switzerland, the United Kingdom and the United States of America. The International Atomic Energy Agency (IAEA), the European Commission (EC), and the International Energy Agency (IEA) also participated in the study. The members of the Expert Group are listed at the end of the report.

At the first meeting, papers on electricity market deregulation and nuclear power in each country were presented by members of the Expert Group. The objective and scope of the study and guidelines about how to provide input to the report were circulated to Member countries.

Expert Group members provided information about the various effects of electricity market deregulation on nuclear power programmes including an assessment of the competitiveness of nuclear power in a changed electricity market and other nuclear issues in the context of electricity market deregulation.

Drafting Groups were organised within the Expert Group to prepare the first draft of the report. The initial draft report was amended, reviewed and completed by the Expert Group and the NEA Secretariat in the course of four meetings and through correspondence. After each meeting, the Group members provided their comments and opinions to the NEA Secretariat for consideration in preparing in a new version of the report. The Expert Group had its final meeting in October 1999.

Other relevant studies

In 1997, the OECD published a study of regulatory reform of important economic sectors, including the electricity sector. It also publishes country-specific analyses of regulatory reform. The IEA is responsible for analyses of regulatory reform in electricity markets. A report has been published by the IEA entitled *Nuclear Power: Sustainability, Climate Change, and Competition*, that explores implications for nuclear power of these three important energy issues. The NEA Committee on Nuclear Regulatory Activities has published a study entitled *Future Nuclear Regulatory Challenges*. Consideration on the potential of electricity deregulation to affect safety and its regulation is included in this report. The IAEA report, *Strategies for Competitive Nuclear Power Plants*, provides specific strategies and techniques that utility and NPP managers might adopt in order to succeed in a competitive electricity market. Other relevant studies are listed at the end of this report.

2. ELECTRICITY MARKET DEREGULATION AND NUCLEAR POWER

Deregulation of the electricity sector

For many decades, OECD Member countries have controlled their electricity sectors as government-regulated monopolies. These monopolies, usually in the form of a franchised and protected market, covered specific geographical areas. Market areas were different among countries, e.g. regional, state or whole country. The type of ownership was also different among countries, i.e. privately owned, state-owned or mixed. Regulators often controlled the price of electricity, and complicated regulatory systems guaranteed protected markets in exchange for a safe and reliable supply of electricity at a reasonable price to the public. This situation is changing now that the electricity sector is being deregulated and opened to competition.

Deregulation of the electricity sector is largely driven by the pursuit of greater economic efficiency. Electricity market competition provides strong incentives to reduce costs and increase productivity. In competitive markets, low-cost plants thrive and high-cost plants either reduce costs or cease operating.

The electricity sector is likely to respond to competitive markets with innovation and improvement in performance and business practices. Power companies will become more service oriented, more conscious of marketing, and more focused on profitability. They might consider changes in management, staffing policies, investment policies, customer relations, and in relationships with owners, banks and rating institutes in order to be competitive.

Currently, deregulation of the electricity sector is focused on competition in power generation and sales. Transmission still will be maintained as a monopoly for the time being in many OECD countries, but elements of competitive behaviour will increase. A significant change in competitive markets may be marked by the appearance of electricity brokers and traders who buy electricity from markets such as long-term contract markets, spot markets, or financial electricity markets and sell it without having their own generation facilities.

There are two key points for achieving full competition in the electricity market. The first is to adjust transmission conditions to allow full competition among power suppliers and to provide consumers with a choice of suppliers. The second is to extend competitive markets far beyond geographically franchised areas. These two points will ensure open, transparent and fair access to the power network, and non-discriminatory transit rights within and between networks.

There are a number of possibilities for introducing competition in electricity markets and each country will select its own methods by taking into account economic and other considerations. These approaches include: beginning with large customers and expanding to smaller customers; simultaneously opening markets to all customers; opening markets to generators only, or to brokers/traders as well; providing only for exchange of electricity; and including other types of exchanges, e.g. financial exchanges.

The number of countries that are electrically inter-connected is increasing and these countries sometimes create a single large electricity system, e.g. the system in the Nordic countries. In such circumstances, some international harmonising agreements or regulations may be required in the following areas: network access; transmission tariffs; conditions for border crossing; achieving a balance between generation and consumption; dealing with bottlenecks; taxes and environmental protection; and ensuring that there is no discrimination among electricity generating technologies.

Deregulation of the electricity sector is expected to make electricity prices more transparent and flexible to reflect market conditions. In addition, deregulation is expected to lower electricity prices in most countries, especially where over-capacities exist. However, in some countries, deregulation can temporarily raise the price of electricity owing to market-driven pricing and elimination of cross subsidies.

A concern about deregulation is maintaining the stability of the power supply. If system operators or network companies are not given sufficient economic incentives for reserve capacity, the necessity of cost reduction in competitive markets will lead to a decrease in reserve capacity. This may cause problems in supplying electricity during times of high peak loads and power system disturbances. The problem could be mitigated, however, if price signals are efficiently transmitted to customers so that demands can be adjusted during high price times.

Privatisation of the electricity sector

In parallel with competition there is a strong move to privatise the electricity sector, that used to be totally or partly state-owned in many countries. State-owned electricity companies are often obliged to accommodate governmental/public policy goals in addition to achieving their business goals. In addition, they are sometimes hampered by socially imposed cross subsidies. Since competitive markets are efficiency-driven, there is great incentive to increase efficiency through private ownership.

Another basis for privatisation is to relieve governments of financial burdens. A number of governments, facing increasingly stringent budgets and conflicting demands for public moneys, are unwilling or unable to continue funding the electricity sector. The sale of state-owned assets, moreover, should result in significant revenues for national treasuries.

Deregulation of electricity markets and privatisation of the electricity sector are not the same, but neither are they mutually exclusive. Either one can be implemented without the other, even though they are highly synergistic. For example, a state-owned company can be privatised as a monopoly in a non-competitive market and this would not create an impetus for greater competition. In many cases, however, privatisation and competition are linked to each other and are executed together.

There are different ways to move toward privatisation and government's choices that mainly depend upon the goal to be achieved. If the government wants to maximise revenues from the sale of its electricity assets, sale at auction may provide the best method. A government may choose this opportunity, however, to encourage foreign investment, or to strengthen domestic capital markets by selling company stock or issuing bonds.

Generic issues confronting power generators in a deregulated market

Power generators typically have operated with a certain degree of uncertainty about future electricity demand, but they have had protected markets for their outputs and assured rates of return in traditional markets. In a monopoly, financial and market risks effectively are allocated to customers. For example, the cost of poor forecasting generally was borne by customers, and the economic penalty to the utility for over-investment was minimal or nil, with the excess investment costs being passed on to customers through higher electricity prices. This will change in competitive markets. The change is not different from the situation in other businesses, but it is a new experience for many utility managers.

In a competitive market, power generators can gain or lose customers to the competition. The contracts between suppliers and consumers are based on the market price and are valid for terms that reflect the customer's option to switch suppliers. This contributes to a new market risk for power generators. Market pressure is especially great when there is a surplus of generating capacity and sluggish demand for growth. Power generators run the risk of not selling their full output capability unless their marginal costs are low enough, or unless they can negotiate sales at acceptable terms on spot and contract markets.

Competition can produce negative effects on the ability of power generators to pay off their debts, because some power plants will be retired early if their marginal generating costs are higher than the market price. As the electricity market becomes deregulated, some of these unrecovered capital costs may become stranded costs.

In a competitive market, power generators may need to redefine what constitutes an adequate reserve capacity because they have to rely more on the grid and the market and, above all, on efficient and effective peak pricing. The heavy cost burden of maintaining a high level of spinning reserves that does not produce revenue most of the time cannot be passed on to the customer.

Because of competition, electricity prices may approach the level of the marginal costs of the marginal supplier (i.e. the supplier providing the next increment of supply). Where competition is introduced into markets with over-capacity, prices will reflect primarily the short-term marginal costs of the marginal supplier, which could be lower than the average embedded costs traditionally charged by monopoly utilities.

In a deregulated environment there might be a variety of electricity markets, e.g. contract markets (both long-term and short-term, but probably not on a fixed-price basis); future and hedging markets (both financial and physical); and spot markets (where price is a result of a short-term bidding procedure). Power generators probably will aim to sell their electricity in several markets, and through the use of a portfolio of sale mechanisms. If the electricity markets work well, prices will reflect the balance between the opportunity costs of electricity demand and the marginal costs of electricity supply. The balance, however, is affected by the conditions of supply and demand. If the balance changes, electricity prices will change also.

