

# Nuclear Power Plant Life Management in a Changing Business World

Workshop Proceedings  
Washington DC, United States  
26-27 June 2000



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## **INTERNATIONAL WORKSHOP ON NUCLEAR POWER PLANT LIFE MANAGEMENT IN A CHANGING BUSINESS WORLD**

**Washington, D.C., United States  
26-27 June, 2000**

**Hosted by  
United States Department of Energy**

**In co-operation with the  
Electric Power Research Institute and the Nuclear Energy Institute**

NUCLEAR ENERGY AGENCY

ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT

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- 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.

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## FOREWORD

Plant life management (PLIM) activities are ongoing in many OECD Member countries. PLIM brings economic benefits, adds to the diversity of energy supply, and reduces carbon dioxide emissions and other environmental impacts. Some governments are taking initiatives to support nuclear industry PLIM programmes.

Nuclear power plant life extension is an attractive option for utilities supplying electricity, as the marginal cost of most existing nuclear power plants is lower than almost all other energy sources. In many cases, deregulated electricity market conditions have made the life extension option even more favourable economically.

However, there have been some early shutdowns of nuclear power plants due to more severe economic competition, uncertainty over future expenditures and for political reasons. Nevertheless, many governments, utilities and generating companies are interested in nuclear power plant life management and wish to obtain perspectives for long-term, safe operation. There are challenges to PLIM owing to technical, regulatory and economic factors and, perhaps more importantly, to the interdependencies between and among these factors.

In this changing environment, the NEA identified the need for an international exchange of information and ideas on the economics and policy aspects of nuclear power plant life management. Such an exchange would involve governments and industries and would include lessons learned from past successes and failures, information on costs and resources, together with other topics of concern.

In order to provide a forum for this information exchange, the international workshop on “Plant Life Management in a Changing Business World” was held in Washington, DC, on 26-27 June 2000. This workshop was hosted by the United States Department of Energy (USDOE) in co-operation with the Electric Power Research Institute (EPRI) and the Nuclear Energy Institute (NEI), and was attended by some 50 senior utility executives and policy makers from 12 OECD Member countries, the International Energy Agency (IEA) and the European Commission (EC).

The workshop provided an opportunity for active discussions on technology, regulation and business issues related to decision making on nuclear power plant life extension, as well as plant life management by senior utility executives and policy makers. The focus was on enhancing the viability of safe and economic nuclear power in a changing business environment. It was anticipated that improved understanding of the current situation throughout the world and discussions on approaches towards PLIM would be helpful as industry and governments develop new ideas and strategies.

These proceedings include the formal papers presented at the workshop and summaries of the discussions and findings of the three separate working groups on technology, regulation and business. A summary of the final plenary session, at which the working group findings were presented to all participants, is also provided.

## **Acknowledgements**

We would like to express our thanks to the Organising Committee, the speakers and the session chairmen, and to all those who contributed to the success of the workshop by presenting their papers and taking an active part in the discussions.

Our gratitude goes to the United States Department of Energy (USDOE) for hosting the meeting. Special thanks are also due to the Electric Power Research Institute (EPRI), the Nuclear Energy Institute (NEI) and their secretariats for taking care of the local arrangements and their dedication in preparing and editing these proceedings. We also wish to express our gratitude to the United States Department of Energy (USDOE) and the Argonne National Laboratory (ANL) for facilitating the publication of this report.

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## EXECUTIVE SUMMARY

At the end of 1999, there were 348 nuclear power plants connected to the grid in OECD Member countries, representing a total capacity of 296 GWe and generating some 24% of their electricity. One-third of these nuclear power plants had been in operation for over 20 years.

The demand for electricity throughout OECD countries is increasing steadily but the construction of new nuclear power plants has become increasingly difficult. Many utilities would like to keep existing nuclear power plants operating for as long as they can continue to function safely and economically because extending the lifetime of nuclear power plants is a substitute to constructing new plants. Therefore, nuclear plant life management (PLIM) has been carried out in many OECD Member countries and has played a very important role in the nuclear generation field.

Nuclear power plant owners seek to economically optimise the output from their plants, taking into consideration internal and external influences, as well as equipment reliability and maintenance workload. Nuclear power plant life management and extension is generally an attractive option for utilities supplying electricity because of its low marginal cost and low investment risk. PLIM has become an important issue in the context of changing business circumstances caused by regulatory reform of the electricity market. Specifically, the economic aspect of PLIM has become an important focus in the competitive electricity market.

The international workshop on “Plant Life Management in a Changing Business World” was hosted by the United States Department of Energy (USDOE) in co-operation with the Electric Power Research Institute (EPRI) and the Nuclear Energy Institute (NEI) in Washington, DC, on 26-27 June 2000. Some 50 senior utility executives and policy makers from 12 Member countries, the International Energy Agency (IEA) and the European Commission (EC) attended the meeting.

The objective of the workshop was to examine the status of PLIM activities in OECD Member countries and to develop a set of recommendations that plant owners/operators, governments, industry and international organisations could consider as they take decisions on whether to keep the nuclear power option viable through improved plant life management. These recommendations were developed from technical, economic and regulatory viewpoints. The workshop also provided an opportunity for exchanges of information on lessons learned from past successes and failures and to encourage the elaboration of new ideas and strategies for success under deregulated electricity market conditions.

The workshop included three working groups on technology, business and regulation, as well as presentations of country reports and discussions in plenary sessions. The main outcomes from the presentations and discussions were:

- PLIM activities have proven to be effective and safe. They have maintained diversity of supply within the developing, free electricity market, and brought economic benefits to plant owners and other stakeholders through low and stable electricity generating costs. They have also contributed to reducing carbon dioxide and other environmental emissions.

- Some governments are taking initiatives to support nuclear industry PLIM programmes. There are policies and strategies for the promotion of plant life management, providing with industry-government co-ordination mechanisms for research and development of plant life management.
- Technology, regulation and business issues in the PLIM activities are closely related. Specifically, inspection of the system, structure and components (SSCs) is an important factor in all three. For example, regulation requires that inspection of SSCs confirm safe operation, and that technology can promote advanced maintenance and inspection methods. Business decisions depend on the results of those inspections.
- Public attitudes towards ageing nuclear power plants will be key in terms of gaining acceptance for implementation of PLIM activities. Communications with the public and public acceptance are important on technology, regulation and business issues.

The main outcomes from each working group (technology, regulation and business) are presented below.

### ***Technology working group***

A consensus was reached on the following points:

- Systems, structures and components (SSCs) that are important to safety and irreplaceable or require large-scale repair/replacement are considered as critical from a technical and safety viewpoint for safe operation of ageing plants. Criteria are safety significance, reliability, cost, technical and economic feasibility of replacement, and knowledge of degradation phenomena.
- A few regulators have accepted a technical lifetime of up to 60 years. The process of reviewing nuclear power plant lifetimes varies with the legislative framework of the country where the plant is operated. Technically, prospects for long-term safe operation with reasonable maintenance is confirmed.
- The technical evaluation process has been or can be introduced to evaluate the feasibility of safe, long-term operation of nuclear power plants and its fundamental concept has been systematically established.

The following recommendations were made:

- Actions necessary to address technical issues related to maintaining reliability for long-term operation include: identify critical ageing mechanisms which enable prediction of long-term safety and reliability; develop ageing-effect identification technologies; clarify the ageing mechanism to allow prediction of component lifetimes; and improve inspection and monitoring practices.
- The following advanced maintenance technologies are needed to enhance PLIM programmes: ageing-mitigation technologies; advanced repair/replacement technologies; and non-destructive inspection technologies.

- With respect to maintenance methodologies, there is a need to change from time-based maintenance (TBM) to reliability-centred maintenance (RCM), condition-based maintenance (CBM), or break-down maintenance (BDM) and to systematically integrate optimised maintenance methodologies with regulatory requirements.
- Power plant owners should participate in the accelerated pace of international co-operation on PLIM R&D programmes. Such co-operation includes the sharing of lessons learned and other types of communication. Owners should also note that retired plants can be utilised as important sources of confirmatory data regarding PLIM activities.
- Up-rating, adoption of high burn-up fuel assemblies, risk-based assessments, and other PLIM-related enhancements are needed to achieve and maintain greater cost competitiveness of nuclear power plants.

### ***Regulation working group***

A consensus was reached on the following points:

- There are benefits from having standardised plant designs and sharing costs and knowledge over a larger base of utilities.
- The safety regulation approach to ageing varies between countries. Some countries have established safety regulations concerning the ageing of nuclear power plants. Generic methods are needed to make regulation consistent and reduce regulatory risk to plant owners.
- In some countries, economic and environmental regulatory policy is not unique to nuclear plant ageing, life management, or life extension, but applies to all forms of power generation.

The following recommendations were made:

- International standards on regulatory actions, for example backfit criteria, should be developed, based on results of periodic safety reviews (PSR).
- Guidelines should be developed for maintenance programmes for current and long-term operations to establish high reliability; high availability; and assess the impact of maintenance on reliability and availability.
- In order to facilitate change management, planning and preparation is necessary and monitoring criteria should be established.
- Mutually acceptable inspection programmes are necessary to develop a universal set of programme attributes to be used in the management of ageing from a regulatory point of view. Such inspection programmes could be based on reference IAEA guidance with decision criteria being added as appropriate.
- Improved co-operation among safety and economic regulators and increased co-ordination among regulatory bodies is needed. One method of achieving this could involve workshops to bring various regulators together to improve co-ordination.

## ***Business working group***

A consensus was reached on the following points:

- There are concerns about retaining experienced/trained personnel, and maintaining a good working relationship among them, as well as about the closure of research facilities, the reduction in staff numbers under increasing economic pressure and the lack of new nuclear power plant constructions.
- The marginal cost of producing electricity is lower for most existing nuclear power plants than for almost all other energy sources. Refurbishment costs are usually relatively small compared with new investments. The ongoing regulatory reform of the electricity market will bring increasing competition.
- Although PLIM has been carried out in many countries with favourable results, there are still uncertainties which affect business decisions regarding financial and market risks in PLIM activities.

The following recommendations were made:

- A template for “restarting and relicensing activities/requirements” should be developed. Such a template should describe minimum requirements, be acceptable internationally, and allow an adequate planning time horizon to make sound business decisions.
- A public awareness programme describing re-licensing methods and benefits should be developed and implemented by regulators.
- Information on the value of a nuclear power plant (NPP) in the market place should be communicated to financial analysts so that this new economic outlook is reflected properly in the stock price and the credit rating of NPP operating companies.
- General cost data on replacement or refurbishment of major SSCs should be developed.
- Because of downsizing and/or phasing-out of nuclear manufacturers, a strategy that addresses the sourcing of replacement components and nuclear services should be developed.
- Strategies aimed at retaining personnel, attracting new personnel, and maintaining good labour relations should be developed and implemented.
- An international strategy to inform legislators and the general public should be developed to ensure consistency and harmonisation of regulation for comparison with other energy resources that are needed in an international competitive market.

## SUMMARY AND CONCLUSIONS

The international workshop on “Nuclear Power Plant Life Management in a Changing Business World” was held in Washington, DC, on 26-27 June 2000. This workshop was attended by more than 50 experts from 12 countries and three international organisations. The workshop included a series of presentations to a plenary session of all participants. These presentations are noted in the workshop programme, included in these proceedings as Annex 1. A spectrum of experiences in plant life extension activities as well as experiences in operating a nuclear power plant (NPP) in a “free-market” electricity environment were presented.

The workshop also included three working groups in which major issues facing PLIM activities for NPPs were identified and discussed. The three working groups covered technology, regulation and business. The general format used in these working groups included:

- A presentation by the Group Chairperson.
- An identification of specific issues within each of the three general categories.
- Discussions regarding what actions should be taken to address these specific issues and what organisations (or types of organisations) should take these actions.

The following sections of this report consist of summaries of the discussions that took place in each of the three working groups.

### **Technology working group**

Chairperson: Dr. Yonezo Tsujikura, The Kansai Electric Power Co., Inc, Japan.

#### ***Objectives***

There were three basic objectives for the Technology working group:

- 1) Documenting how the safety of NPPs’ long-term operation has been confirmed, and suggesting ways of sharing this information.
- 2) Addressing development of advanced technology needed to enhance operation over the plant lifetime.
- 3) Suggesting potential areas of R&D that might be necessary.

**Background**

In order to meet the objectives of the Technology working group and the overall workshop, several basic points of discussion were identified. These points would then provide a basis for presenting the current status of important technology-based issues and for recommending potential courses of action to be taken. Major areas of concern for the working group focused on systems, structures, and components (SSCs). The points of discussion for the Technology working group are:

- 1) Verification of PLIM activities
  - Perspective on nuclear power plant’s lifetime.
  - Technical evaluation for verifying the feasibility of long-term operation.
  - Technical issues needed to maintain reliability for long-term operation.
- 2) Maintenance optimisation for the long-term operation
  - Advanced maintenance technology needed to enhance PLIM.
  - Advanced maintenance methodology needed to enhance PLIM.
- 3) R&D organisation
- 4) Other issues

**Issues and recommendations**

The current status of each of the issues identified by the Technology working group was discussed. A consensus of agreement within the group was established. On some issues, no recommendations for further actions were considered necessary. Table 1 presents the issues and recommendations of these issues as agreed to within the Technology working group.

Table 1. **Issues and recommendations from the Technology working group**

Issue	Working group findings
Perspective on nuclear power plant’s lifetime	<p><b>Current status</b></p> <p>United States</p> <ul style="list-style-type: none"> <li>• 2 plants (5 units): license renewal for 20 years has been approved</li> <li>• 2 plants (3 units): undergoing</li> <li>• Other 14 plants (22 units): submit applications by 2003</li> </ul> <p>Japan</p> <ul style="list-style-type: none"> <li>• 3 plants (3 units): integrity evaluation for 60 years has been approved with proper maintenance and management</li> <li>• Other units: evaluation planning at approximately 30 years</li> </ul> <p>France</p> <ul style="list-style-type: none"> <li>• Plant life programme: integrity evaluation in progress</li> <li>• Perspective: over 40 years (50 years) is feasible</li> </ul> <p><b>Consensus</b></p> <ul style="list-style-type: none"> <li>• Technically, the perspective of the long-term safe operation with reasonable maintenance is confirmed.</li> <li>• Plant life should be evaluated periodically incorporating progress in the technology.</li> </ul>

Table 1. Issues and recommendations from Technology working group (contd.)

<p>Technical evaluation for verifying the feasibility of long-term operation</p>	<p><b>Current status</b></p> <ul style="list-style-type: none"> <li>• Common concept in PLIM activities. <ul style="list-style-type: none"> <li>* Selecting SSCs for evaluation, and evaluation method.</li> <li>* Main SSCs: selected based on safety and difficulty to repair or replace with consideration for past specific evaluation.</li> <li>* Integrity evaluation showed NPPs' long-term integrity can be maintained.</li> <li>* Additional inspections or maintenance are reflected in their maintenance programme.</li> </ul> </li> </ul> <p><b>Consensus</b></p> <ul style="list-style-type: none"> <li>• The technical evaluation process has been or can be introduced to evaluate the feasibility of long-term safe operation of NPPs, and its fundamental concept has been systematically established.</li> </ul>
<p>Technical issues needed to maintain reliability for long-term operation</p>	<p><b>Current status</b></p> <ul style="list-style-type: none"> <li>• Current technologies and experiences give perspective on extending plant life.</li> <li>• In the world, the following activities are underway: <ul style="list-style-type: none"> <li>* Ageing-effect identification technology for reliable long-term operation.</li> <li>* Inspection/monitoring technology for reliable ageing evaluation of SSCs.</li> </ul> </li> </ul> <p><b>Recommendations</b></p> <ul style="list-style-type: none"> <li>• Identify critical ageing mechanisms to enable prediction of long-term safety and reliability.</li> <li>• Develop ageing-effect identification technologies: <ul style="list-style-type: none"> <li>* SCC of the RV internal structure.</li> <li>* Metal fatigue (thermal/environmental effects).</li> <li>* Neutron irradiation embrittlement of the RV, etc.</li> </ul> </li> <li>• Clarify the ageing mechanism to allow prediction of lifetime of components.</li> <li>• Improve inspection and monitoring practices for the ageing mechanism: <ul style="list-style-type: none"> <li>* Reconstitution technique of surveillance test specimen.</li> <li>* Screening and characterising cast austeno ferritic steel thermal ageing.</li> <li>* Advanced ultrasonic testing technique, etc.</li> </ul> </li> </ul>
<p>Advanced maintenance technology needed to enhance PLIM</p>	<p><b>Current status</b></p> <ul style="list-style-type: none"> <li>• Keeping cost competitiveness while not compromising safety and improving reliability of NPPs.</li> <li>• Desirable maintenance technologies as follows: <ul style="list-style-type: none"> <li>* Ageing mitigation technologies.</li> <li>* Advanced repair and replacement technologies.</li> <li>* Advanced non-destructive testing technologies, etc.</li> </ul> </li> </ul>

Table 1. **Issues and recommendations from the Technology working group (contd.)**

<p>Advanced maintenance technology needed to enhance PLIM (<i>continued</i>)</p>	<p><b>Recommendations</b></p> <ul style="list-style-type: none"> <li>• Ageing-mitigation technologies:             <ul style="list-style-type: none"> <li>* Elongation of component's lifetime (surface modification by cladding, annealing, peening, etc.).</li> </ul> </li> <li>• Advanced repair/replacement technologies:             <ul style="list-style-type: none"> <li>* To have various options for maintenance (CIR, baffle former bolts replacement, etc.).</li> </ul> </li> <li>• Non-destructive inspection technologies :             <ul style="list-style-type: none"> <li>* Evaluate component's ageing precisely (ECT of SG, cable ageing monitoring, etc.).</li> </ul> </li> </ul>
<p>Advanced maintenance methodology needed to enhance PLIM</p>	<p><b>Current status</b></p> <ul style="list-style-type: none"> <li>• Optimisation of maintenance based on the progress of inspection and monitoring technologies.</li> <li>• Current maintenance based on time-based maintenance (TBM) should be optimised.</li> <li>• Nowadays, optimised maintenance has been put into practice, such as RCM, CBM and BDM.</li> </ul> <p><b>Recommendations</b></p> <ul style="list-style-type: none"> <li>• Change from TBM to RCM, CBM or BDM.</li> <li>• Systematically integrate optimised maintenance methodologies with regulatory requirements.</li> </ul>
<p>R&amp;D organisation</p>	<p><b>Current status</b></p> <ul style="list-style-type: none"> <li>• R&amp;D programmes have been carried out in each country, or sometimes as an international project.</li> <li>• Joint R&amp;D projects have been organised and effectively managed.</li> </ul> <p><b>Recommendations</b></p> <ul style="list-style-type: none"> <li>• International co-operation should be accelerated for the R&amp;D programme.</li> <li>• Knowledge will be shared in the world.</li> <li>• Mutual communication.</li> <li>• Retired plants could also be utilised as important sources of confirmatory data.</li> </ul>
<p>Other issues</p>	<p><b>Recommendations</b></p> <ul style="list-style-type: none"> <li>• More cost competitiveness of nuclear power plant, such as:             <ul style="list-style-type: none"> <li>* Uprating.</li> <li>* Adoption of high burn-up fuel assemblies.</li> <li>* Risk-based technology, etc.</li> </ul> </li> <li>• Government regulation, business, and public relation issues, such as:             <ul style="list-style-type: none"> <li>* Maintaining knowledge and skills.</li> <li>* Public acceptance, etc.</li> </ul> </li> </ul>



## ***Conclusions***

The Technology working group reached the following conclusions regarding PLIM for NPPs:

- The perspective of long-term, safe operation has been confirmed, and the technical issues to be addressed for long-term operation have been identified.
- Technical issues related to achieving more effective operation while maintaining safety and improving reliability have been identified. The importance of international R&D projects in solving technical issues has been recognised.
- Roles and responsibilities of government, research institutes, utilities and vendors have been identified.
- Technical understanding of, and the technology for, managing plant ageing continues to improve, so the lessons continually learned should be reflected in enhancing the evaluation of SSCs and increasing the reliability of the plants.

## **Regulation working group**

Chairperson: Dr. Jack Roe, Sciencetech Inc., United States.

## ***Objectives***

The basic objectives of the Regulation working group were:

- Discuss ways to address plant life management within a regulatory framework.
- Consider perspectives from business, technology and regulatory points of view.
- Identify issues affecting nuclear power plant regulation, actions and parties responsible for them.

## ***Background***

The participants in this working group were from several different countries. Both regulators and owner/operators were represented in this working group. Thus, there was a spectrum of ideas and perspectives concerning the status of regulation with respect to PLIM as well as a spectrum of perspectives concerning the business environments in which NPPs operate. To gain an idea of the range of regulatory issues, representatives from each country were asked to discuss the regulatory status and to provide an initial set of issues of particular interest to their country. From this initial set of issues, the working group then selected a smaller number that appeared to be somewhat generic to most if not all of the countries represented in the working group.

Without identifying the specific country that expressed concern over each specific issue, the following initial set of issues was identified:

- It is important to develop and implement national and international standards for all nuclear power plants. There is also a need to standardise the regulatory regime in all countries. International regulatory focus with respect to plant life extension should be standardised with regard to safety.

- In some countries licenses have no pre-set expiration date. In some countries periodic safety reviews are not systematically required everywhere; consequently, rules for license renewal should be developed and implemented.
- License renewal is not a major issue in some countries. The first priority in all countries is safety. The second priority is efficient operation. The third priority is knowledge of the design and construction of selected plants. A few participants noted that the materials and components supplied from Russia are of questionable quality. The quality assurance records are lacking for some materials and components. It is noted that the instrumentation and control systems are of special concern in plants of older Russian design. However, most of these systems have been replaced with digital reactor protection and emergency core cooling instrumentation systems. In such cases, a fundamental problem is non-standard designs. The technical review of each reactor is a new challenge for license renewal.
- Since the preventive maintenance backlogs at some nuclear power plants are becoming quite long, the regulatory authority should be consulted concerning the preventive maintenance schedule in the future. There was a need to achieve a balance between preventive maintenance and unavailability of the systems. It is important to concentrate on safety-related preventive maintenance and to cancel any unnecessary work. It was also noted that by applying the maintenance rule, new perspectives on preventive maintenance and unavailability of the systems were revealed.
- There is concern over how to inspect reactor internals and other inaccessible areas. The inspection of reactor vessel internals, fatigue, cable ageing, and void swelling of reactor internals are significant technical issues. The regulatory process in each country should deal with managing these ageing issues and determining with what frequency they should be reviewed. It was noted that some regulatory agencies tend to base inspections on performance indicators, which require action before catastrophic failures.
- Deregulation is an opportunity for effecting positive changes in plants. At the same time, deregulation is causing change for many nuclear power plants. This change must be carefully managed to ensure that safety is not impacted. Privatisation of nuclear utilities could lead to cost cutting in safety-related systems. Examples in some other industries and with some nuclear power plants suggest that this is not necessarily true, but the concern remains. The concept of managing change, e.g. change of management structure within a regulatory framework, was discussed. The change management process helpful to document maintenance of safety was discussed. The utility would have to prove that change is not detrimental to safety.
- The owner/operators stressed that three things keep them in business: economics, safety and public opinion, and added that they consider safety an individual responsibility. They stated that industry places safety at the top of the list.
- Research in a state-owned utility does not necessarily benefit the utility, but benefits the global industry. In a free-market business environment, the utility only wants to do that which supports its primary mission of safely generating electricity.
- Labour unions are concerned about the impact of privatisation on plant operating budgets. Radiation protection might be jeopardised by cost cutting. Worker training is an issue since there appears to be fewer skilled craftsmen and radiation protection personnel. Regulators must investigate alleged safety issues raised by trade unions but must be careful not to let PLIM regulation be a venue to air grievances.

- Several participants noted that nuclear accidents have resulted in loss of public confidence in nuclear technology. They believe that regulatory bodies should be concerned with the public views on nuclear safety. It was also noted that the regulatory aspects of waste storage/disposal must be resolved for public acceptance.

### ***Issues and recommendations***

Each member of the Regulation working group was then asked to identify those issues that he felt were of greatest importance with respect to PLIM in a changing business world. The group then selected a final set of issues and suggested potential actions that could be taken to resolve these issues and what organisation or type of organisation should take these actions. These issues and recommendations are presented in Table 2.

**Table 2. Regulatory working group issues and recommendations**

<b>Issue</b>	<b>Recommended action</b>	<b>Responsible party</b>
Role of PSR in regulatory process for plant life extension	International standards on regulatory actions. Establish backfit criteria based on results of PSR.	NEA should draft standards and submit for discussion, not necessarily consensus.
Maintenance programmes may not be optimal for addressing regulatory needs associated with PLIM activities and life extension.	Develop guidelines for maintenance programmes to establish high reliability, high availability, assess impact of maintenance on reliability and availability for current operations and long-term operations.	NEA should put a working group or task force together to develop guidelines for maintenance programmes.
Change management	Plan and prepare for change. Establish monitoring criteria.	Individual regulators and owners; NEA
Waste management – address long-term storage of high-level waste.	Policy issue. Discuss on the national level the environmental benefits of nuclear power. Nuclear power does not produce the greenhouse gases that fossil-fuelled plants produce. Nuclear waste can be safely stored in a geologic repository for thousands of years.	IAEA, NEA, individual countries.
Need for a mutually acceptable inspection programme for management of ageing.	Develop a set of programme attributes. Use as reference IAEA guidance and add decision criteria.	NEA to develop guidelines. Individual national regulators to implement.
Need for improved co-operation between safety and economic regulators.	Increase co-ordination among regulatory bodies; host workshops to bring various regulators together to improve co-ordination.	National level; also, NEA to host workshops.

## **Business working group**

Chairperson: Mr. Barth Doroshuk, Constellation Nuclear Services, United States.

### ***Introduction***

The Calvert Cliffs nuclear power plant (NPP) was the first in the USA to obtain a license extension. The approximate costs for the Calvert Cliffs programme on plant life management (PLIM) and re-licensing were about \$20M. For subsequent plants, these costs are expected to be smaller for most cases. At an investment of approximately \$5/kW, Calvert Cliffs NPP is now licensed to operate an additional 20 years, i.e. until the year 2034 (as opposed to 2014, under the original license). Clearly, under these circumstances and in a de-regulated market, the business aspects of life extension are very attractive and compelling.

The decision to initiate and continue a PLIM programme for the Calvert Cliffs NPP was not a simple one, requiring considerable foresight and steadfastness. This was particularly so in the year 1989 when the outlook for continued future operation of the Calvert Cliffs NPP (among others) reached a low point, because of some regulatory difficulties.

The Oconee NPP was the second in the USA to obtain license extension, resulting in a total up to this date (July 2000) of five re-licensed units. More NPPs in the USA have filed applications for re-licensing or have announced the intention of doing so. A similar trend is observable in other NEA countries.

### ***Principal business issues***

Among the principal business issues to be considered in PLIM and possible life extension (re-licensing) are the following:

- Technical issues.
- Nuclear regulatory issues.
- Environmental regulatory issues.
- Personnel issues.
- Legislation.
- Public acceptance.
- Cost of alternatives.
- Economic/financial factors.
- Electricity market place.
- Nuclear industry issues.

These issues will be discussed in greater detail in the following paragraphs.

### ***Technical issues***

The various types of potential technical issues, related to the ageing of NPPs, are reported in the summary for the Technology working group. The costs associated with remedial actions to correct potential deficiencies (if any) in structures, systems and components (SSCs) due to ageing, are plant-specific and cannot be dealt with in a generic way. However, some general cost data should be developed and/or catalogued for replacement or refurbishment of major SSCs.

## *Nuclear and environmental regulatory issues*

Some of the business-related nuclear regulatory issues are:

- Life extension (re-licensing) should not become a reason for backfitting new regulations in order to bring the plant “up-to-date”; the cost for this might be prohibitive.
- Differences in regulatory regimes in adjacent countries (e.g. those in Europe) may result in substantial differences in regulatory burdens and consequently in the cost structure of the electrical energy produced in these countries.
- Regulatory performance and economic performance should no longer be considered as being unrelated issues.

## *Personnel issues*

Personnel issues are an important part of a well-conceived and well-conducted PLIM programme. A plant with only a few years left on its operating license may encounter difficulties in retaining its experienced personnel and in attracting new personnel. In that case, the plant may be forced to shut down prematurely because of regulatory or other reasons. Furthermore, because of the nature of NPP construction and operation, many staff members tend to be in the same age group. Therefore, adequate attention should be given to training younger staff members to replace older staff when retiring. Another important part of a PLIM programme should be directed towards maintaining good labour relations: without the full support of the entire personnel of the NPP, the chances for obtaining license extension are low.

## *Legislation*

Legislation can have an important impact on the competitive position of NPPs in the market place. Examples of such legislation are pollution credits and the often-mentioned carbon tax (the latter not yet enacted). To create a level playing field for all energy technologies, it would be desirable to enact legislation requiring that all external costs are to be accounted for, including impacts on public health, environmental impact, and global warming. In some countries, rather than getting credited as a non-polluting energy source, nuclear energy is penalised with a special tax.

## *Public acceptance*

Creating and maintaining a good level of public acceptance for a NPP is one of the most important aspects to be considered in PLIM. Different NEA countries are being faced with different problems in this respect. Guidance for a successful public acceptance campaign is desirable for all. Some of the public acceptance issues in NEA countries are related to:

- Fuel reprocessing and the final repository of radioactive waste.
- Unjustified demands for (new) environmental assessments.
- Small political parties having a disproportionate influence, resulting in political uncertainty and a short planning horizon.
- Foreign political pressure to shut down plants.

Assistance in promoting public acceptance of nuclear energy would be helpful. International guidelines for this would be very useful. In general, it is felt that increased publicity for the successful re-licensing of NPPs in one country will be very helpful in promoting public acceptance and facilitating the re-licensing of NPPs in other countries.

### *Cost of alternatives*

The cost of alternative sources of electrical energy is an important consideration in decision making concerning life extension. In this respect, the reliability of the available data is of great importance. Various options exist, such as:

- Perform independent assessments.
- Rely on data from a “clearing house” concerning available alternative energy sources (by region or country).
- Rely on (catalogue/library of) available studies, addressing cost models for alternatives.
- Evaluate possible future fuel supply issues (availability, costs, etc.).
- Evaluate possible future developments concerning external costs for nuclear power and fossil-fuelled plants (public health, environmental impact, global warming).

### *Economic/financial factors*

Life extension and de-regulation will change the financial outlook of NPPs: re-licensed NPPs have the potential of joining the most economical producers of electrical energy on the grid. This changed economic outlook may be attained even without accounting for the substantial external costs of fossil-fuelled power plants (public health impact due to air pollution, detrimental environmental impact, CO<sub>2</sub> emissions, etc). It is important that this new economic outlook be made known to the financial circles (stock markets and financial analysts) in order that this concept be reflected properly in the stock price and the credit rating of companies operating NPPs. The following questions/issues are of importance in this respect:

- What is the score card determining the value of a NPP in the market place?
- Which financial self-assessment model should be used?
- What will be the NPP's competitive position in the market place?
- The economic model must be forward-looking with respect to the addition of new NPPs.

### *Electricity market place*

The electrical market place is evolving rapidly. Specific issues that have strong financial implications are:

- What will be the price of electrical energy during peak demands?
- What will be the price for reliability?
- What are the advantages of nuclear over alternatives (if any)?
- What “products” will be sold in the market place?

*Nuclear industry issues*

The lack of new orders for NPPs has resulted in downsizing and phasing out nuclear manufacturers and industry segments capable of supplying components and services to NPPs. Because of this, one of the important issues being faced by NPPs with respect to PLIM is the availability of replacement components, which are often difficult to obtain or not at all for sale.

*Issues and recommendations*

Based on discussions of the preliminary issues noted above, a final set of business issues was selected. Suggested potential actions that could be taken to resolve these issues and what organisation or type of organisation should take these actions were also identified. These issues and recommendations are presented in Table 3.

**Table 3. Business working group issues and recommendations**

<b>Business issue</b>	<b>Recommended action</b>	<b>Participating organisations</b>
<p><b><i>“Template” for restart and relicense activities/requirements</i></b>                      Discussion: Currently different countries have different requirements for re-starting and relicensing NPPs. It is desirable to strive internationally for more uniformity in this respect, in particular as regards providing utilities with an adequate business planning horizon.</p>	Develop a “template”, describing minimum requirements, acceptable internationally and allowing an adequate planning time horizon for making sound business decisions.	NEA, IAEA, regulatory bodies, utilities, NEI, EPRI
<p><b><i>Improve public awareness of relicensing</i></b>                      Discussion: Increased publicity for the successful relicensing of NPPs in one country will be very helpful in facilitating the re-licensing of NPPs in other countries.</p>	Develop a public awareness programme for re-licensing and the benefits derived from it.	NEA, IAEA, utilities, NEI, professional societies, federal agencies or ministries
<p><b><i>Value of a NPP in the market place</i></b>                      Discussion: Life extension and de-regulation will change the economic outlook of NPPs: re-licensed NPPs have the potential of joining the most economical producers of electrical energy on the grid.</p>	Inform financial analysts so that this new economic outlook is reflected properly in the stock price and the credit rating of NPP-operating companies.	NEI, utilities
<p><b><i>Cost data on replacement or refurbishment of major SSCs</i></b>                      Discussion: The costs associated with remedial actions to correct potential deficiencies (if any) in SSCs due to ageing, is plant-specific and cannot be dealt with in a generic way. However, some general cost data should be developed and/or catalogued for replacement or refurbishment of major SSCs.</p>	Develop/catalogue general cost data on replacement/refurbishment of SSCs.	NEI, vendors, AEs, service providers, EPRI, IAEA

Table 3. **Business working group issues and recommendations (contd.)**

<b>Business issue</b>	<b>Recommended action</b>	<b>Participating organisations</b>
<p><b><i>Downsizing and/or phasing out of nuclear manufacturers</i></b>            Discussion: Because of downsizing and/or phasing out of nuclear manufacturers, one of the important issues being faced by NPPs with respect to PLIM is the availability of replacement components and nuclear services.</p>	Develop a strategy concerning industry downsizing with respect to replacement components and nuclear services.	Utilities, NEI
<p><b><i>Personnel issues</i></b>            Discussion: Retaining and attracting highly qualified personnel and maintaining good labour relations are prerequisites of a successful PLIM programme.</p>	Develop and exchange information on strategies concerning personnel issues, aimed at: <ul style="list-style-type: none"> <li>• retaining personnel;</li> <li>• attracting new personnel;</li> <li>• maintaining good labour relations.</li> </ul>	Utilities, NEI, EPRI, IAEA
<p><b><i>Legislation</i></b>            Discussion: In a deregulated market place, it is important to create a level playing field for all energy technologies. In this respect, it would be desirable to strive for enactment of legislation requiring that all external costs are to be accounted for, including impact on public health, environmental impact, global warming, etc.</p>	Develop a strategy on an international scale to inform legislators and the general public.	NEI, IAEA, NEA, professional societies, federal agencies or ministries

### **Concluding remarks**

Workshop general chairperson: Dr. John J. Taylor, Vice President (Retired), Electric Power Research Institute, United States.

Each of the three working group chairpersons presented summaries of the issues and recommendations from their respective working group. There was significant discussion among the workshop participants in response to these recommendations.

There appeared to be a strong consensus that those issues raised by the Technology working group were important for meeting PLIM goals. These issues have application in all countries considering PLIM and might help in the decision process for those countries currently considering their options with respect to PLIM and life extension.

Issues raised by the Business working group also received a strong consensus of agreement although there are differences among the various countries with respect to economic and political conditions that can impact business decisions. There was also agreement regarding the interdependence of technology developments and regulatory requirements in impacting business decisions. A known regulatory environment is extremely important in making long-term business decisions.



Issues raised by the Regulation working group prompted considerable discussion among the plenary participants. There were probably two reasons for this. First, the large number of countries represented at the workshop provides a range of regulatory environments. As such, there was some diversity from country to country as to the type of issues that are of most importance from a regulatory point of view. When combined with the range of PLIM activities that have been undertaken throughout the world, these differing regulatory points of view result in different priorities. The second cause of the higher level of discussion for the regulation issues stems from the greater number of owner/operators with respect to regulators in the plenary session. There are understandably different perspectives from these two groups of experts. With a rewording of one of the issues delineated by the Regulation working group, a mutual understanding of all issues was achieved.

### **Common themes**

There were at least five themes that entered into the discussions and identification of issues for each of the three working groups. These common themes suggest a high priority in addressing related issues to help assure the continuation of the nuclear option for efficient, economic and environmentally acceptable electricity generation. These common themes are:

- 1) There are strong interactions among technology, regulation and business actions that influence PLIM activities in general and life extension in particular.
- 2) Inspection of SSCs is a consideration in all three areas of concern to this workshop. Technologies for accomplishing inspections, regulatory requirements for such inspections, and business decisions based on the results of such inspections can have significant impacts on PLIM actions.
- 3) Age management is another common theme. Technologies and methodologies for assessing ageing issues, regulatory requirements and business decisions are once again influenced by an understanding of this phenomenon.
- 4) Maintenance activities and long-term requirements also were considerations in all three working groups. It was noted that some information on maintenance programmes has been published. However, each of the three working groups expressed an interest in enhancing this information with respect to PLIM actions.
- 5) Public acceptance and communications with the public was another common theme among the three working groups. The need for technologies to effectively demonstrate that the public safety concerns are being addressed, for regulations to allay public concerns about life extension, and a willingness of the public to accept life extension as a business option were all emphatically stated in the working groups as well as in the plenary sessions of the workshop. The importance of this issue cannot be overstated.



**WELCOME ADDRESSES**



## **WELCOME ADDRESS**

**Dr. John J. Taylor**  
General Chairperson,  
Vice President (retired), EPRI, United States

Good morning, Ladies and Gentlemen,

It is my pleasure to welcome you to this International Workshop on Nuclear Power Plant Life Management in a Changing Business World. I would like to thank all of you for taking time from your busy schedules to be here, particularly those who have contributed papers for presentation. I would also like to express my gratitude to the organising committee of this Workshop and the United States Department of Energy (USDOE) and Argonne National Laboratory (ANL) for the local arrangements and secretariat.

This workshop is sponsored by the OECD Nuclear Energy Agency (NEA) and hosted by the USDOE, in co-operation with the Electric Power Research Institute (EPRI) and the Nuclear Energy Institute (NEI).

Present economic and market conditions, particularly with the advent of deregulation of electricity generation, give limited opportunities for the expansion of nuclear power capacity through new plants. Yet, there is an important opportunity for expansion of nuclear power electricity production through successful implementation of the technical work encompassed in the scope of this workshop. The fruits of this effort, increased capacity factors and increased operational life, are equivalent to constructing substantial new capacity. We are already seeing these fruits in the U.S. Nuclear plant reliability has greatly improved, with average plant capacity factors rising from 57% in 1980 to 86% in 1999, a major increase in equivalent capacity. Similar improvements are being experienced worldwide. In the U.S., two utilities, Baltimore Gas & Electric and Duke Power, have obtained licenses to extend their operation twenty years longer than the original forty year licensing basis. Extended operational capacity for twenty years is equivalent to a whole new fleet of new plants over that time frame.

In sum, the present operating nuclear power plants have the clear prospect of being top competitors in the generation of electricity for 30 to 40 years into the new century in a de-regulated market. The big condition on achieving that prospect is that they maintain their present safety and reliability performance levels over that time frame – they must keep running safely and at high capacity factors. This is the task that those of you attending this meeting have taken on. In a sense you have taken on the responsibility of assuring the continuation of a strong nuclear power industry even in the absence of new nuclear plant orders. You are to be commended for that.

I would now like to introduce the workshop programme. Firstly, there will be several presentations on lessons-learned by participants in the plenary session. Secondly, participants will attend the three separate working groups: technology, regulation and business. Through interactions

within the working groups, participants are expected to examine the issues and identify actions needed to enhance nuclear power viability in the immediate future. The chairman of each working group will then present the consensus and recommendations resulting from the discussions in the plenary session.

Finally, I would like to take this opportunity to invite you to a reception this evening at 6.30 p.m. so that you may continue to develop your ideas and relax after a hard day's work in more pleasant surroundings.

I wish you a successful meeting and a pleasant stay in Washington.

Thank you.

## **WELCOME ADDRESS**

**Mr. Sam Thompson**

Deputy Director-General, OECD Nuclear Energy Agency, France

Good morning, Ladies and Gentlemen

On behalf of the OECD Nuclear Energy Agency based in Paris, it is my pleasure to welcome you to this International Workshop on “Nuclear Power Plant Life Management in a Changing Business World” that is one of the activities of the Nuclear Development Committee of our Agency.

At the end of 1999, there were 348 nuclear power plants connected to electricity grids in the 29 OECD Member countries, representing a total capacity of 296 GWe and generating some 24% of the electricity produced in these countries. About one third of these nuclear power plants have been in operation for over 20 years. These operating nuclear power plants represent a significant energy source that utilities and governments cannot overlook in present and future decision taking.

### **Background of PLIM (utility and plant owner)**

The demand for electricity throughout OECD Member countries is continuing to grow steadily and there are no signs of its diminishing in the foreseeable future. Over the next decade, electricity demand in Member countries is expected to grow at a rate of about 1.7% per year. Electricity's share in final energy consumption throughout the world is also projected to increase. Although the projected rate of growth in electricity demand varies from country to country and region to region, it is clear that efficient, safe, and economical electricity production and distribution are vital. These are the foundation stones of continued economic growth, competition in world markets and high standards of living and quality of life.

The construction of new power production capacity proceeds in response to the electricity supply situation, complemented by energy conservation measures. However, few new nuclear power plants are expected to be constructed in OECD countries in the next decade or so, except in Japan and Korea. New sites for all types of electricity generation are becoming increasingly difficult to locate. This is due not only to a diminishing availability of sites which can meet the technical requirements of a power plant but also simply to increased public resistance to new industrial facilities as a whole, the so called NIMBY syndrome.

In the face of growing demand as well as the limited potential of energy conservation and the very limited availability of renewable sources and new hydro options, most plant owners would like to keep existing nuclear power plants in operation for as long as they can continue to function safely and economically. This would then complement fossil plant construction programmes, particularly the penetration of combined cycle gas turbine plants.

In the late 1980s, when competition in electricity supply was developing and the low capital cost of combined cycle gas turbine plants began to challenge new nuclear plants, the nuclear plant lifetime extension option came to be regarded as particularly desirable. That position persists today.

For many decades, OECD Member countries have controlled their electricity sectors as government – regulated monopolies. Regulators often controlled the price of electricity and complicated regulatory systems guaranteed protected markets in exchange for a safe and reliable supply of electricity to the public at a reasonable price. This situation is changing rapidly now that the electricity sector is being deregulated and progressively opened to more competition.

In parallel with competition there is a strong move to privatise the electricity sector, that has previously been state-owned or subsidised in many countries. State-owned electricity companies are often obliged to accommodate governmental/public policy goals in addition to achieving their business goals. These policy goals can no longer be accommodated by private companies since competitive markets are efficiency-driven. There is a drive towards short-term efficiency gains through private ownership without regard to national strategic aims.

Power generators have traditionally 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 on their investments. In such monopolies, financial and market risks were effectively allocated directly to customers. For example, the cost of poor forecasting generally has mainly been borne by customers; the economic penalty to the utility for over-investment was minimal or nil, with the excess investment costs being passed on through higher electricity prices. This changes in competitive markets; the change is not different from the situation in other businesses but is a new experience for many utility managers.

In a competitive market, power generators can gain and 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 growth. Power generators run the risk of not selling their full output unless their marginal or avoidable costs of production are low.

High capital costs and high risk to 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 carry greater performance, financial, and market risks than in the past. Considerations that have an increased influence on investment decisions include capital requirements; demands for shorter pay-back periods; and more stringent cash flow requirements to secure debt and equity capital at reasonable cost.

There is substantial interest in nuclear power plant life extension in OECD Member countries, because the costs, time, and risks associated with life extension are expected to be much less than those of building any new power plant. In the United States, the US Nuclear Regulatory Commission has already approved extension of nuclear power plant operating licenses in two cases by 20 years, to 60 years. This bodes well for the outlook for operators in the US and elsewhere. It is clear that license renewal will allow utilities to maintain generating capacity without incurring large investment costs for the construction of new plants as replacements.