In competitive markets, power generators are increasingly pressed to operate like other businesses and their performances are evaluated primarily by the market. They no longer are insulated from market changes and are required

to cope with market forces through increased operating efficiency, cost reductions, effective pricing, market sensitivity, better risk management, more flexibility and greater transparency.

Power generators can have long-term power supply contracts with customers in competitive markets, but risks and benefits must be efficiently allocated to all parties, and the price system must be free to reflect market demands. In addition, if the market has over-capacity, which lowers the price, long-term power supply contracts will be less appealing to power suppliers.

High capital costs and high risk/reward ratios are of greater concern in decisions about building new power plants than they are for existing power plants and for plants under construction that already have some sunk costs. In competitive markets, generating companies are required to bear greater performance, financial and market risks than in the past. Considerations that have an increased influence on investment decisions include capital requirements (initial capital outlay and the costs of various forms of capital); demands for shorter pay-back periods; and more stringent cash flow requirements to secure debt and equity capital at reasonable cost.

Investors choose among options based on the rate and size of potential returns and on the risk that these will not materialise. They will invest in profitable options and may be reluctant to invest in capital-intensive power plants, in particular those with long pay-back times. Therefore, they probably will look for more flexible and shorter term investments, lower risk investments, or those with higher risk but higher potential returns. New and efficient technologies may encourage new entrants to carve out a market niche for themselves even when there is over-capacity.

Special considerations for nuclear power in a deregulated market

Nuclear power raises specific issues with regard to waste disposal and liabilities. Uncertainties about the costs of waste disposal and decommissioning increase the investment risks for nuclear power. These costs must be and have been included in the electricity price. The market discipline of competition however, will make these costs and the associated economic risks more apparent.

In many OECD Member countries, the commercial risks of nuclear power have been compounded by the political risks that may, in fact, outweigh all other factors. Regulatory requirements for nuclear safety in a deregulated market might be another significant issue for the future of nuclear power.

Nuclear power does not emit greenhouse gases, therefore, the competitiveness of nuclear power will significantly improve if the external environmental costs are reasonably reflected in market prices, e.g. through a carbon dioxide tax.

Other characteristics of nuclear power plants, such as high capital cost, long construction time, and need to operate at base load in order to be competitive, may also raise significant concerns regarding investment in new nuclear power plants. These characteristics and the concerns that they raise are not, however, unique to nuclear power and may apply to some extent to some other power technologies as well.

3. IMPACTS OF ELECTRICITY MARKET DEREGULATION ON CURRENT NUCLEAR POWER PLANTS

Performance of nuclear power plants

The impact of electricity market deregulation on the performance of nuclear power plants is expected to be positive. Increased competition in a deregulated market should bring about cost reductions through reductions in staffing, increased productivity, and higher availability factors, thereby improving economical performance.

For example the performance of nuclear power plants in the United States has improved markedly. In 1987, only 42% of the nuclear units had capacity factors above 70%. In 1997, despite the fact that 10 units were shut down all year and four others were down much of the year due to regulatory compliance issues, nearly 75% of nuclear units in the United States had capacity factors of 70% or higher. In 1998, the average capacity factor reached 78.2%. From 1990 to 1996, plant thermal efficiency increased by 0.2%, nuclear plant staffing decreased by 7%, and refuelling times dropped by over one-third.

In the United Kingdom, British Energy experience in a competitive electricity market has been positive. The company has increased output from 54 TWh in 1994 to 67 TWh in 1998, and achieved a load factor of 81% in 1998. Unit operating costs have been brought down by over 20% over the same period.

Some other countries in Europe, which is moving towards a common European market for electricity, also have shown good performance of nuclear power plants in the 1990s, although they have very limited experience in electricity market deregulation. In the Netherlands, actions to improve competitiveness have resulted in 4% improvement in availability and 10% reduction in operating costs. In Germany the availability, capacity, and load factors of nuclear power plants increased during the period 1991 to 1997 as follows: the average of the availability factor increased from 78.2% to 92.9%; the average capacity factor increased from 79.7% to 92.3%, and the load factor increased from 74.9% to 87.3%. In Belgium, staffing levels were reduced by 4% and O&M (Operation & Maintenance) costs per kWh were decreased by 17% during the period 1990 to 1997.

In general, improvement in power output of nuclear power plants has been achieved mainly through improved refuelling operations, longer intervals between outages and reduced outage times, and power upgrades. Furthermore, reductions in staff levels and increases in productivity and reliability have resulted in enhancing the competitive position of nuclear power plants.

Safety and regulation

While it is too early to draw definitive conclusions on the effects of competition on nuclear safety, it can be argued that nuclear safety should be improved in a competitive market. Indeed, safe and efficient operation of nuclear power plant may fulfil at the same time the goal of competitiveness and the requirements of nuclear safety regulation.

Some safety regulators are of the opinion that economic competition and safety are compatible. Critics argue, however, that nuclear safety could be compromised if management decisions at nuclear companies over-emphasise short-term economics. Since economic effectiveness is the most important factor in a competitive market, nuclear operators must examine all aspects of electricity generation with strategies and techniques that are oriented towards cost-reduction. In the context, safety upgrades are unlikely to be undertaken unless seen mandated by regulatory agencies, or there is an economic gain through associated productivity increases.

Moreover, there is concern that with market deregulation nuclear safety regulatory authorities may tend to tighten their administrative control over nuclear generators, and intensify their overview in order to assure that economic deregulation does not compromise nuclear safety. This could have a negative effect on the competitiveness of nuclear power.

According to the Nuclear Energy Institute (NEI), however, high safety levels go hand-in-hand with good economic performance. Although US nuclear power plants have reduced their production costs by one-third, they have achieved a high record of safety and reliability. Key performance indicators tracked by the Institute of Nuclear Power Plant Operations (INPO) show that unplanned automatic plant shutdowns were reduced by more than 90% from 1990 to 1996, while capacity factors were going up. In addition, nuclear power plants having the best performance ratings with the US Nuclear Regulatory Commission (USNRC) also have the best capacity factors and the lowest O&M costs. According to USNRC data, there has been a steady reduction in the number of significant events in US nuclear power plants, from an average of 2.4 events per unit in 1985 to 0.1 event per unit in 1995.

The USNRC states in its final policy statement on the *"Restructuring and Economic Deregulation of the Electric Utility Industry"* that economic deregulation does not preclude adequate protection of public health and safety.

In the United Kingdom, there has been no conflict between commercial decisions and safety of nuclear power plants since the electricity market was deregulated. For British nuclear power operations, the introduction of competition in the electricity market has stimulated a drive to improve performance, but safety has remained the priority including the need to address issues of public concern.

In summary, it appears that nuclear safety, regulatory compliance and efficient economic performance are not in conflict, but in fact are complementary. Safety is a key factor irrespective of the market conditions monopoly or deregulated, since a nuclear power plants will be shut down if not operated safely.

Plant life extension and power upgrades

There is substantial interest in nuclear power plant life extension in OECD Member countries, because the cost of life extension is expected to be much less than that of building a new power plant of any kind. In the United States, the USNRC has issued rules that permit extension of nuclear power plant operating licenses by up to 20 years, and several utilities already have submitted applications under these rules. It is estimated that life extension of nuclear power plants in the United States will cost approximately $10 million on average, to prepare a renewal application and for USNRC review fees. Hearings may add to these costs, but it is clear that license renewal will allow utilities to maintain generating capacity without large investment costs for the construction of new plants as replacements.

Nuclear power plant power upgrades also are becoming common in many OECD countries, since upgrading can result in increased capacity at low investment cost. A number of upgrades already have been carried out or are being planned in Germany, Korea, Spain, Sweden, Switzerland and the United States. However, major and expensive upgrades will be unlikely in competitive electricity markets unless there may be a clearly demonstrated potential for a satisfactory rate of return on the investment.

Competitive electricity markets likely will increase the incentive for life extension and upgrades of nuclear power plants, particularly for plants that are economically competitive, although there may be some concern about adequate return on costs in the long term.

Stranded costs

Stranded costs are expenses resulting from investments and other obligations that utilities assumed in order to fulfil their responsibilities as regulated public utilities, with the understanding that the costs could be passed on to customers, but that cannot be recovered fully when operating in a deregulated electricity market.

According to the Nuclear Energy Institute, stranded costs in the United States are the result of state and federal government mandates in the market over the last twenty years. Stranded costs in the US electric utility industry fall into four areas:

- Power Purchase Contracts: These contracts, mandated by the Public Utility Regulatory Policies Act (PURPA), require utilities to buy power at prices well above market-clearing levels. By some estimates, PURPA contracts may represent as much as one-third of the stranded costs in US utilities.