Nuclear power plant power upratings also are becoming common in many OECD countries, since this frequently results in increased capacity at an attractive, low investment cost.



In summary, competitive electricity markets increase the incentive for plant life extension and upratings of nuclear power plants. It is often an attractive business option.

### **Background of PLIM (government)**

While nuclear power plant life management brings the economic benefit to the plant owners in competitive markets, it may also bring economic and environmental benefits to other stakeholders through a low and stable electricity price and reduced carbon dioxide emissions.

Nuclear power plant life management may help to lower costs and prices, and to stabilise electricity prices. In a competitive market, most existing nuclear power plants are expected to be able to compete because their marginal costs are lower than those of almost all other sources. The price of nuclear fuel is independent of fossil fuel price disruptions. Furthermore, the proportion of fuel in the total cost of nuclear is lower than for most other sources (the exceptions being hydro and renewables) so the generating cost of a nuclear power plant is relatively stable. This stability reflects into the market and has a synergistic effect on overall electricity prices.

Nuclear power plants can particularly contribute to energy security in countries without substantial indigenous energy resources. The technology itself can be made largely indigenous. Nuclear fuel is a relatively more predictable resource than fossil fuel; there is a current surplus of uranium on the world market and known uranium resources are expected to last well into the next century or beyond with nuclear fuel recycling. Moreover, as some OECD countries supply nuclear fuel, the risk of interruption in nuclear fuel supply is very much lower than for fossil fuels. Nuclear programmes offset the import of fossil fuel.

Nuclear power plants emit no carbon dioxide and, in general, far less environmental pollution than fossil fuel plants. The retirement of nuclear power plants without replacing them by a carbon free generating source will lead to an increase in the emissions of greenhouse gases and make it more difficult to achieve Kyoto Protocol targets. In 1998, nuclear power plants reduced carbon dioxide emissions in OECD countries by 1 900 million tonnes, i.e., by 13% of total emissions.

We need to recognise the political choices of some governments that choose to forgo the continued use of nuclear energy within their national energy portfolio including the potential of PLIM to offer significant economic benefits. The developments in Germany two weeks ago are an example of this although the major repercussions there are distinctly medium term and not short term. Experience in Sweden, having expressed a similar intention to that of Germany but earlier, twenty years ago in fact (in 1980), is interesting. With the exception of one of the two Barseback units (which was closed at the end of last year, 1999) the Swedish national policy intention has been difficult to implement without there being unacceptable economic and environmental repercussions.

### **Past activities**

Now I would like to turn to some related activities of the Nuclear Energy Agency. A number of safety studies at the company, national and international levels contribute to the recognition and control of degradation mechanisms. The Nuclear Energy Agency (NEA) and the International Atomic Energy Agency (IAEA) provide fora for exploring on a co-operative basis what, if any, are the technical factors that will limit component and plant life. They also provide fora for discussion of the procedures for re-licensing older plants in the context of updated regulations.

The NEA provides an opportunity for international exchanges of information on strategic, economic, and safe handling of nuclear plant life management for governments and plant owners. In this connection, the NEA specifically:

- published an international common ageing terminology for nuclear power plant life management in five languages (English, French, German, Spanish and Russian) in 1999;
- completed a study on the Refurbishment Costs of Nuclear Power Plants also in 1999;
- published the summary report on “Nuclear Power Plant Life Management” in 2000, which has been provided as a background document for this Workshop;
- held a “Special Issue Meeting” last week on the regulatory aspects of plant life extension and uprating;
- will publish a report later this year on the impact of deregulation on nuclear power in competitive electricity markets.

### **Now I would like to touch briefly on the objectives and scope of this workshop**

While the degradation mechanisms of nuclear power plants have been identified and controlled, we have, in reality, observed a limited number of early shutdowns. The attributed reasons in some of these cases were the impending severer economic competition and the uncertain future expenditure.

Ongoing reform of electricity markets introduces considerable uncertainty about the nuclear power option. In a deregulated and competitive market, pressure on nuclear power plant owners to reduce generation costs will increase in order for them to compete successfully within the market, particularly with gas, and maximise shareholder value. As a result, the decision-making framework and criteria for operating nuclear power plants are changing.

Nuclear power plant life management and extension is an attractive option for utilities to supply electricity because of low marginal cost and low risk of investment. Consequently, nuclear power plant life management (PLIM) has become an important issue in a changing business environment caused by the reform of the electricity market.

Governments recognise the implications for medium and long-term energy and environmental policies of the evolution of PLIM. Some are taking initiatives to support nuclear industry PLIM programmes in order to pursue national objectives, recognising the importance of the technical, regulatory and economic factors involved and the interactions between them.

The Workshop will provide an opportunity to exchange information on lessons-learned from past successes and failures and to develop new ideas and strategies for success. The primary purpose of the Workshop is to develop a set of recommendations that plant owners/operators, governments, industry organisations, and international organisations should consider in order to maintain nuclear power industry viability.

### **Thanks to host organisations**

I am sure that your expertise in the field will provide a comprehensive approach to the analysis of technical, regulatory and economic factors in nuclear power plant life management and I am looking forward to your conclusions and recommendations.

Finally, I would like to thank you for your interest in the work of the Nuclear Energy Agency, and for taking the time to come to Washington for this Workshop.

I would also like to thank the United States Department of Energy, the Electric Power Research Institute, and the Nuclear Energy Institute for their hospitality and for their co-operation in the organisation of the Workshop.

I do hope that you will enjoy your stay here in Washington DC and wish you an interesting and successful two days.

Thank you.



# **NUCLEAR POWER PLANT LIFE MANAGEMENT IN A CHANGING BUSINESS WORLD**

**Workshop Proceedings  
Washington, DC, United States  
26-27 June 2000**

**Hosted by the  
United States Department of Energy**

**In co-operation with the  
Electric Power Research Institute and the Nuclear Energy Institute**

**NUCLEAR ENERGY AGENCY  
ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT**

## WELCOME ADDRESS

**Marvin Fertel**  
Senior Vice President,  
Nuclear Energy Institute (NEI), United States

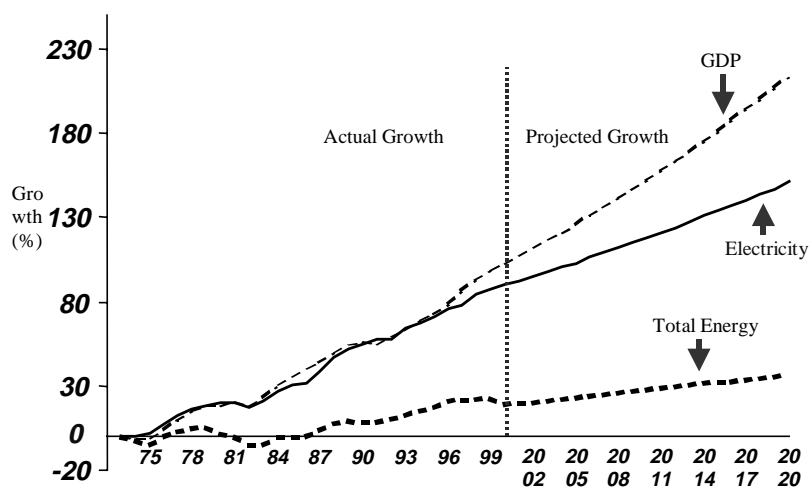
Mr. Fertel greeted the participants and gave the following slide presentation:

### Agenda

- Nuclear energy worldwide
- Clean air benefits of nuclear energy
- Nuclear competitiveness – U.S.
- Public support for nuclear energy
- Conclusions

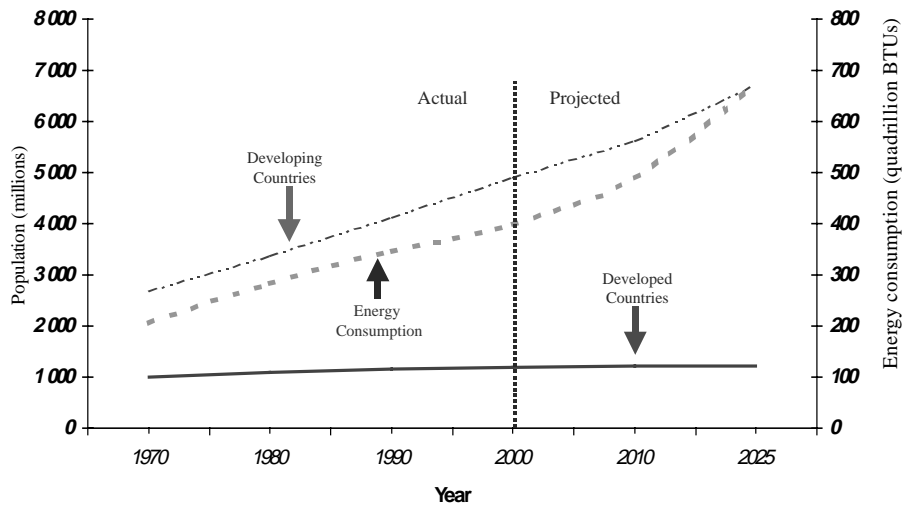
### Nuclear energy worldwide

#### *Actual and projected growth in electricity supply and the economy (1973-2020)*



Source: EIA

**Population and energy consumption growth (1970-2025)**

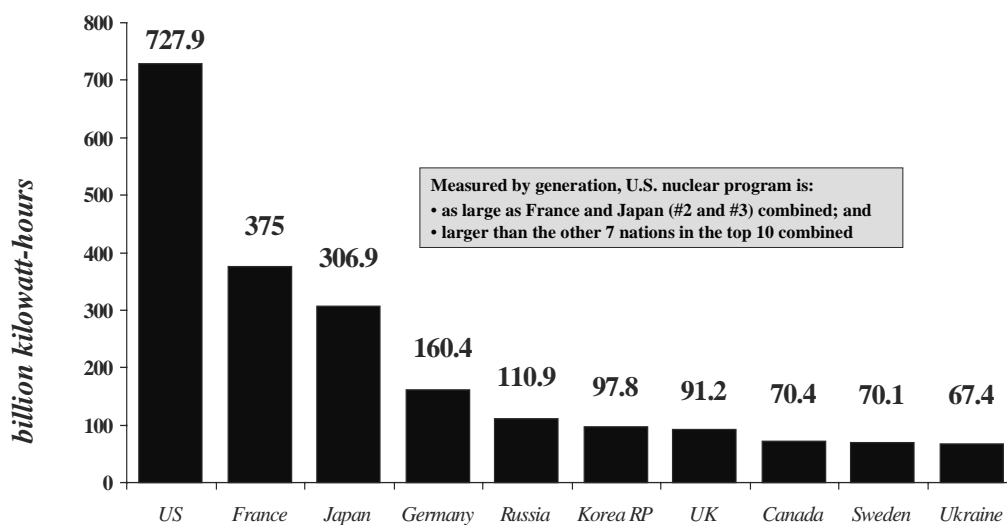


Sources: EIA, International Energy Outlook 2000, US Bureau of the Census, International Database

**Nuclear energy – a key player worldwide**

- 17% of the world’s electricity
- Critical component of energy security strategy for specific countries
- Important factor for achieving carbon emission reductions in developed countries
  - Potential factor in developing countries
- Civilian uses of nuclear energy integral to support strengthened non proliferation regime

**Top 10 nuclear countries (1999 generation)**



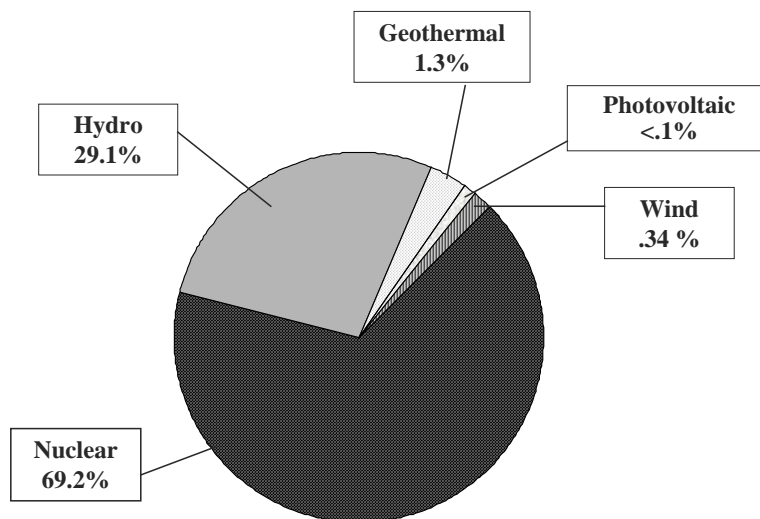
Source: IAEA

### *Nuclear energy – worldwide trends*

- Evolving competitive electricity markets
  - Implications for existing plants: safety and economics
  - Major challenge for new plants
- Industry consolidation
  - Supplier and support services
  - Fuels
  - Generators
- U.S. and Russian surplus weapons material disposition
- Safety performance improving worldwide
- Only large near-term growth markets – Asia
  - Limited opportunities elsewhere
  - No near-term growth in Europe/loss of capacity likely
  - No near-term growth in U.S.
- Environmental groups reassessing value of nuclear energy
  - Antinuclear groups increasing opposition to nuclear energy
  - Renewables and efficiency advocates perplexed by electricity competition

### **Clean air benefits of nuclear energy**

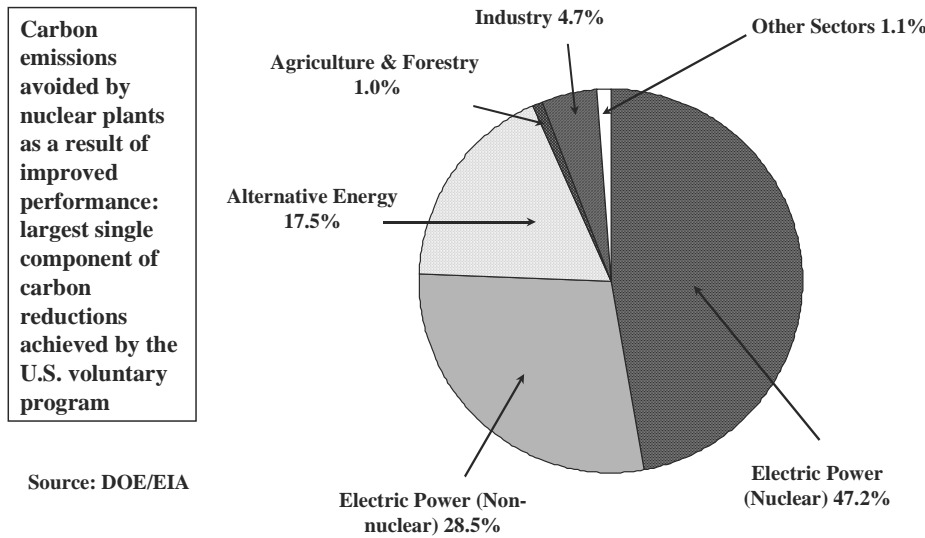
#### *Breakdown of U.S. sources of emission free generation (1999)*



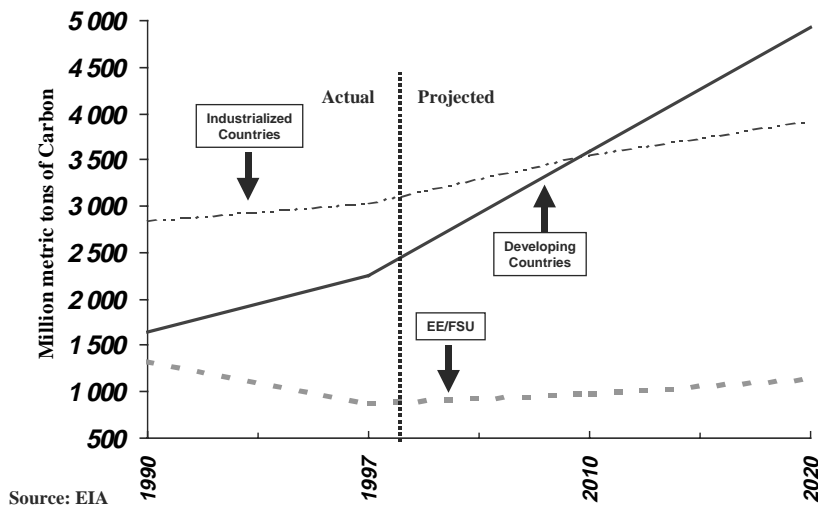
Source: EIA



**Carbon reductions: nuclear power dominates U.S. voluntary programme**



**Actual and projected carbon emissions (1990-2020)**



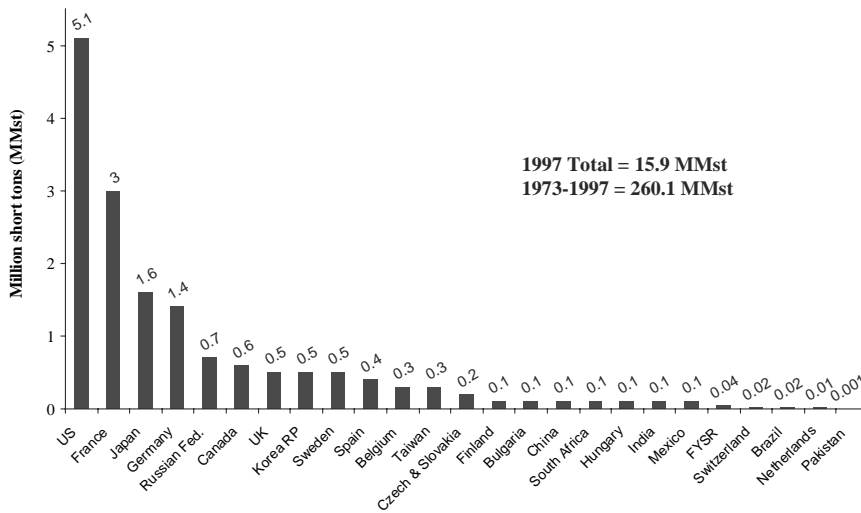
**Clean air compliance value of existing nuclear power plants**

- Nuclear power plants (and other emission-free sources) are “silent partner” in compliance plans: emissions avoided not explicitly recognised
- Emission-free sources reduce compliance cost otherwise imposed on fossil-fired units
- Clean air compliance value is “hidden” value:
  - Ceases to be “hidden” when nuclear unit shuts down
  - In the absence of nuclear energy, increased compliance cost for new and existing replacement capacity

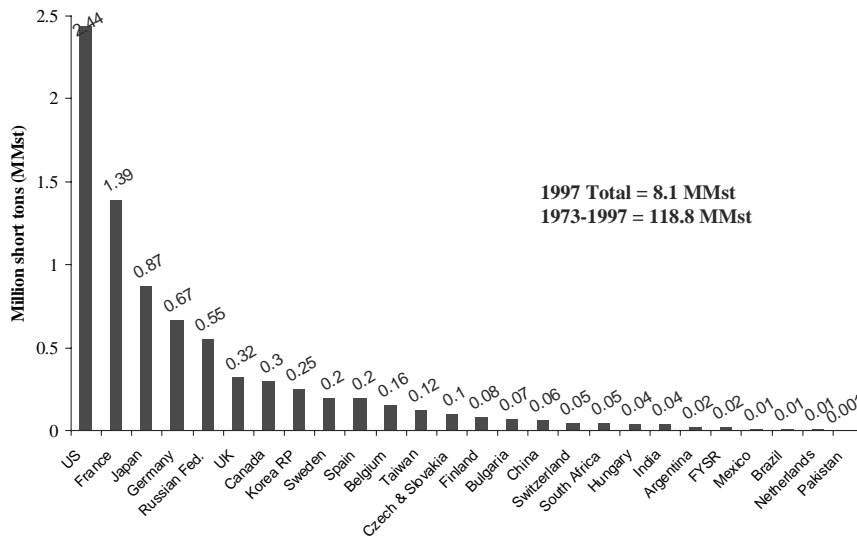
**Clean air compliance value of existing nuclear power plants**

- NO<sub>x</sub> Emissions
  - 1.29 mills per kWh (Rothwell)
  - 2.5-4.1 mills per kWh (First Energy)
- CO<sub>2</sub> Emissions
  - 6.1 mills per kWh
  - \$15 per ton of carbon
- Context
  - 1 mill per kWh = \$7.5 million per year
  - annual O&M spending = \$60 million per year (best plants)

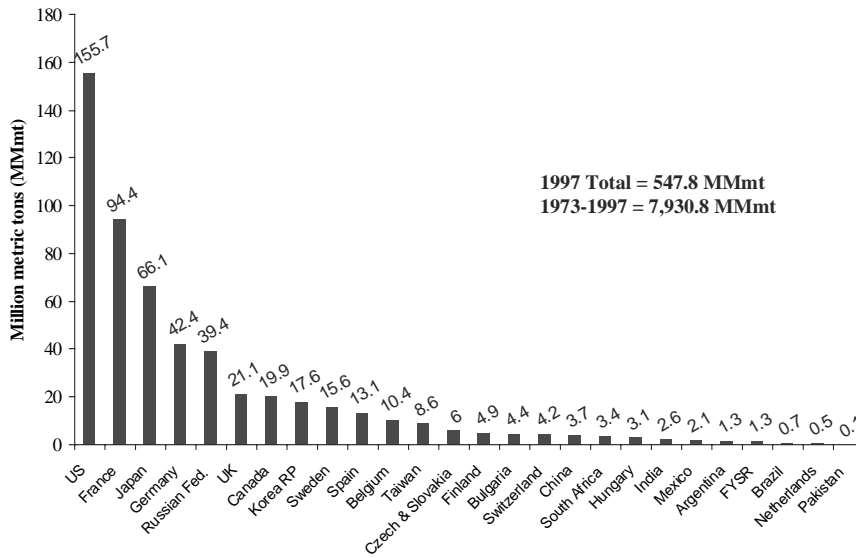
**Nuclear industry's worldwide contribution to the reduction of SO<sub>2</sub> (1997)**