- Regulatory Assets: These are costs incurred with the approval of state regulatory agencies with recovery taking place over a period of years. Regulatory assets include such things as the cost of energy efficiency programmes, low-income energy assistance programmes, and deferred fuel costs.

- Unrecovered Capital Investment: Regulated electric utilities typically recover their investment in power plants through rates charged to consumers over a period of thirty to forty years. Some portion of the investment is at risk of being stranded if markets are opened to competition before the investment is recovered through regulated rates. Nuclear power plants, particularly those that were completed or started during the 1980's, represent most of the capital investment at risk of being stranded in the transition to a competitive market.

- Nuclear Power Plant Decommissioning: Decommissioning obligations are unlike other stranded costs in that funding required for decommissioning is a future cost, not a sunk cost. Unfunded decommissioning liabilities represent a significant portion of the electric utility industry's stranded costs. It is estimated that the industry-wide obligation for decommissioning US plants is around $40-45 billion. Of this total liability, approximately $12 billion had been collected as of 1997. Assuring the collection of funds for decommissioning is an integral part of any transition to a competitive

generation market. Defining mechanisms to ensure recovery of unfunded decommissioning obligations is a high priority for the nuclear industry.

In the United States, the Federal Energy Regulatory Commission's Order 888 (that implemented the Energy Policy Act of 1992 mandating competition at the wholesale level, but leaving the decision of competition at the retail level to the states) affirms the principle that companies must be allowed a reasonable opportunity to recover their costs in a transition to a competitive marketplace. States that have passed legislation to restructure electric industries to require competition at the retail level have allowed electric utilities to recover their stranded costs over a limited period, typically through a surcharge on every customer's electric bill. For example, legislation in California allows electric utilities to recover up to $28 billion "stranded investments" in nuclear power plants.

In Germany, the stranded costs of nuclear power plants are not an important public issue at present. Stranded costs may not significantly affect short-term competitiveness because it is determined by short-term marginal costs, which are mainly fuel costs. There may be some stranded costs in the back-end of the nuclear fuel cycle, which will have a negative effect on the long-term competitiveness of nuclear power plants.

In the United Kingdom, the government recognised at the time of the power industry restructuring in 1990 that the overall cost of electricity from existing nuclear power plants was high, primarily due to high back-end fuel cycle and decommissioning costs. The government also recognised, however, that there were advantages to be gained from the continued operation of existing nuclear power plants. The avoidable cost of nuclear generation was recognised as being low, and output from nuclear power plants contributed to diversity of supply and to protection of the environment.

The UK government concluded, therefore, that nuclear power plants should continue to operate. New arrangements were put in place to ensure that the full costs of nuclear generation could be met once the remainder of the industry had been privatised. These arrangements consisted of the nuclear "Non Fossil Fuel Obligation" (NFFO) and the "Fossil Fuel Levy". Under these arrangements, suppliers were obliged to purchase a specified amount of electricity from non-fossil fuel sources, including nuclear power, at premium market prices. The additional costs incurred by suppliers in meeting this obligation were reimbursed through the "Fossil Fuel Levy". The levy was charged as a fixed percentage tax on all electricity sold. The nuclear element of the levy was

discontinued when British Energy was privatised in 1996, recognising that nuclear power was by that time fully competitive. Similar arrangements, however, continue to be used to support the development of energy from renewable sources.

The stranded costs of nuclear power plants are essentially no different from those of other power plants. To the extent that a utility is permitted to recover stranded costs, the stranded costs of nuclear power plants will be handled on a system-wide basis. Some countries have decided to allow the recovery of stranded costs. The debts of some nuclear power plants have already been written-off without recouping from customers and, therefore, their competitiveness has not been affected. Such write-offs will, however, probably have a negative effect on the financial health of the utilities owning the plants and on the willingness of shareholders to invest in new nuclear power plants.

Stranded costs are important to the viability of the company and its shareholders, but are not relevant to the ongoing economic viability of the power plant itself. They are considered to be sunk costs for the purpose of determining whether an existing nuclear power plant can continue to operate economically. Whether or how stranded costs are to be recouped should not affect the economic decision of whether it is economic to operate a plant.

Competitiveness of existing nuclear units

Marginal costs of operation, i.e. fuel costs and O&M costs plus applicable repair and refurbishment expenses, are the determining costs in decisions on whether existing nuclear power plants will continue to operate in a competitive market. Marginal costs are the costs for production of an additional (marginal) amount of electric power. These marginal costs vary with different time horizons and are applied differently for existing plants and new plants.

For existing power plants, marginal costs are relevant in deciding whether to continue producing power at the current level, increase power output, or permanently shut down the plants.

The merging, buying and selling of nuclear power plants in the United States today is an indication that well-run nuclear power plants are valuable assets and as such probably will reduce the risk of early retirements. In the United Kingdom, it is clear that nuclear power has some major challenges if it is to compete with alternative forms of power generation in a competitive market. It also has some unique advantages as the only large-scale form of power generation that is both proven and has practically zero impact through atmospheric emissions.

According to the French Utility EDF, French nuclear power plants are competitive with fossil fuelled power plants due to three factors: low construction costs due to standardisation; investment is already 50% amortised; and plant lifetime is expected to exceed forty years. Nuclear power plants in Finland and Sweden have been operating successfully within the Nordic electricity market and Spanish and German nuclear power plants have competed successfully in the competitive markets that were introduced at the beginning of 1998. In the Netherlands, no problem is anticipated for the single operating nuclear power plant under the new competitive system agreed to in 1998.

Based on current production costs and the trend of performance improvement in many OECD countries, a large number of existing nuclear power plants are expected to compete well with other power technologies in competitive electricity markets.

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4. IMPACTS OF ELECTRICITY MARKET DEREGULATION ON NUCLEAR LIABILITIES AND INSURANCE

Risks and liabilities of nuclear power

All businesses manage financial, commercial and market risks through a variety of instruments such as insurance and escrow funding, negotiation, contracts, regulation and indemnification. In competitive markets, risks and liabilities are effectively traded and ultimately reside with the party that manages them best. Most risks are insurable, but insurance costs are in proportion to the level of risks and potential liabilities. Industries with high risks, therefore, have large insurance premiums.

In a monopoly, electric utilities or regulators assign risks and liabilities as they see fit, often to captive customers. As the electricity sector moves toward competition, risks and liabilities will inevitably be reallocated. This raises the question of whether new financial arrangements will be needed for dealing with nuclear-related risks and liabilities.

Ultimately, the cost of risks must be reflected in the price of electricity. For the most part, utilities have been able to spend money to protect against risks without losing customers. In competitive electricity markets, however, they must bear financial, commercial and market risks without raising costs so high that they cannot sell power at the market price. This represents a big change for utility managers.

As electric utilities move from the public to the private sector, they may have to specify and quantify more precisely the liabilities associated with their activities. Open-ended liabilities are not well tolerated in competitive markets.

In principle, the growth of competition in electricity markets imposes the same financial risks on both nuclear and other power generators. The only essential difference is the degree of these risks, which may be affected by the size of investment. Nuclear power, however, has some specific liabilities and associated risks due to political and regulatory uncertainties regarding plant

decommissioning and waste disposal costs. Other power technologies also have decommissioning and waste disposal costs, but generally they are lower than in the case of nuclear power and may be estimated with reasonable certainty. The difference for nuclear power lies in uncertainties about the magnitude of these costs, for which there is limited commercial experience. Another risk of nuclear power is the small, but non-zero, possibility of a large nuclear accident.

Concerns associated with decommissioning and waste disposal include: the adequacy of funding provisions to meet current estimated target costs; the accuracy of the target costs themselves; and the adequacy of regulatory requirements for ensuring sufficient funding.

Third-party liability and other insurance schemes

Nuclear power plants generally carry at least three kinds of insurance: normal business and commercial insurance; special nuclear insurance; and insurance against third-party liability in the case of nuclear accidents.

Normal business insurance is not relevant to this report since it applies equally to other power technologies. Such insurance can protect against risks of economic loss, financial consequences of plant shutdown or closure, exchange rate fluctuations where these are relevant, occupational health and safety claims, construction delays, cost of outages, etc. The perceived need for such insurance is a corporate decision that is not necessarily related to the choice of generation technology.

Special nuclear insurance, which is provided in most countries through a nuclear insurance pool, covers such things as those operations of nuclear power plants that are conducted in radiation zones. Some utilities claim this insurance carries high fees, in large part because it is usually provided by captive insurance companies. To the extent that this is a problem, competitive pressures on utilities may in turn exert pressure for lowering these fees.