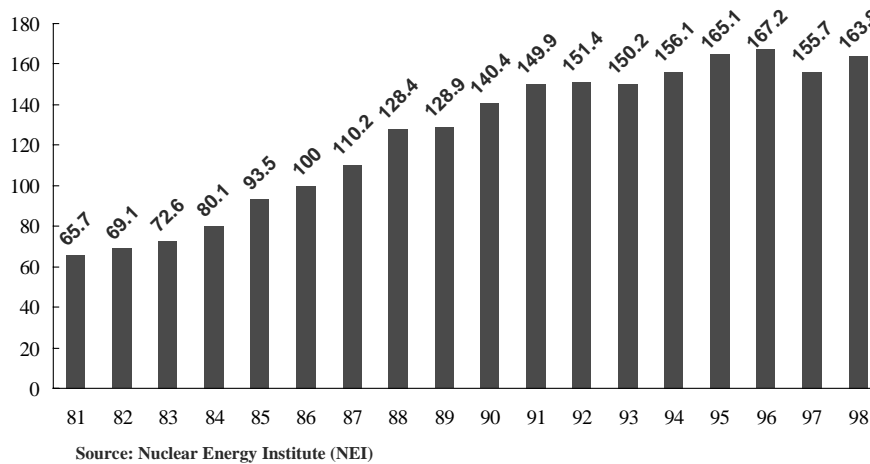
**Nuclear industry's worldwide contribution to the reduction of NO<sub>x</sub> (1997)**



**Nuclear industry's worldwide contribution to the reduction of carbon (1997)**

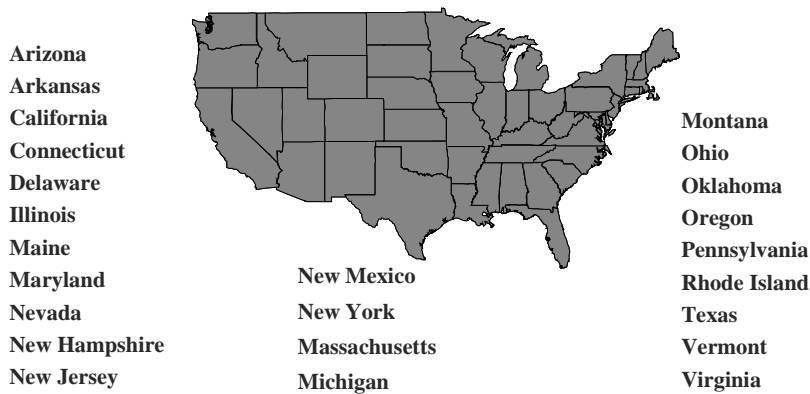


**US nuclear industry CO<sub>2</sub> avoidance in million metric tons of carbon**



**Nuclear competitiveness**

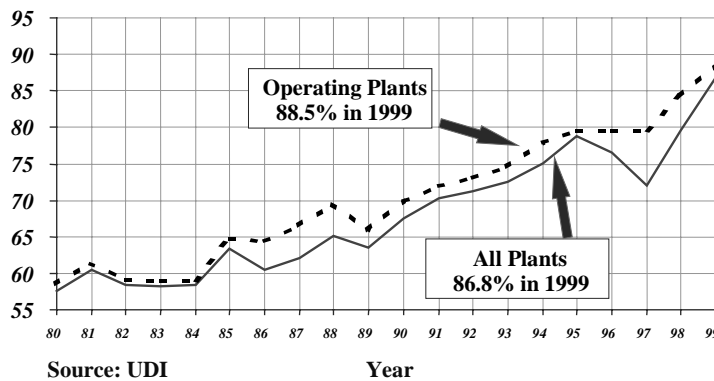
**Restructuring status: 24 states have restructured their electric power industry**



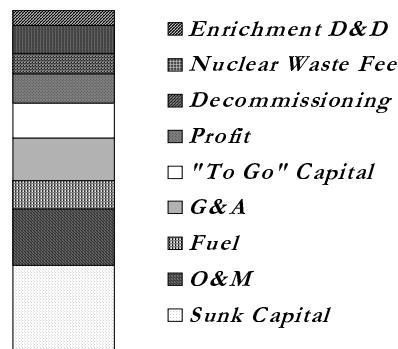
**Consolidation: greater efficiency, lower cost**

- Occurring in all industry sectors:
  - Nuclear plant ownership, operating responsibility
  - Infrastructure (equipment, services, fuel supply)
- Natural business response to competitive pressures, state restructuring initiatives
- Result: safer, stronger, leaner industry going forward

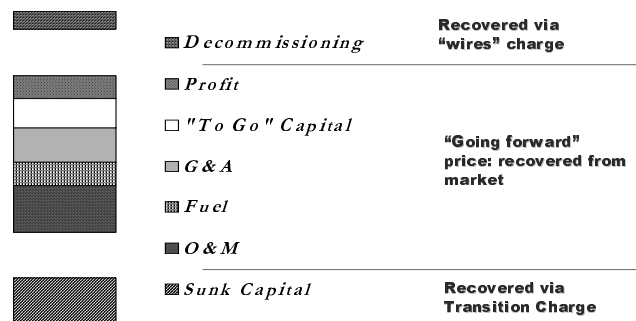
**Industry is achieving record levels of performance (in average industry capacity factors)**



**Electricity price: cost-of-service (all cost elements bundled into single rate)**

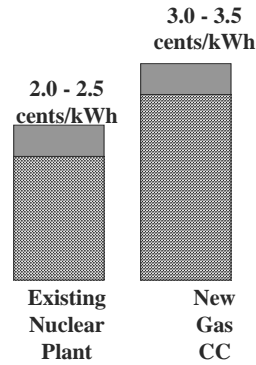


**Electricity price: competitive market (cost elements unbundled)**



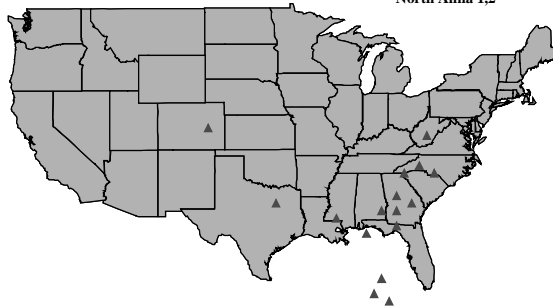
**The generating company's decision: run the nuclear unit or build a new gas plant?**

- “Going forward” cost for a well-run nuclear power plant: 2.0 - 2.5 cents/kWh
- “Going forward” cost for new gas-fired combined cycle plant: 3.0 - 3.5 cents/kWh
  - \$400-450 per kW
  - gas at \$2 per million Btu



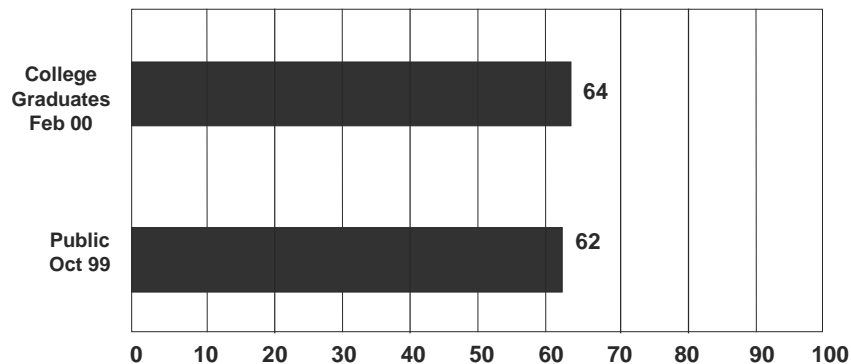
**Competitive market: major stimulus for license renewal**

Extension Granted	Already Filed	2000	2001	2002	2003
<ul style="list-style-type: none"> <li>• Calvert Cliffs 1,2 (March 23, 2000)</li> <li>• Oconee 1,2,3 (May 23, 2000)</li> </ul>	<ul style="list-style-type: none"> <li>• Arkansas Nuclear One Unit 1</li> <li>• Hatch 1,2</li> </ul>	<ul style="list-style-type: none"> <li>• Turkey Point 3,4</li> </ul>	<ul style="list-style-type: none"> <li>• Catawba 1,2</li> <li>• McGuire 1,2</li> <li>• Peach Bottom 2,3</li> <li>• Surry 1,2</li> <li>• North Anna 1,2</li> </ul>	<ul style="list-style-type: none"> <li>• St. Lucie 1,2</li> <li>• Summer</li> <li>• Crystal River 3</li> <li>• Fort Calhoun</li> </ul>	<ul style="list-style-type: none"> <li>• Robinson 2</li> <li>• Farley 1,2</li> <li>• Arkansas Nuclear One Unit 2</li> <li>• Cooper</li> </ul>



**Public opinion**

**Percentage that favour nuclear energy (%)**



Bisconti Research, Inc., 1999

*Opinions on nuclear energy*

**College graduates**

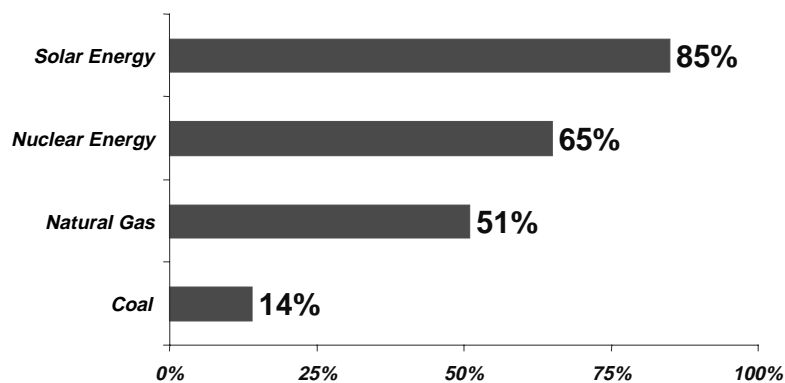
	% Agree	
	Mar 99	Feb 00
Renew licenses	87	89
Keep existing plants	74	77
Keep option to build	73	72
Definitely build more	52	57

Source: Bisconti Research, Inc., 1999

*Nuclear Energy: "Fuel of the Future" Survey*

**Survey of US college graduates and registered voters**

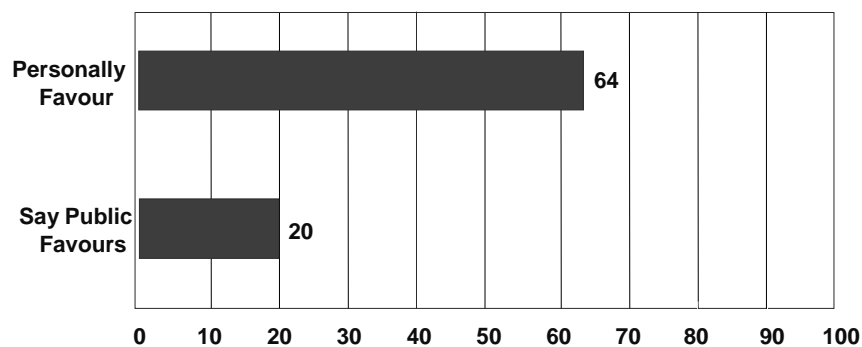
(percentage of respondents rating 6 to 10 on a 0-10 scale)



Source: Bisconti Research, Inc.

*Perception of public opinion on nuclear energy*

**College Graduates/Voters**



Source: Bisconti Research, Inc., March 1999

## **Conclusions**

- Nuclear energy has a vital role to play in satisfying global energy and environmental goals
- Existing plants well positioned for competitive electricity market
- Safe operations is always the prime objective and is fully consistent with economic and reliable operations
- Significant industry consolidation occurring
- Environmental benefits of nuclear energy becoming an important factor to policy makers
- License renewal/life extension both environmentally and economically necessary and desirable
- New plants in the U.S. and worldwide are necessary to address environmental and energy needs

## Welcome Address

**Gail H. Marcus**

Principal Deputy Director,  
Office of Nuclear Energy, Science and Technology,  
United States Department of Energy (USDOE), United States

### Nuclear energy in the U.S. – role of DOE



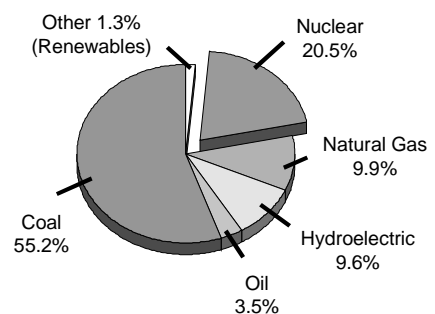
Office of Nuclear Energy,  
Science and Technology

#### Mission Statement

*To foster a secure and reliable energy system that is environmentally and economically sustainable, to be responsible stewards of Nation's nuclear weapons, to clean up our own facilities, and to support continued United States leadership in science and technology.*

- Nuclear energy is a key component of our energy mix
  - Provides 20% of our electricity
  - Avoids over 150 million metric tons of carbon emissions per year
  - Provides stability in electricity prices
- Demand for electricity is projected to increase at 1.4% per year with 300 gigawatts of new generation capacity of all types required by 2020
- National strategy to sustain nuclear energy contribution
  - Improve reliability and availability of existing nuclear power plants
  - Maintain a viable nuclear energy option for the future
- Guidance for our nuclear energy programmes
  - President's Committee of Advisors on Science and Technology (PCAST)
  - Nuclear Energy Research Advisory Committee (NERAC)

Today, 104 commercial nuclear power plants produce more than one-fifth of U.S. electricity



Source: EIA Annual Energy Outlook 2000 (excludes cogeneration)



## DOE nuclear energy programmes

- Nuclear Energy Plant Optimisation (NEPO) Programme
- Nuclear Energy Research Initiative (NERI)
- University programmes
- Accelerator Transmutation of Waste (ATW)
- International NERI (I-NERI)
- Generation IV

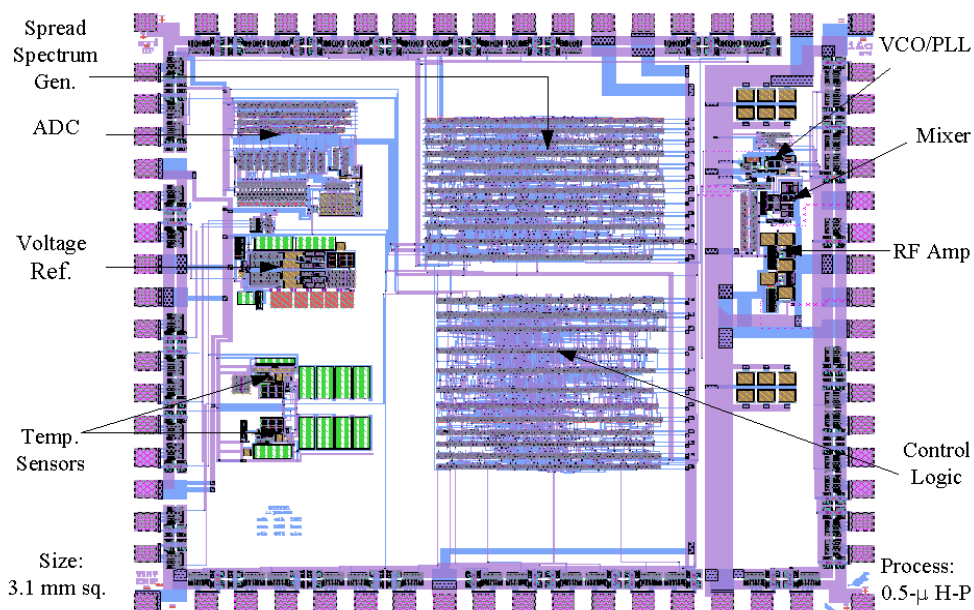
## Nuclear energy plant optimisation programme

- Plant ageing/Materials degradation
  - Advanced steam generator tube defect detection systems and repair technologies
  - Condition monitoring techniques for electrical cables
  - Research to understand, mitigate, and prevent irradiation assisted stress corrosion cracking (IASCC)
  - Management of component fatigue
- Plant efficiency and productivity improvements
  - Smart transmitter qualification
  - Criteria for upgrading to modern digital instrumentation and controls
  - Fuel performance improvement
  - Human performance indicators and corrective action plans

Figure 1. Low intensity cobalt array facility for radiation and thermal ageing



Figure 2. Wireless telesensor chip



## **Nuclear energy research initiative**

**Goal** – Sponsor new and innovative scientific and engineering R&D to address the key issues affecting the future of nuclear energy, and to preserve our nation’s nuclear science and technology infrastructure.

### **Key issues**

- Economics
- Safety
- Proliferation resistance
- Waste

### **R&D areas**

- New reactor designs including low power reactors for higher efficiency, lower cost, and enhanced safety
- Proliferation resistant reactors and fuel technology
- New technologies for management of nuclear waste
- Advanced nuclear fuel
- Fundamental nuclear science

### **University programmes**

- Support the U.S. nuclear engineering education infrastructure to meet the present and future needs of the nuclear community
  - Eight distinct grant activities that benefit universities with nuclear engineering programmes, their students and their research reactors.
  - Increased emphasis on encouraging the involvement of minority institutions and their students in nuclear engineering and science.
- University Programmes activities target schools with nuclear engineering programmes, research reactors and minority institutions with links to nuclear engineering schools.
- Utilities, other private sponsors, national laboratories and international organisations participate in some of our grant activities and programmes.

### **Nuclear energy programmes – looking towards the future**

- Accelerator transmutation of waste
  - Accelerator driven, subcritical reactor could transmute commercial spent fuel.
  - If deployed, ATW systems would reduce radiotoxicity of waste placed in the repository.
  - Technologies developed in ATW programme have potential for application in Generation IV systems.
- International nuclear energy research initiative
  - A new initiative proposed for FY 2001.
  - Will sponsor investigator initiated, bilaterally peer-reviewed innovative scientific and engineering R&D to address the key issues affecting the global future of nuclear energy.
  - Projects will be cost-shared and developed with international partners.
  - Will provide a mechanism for Generation IV R&D collaborations.

- Generation IV reactor concepts
  - New designs must remove long-term technical barriers to expansion of nuclear power.
  - In addition to technology, a regulatory approach must be developed for Generation IV.
  - DOE's focus now is to keep all options open; work with industry and international partners in developing objective attributes and metrics for Generation IV systems.
  - International co-operation for R&D co-ordination is critical to success.

## **Conclusions**

- Nuclear energy is important in the United States
  - for our energy security;
  - to comply with environmental regulations such as the Clean Air Act;
  - to meet our international commitments to limit greenhouse gas emissions.
- The DOE is conducting research and development to sustain the operation of our existing nuclear power plants and to maintain nuclear energy as a viable option for the future.
- International co-operative efforts are critical to success.

**PLENARY SESSION**

Chairperson: Dr. John J. Taylor



## **Current Status of Technology for Plant Life Management**

**Bernard Roche**  
Deputy Director  
Engineering Division – EdF France

In most developed countries of the world, deregulation of electricity markets has been established: competition is fierce, and utilities have to improve the competitiveness of their plants. It is an important challenge for nuclear power plants: a smart way to deal with this problem is life extension of existing units.

The financial stakes associated with maintaining or extending the lifetime of nuclear power stations are very high; thus, if their lifetime is shortened by about ten years, dismantling and renewal would be brought forward which would increase their costs by several tens of billions of French francs. Furthermore, every extra year of operation of a 900 MWe unit should save about 500 million French francs per year on financial charges that would be necessary for a new investment, provided that maintenance costs do not become excessive.

In order to succeed, utilities must improve their knowledge of ageing mechanisms, demonstrate to safety authorities the feasibility of life extension (especially taking into account critical components), operate existing units in an exemplary way, manage and master the long-term evolution of the safety reference state.

### **The ageing issues of critical components**

This first step will be to look at the question of the technical end of life of equipment items, which different degradation modes may bring to a state in which they no longer fulfil their required functions. The ageing of components naturally depends on the conditions in which they are operated and maintained; its impact on the NPP's lifetime depends on the difficulties raised by their replacement. The technical problems alone require to take into account design, manufacturing, operations, maintenance policy as well as R & D issues.

Some components are identified as critical in view of the difficulty or cost of their replacement or, of the extent of the repair actions that could prove necessary: the reactor vessel, the main primary large diameter pipes, the steam generators, the primary pumps, the pressurizer, the control rod mechanisms, the vessel internals, the containment, the turbine, the generator, I & C, the electrical cables, and the cooling tower. All these items have been studied and there remain the following main concerns:

#### ***The reactor vessel***

The reactor pressure vessel is one of the most difficult to replace components in the PWR main primary system. In addition, it represents a second safety barrier between the fuel cladding and the reactor containment structure. The main concern is the neutron-induced embrittlement in the core zone. This ageing phenomena does not jeopardise vessel resistance properties under normal operating

conditions, but in case of cold thermal shock, the integrity of the vessel is threatened. To assess vulnerability to brittle failure, some sophisticated fracture mechanics methods are utilised: it is possible to predict the behaviour of the vessel. In EdF reactors, the embrittlement problem has been taken into account at the fabrication stage, namely by selecting steels with low concentration of embrittlement elements such as copper or phosphorus: so the nil ductility transition reference temperature ( $RT_{NDT}$ ) of French vessels is pretty low compare to other reactors: the forecasted maximum  $RT_{NDT}$  after 40 years of service is 87°C for French CP<sub>0</sub> (Bugey, Fessenheim), 77°C for other 900 MWe reactors, 60°C for 1 300 MWe reactors and 42°C for the latest series, the N4 1 450 MWe. As an indication, for these same vessels, the increase in level of fluence between 40 and 50 years would yield a 10°C gain in transition temperature. By comparison, under the same conditions, a large proportion of the rest of the world's reactor vessels would register final  $RT_{NDT}$ s well above 100°C.

Some other countries (Russia for instance) developed some methods (thermal treatment) to deal with embrittlement and to restore the initial characteristics of the steels.

At the operating stage, it is also possible to limit the fluence on the vessel by utilising a smart low fluence fuel management. A strong monitoring programme based on removable specimens located on the internals (at positions exposed to greater neutron flux than the vessel wall itself) allows to anticipate actual trends in the vessel embrittlement.

It appears at this time, that there remain sufficient margins during a 40/50 lifetime; there is probably room for additional margins.

The vessel also contains a number of alloy 600 (inconel) areas which are susceptible to primary water stress corrosion cracking. Although the number of cracking cases is still small, it is possible to guarantee that the risk will be limited to some penetrations or units. As a result, this problem is solved by the progressive replacement of all our 54 vessel heads as soon as they are cracked. These operations, limited in terms of cost and dosimetry and without effect on the outage duration, do not however compromise the lifetime of the NPPs.