Insurance for nuclear accidents has been structured to provide limited third party liability, with nuclear plant owners being liable for some specified first substantial tranche of damages to third parties. The government assumes liability for some specified substantial second tranche of third-party damages, with any remaining damages to be considered by the national legislature. Such insurance schemes have been part of the nuclear power sector since its inception and have been considered essential to the development of nuclear power for two main reasons.

First, they resolve the problem of open-ended liabilities for investors. Second, they provide some measure of assurance to a public concerned about the possibility of accidents, however small the probability.

Experience to date shows that neither the ability to obtain insurance nor the cost of premiums has been adversely affected for nuclear power plants now operating in deregulated electricity markets. If the cost of commercial or nuclear insurance should be considered too high for nuclear power plants to sell their output in competitive markets, their options are to negotiate lower premiums or obtain different coverage since insurance remains a necessity. Third-party liability programmes, established by law in most countries, are not likely to change much with deregulation. It is possible that governments facing tighter budgets may seek to reduce their share of potential liability, but this is not related to the change to greater competition in the electricity sector.

Adequacy of decommissioning funds in competitive markets

Decommissioning of nuclear power plants is expected to be a costly process, but how costly will depend in large part on the extent and timing of the site restoration process. Nuclear power plants are somewhat different from other power plants in this respect. Once a nuclear power plant is closed, the irradiated plant components have very little salvage or recycling value and the plant will be completely dismantled, or at least to a large extent. Since this process begins after the plant stops generating revenue, prudent management is required to set aside funds for this work while the plant is operating. Some countries require an initial endowment and annual contributions from nuclear generators, usually assessed as a fixed amount per kWh of generation, while others require nuclear generators to include funding for decommissioning costs in their financial plans. In many OECD countries a separate fund, managed by the government or by power generators, has been established to cover decommissioning costs.

In principle, power generators estimate the anticipated costs of decommissioning and accumulate the funds over the life of the plant. There is uncertainty about the accuracy of the cost estimates and, hence, about the adequacy of funds accumulated. This concern can become greater as the market assumes more control of electricity pricing. Contributions to decommissioning funds for existing power plants have been predicated on assumed electricity sales volumes, and fund contribution per kWh of sales. In competitive markets, it cannot be assured that sales volumes will remain at these assumed levels, which could lead to a shortfall in fund contributions.

Another problem for funding decommissioning is early closures of nuclear power plants. Since the per kWh charge is based on accumulation of decommissioning funds over the total life of the plant, leading to a sufficient amount at the end of the planned plant lifetime, early closures will result in insufficient funds to cover decommissioning costs. Early plant closures may cause a serious shortfall, since shortening of a plant life will not greatly reduce total decommissioning costs. Assessing and allocating financial responsibility for a shortfall is a growing concern. Pressure to resolve this matter arises in countries where there is political debate about whether to close down nuclear power plants either before the end of the operating period authorised by license, or before the end of their viable economic life.

As competition increases, it is more likely that shortfalls in decommissioning funding will be identified before the plant is closed, perhaps easing adjustment measures, since there will be strong pressure from investors and shareholders to identify, quantify and secure all liabilities as soon as possible. Utilities and regulators might negotiate a limit on the total amount of the fund to be accumulated by operators. In order to provide reasonable assurance that governments will not be burdened with decommissioning costs, funding might exceed projected costs. Even so, shareholders and management could have some assurance that they know the extent of their liabilities, with no surprise arising at the time of decommissioning.

A related issue is how to make up future shortfalls in these funds should they arise. The essential question is who, among the beneficiaries of plant operation (i.e., electricity consumers, plant owners or the general public) should absorb the additional costs. In the past, the answer was almost invariably that electricity consumers should pay through higher regulated electricity prices. In competitive markets regulators may be more inclined to require nuclear plant owners to bear all decommissioning costs. Depending on the level of an anticipated shortfall, however, this solution could threaten the financial survival of the company. This would create a strong incentive for utility management to minimise decommissioning costs. If the shortfall occurs because the regulators have changed their requirements for decommissioning, however, then a full allocation of costs to the shareholders may not be equitable. A more equitable solution in such a case might be cost sharing between ratepayers and shareholders, which would still provide incentives for cost control, but would broaden the revenue base.

A possible option in the event of a funding shortfall would be for government to declare the shortfall a public obligation and to fund the shortfall through public revenues, either from the national budget or by a special levy. In

countries where compensation for stranded costs is being negotiated as a part of electricity sector restructuring, treatment of the shortfall could be construed as a stranded cost.

Liabilities for spent fuel and high-level waste disposal

Funding for spent fuel and high-level waste disposal is somewhat similar to that for decommissioning. In many cases, a levy for the cost of nuclear spent fuel and/or high-level waste disposal is taken into account in nuclear fuel costs, creating a fund available to plant operators who are generally responsible for financing the disposal. There are, however, two important uncertainties regarding costs of disposal. The first is whether or not the sums accumulated will be sufficient to dispose spent fuel and/or high-level waste according to regulatory requirements. The second is the nature of the ultimate disposal plan and obtaining its approval. Separate arrangements are generally made for non-fuel radioactive waste disposal. In some countries, this is also the responsibility of the power generators.

Most countries have not yet fully implemented spent fuel and high-level waste disposal policies. Some countries require nuclear generators to contribute to a fund for implementing the waste disposal policy that will ultimately be adopted. Nuclear generators in some other countries await policy decisions to create a fund. The inability to reach a political consensus on waste and spent fuel disposal policy has been an issue in most OECD countries for some time, and is not likely to be resolved soon to the satisfaction of all parties. A critical consequence of not having a policy is that a range of uncertainties remain on the cost for waste disposal. This large potential liability stands as a strong deterrent to future private capital investment in nuclear power. Financial institutions will not invest in operations that have undefined and unsecured liabilities of such potential magnitude.

How these liabilities are defined and secured will depend for the most part on the government and the standards and requirements it establishes for the ultimate disposal of spent fuel and high-level waste. The issues include how the government assigns legal responsibility for waste disposal and the degree of responsibility it will assume, including financial responsibility. At some point, costs must be assigned to the myriad of engineering plans that have been developed for spent fuel and waste disposal. Only after these matters are resolved can adequate funding be established and liabilities apportioned.

Some OECD countries, e.g. Sweden, have established a decommissioning and waste disposal funding system by law so that the risk of shortfall in a competitive market is lower. The system has margins for unsecured costs and guarantees for early plant closure and/or high costs.

If governments want to limit their involvement in nuclear waste disposal, they might consider complete privatisation of this area, similar to decommissioning. Some private companies position themselves to assume these tasks by capitalising on their specialised ability to do the jobs more efficiently than power generators. Funds put aside by utilities to cover waste management and disposal expenses may be passed to those companies that will then be responsible for completing the tasks. The bid price for such tasks can serve to define and cap the price for these undefined liabilities.

5. IMPACTS OF ELECTRICITY MARKET DEREGULATION ON THE STRUCTURE OF THE NUCLEAR POWER SECTOR

Nuclear generating companies

The current ownership structure of nuclear power plants varies widely among OECD Member countries. While the current structures were acceptable in the "cost-plus" regimes of regulated monopolies, they may be impossible to retain in a competitive market. Complex cross-ownership impedes the transparency of operations and leads to conflicts of interest among owners in the critical area of future investment. Holding minority ownership positions in nuclear assets is becoming less acceptable and the opening of the market is likely to lead utilities to divest their minority nuclear holdings. This in turn forces the restructuring of nuclear plant ownership and management in order to achieve benefits from scale of operations. In some countries such as Spain, moves are already being made to group nuclear power plants on a regional basis to enable reduction in central overheads and to facilitate cost sharing. Such groupings also enables plants to share expertise and operating experiences effectively. In the future, further grouping may follow in order to enable plants to share functions such as procurement and inventory even when plant ownership may be different.

In a competitive market, an upsurge in mergers and acquisitions of generating companies is expected as companies seek to attain the benefits of size in the market. This already has resulted in a number of strategic partnerships, share swaps and other types of alliances as companies seek to gain additional expertise or experience and access to new markets. Nuclear plant owners will be forced to ensure that they gain operational flexibility through this process.