### ***Vessel internals***

The vessel internals take the form of a complex mechanical structure, the in-service behaviour of which is difficult to accurately model and predict.

The most delicate problem came after the discovery, in some French 900 MWe units, of a number of baffle bolts that were cracked in service in high-flux zones. This phenomena appeared later at Tihange and US power plants (Point Beach, Ginna, etc). An international programme involving EdF, EPRI and other partners has been launched recently. Some vendors developed methods for baffle bolt replacement. The loss of ductility due to irradiation may play a major role in the development of this phenomenon. Moreover, it cannot be ruled out that the degradation will spread to other internal components (baffles, etc). This issue is being investigated. Safety studies and a materials irradiation programme are in progress to gain insight into the in-service materials properties and to validate any substitute materials.

EdF's decision was whether it would be able to replace internals; the feasibility of such a replacement was proved and EdF purchased one 900 MWe vessel internal piece.

### ***Steam generators (SG)***

As for other utilities, some EdF steam generators have been or need to be replaced following the various degradation phenomena affecting the alloy 600 tubes. It seems that alloy 600 tubes that did not receive a special thermal treatment are more damaged than those that got benefits of this treatment. The alloy 690 has been chosen by EdF for the replacement of SG's tubes, but other utilities made the choice of alloy 800. Everything is done by EdF to ensure that a second replacement is not necessary in a unit operated for 40-50 years. The technical and industrial aspects of replacement are fully controlled (with a minimum duration of 33.5 days and maximum dosimetry of 0.60 h. SV).

This SG maintenance and replacement strategy is based on studies relying particularly upon the results of exhaustive investigations including examinations of hundreds of removed tubes.

### ***Main primary system pipes***

Cast austeno-ferritic with molybden additions grade steel (CF8-CF8M), particularly used for the primary system elbows, have proved to age at service temperature. The phenomenon, which results in a decrease in material toughness is sensitive to the chemical composition and elaboration process of the product. Moreover, these items feature foundry defects, like all castings. They were considered acceptable at plant start-up, but justification of their in-service strength has had to be confirmed owing to the decrease in operating toughness of the material.

An important R & D programme has been launched by EdF to find better ageing mechanisms; in partnership with Framatome, sophisticated mechanical calculations have been developed in addition to on-site monitoring actions to establish correlations with theoretical studies. This monitoring process will last during the entire life of the units. In order to foresee the evolution of the elbow mechanical characteristics, samples taken from the elbows have been submitted to accelerated ageing at higher temperature. The results of these studies show that the elbows (especially on cold leg) will be able to last at least 40 years.

### ***Containment***

Of all the "critical" components, the containment is the only one that cannot be replaced. Its ageing must therefore be closely followed.

In EdF reactors, we have two kinds of containment: a single wall (prestressed concrete) with a metal liner in the 900 MWe series and a double wall containment for N4 and 1 300 MWe series. For containment of the 900 MWe series, the principle is to separate the mechanical strength function performed by the prestressed concrete wall from the leak tightness function performed by the metal liner anchored to the inner surface. The result of the first construction contracts fairly quickly showed that this option made it more difficult to optimise deadlines and therefore construction costs: as a consequence, the design was modified for newer units.

For containment of 1 300 MWe series, the containment is composed of two concentric walls, the inner one (prestressed concrete) performing the confinement function and the outer one (reinforced concrete) being designed to resist external hazards.

A leak filtration system has been set up; it collects leaks in the space between containment walls kept at a negative pressure. This feature has been recognised as providing an important safety factor with regard to the radiological consequences of a design accident situation.



Like most prestressed concrete structures, the containment is subjected to the combined effects of concrete creep and relaxation of tendons over the long term. These phenomena evolve, but changes reduce with time. These two mechanisms lead to a reduction in the initially applied prestressing force.

For 900 MWe reactors, there is no particular doubt about the containment: the behaviour of all units is consistent and the second 10-year inspection of Tricastin carried out in March 1999 confirmed the good leak-tightness and results of the 1990 tests.

For the double wall containment units situation varies: due to various reasons (characteristics of aggregates, construction methods, etc.), the inner containment leakage rate of some plants is higher than the regulatory limit. Despite there is no safety problem (studies have demonstrated that reference values of radiological consequences could be respected under the accident conditions defined in the Safety Report studies for leakage rates very much higher than those defined in the regulatory limit), EdF studied means for restoring leak values respecting the regulatory limit by different ways (reinjection of concrete construction joints, partial composite liner around the equipment access hatch, repairing of identified leaks).

In order to confirm its strategy, EdF has initiated an R & D programme with the objective of validating digital simulation models for the behaviour of containments, making use of behaviour laws adjusted to represent long-term phenomena in concrete. A large mock-up (MAEVA) has also been erected for tests.

Finally, individual monitoring of structures has been considered necessary in order to achieve a life of at least 40 years for 1 300 MWe units.

### ***Instrumentation and control***

In France, I & C equipment used in nuclear units made increasingly widespread use of electronic components during development of the 900 MWe, 1 300 MWe (introduction of digital electronics) and then the 1 450 MWe series (digital electronics, computers and computerised MMI). These changes to the technology and architecture have improved the safety and availability of I & C, but have increased its sensitivity to variations in the electronic components market. The required reliability of I & C functions is achieved through the reliability of equipment within an appropriate architecture. Periodic tests verify these functions. Consequently, it is fundamental that equipment should remain reliable to ensure the safety and economy of units in the long term. If this is found impossible, it will be necessary to plan renovation of functions and the use of new equipment. The stakes are then mainly economic, since complete renovation of the instrumentation and control of a unit is estimated at several hundred million French francs.

The operational reliability of I & C equipment may be considered very satisfactory since several years although some subassemblies need to be replaced. Technically, a solution has to be found for obsolescence of electronic components, which may make it impossible to repair equipment and may make units unavailable. Industrially, one of the results of special developments carried out at the design stage of the units is that EdF is frequently the only customer for the equipment type considered.

Thus EdF organised the “durability approach”, that made a distinction between I & C system suppliers:

- manufacturers of main equipment for which 25-year life protocols have been negotiated;
- other manufacturers, for which an attempt is made to use existing maintenance structures.

Studies made in preparation for the second 10-yearly outage of 900 MWe and 1 300 MWe units were carried out after about 15 years of operation; they demonstrated that it was possible to continue maintenance for most of these equipments, at least till the third 10-yearly outage of units. Provided that functional needs are stable, preventive maintenance is optimised, obsolescence problems are anticipated by the storage of components and the necessary renovations remain limited.

### ***Generators***

Generators have been responsible for significant plant unavailability. This was due to the fact that these pieces of equipment are complicated assemblies of heterogeneous parts which are difficult to monitor and maintain. However, developing appropriate technology allows to handle these difficulties with less and less impact on production and in no case may it endanger plant lifetime.

### ***Conclusions of the ageing of critical components***

The reservations identified above may have consequences for the maintenance programmes. But on the strength of the current knowledge, it is possible to assert that no equipment problem should prevent NPPs from reaching and passing the 40-year mark. And, it appears that, for PWR units submitted to appropriate equipment operating, surveillance and maintenance conditions, a 40-50 year time span is a reasonable target. Nevertheless some vessels and containments will deserve special attention.

### **The anticipation of exceptional maintenance programme: a consequence of standardisation<sup>1</sup>**

The fact that EdF's NPPs are highly standardised makes it necessary to have advance knowledge of major degradation that could affect the main components and to determine the most robust possible long-term renovation/replacement strategies.

“Exceptional Maintenance” means all maintenance operations programmed nationally on a large number of power stations, usually carried out once during the lifetime of units and which have a significant cost and/or impact on availability. Exceptional maintenance actions (for example: the replacement of steam generators, vessel heads, rod control mechanisms, rewinding of some alternator stators) represent an annual expenditure of about FRF 1.5-2 billion, compared with systematic costs of 9 billion French francs per year for routine maintenance.

The “Anticipation of an Exceptional Maintenance” Programme consists firstly in identifying exceptional maintenance operations that could “probably” be carried out one day, and making sure that all the appropriate measures are taken to minimise the effect of their implementation on network performances. In particular, it is essential to avoid being obliged to carry out a large number of important operations in the same period of time. This programme periodically reviews design, manufacturing conditions and operating experience with the most “sensitive” components, identifies major degradations that could occur on these components, evaluates the potential consequences and suggests the most appropriate strategies to deal with the consequences in order to achieve a lifetime of at least 40 years.

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1. Revue Générale Nucléaire n° 5 – MM. Dubois, Hutin, Villemeur – “La gestion de la durée de vie des centrales nucléaires françaises”.

This is the context in which EdF has decided to initiate a “Components Replaceability” project, combined with a development programme with defined priorities in order to ensure that an industrial qualified assembly (techniques, operating methods, tools, personnel) is available for some components.

### **The “Lifetime” programme<sup>2</sup>**

Since 1987, EdF has been setting up a “Lifetime” programme in order to understand and anticipate ageing problems. This programme functions as an active “observatory” assigned to do everything necessary to achieve the expected lifetime. It regularly reviews everything that can have an impact on the lifetime of installations, considering purely technical aspects related to equipment, and industrial, economic and regulatory aspects.

The “Lifetime” programme also identifies progress necessary to improve knowledge about ageing phenomena and to support R & D actions in order to create a better link between operating conditions and maintenance conditions for components and their lifetime.

This programme distinguishes between:

- Two non-replaceable components: the reactor vessel and the containment. A summary file related to the behaviour of 900 MWe PWR vessels in service for at least 40 years is currently being investigated by the Safety Authority. In particular, this file allows for reinforcement of the irradiation resistance monitoring programme, taking account of specific characteristics of each vessel. For containments, the lifetime of at least 40 years has been globally accepted for the 900 MWe series. Containments for the 1300 MWe series must be monitored and solutions must be adapted for each individual case.
- Fully or partially replaceable components, sometimes involving expensive but well controlled operations for some components such as steam generators (already replaced on 7 units) or vessel heads (already replaced on 30 units). The corresponding actions are included in exceptional maintenance strategies with the objective of reaching a lifetime of at least 40 years in the maintenance policy.

Obviously, ambitious R & D programmes are being carried out in order to understand degradation mechanisms such as erosion, corrosion, fatigue, wear, thermal ageing, ageing under irradiation, and the dynamics of these mechanisms. Expertise programmes on real equipment have been carried out in order to confirm this work; thus an important expertise programme has been initiated on the Chooz A power plant (300 MWe) which was the first pressurised water reactor built in France and which was decommissioned in 1991 after 24 years of operation.

Furthermore, operating experience on nuclear power stations located in other countries and older than French units is monitored attentively (co-operation efforts have been organised with the operators concerned). In particular, there are about a hundred PWR nuclear units in the United States with an average age of 10 years more than the average of EdF’s units, providing a major source of operating experience about the technical life of equipment; the performances of most of these power stations are continuing to improve, which confirms the concept that there are large operating margins in the life of these units. The recent license renewal granted to Calvert Cliff units for 20 additional years (beyond the 40 years of initial license) confirms this idea.

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2. Revue Générale Nucléaire n° 5 – MM. Dubois, Hutin, Villemeur – “La gestion de la durée de vie des centrales nucléaires françaises”.

The “Lifetime” programme includes studies about the long-term future of the nuclear industry, monitoring the situation of industrial facilities that will be both “sensitive” due to the essential nature of their capabilities for EdF, and “fragile” due to the lack of any new construction for a number of years.

Based on current knowledge, 900 MWe and 1 300 MWe units should apparently be able to achieve their 40 year lifetime objectives, provided that appropriate operating, monitoring and maintenance conditions are adopted.

In this respect, it is worth noting that this objective (at least) has now been announced by other countries such as the United States, Japan, the United Kingdom and Spain. In Japan, leading operators have recently concluded that the life of PWR nuclear power stations could reach 60 years, provided that appropriate maintenance actions are carried out.

### **Mastering the evolutions of safety reference state and periodic safety reassessment**

The main duty of utilities is to run NPPs safely and economically, which is an achievable aim. The interest of extending life of existing nuclear units remains as long as their competitiveness is proven; for that reason, it is absolutely necessary to master the evolutions of the safety reference state: a major unpredictable rupture in this matter could lead to unacceptable increases in costs or to the impossibility of backfitting operations (if the modifications affect the major technical features of the original design).

In France, like in some other European countries, periodic safety review and inspection are performed on a 10-yearly basis. We call them “visites décennales” (VD). This process, agreed with the Safety Authorities, is carried out every 10 years in 3 main steps:

- Clarification of the safety requirements reference state (rules, criteria, applicable specifications, etc.).
- Evaluation of the differences between the real plant situation and the current licensing basis (the reference state), and creation of a list of essential modifications (some minor non-compliance to the reference state don’t need to be corrected from a safety point of view).
- Reassessment of the safety reference state by taking into account feedback of experience and the licensing basis of the most recent units. This stage leads to establish the backfitting programme, and requires more detailed analysis, both qualitative and quantitative, of the key solutions. Backfitting strategy begins with the determination of whether or not the regulatory provisions are needed to maintain nuclear safety. If not, a backfitting programme must be worked out on the basis of a cost-benefit balance. Both deterministic and probabilistic approaches should be properly combined to achieve a more balanced modification programme. Factors to be considered are the feasibility of implementation, costs, risks, radiation doses, radwaste, and some other aspects.

The safety re-evaluation for the two Fessenheim units and the four Bugey units, which are now the oldest in France, was carried out starting from 1987; for example, significant improvements were made in protection against fire and internal floods. In general, the safety of these units after the modifications is equivalent to the safety of the other CP1-CP2 900 MWe units. The ongoing safety reassessment of units in the CP1-CP2 series is based on previous information, the revision of safety report accident studies and the results of probabilistic safety studies. Technical modifications approved by the Safety Authorities will be carried out consistently in the second VD (VD2) for the CP1-CP2 series, the first of which has just been completed at Tricastin 1. Furthermore, these VD2 inspections

provide an opportunity to carry out a Complementary Actions Programme in order to verify assumptions made about the lack of degradation in areas not inspected within the preventive maintenance programmes. The cost of this project will be about FRF 10 billion for the thirty-four 900 MWe units. The first VD2 for the 1 300 MWe series will start in about 2005. Obviously, preparation of the third 10-year inspections (VD3) for 900 MWe units will have an important influence on their lifetime. Therefore, good preparation of this VD3 project is essential.

Utilities must also pay attention to the lessons learned from the life extension process that is carried out at this time in the USA: it seems that the utilisation of risk informed regulations leads to a lightened safety backfitting programme as a counterpart of development of individual PSA and of an intensive monitoring programme.

### **General conclusion**

Based on technical, economic and regulatory data available now, the main objective of operating existing nuclear power plants during a lifetime of at least 40 years is quite possible provided that the necessary actions continue to be implemented. This is confirmed by international operating experience.

The 10-year safety reassessment process, and the “Lifetime” and the “Anticipation of Exceptional Maintenance” programmes, will help to prepare decisions to be made to achieve this objective.

It is also very important to master the evolutions of the safety reference state.

# Current and Future Technologies for Plant Life Management

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## Abstract

It is approximately 30 years since the first commercial light-water reactor went into operation in Japan. The number of plants with operation experience of more than 30 years will be 18 during the next decade. As adequate maintenance or replacement has been implemented based on the results of annual inspections, troubles do not increase in line with plant ageing in Japan. To ensure safe and reliable operation of aged plants, however, the Ministry of International Trade and Industry (MITI) and three electric utilities started the plant life management study (the PLIM study) in 1994 and evaluated the integrity of major plant components assuming 60-year operation. As a result of the study, they compiled additional maintenance programmes for long-term operation in February 1999. In this study, the following ageing degradation phenomena and their countermeasures were discussed: stress corrosion cracking (SCC) of stainless steel and nickel based alloy components; reactor pressure vessel embrittlement; erosion-corrosion of carbon steel components; thermal fatigue; ageing of electric cables, etc. On the other hand, Japanese electric utilities have been engaged in developing repair and preventive maintenance technologies against the above mentioned ageing phenomena and have applied them to their plants. This paper briefly introduces some of these PLIM technologies mainly related to Japanese BWR plants.

## PLIM technologies in Japanese BWR

### *Countermeasures for SCC (Stress Corrosion Cracking)*

SCC found in stainless steel and nickel based alloy is one of the most important issues for BWR owners to operate their plants for a long time. Many countermeasures for SCC have been developed and applied to the plants.

### *Countermeasures for SCC in the 1970s*

In the 1970s, IGSCC (Inter Granular Stress Corrosion Cracking) was found in weld Heat Affected Zone (HAZ) of the stainless steel pipes such as Primary Loop Recirculation system (PLR). As a result, the capacity factor of BWR plants in Japan hovered around 20 to 50% (Figure 1). Some countermeasures for IGSCC from the standpoints of material, reduction of residual stress, and improvement of water chemistry were implemented.

The countermeasure from a standpoint of material was to replace stainless steel pipes with carbon steel pipes. We adopted IHSI (Induction Heating Stress Improvement) as the countermeasure to reduce residual stress. IHSI is the method to turn tensile stress in the HAZ of pipes into compressive stress by using thermal stress generating from the difference of temperature between the outer surface heated by a high frequency induction solenoid and the inner surface cooled by water (Figure 2). From a standpoint of water chemistry, the dissolved oxygen content of feed water that increases the sensitivity of stainless steel to SCC is lowered and maintained to the level of 0.2 ppm before plant start-up.

*Countermeasures for IGSCC of Reactor Internals*

IGSCC is a phenomenon in which the lack of chromium appears in some area of material by chromium carbide gathering between the grains. This phenomenon is enhanced under high carbon content of material. Stainless steel with low carbon content such as SUS304L, SUS316L which contains 0.02% carbon or less has been applied to the material of reactor internals manufactured since around 1980 (Figure 3).

Nickel base alloy (alloy 600) is the main material of the shroud support of BWR. Japanese BWR owners and domestic manufacturers jointly developed nickel base alloy with improved anti-SCC properties by adding 2~3% niobium, which has been applied to some plants since around 1990.

At the same time improved Inconel 182 or Inconel 82, both of which have better properties against SCC than Inconel 182 by increasing the content of niobium, have been applied as the welding material.

Knowledgeable and experienced persons, BWR owners, and manufacturers in Japan have been making the guideline about inspection and maintenance for reactor internals such as the shroud support under TENPES (Thermal and

Figure 1. Capacity factor of Japanese BWR plants

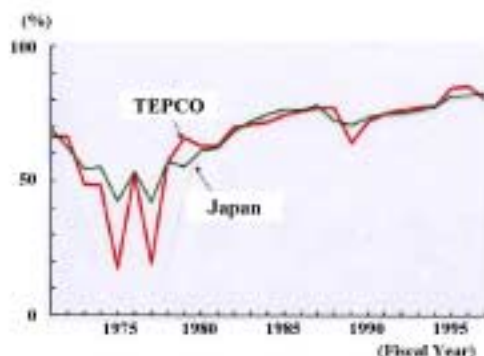


Figure 2. IHSI method

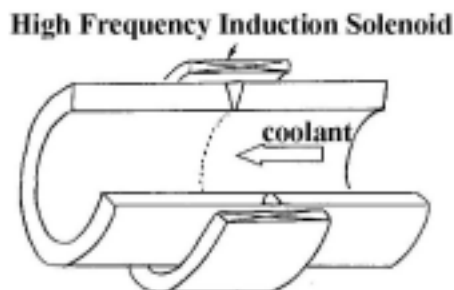
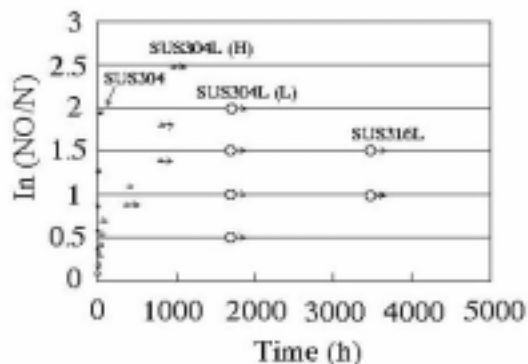


Figure 3. Comparison of failure time of stainless steels by UCL (3.5 Sm with crevice)



C content: SUS304≤0.08, SUS304L (H)≤0.03 SUS304L(L), SUS316L≤0.02 288°, 8ppmO<sub>2</sub>, 50ppmH<sub>2</sub>O<sub>2</sub>, 0.06μS/cm, ECP250mV, 620°C × 24hrs heat treatment

Nuclear Power Engineering Society) after cracks in Inconel 182 welding between the shroud support and RPV were found in a BWR plant in Japan in 1999 (the root cause study on the cracks is also underway). It is reasonable to continue operation of the plants after evaluating crack propagation with some conservatism by using the data obtained from the studies by utilities and some organisations. This concept will take into account the guideline which will be applied to the operating plant for the first time in Japan.

*The core shroud replacement project (the CSR project)<sup>(1)</sup>*

The CSR projects are underway at Fukushima Daiichi Units 1,2,3, and 5 (1F-1,2,3, and 5), Tsuruga Unit-1 (T-1) and Shimane Unit-1 (S-1) that have core shrouds made of SUS304. The purpose of these projects is to replace core shroud and other components made of SUS304 with those made of SUS316L as preventive maintenance. 1F-3 and 2 finished their replacements in 1998 and 1999 respectively and are now operating. The projects of 1F-5 and T-1 are underway, and those of 1F-1 and S-1 will start this year.

The project was triggered by the IGSCC found in many cases of core shroud cracking in the world including 1F-2. Japanese BWR owners conducted the joint study on the method of replacement of the core shroud with the BWR manufacturers. The developed method was confirmed through demonstration tests by the Japanese Government (MITI), and was applied to weld-type core shroud in 1F-3 for the first time in the world.