A large number of plant sales, generally resulting in consolidation into larger generating companies, are expected in the OECD countries. This is being done already in the United States. Where, although initial plant sales covered fossil and hydro-generation, three nuclear power plants have been sold and an additional four sales are likely. Amergen has completed the purchase of Three

Mile Island Unit 1 and Clinton and Entergy has completed the purchase of the Pilgrim nuclear power plant. Amergen hopes to complete two more purchases within the next few months (Vermont Yankee and Oyster Creek). Entergy announced that it has agreed on terms for Fitzpatrick and Indian Point 3.

Ownership consolidation is likely, leading to a relatively small number of nuclear operators with the expertise and resources necessary to manage plants safely and efficiently in a competitive environment.

Reactor vendors and architect engineers

Reactor vendors and architect engineers in the OECD countries have sometimes developed their business from government-led and government-funded civil nuclear power programmes, which grew out of military programmes such as the development of nuclear reactors for naval ship propulsion. In recent years a number of factors have influenced changes in the traditional business of reactor vendors and architect engineers, the most recent of which is the global trend of deregulation and competition in the electricity market. Not surprisingly, reactor vendors and architect engineers experience some difficulty in this evolutionary process.

Survival in competitive markets is forcing a trend towards fewer vendors with larger market shares and global business strategies. Siemens and Framatome merged their nuclear activities in late 1999, and the Westinghouse nuclear energy business was sold to a joint venture between Morrison Knudsen and BNFL. BNFL also has merged with ABB Nuclear in the United States.

Adaptation is essential to succeed, indeed to survive, under the pressure of competition. The key to success lies in achieving higher added value from the inherent strengths of core skills through the provision of such diverse services as:

- fuel manufacture and supply;
- maximising the performance of operational reactors;
- increasing plant service life;
- improving plant availability;
- consulting and other engineering services;
- maintenance and after sales services; and
- project management.

Geographically, reactor vendors and architect engineers now have to look well beyond their home markets for new revenue streams. This search entails the costs and uncertainties of doing business in the global arena. Additional resources must be employed in tendering services and much greater time and effort must be spent in identifying and developing opportunities that are often slow to bear fruit. As a result of competitive tendering processes, multi-million dollar tendering costs can remain unrecovered, adding to the operating overhead of a business. On the other hand, competition does provide greater opportunities to build a portfolio of customers in various countries and economic contexts rather than relying on a single country or utility source, with the consequent impacts of upsurges and downturns in business.

Alliances, consortia and joint ventures between relevant companies, e.g. reactor vendors, engineering companies and nuclear operators, appear to be the way forward. They provide the opportunity to share the costs and risks associated with entry into new markets and offer benefits from business synergy and economies of scope and scale. A good example is the merging of nuclear activities carried out by Framatome and Siemens.

A number of nuclear power plant are approaching the end of their originally planned lives. The pressures of market competition and deregulation may lead either to early closures or lifetime extensions, based upon financial contributions of the plants to the bottom line of the deregulated business. Early closure raises the potential for diversification by the growing decommissioning business. Conversely, consideration of lifetime extension provides opportunities for services to assess plant conditions.

Business synergy in research and development will help speed response to customer requirements. It will assist in reducing research and development costs as the nuclear industry narrows the number of standard reactor types offered in the market. Global manufacturing networks could similarly reduce costs as the nuclear industry seeks to become more competitive in response to deregulation.

The future for reactor vendors and architect engineers is likely to be one of fewer suppliers with broader capabilities and a global reach.

Equipment suppliers and companies supplying services

Deregulation of electricity markets does not include deregulation of equipment and service supply industries, but it may have both direct and indirect repercussions on these industries. Competition increases price pressures on these and other industries. Changing conditions in the market may bring

about changes in customer requirements that impact equipment and service suppliers. The degree of these impacts might be different between those suppliers geared to nuclear activities and those that carry a transferable product or service.

Suppliers whose markets are not limited to nuclear power already have experienced strong competition. On the other hand suppliers that provide services or equipment specifically related to nuclear power have been less subject to competition, and have had high expectations in terms of profit and overhead recovery. There have been relatively few nuclear contractors prepared to make a significant long-term investment in this market. Nuclear suppliers cannot realistically plan for new construction; consequently, they may become overly dependent on an increasingly cost-focused market.

Electricity market deregulation likely will result in changes in contracting arrangements. In the past, the nature of contracts was extremely prescriptive, as in "contracting by instruction". Engineers within a utility instructed contractors on what to do and how to do it. This method ensured that responsibility for costs and performance lay with the utility. The contract model was generally based on retention of experience within the engineering base of the utility. This traditional model had some distinct advantages, including retention of control and avoidance of over-dependence on contractors. There were significant disadvantages, as well, that primarily centred upon conflicts of interest including the contractor's motivation to do more work and maximise profitability.

Traditional methods of contracting and commercial arrangements between customers and suppliers are changing to meet new objectives. Contractors are now being required to achieve continuous improvements in performance, cost and safety. In addition, there is a shift in the roles of customers and contractors. For example, customers specify a functional requirement with contractors being responsible for design and design specifications. The responsibility for performance is, therefore, shared with the contractor to a degree not previously encountered. Even on relatively simple service supply contracts, there is a clear understanding of the expectation to contribute towards the objectives of the customer, contractual or otherwise. An optimisation of the supply chain in which risks and profits are shared will evolve from this process.

Fuel cycle industries

Uranium supply in a competitive market will come under greater price pressure. Nuclear generators are likely to experience the need for greater flexibility. Consequently, the practice of procuring uranium and services on

long-term contracts, aimed at ensuring security of supply, is changing to one of shorter-term contracting and the development of spot-related markets in order to benefit from short-term price fluctuations and alternative supplies.

Many nuclear utilities hold large fuel stocks to protect against supply disruption. This results in not optimal utilisation of assets and increases the cost of the fuel cycle. There will be greater pressure therefore, to reduce both stocks and the lead-times for producing fuel and its intermediate products.

Groups of nuclear power plant operators may form consortia to gain economic advantages in purchasing nuclear fuel and nuclear services. This can lead to changes in the nuclear fuel cycle market. Restructuring of the nuclear fuel cycle industry is expected to include: vertical integration of the front-end fuel cycle industries; vertical integration between the front-end and back-end fuel cycle industries; and horizontal integration within each nuclear fuel cycle stage. It might be foreseen that there will be renewed interest in exploring possibilities for international schemes for radioactive waste disposal facilities, in response to market pressures to reduce costs in the back-end of the fuel cycle.

Cost pressures on nuclear operators will stimulate measures, possibly including changes in regulatory requirements, to improve fuel utilisation and minimise refuelling times. There will be more demand for optimising fuel cycle length and fuel burn-up. Although the length of the fuel cycle depends on the technical and economic conditions of each reactor, extending fuel cycle length can decrease operation costs by minimising outage time. A higher burn-up of nuclear fuel can reduce generating costs by producing more output and can also decrease spent fuel discharges per kWh. Nevertheless, higher burn-up fuel sometimes requires higher initial enrichment, leading to higher costs per unit of fuel.

More generally, there will be increased pressure by nuclear generators for fuel and fuel service suppliers to share risks in the electricity market. These could be reflected in contracts for fuel and services, price reviews based on electricity market conditions, joint ventures, etc.

Reprocessing of spent fuel is currently uneconomical for some nuclear utilities. Existing movements away from reprocessing in favour of long-term passive storage are likely to accelerate. This maintains the option for eventually reprocessing or disposing of the spent fuel, depending on the economics prevailing at the time a waste repository is available.

A significant proportion of fuel service providers, particularly those at the back end of the fuel cycle, are monopolistic state-owned bodies. Market pressures are likely to lead to questioning the rationale of continuing

state-owned operations and the development of more flexible private sector suppliers capable of delivering the cost efficiencies and responsiveness required by competitive generators.

There already has been some consolidation of fuel cycle supply. This is likely to continue into the future in an effort to respond to price pressures.

Nuclear research activities

Competition is likely to stimulate and reward initiative and innovation that often result in cost and risk reduction. Even innovation that carries high costs and high risks can be competitive and profitable, if the anticipated rewards are commensurate. By contrast, heavily regulated markets have typically discouraged innovation and initiative. These markets do not react well to efforts outside of prescribed norms and do not permit high rewards commensurate with the high risks of innovation.

Government funding of research and development has declined in recent years owing partly to a general shortage of public funds. Tight government budgets have become one of the driving forces for the privatisation of public service industries and increased competition. As government funding has declined, many nuclear research institutes must find other sources of funding or close down.

The effect of a general decrease in funding for research and development has been to increase competition for the limited funds available from industry, thus requiring research institutes to become more market-focused and accountable for their use of funds. Cost-reduction efforts have led to an increase in the number of non-permanent research posts and to a reduction in the number of young researchers entering the nuclear field.