Jet pumps, top guides, core plates, core spray pipes and so on, all of which are made of SUS304, have also been replaced with those made of SUS316L (Figure 4). Outline of the replacement sequence is as follows (Figure 5):

- i) Remove fuels and core components
- ii) Chemical decontamination
- iii) Remove upper part of core shroud, feed water spargers and top guide
- iv) Remove lower part of core shroud, core plate, ICM guide tubes and DP/LC Pipe
- v) Remove jet pumps
- vi) Install new jet pumps
- vii) Install a new core shroud
- viii) Install DP/LC pipe, ICM guide tubes, core plate, top guide and feed water spargers
- ix) Restore fuels

Figure 4. Scope of the CSR

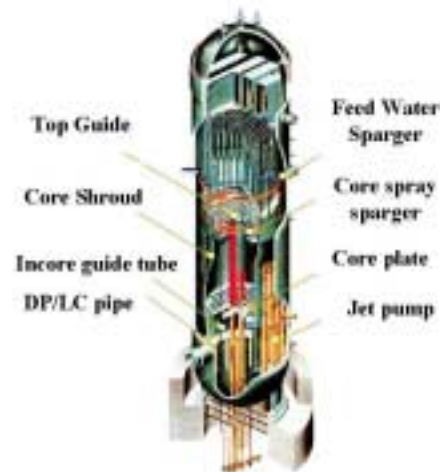
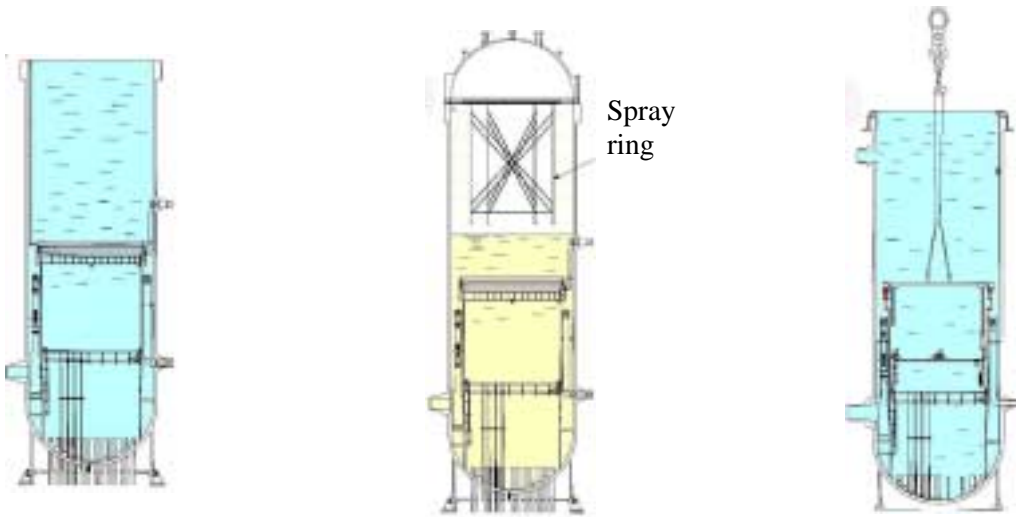




Figure 5. Core shroud replacement sequence



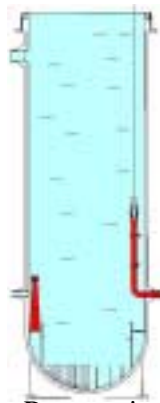
Remove fuels and core components

Chemical decontamination

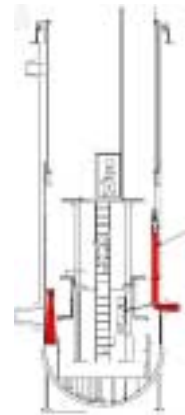
Remove upper part of core shroud, feed water spargers and top guide



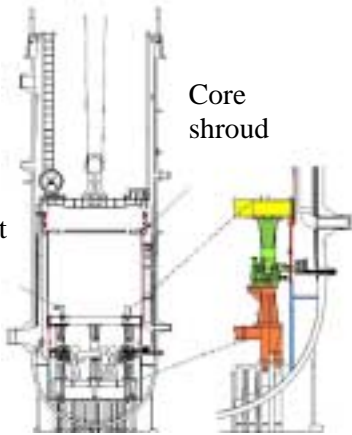
Remove lower part of core shroud, core plate, ICM guide tubes, DC/LP pipe



Remove jet pumps



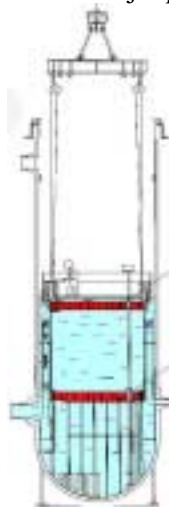
Install jet pumps



Alignment tool

Core shroud

Install core shroud



Top guide

Core plate

Install DP/LC pipe, ICM guide tubes, core plate, top guide and feed water spargers



Restore fuels

The most critical issue in the planning phase was how to create an environment for workers to enter the RPV from the viewpoint of radiation protection. We achieved the dose rate of about 0.2 mSv/h at the bottom of the RPV which is the main work place using a chemical decontamination called CORD method and through the use of exclusively used shielding plates made of lead coated with stainless steel installed on the wall of the RPV (Figure 6). Total dose was about 8 personSv for the replacement (1F-2).

The old core shroud is divided into 2 parts by the cutting tools prior to transporting to Dryer/Separator pit (DSP) where they are then sliced into small pieces by slicing tools to keep them in the exclusively used containers. In 1F-2 and 5, the upper and lower part of core shroud were cut by the roll cutter (Figure 7) and EDM (Electric Discharge Machining) cutting machine (Figure 8) respectively.

The roll cutter cuts the structure mechanically by rotating itself and has merits of no emission of radioactive gases. But it is difficult to cut lower part of core shroud by it because it makes plastic deformation on the cut surface of the shroud support to be later welded with a new core shroud. Furthermore EDM also emits little radioactive gases because of almost no radioactivated structure.

In 1F-2 and 5, UHP-AWJ (Ultra High Pressure-Abrasive Water Jet) was adopted as a slicing tool (Figure 9). UHP-AWJ cut the removed reactor internals mechanically (generating little radioactive gases) by blowing high pressurised water mixed with iron abrasive of approximately 0.2 mm in diameter into the components.

A new core shroud was installed into the finished surface of the shroud support with a butt weld by the automated remote welders (for the outer side and the inner side) newly developed for reduction of dose. Since the clearance between new jet pumps installed before and the core shroud was about 70 mm, the wire reel of the welder was eliminated, and the wire was placed on the fitting of the core shroud (Figure 10).

*The replacement method of Incore Monitor Housing (ICMH)*

Figure 6. Dose rate in the CSR project

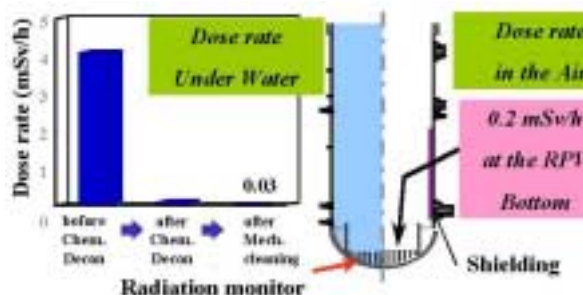


Figure 7. Roll cutter

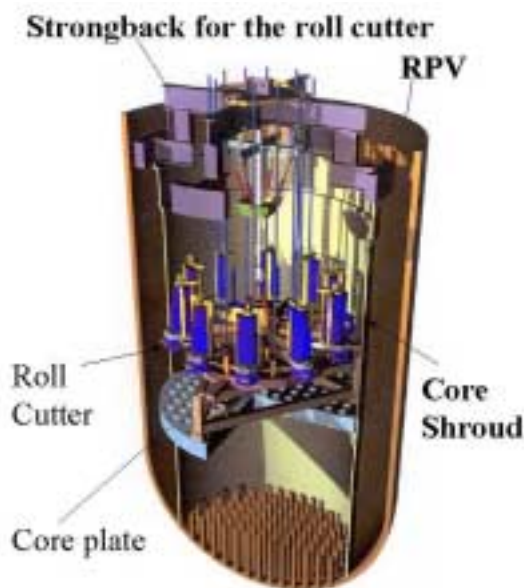


Figure 8. EDM cutting machine

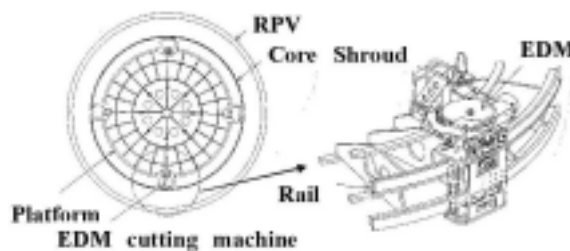


Figure 9. The UHP-AWJ

We introduced the replacement method of ICMH to 1F-4. Figure 11 shows the replacement sequence and the features are as follows:

- Stress relief is not required because heat input by the welding shown in STEP 5 was confirmed to be sufficiently small for low alloy steel of the RPV due to shielding effect of the inner surface made of Inconel.
- J groove for welding between ICMH and a new stub shown in STEP 9 is designed to be axially symmetrical to install it easier, compared with 3D shape in the original.
- ICM guide tube is attached to ICMH by SMA (Shape Memory Alloy) for easier installation.

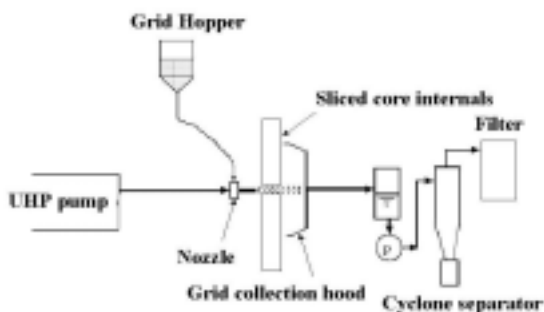
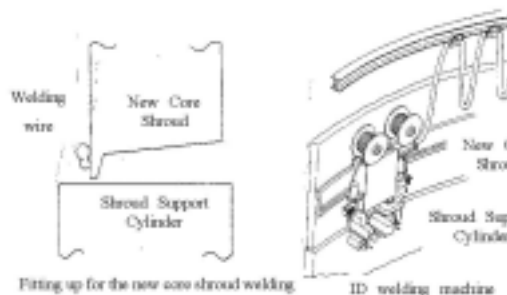


Figure 10. New core shroud welding

*Preventive maintenance for ICMH*

Laser surface cladding and TIG cladding welding process has been adopted to all units in 1F except 1F-6 as a preventive maintenance, which is the cladding on the HAZ of inner surface of ICMH to the RPV to prevent the HAZ from being exposed to reactor coolant.



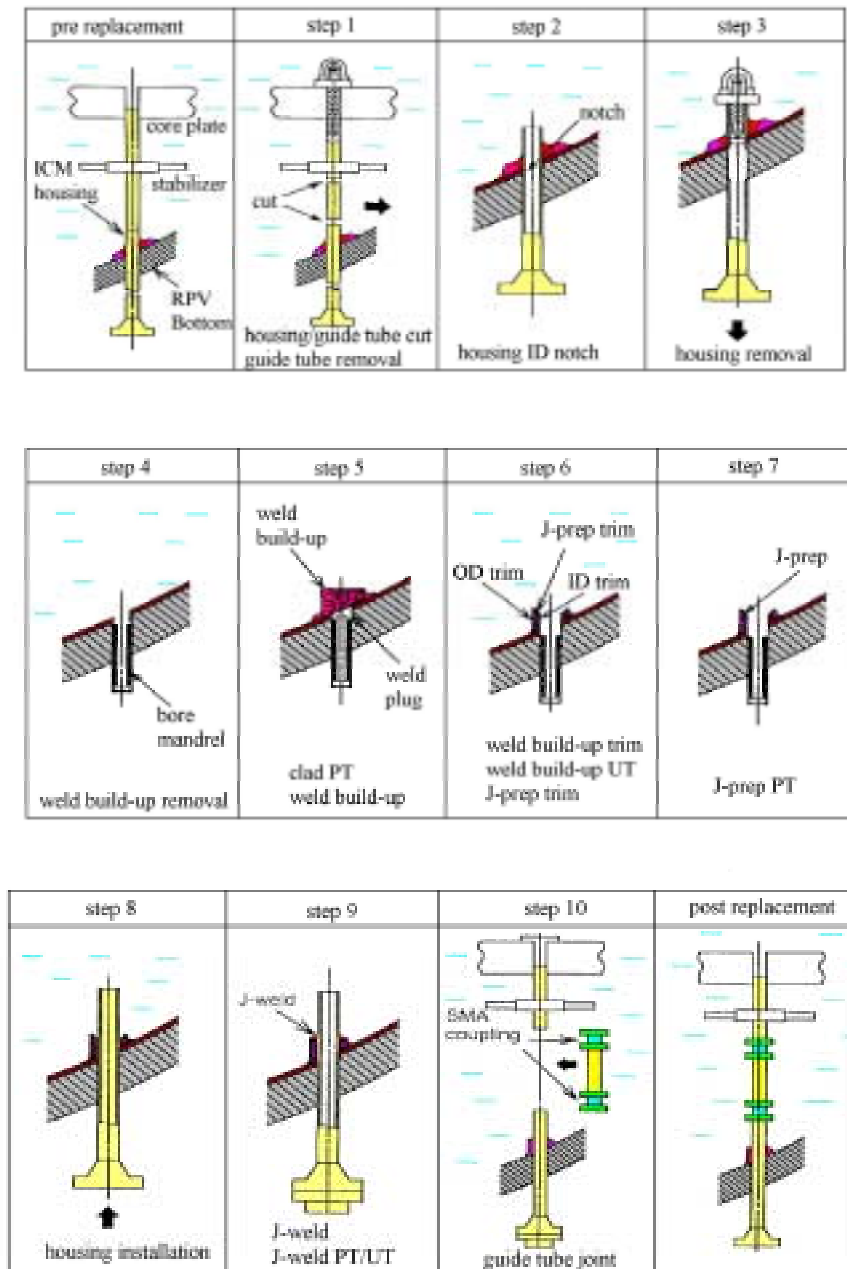
*Hydrogen water chemistry (HWC)*

The lower Electro-Chemical Potential (ECP) reduces the sensitivity to SCC. Japanese BWR owners have adopted HWC to lower the ECP of reactor internals (Table1).

Table 1. HWC experience in Japan

Plant name	Reactor type	Status	Remarks
T-1	BWR2	acting	
S-1	BWR3	acting	
1F-1	BWR3	acting	
Hamaoka-1	BWR4	acting	NMC test addition in 2000
Hamaoka-2	BWR4	acting	NMC test addition in 2000
1F-2	BWR4	acting	
1F-3	BWR4	acting	
1F-4	BWR4	acting	
1F-5	BWR4	acting	
Tokai-2	BWR5	acting	
1F-6	BWR5	acting	
2F-3	BWR5	acting	NMC test addition in 2001
KK-7	ABWR	Test injection	

Figure 11. ICMH replacement sequence<sup>(2)</sup>



Targeting one order reduction of the crack growth rate of materials in the lower plenum by HWC, Japanese BWR utilities have been studying the effect of HWC on lowering ECP using both actual data of their plants and analytical approach.

The effect of HWC in some locations, such as the bottom of shroud support legs, core shroud H3 welding and so on, are being studied quantitatively with numerical analysis for each type of reactor.

### *Noble Metal Chemical Addition (NMCA)*

Noble metal such as platinum or rhodium stuck on the surface of structures increases the hydrogen anode current, resulting in a decrease of ECP. So, with NMCA, a smaller amount of hydrogen injection enables ECP to be lowered to the expected level.

The first application of NMCA to an actual plant was at Duane Arnold in U.S. in the BWR/VIP programme. We participated in this programme, and have received the data about the effectiveness, and influences on the plant parameters. We have made a plan to confirm the effectiveness and influences by NMC test addition to 2F-3 in 2001.

### *Irradiation assisted SCC (IASCC)*

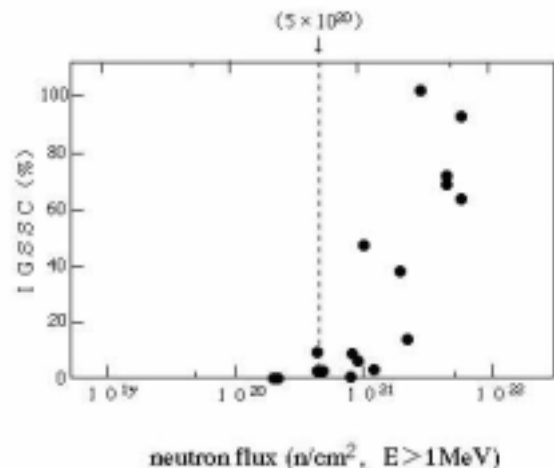
There are examples of IASCC in control rods, ICM tube and so on in BWR. Considering long-life operation of plants, possibility of IASCC in core shroud, top guide or core plate cannot be denied because the neutron fluence of these components ( $E > 1\text{MeV}$ ) will reach approximately  $3\text{E}21 \text{ n/cm}^2$ ,  $2\text{E}22 \text{ n/cm}^2$ ,  $1\text{E}21 \text{ n/cm}^2$ , respectively, and the threshold of the IASCC in SUS304 is considered to be approximately  $5\text{E}21 \text{ n/cm}^2$  (Figure 12).

We have obtained the data on relationship between neutron fluence and IASCC initiation, and the IASCC mechanism through irradiation tests in MIT reactor and Kashiwazaki-Kariwa Unit 5. These tests are carried out for the purpose of prompt evaluation of PLIM or cracked reactor internals after use for a long time. One of the data from this study has revealed the correlation between phosphorus content in SUS316L and its sensitivity to IASCC. Judging from the data, we adopted SUS316L with 0.03% phosphorus or less to new shrouds and new top guides in 1F.

### *Reconstitution technique of RPV surveillance test piece*

In the PLIM evaluation for 1F-1(BWR) carried out by TEPCO and reviewed by the authority, which opened to the public in February 1999, the reference temperature of nil-ductility transition (RTNDT) and upper shelf energy (USE) after 60 years operation were predicted according to the method defined in JEAC4201-1991. The evaluation concluded that embrittlement of RPVs will not be an issue even after the long-operation period (Table 2). On the other hand, the lack of surveillance test pieces in number may become a problem considering long-term operation. So the development of reconstitution technique of RPV surveillance test pieces has been carried out by Japan Power Engineering and Inspection Corporation (JAPEIC) under the support of MITI since 1996. This project under the support of MITI will continue to 2005.

Figure 12. IASCC sensitivity of SUS304 by irradiation<sup>(3)</sup>



Sharp test pieces will be reconstituted by SAJ (Surface Activated Joining) so that the HAZ by SAJ does not interfere with the projected plastic area (Figure 13). SAJ is the technique which connects activated surfaces by heat after removing the oxidised layer or contamination in vacuum, and is expected to satisfy the requirement for reconstituted test pieces because of its thin HAZ (approximately 2mm).

Table 2. The Prediction of RTNDT and USE for 1F-1

Period	RTNDT (°C)			Minimum operation temperature
	Base metal	Weld metal	HAZ	
The end of 1994	7.0	-0.2	-0.8	44.0°C
60 years after turnover	12.3	13.7	8.3	50.7°C

Period	USE (J)		
	Base metal	Weld metal	HAZ
The end of 1994	94	131	124
60 years after turnover	91	129	120

This reconstitution technique will be established through the 3 steps as follows:

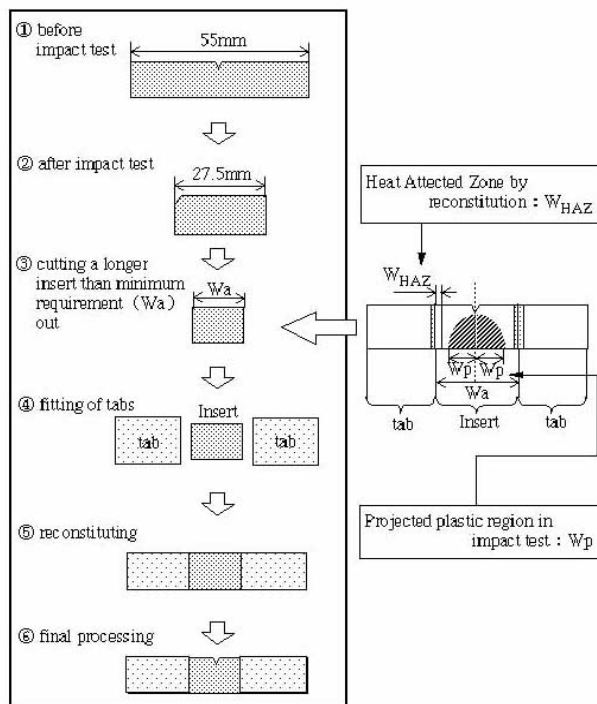
- i) Base test using non-irradiated specimen, to confirm that test pieces reconstituted by SAJ satisfy the requirement that the HAZ by SAJ should not interfere with the projected plastic area.
- ii) Confirmation test using non-irradiated specimen, to confirm the validity of remote operation in a hot laboratory for reconstituting test pieces and performing impact tests.
- iii) Confirmation test using original test pieces (without reconstitution), to confirm the properties of reconstituted test pieces by comparing with non-irradiated specimen.

### *Erosion and corrosion in pipes made of carbon steel*

Carbon steel is one of the main materials used in pipes and BOP equipment, whose typical mode of degradation is erosion or corrosion. Pipes, heaters, and main turbine inner casings made of carbon steel which were severely eroded or corroded have been replaced with those of low alloy steel.

Because the number of the measured and recorded points of their thickness rises up to tens of thousands, one of the important things in the management of erosion and corrosion is therefore how to

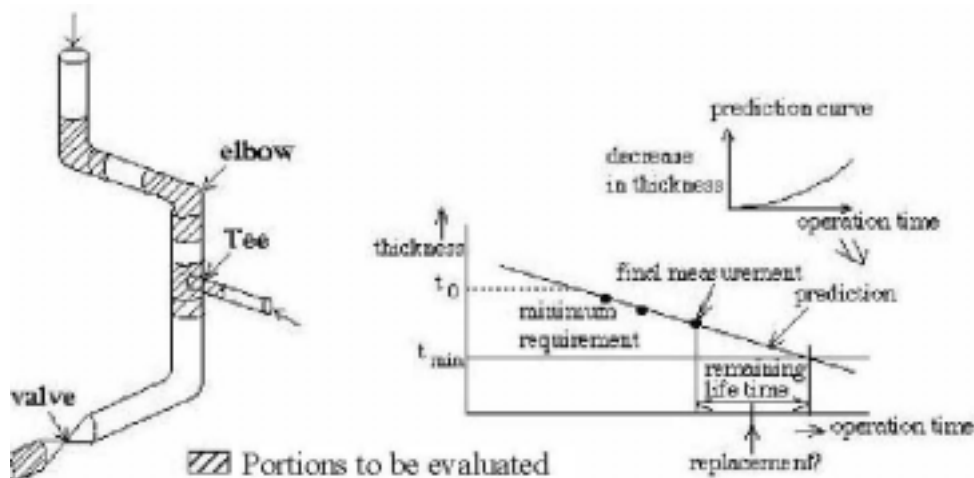
Figure 13. Reconstitution sequence<sup>(4)</sup>



plan the inspection points and prediction intervals effectively using accurate methods. We must measure the thickness with shorter intervals, at much more points without a decrease in good prediction about the tendency of thickness, which is affected by material, configuration, velocity and temperature of the fluid, dissolved oxygen content and so on. In order to rationalise the management of pipe wall thickness and to improve its reliability, we have begun developing the prediction method based on the data measured in our plants. The method will employ statistical analyses of the data categorised by influence factors (Figure 14).

There is no regulation or manual to manage thickness of pipes at present, which is maintained above minimum thickness calculated by design by all means. The method with high accuracy will be very useful together with an appropriate manual in future.

Figure 14. **Prediction of decrease in pipe wall thickness**



### ***Welding technique to irradiated structure***

Irradiated reactor internals contain helium in their structure generated by the reaction of boron with neutrons. When welding the structures for replacement or maintenance, welding heat makes helium gather at the grain boundaries, and it forms bubble causing cracks by thermal stress when shrinking.

We have obtained the correlation among density of helium in the material, input of heat, and potential of crack from both welding tests of the irradiated control rod handles and the mechanical tests of irradiated welding plates. It has been concluded through these tests that there will be no crack when stainless steel with less than 0.14 appm helium is welded under welding heat input of less than 20kJ/cm. After the investigation of the stainless steel of the jet pump riser pads of 1F plants to confirm that boron content was much lower than the critical level, new jet pumps were welded to the pads in the course of the CSR projects.

### ***RVR (Reactor Vessel Replacement) technique***

We have been studying RVR technique as a preventive countermeasure for many kinds of problems in RPV and reactor internals. In RVR, an old RPV, together with old reactor internals is replaced by a new one. We have confirmed that the technique is basically feasible.

Main features of the technique are as follows (Figure 15).

- The large crawler crane (1 200 tons) carries an old RPV together with its internals out from the reactor building.
- Concrete is filled up to the lower plenum of the RPV, and temporary iron shielding is installed over the top guide and around the RPV for radiation protection.
- The old RPV will be stored in an underground pit.

RVR to 800 MWe class plants takes approximately 210 days with 6 personSv, compared with approximately 330 days with 8 personSv in the CSR project. The direct cost in RVR is estimated to be 1.5 times higher than that in the CSR project. However the shorter construction period of RVR can compensate for the difference from a standpoint of loss of electric generation loss.

The replacement of steam generator (SG) in Ikata Unit-1 of Shikoku Electric Power Company (PWR plant) in 1998 was very useful for our RVR study. They carried the old SG out from the containment vessel by a large crawler crane.

### ***Ageing of electric cables***

Electric cables ranging from 1 000 to 2 000 km in length are used in a nuclear power plant. It is important to maintain their insulation for safety operation of the plant. However the insulation of cables is degraded by thermal influence or radiation. So, the technique to evaluate ageing of cables is required and its development is being planned by MITI.

### ***Environmental effects on fatigue evaluation***

Fatigue evaluation considering environment effects were carried out in the PLIM study for RPV and reactor internals of the three oldest plants in Japan (T-1, Mihama Unit-1 and 1F-1). The cumulative usage factors (CUF) for 60-year operation were calculated based on Higuchi-Iida formula for low alloy steel and NUREG/CR-6260 for stainless steel, and carbon steel. CUFs of 1F-1 are shown in Table 3. It is concluded that environmental effects on the fatigue evaluation will not be a significant issue for 60-year operation.

Figure 15. Reactor vessel replacement

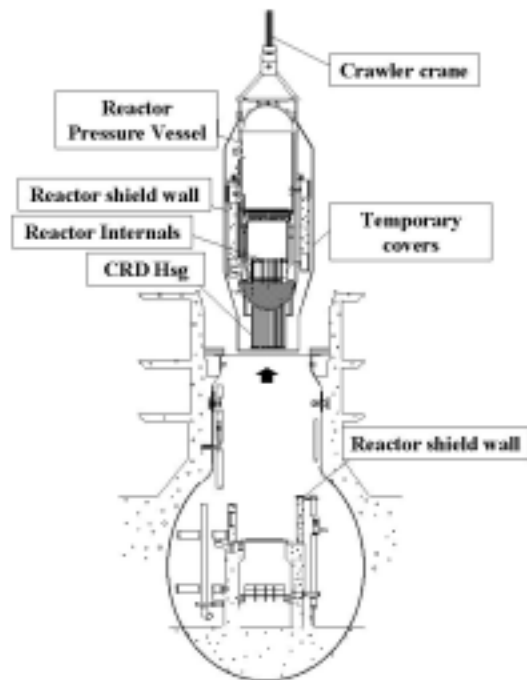




Table 3. Cumulative usage factors

RPV feed water nozzle (low steel alloy)	Shroud (stainless steel)	Feed water piping (carbon steel)
0.031	0.001	0.219

JAPEIC has carried out experimental studies on the environmental effects under the support of MITI since 1994.

## Conclusion

We have promoted the development of techniques for PLIM, and these techniques have contributed to improving the reliability of the nuclear power plants. We have obtained the results from the PLIM study that the ageing plants can operate safely for 60 years by conducting appropriate inspection and maintenance.

Since nuclear power plays an important role in electricity supply now and also in the future, utilities must continue to develop techniques contributing stable and long-term operation of nuclear power plants.

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# **License Renewal in the United States – Enhancing the Process through Lessons Learned**

**Douglas J. Walters**

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## **Enhancing the process through lessons learned**

The Nuclear Energy Institute (NEI) is the Washington based policy organisation representing the broad and varied interests of the diverse nuclear energy industry. It comprises nearly 300 corporate members in 15 countries with a budget last year of about USD 26.5 million. It has been working for 10 years with the Nuclear Regulatory Commission (NRC), colleagues in the industry and others to demonstrate that license renewal is a safe and workable process. The first renewed license was issued on 24 March to BGE for the the Calvert Cliffs plant. One month later the NRC issued the renewed license for the Oconeplant.

## **Overview**

By “Enhancing the process through lessons learned”, we mean reducing the uncertainty in the license renewal process. This is achieved through lessons learned from the net wave of applicants and the reviews of the Calvert Cliffs and Ocoenne applications. Three areas will be covered:

- Incentive for minimising uncertainty as industry interest in license renewal is growing dramatically.
- Rigorous reviews by Nuclear Regulatory Commission assure continued safety: process put in place by the Nuclear Regulatory Commission to assure safety throughout the license renewal term, specifically areas where the lessons learned suggest improvements can be made.
- Lessons learned have identified enhancements to the process: numerous benefits associated with renewal of nuclear power plant licenses for consumers of electricity, the environment, the nuclear operating companies and the nation.

## **Company and national benefits of license renewal**

- Extends the life of a valuable generating asset with significant earnings potential
- Improves company’s competitive position
- Enhances workforce stability: easier to retain and attract talented employees
- Renews confidence in nuclear energy in the United States
- Lowest-cost source of new electricity supply available

At the end of their initial 40-year licenses, nuclear power plants will be fully depreciated, or very nearly so. In a competitive market, not subject to cost-of-service, rate-of-return regulation, a productive asset with little or no embedded capital is highly desirable and has significant earnings potential. In economic terms, it is estimated that the nuclear units will be able to outperform most other sources of electricity, particularly as coal-fired generation is required to meet increasingly stringent environmental requirements, and this economic edge will help to retain the customer base and remain competitive.

Other benefits to the company: an additional 20 years of plant life has made it easier to retain and attract the skilled and dedicated employees that are essential to a successful nuclear power operation.

National benefits are also measured. License renewal represents a vote of confidence in the future of nuclear energy in the United States, and the country will need its existing nuclear capacity – and will need to build more – if it hopes to meet its commitments under the Clean Air Act and under international protocols designed to mitigate growth in greenhouse gas emissions.

License renewal is a benefit to consumers because it provides the lowest cost source of new electricity supply available anywhere from any energy source.

The cost of license renewal is estimated at approximately \$11 per kilowatt installed which is impossible to beat. The least costly source of new baseload power gas-fired combined cycle capacity comes in at between \$350-400 per kilowatt installed.

Industry experience has revealed that a well-run nuclear power plant can produce electricity at between 2 and 2.5 cents per kilowatt-hour. That is a total going-forward cost and includes everything – fuel, operating and maintenance costs, decommissioning charges, the nuclear waste fee, G&A expenses, property tax, ongoing capital requirements.

A gas-fired combined cycle plant produces electricity at between 3 and 3.5 cents per kilowatt-hour, assuming a capital cost of \$350-400 per kilowatt and a gas price of approximately \$2 per million Btu.

So the conclusion is clear. A new gas-fired capacity to meet new load may be built, but it does not make economic sense to build new gas-fired capacity to replace existing nuclear capacity or as an alternative to license renewal of an existing nuclear power plant.



Three more units have filed their applications since then, and more than 20 more have formally indicated to NRC that they intend to seek license renewal over the next few years. You can see the names here. They represent approximately one-quarter of the US fleet of 103 units.

It is expected that virtually all U.S. nuclear plants will renew their licenses partly because these plants have significant earnings potential, and partly because it is dramatically less costly to renew the license of a nuclear plant than to build replacement capacity of any kind.

## **Overview of the regulations**

- Nuclear power plants licensed for 40 years; Atomic Energy Act allows license renewal.
- Initial 40-year license term has no safety, technical significance.
- NRC has rigorous, credible regulations in place to assure safety through renewal term:
  - Part 54: Technical requirements for renewal;
  - Part 51: Environmental review for renewal.

Nuclear power plants in the United States are licensed to operate for 40 years. The existing law – the Atomic Energy Act of 1954 – permits nuclear power plants to renew their 40-year operating licenses.

The 40-year license term was selected because 40 years was a typical amortization period for an electric power plant. The 40-year license term was not based on safety, technical or environmental factors and can be renewed for up to 20 additional years.

For the NRC, a license renewal review must answer one basic question: Can the plant continue to operate safely in the renewal period?

On June 7, 1995, the NRC implemented its license renewal rule, which focuses on managing the effects of ageing on the plant, something a company does from the time a nuclear plant starts operating, through extensive maintenance and inspection activities.

Under the rule, the NRC also recognised and gave credit for existing plant programs in inspection and maintenance. To obtain a renewed license, a company must demonstrate to the NRC that it can manage ageing effects adequately during the renewal term. While some nuclear power plant components are replaced on fixed schedules, others are used until they wear out, and then replaced. The situation is somewhat different for components that were designed to last the life of the plant and might never be replaced. License renewal reviews will focus on these “passive,” long-lived components that are important to safety: for example, the massive concrete containment building that surrounds the steel vessel holding the plant’s fuel, and the vessel itself.

## **License renewal: key steps in the review process**

There are four key steps in the NRC’s license renewal process before the Commission will issue a renewal:

- A technical or plant ageing evaluation must demonstrate that plant ageing will be managed.
- An environmental review must find that continued operations will not unreasonably impact the environment.

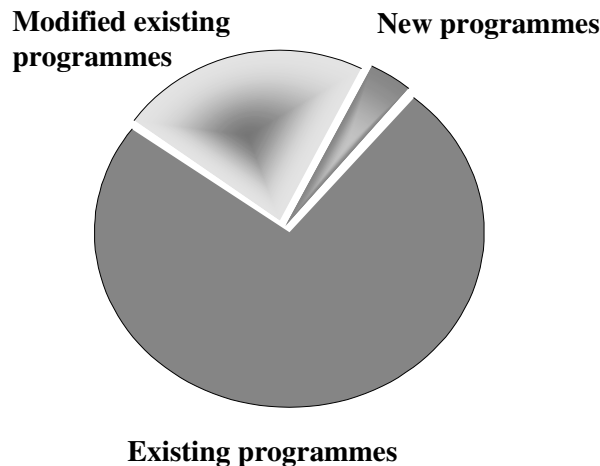
- NRC plant inspections must verify technical assertions, ageing management activities and plant condition.
- The NRC's Advisory Committee on Reactor Safeguards (ACRS) must provide an independent review of the application.

**License renewal: lessons learned**

To summarise, the lessons learned from going through this process at Calvert Cliffs, are the following:

- No ageing effects unique to license renewal.
- Current inspection activity on site, with some additions, will ensure that ageing is managed cost-effectively.
- Effective communication with all stakeholders – members of the local community, employees, state and federal legislators, and the financial community – is essential. Throughout this process, extremely strong and unequivocal local support for the license renewal efforts have been noted, possibly because of vigorous outreach. The Calvert Cliffs plant is a good neighbour and, like most of the nuclear power plants in the United States, it is an anchor for the local communities – providing jobs and, indirectly, through payment of taxes, support for local services and infrastructure.
- Finally, the future cost of license renewal, and the time required to do the planning, prepare the application and negotiate the NRC process, can be reduced significantly. NEI's effort took 10 years, start to finish, and cost about \$20 million. Future efforts can be reduced to \$10-15 million and take about 5 years, of which 2 to 2½ years is for NRC review of the application.

At Calvert Cliffs, it was found that 96% of the required ageing management programmes already existed. Of that 96%: ¾ of them (existing programmes) required no modification; ¼ of them (modified existing programmes) needed some enhancement.



Most of the ageing management activities fall into the categories of preventive maintenance and additional surveillance tests.

- Severe accident mitigation alternatives analysis did not find any cost beneficial alternatives related to ageing management.
- The underlying assumption in the GEIS is not representative of actual plant operation.

### ***Enhancing the process***

- Understand past plant performance.
- Develop ageing discovery techniques and confirm.
- Put ageing mitigation measures in place.
- Use corrective actions and follow-up.
- Implement license renewal activities in existing plant procedures.
- Generic ageing lessons learned report.
- License renewal standard review plan.
- NEI 95-10.
- Severe accident mitigation alternatives rulemaking.

### **Conclusion**

License renewal provides benefits for consumers, the environment, companies and the nation.



# **Competitive Nuclear Production on the Nordic Deregulated Electricity Market**

**Torsten Bohl**

Public Relations Manager, Ringhals AB, Sweden

## **The company group Vattenfall**

The Vattenfall Company group is one of the largest energy companies in Europe, accounting for 25% of the total electricity sales in the Nordic region. The total electricity generation is 85 TWh/year. Vattenfall is a leading operator of regional and local distribution networks serving 1.1 million customers. The company owns seven nuclear reactors. Ringhals AB is a daughter company of Vattenfall with four reactors and a yearly production of 25 TWh.

## **The deregulated Nordic electricity market**

The Nordic electricity market has been partly deregulated since 1994. Today only Denmark follows the timetable recommended by the European Union, while Sweden, Norway and Finland are completely deregulated. As in most countries, the production of electricity is deregulated while the distribution is still a monopoly.

Approximately 30% of the production in the Nordic countries is sold on the common electricity exchange, NordPool, in Oslo. The competition on the market is extremely hard because there is a 10 to 15% overcapacity. This is due to low demand depending on mild winters and a number of years with very much precipitation. The difference in hydroelectric production between a dry year and a year with much precipitation is more than 60 TWh. The total consumption on the Nordic market is 370 TWh.

Overcapacity has caused the prices to be extremely low for the last three years. The mean price on the NordPool exchange was 11.9 öre/kWh for 1999, which is approximately 14.2 milli euros. The future prices on the exchange continue to be extremely low. Today it is possible to buy electricity for the year 2003 for 14 öre/kWh which is 16.6 milli euros. This price press has caused a completely new situation for the operation and plant life management of the nuclear power plants in the Nordic countries.

## **Nuclear power production in the Nordic countries**

Today there are in total six nuclear sites with 15 operating reactors in Sweden and Finland. On the 30<sup>th</sup> November 1999 one of the two reactors at Barsebäck nuclear power plant, Barsebäck 1 was closed because the government withdrew the operating license for that reactor.



The 1999 nuclear production in the Nordic countries was 92 TWh, which is a little bit more than 25% of the total electricity production. The overall results were good with low costs, high availability and few technical problems. In Sweden nuclear power covered 47% of the total consumption despite the close down of Barsebäck 1. Ringhals AB had its best year ever with high production, high availability and low costs. The three PWRs at Ringhals all had availability figures above 90%, with the 25-year-old Ringhals 2 leading at 92.2%.

This was a very good start for the new company, Ringhals AB, which was formed in the beginning of 1999. Before that Ringhals was part of the Vattenfall AB mother organisation. All shares in Ringhals AB are still owned by Vattenfall.

The total cost for nuclear power production in the Nordic countries was between 17 and 22 öre/kWh (20-26 milli euros). Ringhals was the most competitive nuclear power plant with a total cost of 16.7 öre/kWh (19.9 milli euros) including taxes and funding for waste and decommissioning costs. Since the market price was 11.9 öre/kWh (14.4 milli euros), Ringhals did not get the total cost covered by the market price. This situation will continue as long as the overcapacity remains on the market. The price on the Nordic exchange is, for the largest part of the year determined by the variable cost for coal production in Denmark or the variable cost for hydropower production. The variable cost for coal production is 11 to 16 öre/kWh (16-19 milli euros). The variable cost for nuclear production is only 6 to 10 öre/kWh (7-12 milli euros). This means that nuclear power production creates a positive cash flow most of the year and is competitive.

### **Political situation for nuclear power in Sweden**

Nuclear power in Sweden has been debated since 1974. There have been a number of different decisions in parliament and government during those years. In 1980 there was a referendum in Sweden and the decision was to have a maximum of 12 reactors in Sweden and to phase out nuclear power as soon as other environmentally acceptable means of electricity production become available. The parliament later decided that nuclear power in Sweden must be phased out by the year 2010.

In 1997 there was a new decision in parliament to stop Barsebäck 1 and 2 in 1998 and 2001. The parliament however also stated that all nuclear power must be phased out as soon as environmentally acceptable new energy sources are available but that this will take much longer than the year 2010, maybe 10 to 20 years longer. This means that the old decision to phase out nuclear power before 2010 is no longer valid.

Barsebäck 1 was stopped on 30<sup>th</sup> of November last year after the government had decided to withdraw the operating license. Sydkraft, the owner of Barsebäck, took the final decision to close the reactor. The decision was based on a voluntary agreement between them, the government and Vattenfall. This agreement means that Ringhals AB and Barsebäck AB will form a new company group. This group will own and operate the four reactors at Ringhals and operate the remaining reactor, Barsebäck 2. Vattenfall will own 74.2% of the shares in the new company group and Sydkraft will own the rest.

The parliament decision to close down Barsebäck 2 before 1 July 2001 was conditioned that new production capacity or saving of energy must be available to substitute the production at Barsebäck. In autumn this year the parliament will review that condition and take a new decision on Barsebäck 2. Before the end of 2002 the government will introduce a plan to phase out the remaining 10 reactors.

Those decisions are totally against public opinion in Sweden. In the last opinion poll in April this year more than 80% of the general public thought that the nuclear power plants should continue to operate as long as they are safe or even that new nuclear power plants should be built if needed. Only less than 20% agree with the parliament, that it is right to close down nuclear power plants by political decision.

It is interesting to note that in Finland there is a discussion on new nuclear power at the same time as Sweden is closing down well operating reactors.

### **Plant life management**

The very serious competition on the market and the extremely low prices has changed the conditions for plant life management. Since the start of operation more than 25 years ago the reactors at Ringhals have been continuously upgraded and modernised. The modernisations have been based on long-term strategic plans with the aim of ensuring long-life and safe operation. A number of systems and equipment have been replaced and the replacements have most of the time been introduced before any problems have occurred. It has also always been a goal to increase safety in advance of requirements of the authority. The required investment funding has been available since the market was prepared to pay.

Today the main target is to reduce cost in order to be competitive and to keep the reinvestments as low as possible. Of course safety is most important since the plants can only continue operation as long as they are safe and fulfil the requirements of the authorities.

The long-term strategic planning today is based on minimum investment to maintain plant operation and safety. Instead of planning major modification and modernisation packages, the plans are based on small steps as late as possible in time. In many cases the solution will be maintenance instead of exchange or modification. Availability has been very important in the past but as long as the overcapacity remains on the market it is less important. Unavailability only means that the price on the market will increase for the remaining part of the production. This is of course only valid if the unavailability does not cause higher cost for maintenance and repair.

A very important tool in the strategic planning is the design basis reconstitution projects going on at all old nuclear power plants in Sweden. The oldest reactor in Sweden is now over 25 years old and the design requirements have not in the past been documented in a modern way. Those large projects have been going on for some years and will last for some more years. They are reconstituting and documenting all the requirements the original reactors were designed to. The projects will define the original requirements and in the end compare those requirements with modern standards. The first main output will be new Safety Analysis Reports, which will be very well documented compared to the existing one. The final results of the projects will give a very good picture of all the modifications needed to fulfil today's requirements. This will be input into the new strategic improvement programmes on all reactors.

The projects are also used for knowledge transfer from old experienced staff to younger newly recruited staff. This is an important issue since a generation transfer is going on among the staff on all nuclear power plants in Sweden. The new generation has not taken part in the design and construction of the sites and does not have the natural background knowledge. It is very important to take care of all the experience and undocumented knowledge that the old generation has before they retire.

Since the year 2010 is no longer the final year for nuclear operation in Sweden, all plants are planning for at least 40+ years of operation. The Swedish Nuclear Inspectorate, SKI, is reviewing its requirements in that respect and is just in the phase of preparing its new safety requirements. Those are based on modern safety standards and 40+ years of operation. Those requirements will increase the basic safety level well above the initial licensing safety level. Should the new requirements be confirmed probably none of the reactors in Sweden would be able to continue operation. The changes and modifications to the plant needed to meet the requirements will mean investments well above what the competition on the market will allow. The requirements are being discussed between the industry and SKI and the final decision will not be taken until maybe next year.