Utility support of fundamental nuclear research is expected to decrease. In parallel, there has been a shift towards application-oriented industry research and away from fundamental research. The focus of nuclear research is now directed at supporting the industry’s efforts to address safety and waste management concerns and improving the technical and economic performance of existing nuclear power plants.

Recognising the realities of the situation, many of the research establishments that once specialised in nuclear research are now diversifying into more broad-based research. In addition, as a result of competition, R & D activities are likely to become increasingly focused on areas that promise significant near-term application.

Fundamental research is now undertaken mainly through co-operation between research establishments, both on a national and international level, with universities playing an important role in generating new ideas.

An additional problem of significance is that many research facilities are very old and will need to be replaced. In many OECD countries, the political climate will make it nearly impossible to obtain the necessary agreements for new research facilities. In some OECD countries, however, it may be possible to maintain existing major test facilities, and these might be opened to other countries.

Regulators

Restructuring of the market framework forces regulatory authorities to review the adequacy of existing regulatory requirements in light of new market arrangements. The main technical safety issue raised by moving to a competitive marketplace may be grid reliability. Operational relationships are very complex and can involve many new companies whose operations may impact nuclear power plants. Reductions in system reserve margins and unregulated fluctuations in the grid can cause nuclear reactors to trip. This has potential safety implications for nuclear generators.

Steps have to be taken, therefore, to ensure that grid operation continues in a reliable manner once competition is introduced. In the United States this issue is being addressed by requiring all utilities under federal jurisdiction to join the North American Electricity Reliability Council (NERC) and comply with the organisation's reliability policies. Although membership is not compulsory at present, the Federal Energy Regulatory Commission (FERC) has recommended that federal legislation be introduced requiring membership. The United Kingdom has addressed this same issue through market framework agreements. For example, the Master Connection and Use of System Agreement (signed by users of the transmission system) allows nuclear generators to require other companies to act or not to act in avoiding breach of license requirements related to a nuclear site.

Regulatory attention is increasingly focused on ensuring that competitive pressures do not compromise safety through cost-cutting measures such as engineering, or plant operating staff reductions, or changes in plant procedures or practices. Experience to date in the United Kingdom indicates that there is no inherent conflict between nuclear plant safety and efficient and economic operations.

Competitive pressures will mean that nuclear utilities will increasingly question the necessity and cost effectiveness of proposed regulatory safety measures. This will produce challenges for both nuclear safety regulators and the utilities they regulate. Market-based or negotiated solutions that achieve safety goals are preferable to unilaterally imposed regulatory mandates, as the former are more likely to be generally acceptable to all parties and result in optimum solutions. Ongoing and effective co-ordination between nuclear safety, environmental and economic regulators is essential throughout the regulatory process.

The evidence so far suggests that competition has little impact on resource levels to implement regulatory requirements apart from those in the initial years following the introduction of competition, when increased resources are needed to monitor the adequacy of new arrangements and to assess new work practices.

6. IMPACTS OF ELECTRICITY MARKET DEREGULATION ON NEW NUCLEAR POWER PLANTS

Projected costs of generating electricity

A recently published NEA/IEA joint study on projected costs of generating electricity, for which fourteen OECD countries and four non member countries provided data on more than one generation option, concludes that nuclear power is seldom the cheapest option for plants to be commissioned by 2005-2010. It shows that, at a 5% discount rate, gas is the least expensive (by a margin of at least 10%) in three countries; coal is the least expensive in three countries, and nuclear is the least expensive in five countries. In seven countries, there is less than a 10% difference between the two cheapest technologies.

At a 10% discount rate, the least expensive option (by a margin of at least 10%) is gas in nine countries and coal in one country. Nuclear power is not found to be the least expensive option in any country. In eight countries there is less than a 10% difference between the two cheapest technologies.

A higher discount rate increases the competitiveness of gas generation over nuclear generation because of the larger investment cost for nuclear. In some countries such as Spain and the Republic of Korea, the study results indicate that the competitiveness of gas relative to nuclear depends on the discount rate.

From these results it appears that no single technology has a clear economic advantage in all countries. Specific circumstances within each country will determine the most economic choice. As compared to previous studies in the series, however, the more recent NEA/IAE study shows an increasing competitiveness of gas-fired plants versus coal-fired and nuclear power plants. This is due to several factors, including low-cost construction and maintenance lower fuel cost projections than previously envisioned and low environmental protection costs as compared to other fossil-fuelled technologies.

Electricity market deregulation and future nuclear investment

Nuclear power, however, has special characteristics that make it sensitive to new investment in competitive electricity markets. In deregulated markets, investment in new power plants, regardless of generating type, will largely depend upon construction costs, project execution time and projected profitability.

In general, nuclear power plants take longer planning and construction time and investment costs are higher than for other power technologies. Reference cost studies in France show a ratio of two-to-one for investment costs for nuclear power plants relative to gas-fired plants. Since demand forecasts are uncertain in a deregulated market, large-scale investments entail financial risks and could be difficult to amortise if demand is lower than expected. Therefore, private investors might prefer to invest in technologies that are more flexible and have shorter pay-back times. Lower capital cost as well as diversification of generating technologies may be important factors for generating companies in order to obtain a more favourable risk profile.

The discounted value of decommissioning costs should be included in total investment costs of nuclear power plants. In so far as uncertainties remain on these costs, they add to the financial risks associated with new nuclear power plants. The British experience, however, shows that investors can rationally price risks and costs associated with nuclear plant decommissioning. Rating agencies, e.g. Moody's, and Standard and Poor's, have begun to provide investors with information on these costs by compiling data from several private and public companies.

Fuel costs for nuclear power are much smaller in comparison to costs for fossil-fired power plants and total nuclear generation costs are less sensitive to fluctuation of fuel price. Moreover, utilities may hold rather large strategic fuel inventories guaranteeing fuel cost stability in the short and medium term. As fixed assets are amortised, the advantages of nuclear power due to low fuel costs become more attractive.

Nuclear power plants are generally well suited to supply a steady volume of power, but they have less operational flexibility than gas-fired power plants. Gas-fired power plants are more capable of adjusting their generation to variable volume and time demands, which allows them to satisfy semi-peak and peak demands more efficiently.

Competitive electricity markets are believed to need power supply flexibility to accommodate customer requirements. Therefore, large power companies may spread their investments among different fuel and plant types.

In this context, nuclear power may be considered as an essential component of a large power company because nuclear fuel costs are lower and more stable than fossil fuel costs. Furthermore, since nuclear power plants are generally used as base-load power plants because of their lower production costs, they can provide a steady revenue stream.

Prospects for new nuclear power plant construction

The prospects of building new nuclear power plants in OECD countries are not clear. There are very few projects for the construction of nuclear power plants in OECD countries and this situation is unlikely to change in the near future. However, if nuclear power is regarded as a profitable and competitive energy source, investors might invest in new nuclear units.

In many OECD countries there is limited need for new base load power plants in the short term because existing reserves of electricity supply are sufficient and electricity demand growth rates are modest. In addition to the lack of clean-cut economic incentive to build new nuclear power plants in many OECD countries, decisions are likely to be strongly influenced by public opinion, political will and regulatory policy. Furthermore, uncertainties on nuclear waste disposal and plant decommissioning costs are another burden for potential investors.

The ability of new nuclear power plants to compete will essentially depend upon their capital costs, which make up approximately 60% of total nuclear generation costs. A recently published NEA study identifies various means to reduce capital costs of nuclear power plants including: increasing plant size; standardisation and construction in series; construction of multiple units on a site; improving construction methods; reducing construction schedules; and improving regulation and policy measures. Since one aim of the next generation of reactors is to increase competitiveness of nuclear power plants, a number of significant cost reductions are expected through design simplification and new technology, e.g. passive safety systems. In addition, small reactors may be another nuclear technology development that can improve the competitiveness of nuclear power as compared with other technologies by providing greater flexibility on unit sizes, in particular for utilities with relatively low demand growth rates.

Safety regulations and the way they are implemented by regulatory bodies have a significant impact on decisions for new nuclear power plants. Cost reductions in these areas can be achieved by simplification of the licensing process; elimination of regulatory requirements that do not contribute clearly to improving safety; and maintaining stability in regulatory requirements.

At present, the licensing process for a new reactor can take over a decade. Nuclear safety regulatory requirements are generally conservative and costly, but close co-operation between utilities and safety authorities from the beginning of design can avoid excessive regulatory costs and reduce approval times. The harmonisation of regulatory requirements among countries may bring some economic benefits through standardisation of designs and licensing procedures.

In summary, the competitiveness of new nuclear units could be greatly improved through reduction of capital costs, technology development, streamlining of the licensing process and maintaining a stable regulatory and political environment.

Other factors, such as the increasing awareness of climate change issues could contribute to the development of nuclear power. The competitive margin of nuclear power would significantly increase if market prices would reflect fully environmental costs through, for example, a carbon tax.

7. OTHER FACTORS AFFECTING THE COMPETITIVENESS OF NUCLEAR POWER

Sustainable development

Today the concept of sustainable development[1] is widely accepted and the need to integrate economic, environmental and social aspects within development policies is progressively recognised in OECD countries. However, the rate and degree of sustainable development policy implementation vary from country to country and policy makers have yet to agree on the overall framework and indicators of sustainable development.

In the electricity sector, the environmental dimension of sustainable development is especially relevant since all forms of electricity generation have some impact on the environment. Nuclear power is no exception, but it has some benefits that enable it to make a contribution to environmental protection. For example, a 1 000 MWe nuclear unit uses around 25 tonnes of fuel (derived from about 125 tonnes of natural uranium) per year as compared with four million tonnes of coal burnt by a coal-fired power plant of the same size. Therefore, environmental impacts of mining activities are lower for nuclear power than in the case of coal and this would apply, although to a lower extent, to alternative fossil fuels. The use of fossil fuels for electricity generation leads not only significant emissions of greenhouse gases and sulphur dioxide and nitrogen oxides responsible for acid rains, but also to significant environmental impacts from mining, transport and storage/disposal of residues.

Within OECD countries, however, there are widely divergent views on the potential contribution of nuclear power to sustainable development. Besides economic competitiveness, radioactive waste disposal, accident and other risks raise major concerns and may be an obstacle for considering nuclear power

1. The concept of sustainable development was elaborated in the late 1980s and defined by the Bruntland Report as “a development that meets the needs of the present without compromising the ability of future generations to meet their own needs”.

within a sustainable energy mix in some countries. On the other side, natural resource management and atmospheric pollution control objectives, which are part of sustainable development goals, provide some incentive to keep the nuclear power option open. There are very few alternative technically mature and economically competitive options that can replace fossil fuels for electricity generation on a large scale in the short and medium term. In the long term, a combination of nuclear power and renewable energy sources is likely to be needed in order to support economic growth and sustainable development world-wide.

Climate change

During the late 1980s, indications that the polar ice caps are melting and the occurrence of unusual weather patterns attracted international public attention on environmental effects resulting from the emission of greenhouse gases in the atmosphere. Simultaneously, "green" parties advocating strongly for environmental protection emerged as an important factor in mainstream politics and governments. Those parties focused their actions on raising awareness of environmental impacts from industrial activities with emphasis on the electricity generation and transport sectors.

The United Nations Framework Convention on Climate Change prepared in 1992, and ratified by 169 countries at present, is one of the elements of international policies aiming at addressing climate change risks. The ultimate aim of the convention is "stabilisation of greenhouse gas (GHG) concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system". It is estimated that stabilisation of atmospheric carbon dioxide concentration at its present level would require a reduction of more than 60% in current global emissions. As a first step towards its goal, however, the Convention is aiming towards restraining the increase in GHG emissions, and not towards stabilising concentrations. All countries were called on to prepare inventories of their emissions and sinks for all GHGs not covered by the Montreal Protocol and developed countries undertook to draw up national programmes aimed at returning their GHG emissions to 1990 levels by 2000.

A Conference of the Parties (COP) to the Convention meets regularly to monitor progress and consider new protocols to the convention in light of improving scientific knowledge. At the first COP, in March 1995, it was agreed in the "Berlin Mandate", that stronger commitments should be developed on all GHGs beyond 2000, and proposed for adoption at the third Conference of the Parties to be held in Kyoto, Japan, in December 1997.

The Kyoto Conference agreed to a Protocol to the Convention which includes the following provisions:

- Legally binding limits on the GHG emissions in developed countries leading to an aggregate reduction of at least 5% below 1990 levels by 2008-2012;

- Differentiated targets, ranging from a reduction of 8% for the European Union as a whole and 7% for the United States, to increases of 8% for Australia, and 10% for Iceland;

- Groups of countries, such as the European Union, may opt for a joint target which may be differentiated among its members;

- The greenhouse gases included in the targets are carbon dioxide, methane, nitrous oxide, hydrofluorocarbons, perflurocarbons and sulphur hexafluoride; [2]

- Changes to GHG sinks resulting from land use modifications and some forestry activities are to be included in the inventory;

- Joint implementation of GHG abatement projects is allowed, either between developed countries, or between developed and developing countries in the framework the clean development mechanism; and

- Trading of emissions permits between developed countries is possible.

No new commitments were placed upon developing countries. The mechanisms for joint implementation, emissions trading and monitoring and enforcing the commitments remained to be negotiated after the Kyoto meeting and were discussed at the COP4 meeting held in Buenos Aires, Argentina, in November 1998 and at the COP5 meeting held in Bonn, Germany, in October 1999.

At COP3, the European Union entered into a legally binding commitment to reduce its total emissions of greenhouse gases by 8% below 1990 level by 2008-12. Within this envelope, countries committed to a wide range of targets. For example, Germany has accepted a 21% reduction target while Greece has been granted an increase of 25% maximum. The target was set at 12% reduction below 1990 level for the United Kingdom but the British government intends to

2. In the energy and electricity sector, carbon dioxide and methane are by far the most significant GHGs.

achieve a 20% reduction. Nuclear power plants are expected to be of significant help for the United Kingdom to achieve these reductions. France which already enjoys a low level of GHG emissions, owing mainly to the high share of nuclear power in electricity generation, has a zero reduction target.

Nuclear energy already contributes to reducing GHG emissions. At present, nuclear energy provides the world with 17% of its electricity and its share in electricity supply reaches nearly 25% in OECD countries. If nuclear power plants were replaced by modern fossil-fuelled power plants, carbon dioxide emissions from the electricity sector would increase by more than 15%.

The Nuclear Energy Institute has calculated that since 1973 nuclear energy has been the most important factor in reducing electric utility carbon dioxide emissions. In 1995, nuclear energy avoided the emission of nearly 2 billion tonnes of carbon dioxide that would have been produced if fossil-fuel power plants had been used instead of nuclear units. Between 1973 and 1995, the use of nuclear energy avoided a cumulative emission of well over 22 billion tonnes of carbon dioxide.

A paper by Dr. Wolf-J. Schmidt-Küster, presented at the December 1998 BNES Nuclear Congress sought to highlight the role of nuclear power in helping to achieve the European Union emission reduction targets. Other analysis, presented by FORATOM, the Uranium Institute and the young generation network, in the context of COP4 and COP5, develop arguments in favour of nuclear power as an available, large-scale, non-carbon energy source.

In the longer term, stabilising the emissions of greenhouse gases world-wide could be facilitated through the expanded use of nuclear power since it is one of the few existing technologies that could currently supply a large share of non-carbon energy demand. Compared to other non-carbon electricity sources, it has the advantage of reliability in producing base load, and builds on already substantial share of world power generation base.

Security and diversity of energy supply

Security of electrical energy supply, which was considered extremely important twenty to thirty years ago, seems to have lost much of its importance in many countries. Trade alliances and country groups, such as the European Union, have developed more integrated networks among their members as a mechanism to balance supply and demand. Examples of these include various inter-connections, grid transmission system compatibility improvements, and import/export controls to meet supply and demand peaks and valleys.

Nevertheless, some concerns remain about diversity and security of energy supply. Unless they have a large natural reserve of fuel, many OECD countries, however, still seek to implement a diverse energy mix in order to avoid excessive reliance on any single energy source. An analysis by the International Energy Agency (IEA) concludes that, in the absence of policy measures aimed specifically at alleviating dependence on OPEC oil, the share of world oil supplied by OPEC will grow from the current 40% to 50% or more by 2010. Also, the anticipated "rush to gas" might be challenged on the grounds that presently known reserves of gas represent only some sixty years of supply based on the present yearly rates of consumption, and less if consumption rates increase.

A study carried out in 1995 by the World Energy Council, estimates that global energy demand up to the year 2050 would be dependent on scenarios of economic growth, but could be multiplied by as much as 2.5 as compared to the 1990 level Such levels of energy demand would require contributions from all supply resources available including nuclear power.

The introduction of nuclear power in the energy supply mix contributes to diversity and enhances security of supply. Uranium has no other significant commercial use than fuel for nuclear reactors. The uranium resources are sufficient to support a significant increase in nuclear power capacity world-wide. The geographic distribution of uranium producing countries and their political situations offer some guarantee of security in the future supply.

Political and regulatory risks

Political and regulatory risks are diverse and often unpredictable. The public perception of nuclear energy has been influenced by a range of issues including nuclear weapons, high profile accidents at Three Mile Island and Chernobyl, and various issues concerning nuclear safety and waste disposal. A strong argument heard from the public and politicians, when taking a position against nuclear energy, is that it produces radioactive waste for which there is no approved final solution. Political debates on the future of nuclear energy in Germany and Sweden are relevant examples of the political risks of nuclear energy.

In some respects, the uncertainty of future regulatory positions is as difficult for the industry as are political risks. Nuclear power has been subject to close scrutiny by the appropriate regulatory authorities with emphasis on nuclear and radiological safety. Increasingly, however, other objectives, particularly environmental objectives, have been added to the total cost of

regulatory compliance. An example of this is the OSPAR Convention, which aims to achieve near zero radioactive discharges and emissions by 2020 in north-west Europe, but does not apply to the rest of the world.

Externalities

The largest environmental impacts associated with fossil fuels are carbon dioxide emission and other forms of air pollution which can cause chronic illness. The risks associated with these impacts concern the entire planet. It is not easy to set a monetary value for these risks, but it might become easier through the emergence of emission trading markets.

The environmental impacts of nuclear energy are more of a local nature, and much of the cost is internalised in financial plans. For example, nuclear power operators are required to provide funds to alleviate or eliminate the potential for impacts, e.g. costs of waste management and decommissioning of installations.

The following findings are taken from the European Commission's estimation of external costs by energy type (in mEuro/kWh).

	Range of externality	**Internalisation**	**Minimum cost**	**Maximum cost**
Gas	Global	Emissions trading market	8	35
Nuclear	Local	Funds	2.5	7.4

The deviation between minimum and maximum cost is due to different national valuations of the impacts. The maximum environmental cost for nuclear power, excluding a major accident, is always lower than the minimum cost for gas. Failure to account for environmental costs in economic calculations will diminish the prospect for new nuclear programmes.

A model used by the French Ministry of the Economy, Finance and Industry defines the optimal total electricity generation for France, based on the cost assigned to CO_2 emissions. Results obtained with that model shows that nuclear power becomes attractive as soon as the carbon dioxide cost surpasses a relatively low value of $50 per ton.

Within the EU, more use of environmental taxes is envisaged to achieve these goals. If this is applied equitably across all forms of energy generation and consumption, it is likely to enhance the economic competitiveness of nuclear power for both existing and new plants.

8. CONCLUSIONS

Economic deregulation in the power sector raises new challenges for the prospects of nuclear power. A key issue is to assess whether nuclear power can be competitive in a deregulated electricity market.

The impact of electricity market deregulation on existing nuclear power plants is expected to be generally positive, assuming that competition will result in improved efficiency, increased plant capacity and higher availability. Evidence of this can already be found in some OECD countries, such as the United States, the United Kingdom and the Nordic countries. In particular, British nuclear power plants have performed well since market deregulation in 1989. Based on current production costs and the trend of performance improvement in many OECD countries, a large number of existing nuclear power plants are expected to be able to compete well with other power technologies in competitive electricity markets.

Stranded costs are not important in determining the continuous operation of nuclear power plants, but, if the stranded costs are not covered from external sources, low electricity prices can be a problem for power companies. Competition may increase the chances of nuclear power plant life extension, particularly for plants that are already economically competitive, since the cost of life extension is much less than that of building a new plant of any kind. Nuclear power plant upgrades are becoming common in many OECD countries because they result in increased capacity at low investment cost.

There is some concern that nuclear safety can be compromised by over-emphasis on short-term economics in a competitive market. However, safety remains a prerequisite even in a competitive market, since nuclear power plants that do not operate safely will be closed. Nuclear operations are generally well run, not only because of regulatory requirements but also in order to be competitive. The British experience shows that there has been no conflict between commercial operation and safety at nuclear power plants following electricity market deregulation.

Competitive markets may require clear definition and quantification of all liabilities associated with nuclear power. Current liabilities and insurance schemes in the nuclear power sector are not likely to change in a competitive electricity market. Financial risks associated with decommissioning and waste management may be a concern. If there would be a shortfall in funds for decommissioning and waste disposal, approaches to cope with this issue in a competitive environment may include: a surcharge on electricity consumption; nuclear plant operators bearing the costs; or funding shortfalls through public revenues.

Mergers and other ownership consolidations among nuclear generators are anticipated in competitive markets in order to obtain the benefits of economies of scale and to be more competitive for base-load electricity supply. Restructuring of the nuclear fuel cycle industry, including vertical integration and horizontal integration, and privatisation of the back-end of the fuel cycle is anticipated. Renewed interest in development of international schemes for radioactive waste disposal is also expected as a possible means to solve the problems of high costs and site availability.

Utilities are tending to cut back on R&D investments in order to reduce costs, and their efforts are focusing on applied research aimed at performance enhancement. Competition is likely to be a motivating force for innovation in all sectors of the nuclear industry, with the objective of improving efficiency and reliability of power plants and reducing costs.

Investment in new power plants will largely depend upon investment costs, construction time and projected profitability. Prospects for building new nuclear power plants in a competitive environment are not promising, mainly because nuclear power is generally perceived as not being economically attractive as compared with gas-fired power plants.

Safety regulations have a significant impact on nuclear generation costs and thereby affect the competitiveness of nuclear power. There is only limited, but positive, experience with the regulation of nuclear safety in competitive markets. One of the challenges will be the ability of utilities and regulatory bodies to assume their respective responsibilities in a way that ensures continued safe and economic operation of nuclear units.

In addition to economic considerations, decisions about new nuclear power plants are likely to be strongly influenced by public opinion and political will. Concerns raised by nuclear power include safety, decommissioning and waste disposal. The lack of public acceptance undermines future possibilities for nuclear power plants.

Although in many countries it is not economical to build new nuclear power plants in the current competitive market, it must be recognised that other factors will influence the long-term plant mix. These are principally related to environmental concerns that are likely to become even more important over time. Nuclear power is one of the few proven technologies that could contribute to sustainable development, and it continues to have a valuable role to play in the future energy mix.

Beyond direct costs, factors such as the external benefits of nuclear power and its contribution to reducing greenhouse gas emissions favour the development of nuclear power. External costs of electricity generation include those associated with dependence on imported fuels, global climate change, health and environmental impacts of residual emissions, and waste from generation systems. For nuclear power, costs of waste management and decommissioning are already largely internalised in generation costs. In the long term, the competitive margin of nuclear power could significantly increase if these external costs, which presently are not included in market electricity prices, are taken into account.

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LIST OF EXPERT GROUP MEMBERS

Belgium

Mr. Paul Havard	ELECTRABEL
Mr. Jacques Delvoye	TRACTEBEL
Mr. M. Janssen	Administration de l'énergie

Czech Republic

Mr. Ing. Bretislav Horak	CEZ

France

Mr. Minh Trinh	Secretariat d'État à l'industrie
Mr. Henri Catz	Commissariat à l'énergie atomique
Ms. Catherine Gorski	Ministère de l'Économie, des Finances et de l'Industrie
Mr. Gérard Beraud	Électricité de France
Mr. Stéphane Gallon	Ministère de l'Économie, des Finances et de l'Industrie

Germany

Mr. Peter Drasdo	Institute of Energy Economics, University of Cologne
Mr. Gunter Schmid	Universitat Stuttgart

Hungary

Mr. Istvan Bakacs	Hungarian Power Companies Ltd.

Japan

Mr. Hiroo Inoue	MITI

Netherlands

Mr. J. W. M. Bongers	Borsele Nuclear Power Plant

Spain

Mr. Jorge Mataix Hidalgo	ENDESA

Sweden

Mr. Gunnar Alfors (Chairman)	Vattenfall Generation

Switzerland

Mr. Hans Gubser	NOK

United Kingdom

Mr. D. J. Murray	BNFL
Ms. Amanda Tagg	British Energy

United States of America

Mr. Dennis L. Harrison	US Department of Energy

European Commission

Ms. Isabel Torres	DG Energy

International Atomic Energy Agency

Ms. Lucille Langlois	Division of Nuclear Power

OECD International Energy Agency

Mr. John Paffenbarger	Energy Diversification Division

OECD Nuclear Energy Agency

Mr. Young-Eek Jung (Secretariat)	Nuclear Development Division

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