The constantly increasing safety requirements are a serious threat to nuclear power operation in Sweden since the costs to fulfil the demands are sometimes high and the resulting safety improvement small. It is therefore interesting to hear that NRC in the USA is not talking about increasing safety levels but maintaining safety. All nuclear power plants in northern Europe will soon operate on a common deregulated market and compete with each other. This means that the safety requirements have to be approximately the same all over Europe and there is a great need to harmonise the requirements on an international level.

Nuclear power in Sweden is also disfavoured by taxes. Today the special nuclear tax is 2.7 öre/kWh (3.2 milli euros) and none of the competitors in the other countries have the same burden. The most serious competitor on the Nordic market, the Danish coal based electricity production, have no taxes or fees at all. In the long run, it is impossible to be competitive on a deregulated market with that type of taxation. There is a great need to harmonise the taxation at least all over Europe.

## **Lessons learned**

The deregulation of the electricity market has created a new situation for plant life management.

In order to be competitive on the market it is important to cut cost down a level when the nuclear power companies earn money again. All means to cut cost have to be used while still maintaining safety and the possibilities for operation over at least 40+ years.

The possibilities to invest in modernisations are limited to the absolutely necessary modifications. All investments must be very thoroughly questioned and the money can only be spent where most benefit is gained. This means new prerequisites for the absolute necessary long-strategic planning.

New safety requirements from the authorities have to be discussed between the industry and the authority. The requirement cost must be compared to the benefit to safety. The authority is today requested to carry out such analyses and do so in most cases. Since the electricity market is international the requirements of the authorities must be harmonised on the whole market.

The political threat against nuclear power is serious in many countries and it is important to continue working with public acceptance and lobbying. Especially in Sweden a lot of effort is spent on trying to change the taxation of nuclear power.

In the near future increasing electricity demand will make the prices go up to a level when nuclear power companies earn money again. The very serious worries about climate change will also strengthen the competitiveness of nuclear power.

# **Reorganisation of KEPCO and Lifetime Management Status in Korea**

**Kyung-Nam Chung**

General Manager, Electricity Industry Restructuring Office  
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To date the Korea Electric Power Corporation (“KEPCO”) has been a vertically integrated public utility. It has been the only company engaged in the generation, transmission and distribution of electricity with ownership of 94% of the total electricity generating capacity in Korea.

The restructuring plan published last year by the Government involved a gradual transition to wholesale competition over four years, with the introduction of retail competition for small consumers after 2009. In the initial period, KEPCO’s generation assets will be divided into six generation companies for divestment and/or privatisation. Subsequently, distribution assets will also be divided into a number of companies. KEPCO will remain as a national transmission company offering access to the Grid on non-discriminatory terms to promote the electricity market.

Although many details will require further clarification in coming months, the Korean electricity supply industry will be moving towards a competitive market structure. The impending restructuring will force the nuclear sector to reassess the way they do business. The nuclear sector consisting of 16 units in operation and 4 units under construction has competitiveness over the conventional electricity resource. To survive in the competitive market and the deregulated industry, it is important to reduce the capital expenditure as well as fuel and O&M cost. It was already known in other countries that it is more efficient for competition in the market to better utilise the operating plants rather than to reduce the construction cost of new plants.

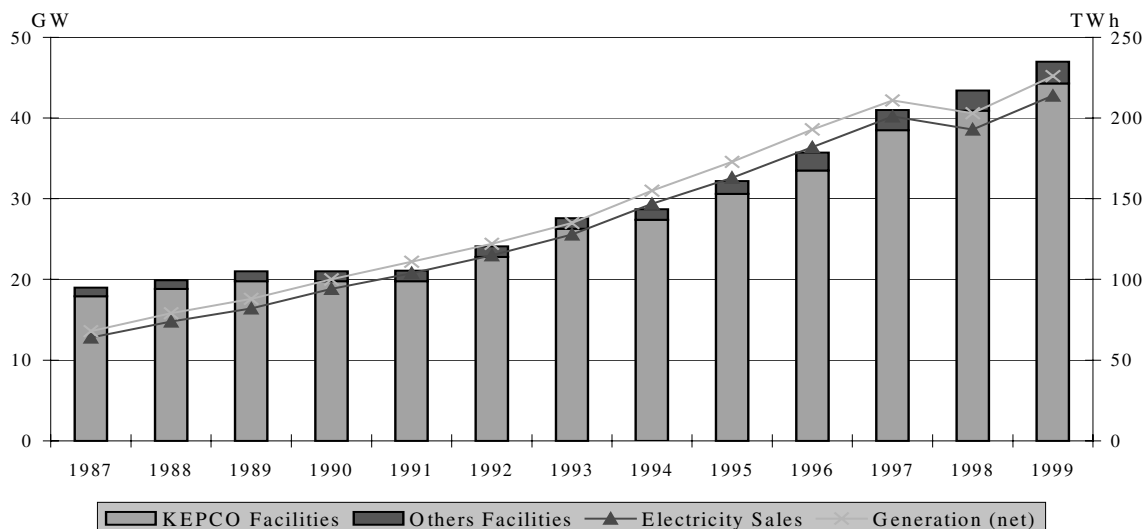
In this context, consideration of lifetime extension for older nuclear units may naturally occur in parallel with elaborate evaluations to make massive capital investments into new power plants. Therefore, the first PLIM programme is applied for Kori 1, the oldest nuclear unit in Korea, which is scheduled to retire in 2008. The first phase of the programme identified that the life extension of Kori 1 beyond its licensed life was technically and economically feasible. Now the second phase is under progress. Also, a periodic safety review (PSR) programme is adopted per recommendation of the International Atomic Energy Agency, which will be very useful to assess and ensure the plant safety of operating units thus contributing to plant life management.

## **KEPCO’s existing operations**

### ***Overview***

Electricity demand in South Korea grew by more than 10% per year on average during the past decade, reflecting the rapid growth of the Korean economy. During this period, KEPCO’s installed capacity increased from 19 GW to 44 GW. Peak demand in 1999 was 37 293 MW, with KEPCO sales of 214 TWh to 14.4 million customers.

Figure 1. KEPCO facilities, sales and generation



At the end of 1997, the Korean economy had experienced the unprecedented financial crisis, which had been a terribly bitter medicine for the Korean people. This turmoil has produced a sharp reversal in electricity demand growth. After a year-long struggle, the South Korean economy has rapidly recovered to achieve positive growth in GDP, which is also shown in the recovery of electricity sale in 1999.

### Generation

At December 1999, KEPCO had 248 generating units in operation with 44 316 MW of installed capacity representing 94% of capacity on the Korean system. A further 28 units, or 13 300 MW of capacity, are presently under construction. The profile of KEPCO's generating plants in operation and under construction is shown in Table 1.

Table 1. The profile of KEPCO's plants

Fuel type	In operation			Under construction		
	Number of units	Installed capacity	%	Number of units	Installed capacity	%
Nuclear	16	13 716	31.0%	4	4 000	30.1%
Thermal						
• Coal	33	13 031	29.4%	8	4 600	34.6%
• Oil	76	4 611	10.4%	–	–	–
• LNG	86	10 823	24.4%	8	2 400	18.0%
Pumped-storage	6	1 600	3.6%	8	2 300	17.3%
Hydro	31	536	1.2%	–	–	–
Total	248	44 316	100%	28	13 300	100%

## ***Transmission and distribution***

At the end of 1999, KEPCO had transformer capacity of 120 257 MVA and transmission line length of 25 254 circuit-kilometres. The major transmission voltages are presently 345kV and 154kV. Currently, a 765 kV nationwide transmission network is being constructed of which 286 kilometres is completed. The distribution network amounts to 344 845 circuit-kilometres.

KEPCO achieved a combined transmission and distribution loss factor of 5.0% and the annual average shutdown time per customer is 23.75 minutes in 1999, which are comparable to those of highly industrialised countries.

## **Restructuring of electricity industry in Korea**

### ***Introduction***

Up to now, the development of the electricity supply industry in Korea has been driven by government. It was inevitable because we had to meet rapidly growing electricity demand with a shortage of private capital to support economic growth.

Most of these circumstances are now changing, however. The Korean economy is no longer at the stage of economic development, but is in urgent need of a reorganised economic system in which the principle of competition takes a major role in every industry. In line with these changes, the electricity supply industry also faces a new phase, the need to advance beyond the existing system in which a single public corporation operates most of the electricity supply industry, and to develop a market-based system driven by price and competition. The restructuring of the electricity supply industry, now in progress, is the very response to these needs and is an autonomous effort to improve on the performance of our electricity industry.

By restructuring the electricity supply industry, we expect the industry to shed the inefficiency that any monopoly system brings with it and to increase efficiency through competition. Of course, the ultimate objective of all these reforms is to guarantee the reliable supply of inexpensive electricity in the long run. In this vein, the restructuring of the electricity industry must be a gateway through which we should pass in order to reshape and improve the Korean economy. KEPCO also recognises that one of its greatest tasks is to achieve efficiency of resource allocation through restructuring and to provide an inexpensive and stable supply of electricity.

An additional benefit that the electricity market reform and industry privatisation brings to the government is a substantial reduction in public debt, particularly in future years. With rapid growth in electricity demand expected to continue in Korea, the estimated investment needed in new generation capacity in 10 years is around USD 30 billion. Without the reforms and privatisation, much of this would by necessity have been funded by raising public debt. It may be argued that some of this capacity could have been provided by IPPs; but in such cases, in the absence of a competitive market, KEPCO would still have been required to accept much of the financial risk associated with such projects.

We are aware, however, that if the industry that has been monopolised by KEPCO was to move directly into a competitive system, both the electricity industry and its customers would necessarily encounter a number of difficulties. That is the reason why we have designed, and are ready to execute, a phased plan that splits the complete restructuring process into several intermediate steps.

As a first step, we plan to separate the generation sector from KEPCO into six subsidiary companies this year, of which the nuclear sector will become a company. This will introduce some initial competition in the generation sector. We have also made preparations to establish a new electricity market, or “Pool”, which is essential for effective competition in generation while still maintaining an orderly operation of the power system.

In 2003 by which time we expect a competitive system to have taken shape in generation, the distribution sector will also be separated into subsidiary companies. At this stage, a wholesale competition system based on trading electricity through a two-way Pool will ensue. In 2009, we will enter the final stage of restructuring by introducing retail competition where every consumer will have the opportunity to choose freely among competing suppliers as in any common commodity industry.

### ***Development and objectives of the restructuring plan***

The electricity supply industry has been considered to be a capital intensive one, thus typically taking the form of a natural monopoly in operation so as to exploit economies of scale.

As technological conditions change, however, the previous view is no longer valid. The development of technologies such as the combined cycle gas turbine have reduced the relevance of economies of scale in the generation sector. Furthermore, we have now highly-advanced computer and telecommunications technology available. These new conditions mean that we are now able to apply the principles of a market economy, that is “Competition and Choice”, to the electricity industry.

From movements all over the world towards competitive electricity markets, we may be greatly reassured about the necessity and the benefits of restructuring. The United Kingdom led the global movement by undertaking restructuring in 1990 and introducing competition to its electricity supply industry. Several countries including Norway, Sweden, etc. followed and have already completed restructuring. More and more countries, like the United States, Finland, Australia, etc. are currently pursuing restructuring. In a word, it is just the global trend now.

In Korea, starting in 1994 the government carried out a 2 year-long evaluation of the management of KEPCO to ascertain where improvements might be made. The result of the evaluation suggested that we should privatise the company in stages. Further, the prescription emphasised the necessity of restructuring the industry as a prerequisite for privatisation. After several-year-long discussions, meetings, consultation, and public hearing the government finally, on 21 January 1999, published the “Basic Plan for Restructuring of the Electricity Supply Industry”. Brief details of the Basic Plan follow.

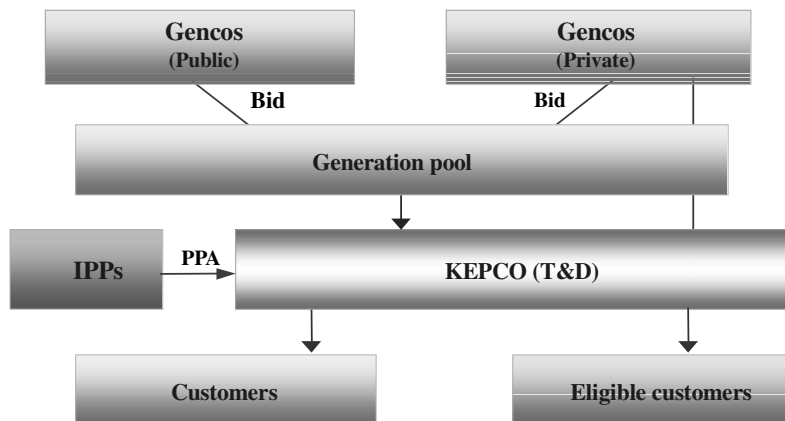
### ***Details of the phased restructuring process***

#### ***Power generation competition phase (2000-2002)***

The establishment of generation subsidiaries, due to occur this year, will introduce the first stage of generation competition. From this beginning, the Korean electricity supply industry which has previously been subject to a monopoly system will enter into a new era.

Generation competition will be realised by making structural changes to the industry. The Generation sector will be separated from KEPCO and divided into six power generation companies. These newly established subsidiary companies will bring about competition in generation. To allocate the power plants owned by KEPCO appropriately to each subsidiary, we have considered 4 practical aspects as follows.

Figure 2. **Competition in generation**



First, in terms of fair competition, we paid attention to the various elements necessary to prevent the possible misuse of market power, to diversify fuels used in generation, and to constitute a balanced mix of power sources. Second, in terms of business, we tried to make sure that each subsidiary obtained some measure of firm value to do business on its own. Third, in terms of technology, we tried to guarantee secure operation of the electricity supply system, providing against the occurrence of low voltage and high load with unexpected occurrences in the power system. Finally, in preparation for future privatisation, we considered how to maximise the selling prices of the subsidiaries.

According to the criteria stated above, we divided the then-42 hydro or fossil power plants, each of which is either currently in service or is under construction, into 5 strategic business units (SBU). In the allocation of hydroelectric or thermoelectric power plants, each SBU is to take over, on average, 7.7 million kW of plant including a large coal-fired power plant as a main plant. These 5 SBUs of conventional power will be divested and privatised to become GENCOs successively once the relevant legislation activities are processed in the National Assembly.

As for the nuclear sector, KEPCO will retain it as a nuclear generating subsidiary. The government has decided not to privatise the nuclear sector after taking into account such factors as problems relating to safety supervision, the domestic condition of energy demand and supply, the development of nuclear generating technology, and the capability of constructing new capacity.

The transmission and distribution sectors are to remain as main part of KEPCO as before. But, on the other hand, we also have a plan to launch a system in which eligible customers who consume greater amounts of electricity have the opportunity to purchase electricity directly from GENCOs in the wholesale market. This is important because the expansion of the range of consumer choice is a foundation for the gradual introduction of the competitive system.

The new competitive system in the generation sector requires the existence of a competitive bidding market for electricity. We must therefore have a new system of power transactions arranged. In the new system, electricity will no longer be traded in the current limited way, but will be traded in essentially the same way as most other commodities.



To promote fair and active competition among GENCOs, based on variable cost or fuel cost, we must complete a number of preliminary tasks. First of all, the rules governing the commercial transactions between the participants, to be called “Pool Market Operations Rules”, are established. The electricity transaction programme for hourly bidding is also developed and the necessary operating personnel are being trained to carry out that task. Other tasks also need to be developed and defined.

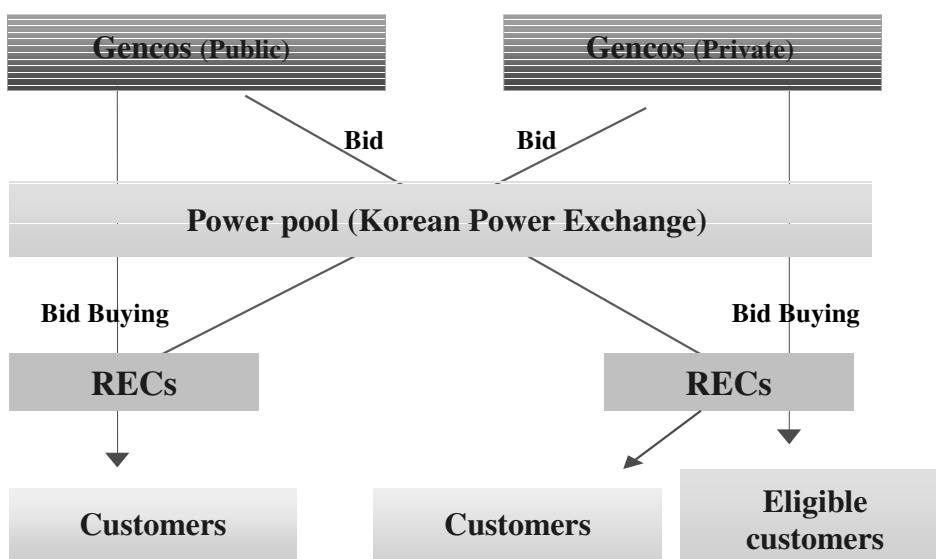
When the generation sector is separated from KEPCO, approximately 16 000 persons (45% of the labour force), 34 trillion won (55% of the assets), and 14 trillion won (58% of the budget) will be transferred to the new generation sector.

Once the National Assembly passes the “Special Law on the Restructuring” and the “Amendment of the Electricity Business Act”, we will complete the registration process for establishment of the new GENCOs. Once we have completed all these procedures which will introduce structural changes as outlined above, together with a suite of new regulatory arrangements, we will find ourselves actually in the era of generation competition.

*Wholesale competition phase (2003-2008)*

Following the initial stage of generation competition, from 2003, the wholesale competition system will be introduced. At this stage, in addition to the separation of the generation sector, we will also separate the distribution sector from the transmission sector and establish several regional distribution companies. The new industry structure will enable each of the distribution companies to choose the power producer who is willing to sell at a lower price. We then expect more intensive competition to be stimulated in the generation sector, and management to be rationalised in the distribution sector.

Figure 3. Wholesale competition



To be precise, the wholesale competition system is the one in which there exists, on the one hand, many GENCOs to deal with the generation side and, on the other hand, many distribution companies to deal with the demand side. Wholesale transactions between generation and distribution companies will then take place. In a similar way to the preceding case of GENCOs entering into the stage of generation competition, the regionally established “distribution subsidiary companies” will also gradually be privatised.

To split up the distribution sector regionally, we should take into account such factors as profitability and the regional distribution of customers. In consideration of the factors, we will be able to ensure well-proportioned separation of the “Regional Distribution Companies” (RDCs), to ensure that differences between retail prices are minimised. As a preparation for this separation, we have begun to prepare detailed schemes to consider how to divide distribution companies and how to operate, support and regulate them, etc.

Direct power transactions that are to be allowed only to certain large customers in the generation competition phase will be extended in the wholesale competition phase. Accordingly, new types of power traders, like electricity intermediaries, are expected to emerge.

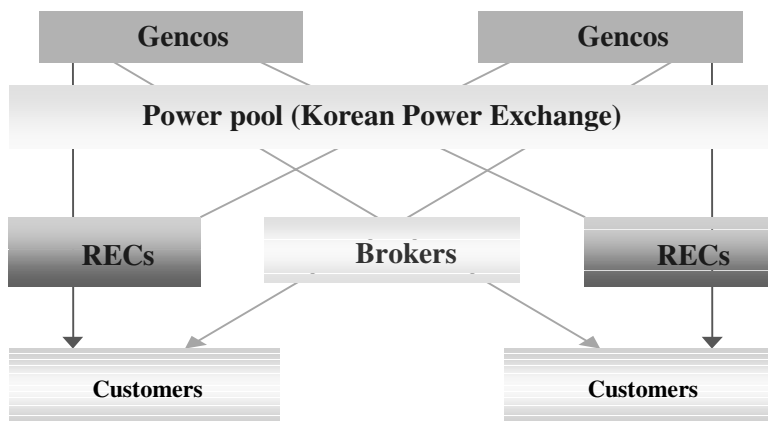
Small customers will still be obliged to purchase electricity only from the distribution companies with franchises for selling in their geographic area. In this phase, we will come to see a “Two-Way Competitive Bidding” market in operation, where generation companies, distribution companies, and large customers participate and trade electricity through a centrally-operated Pool.

In the wholesale competition phase, non-discriminatory access to the transmission network will be guaranteed. So we will have the network open to anyone who agrees to observe the given rules and pay regulated access fees. The energy prices, transmission prices, and distribution prices that apply to those customers who do not have a right to choose their supplier, are to be set monopolistically as before. Therefore, the government will have to regulate such prices.

***Retail competition phase (after 2009)***

Through the preceding stages of generation competition and distribution competition, from 2009, the complete retail competition system is due to be introduced. In this phase, because electricity sales become totally freed, every customer will have the opportunity to freely choose between competing suppliers. This will be the final stage of the restructuring.

Figure 4. **Retail competition**



The retail competition system implies a perfectly competitive market for electricity trade. Therefore, every customer will be able to freely choose electricity from all sorts of suppliers, such as electricity intermediaries, consumer unions, and specialised electricity dealers.

### ***Pending issues for restructuring***

Restructuring of the electricity industry is not a simple project in that it requires the transition from a long-time monopoly by KEPCO to a competitive market. So there are many things to examine as supplementary requirements. Some of them are:

#### *Arrangement of the laws*

In the case of the United Kingdom where restructuring of the electricity industry was completed during the early 1990s, support from appropriate legal arrangements and strong determination of the government are said to have played an important role in the success of the restructuring.

In Korea, however, the laws that are necessary for supporting the restructuring institutionally are not yet ready. We need to amend the “Electricity Business Act” so as to provide an institutional foundation for the introduction of competition. And we also need to prepare a definite legal framework for the operations of the power trade market and direct power transactions.

Especially, in order to advance the restructuring efficiently, we need a “Special Law” to simplify the procedures of GENCO establishment and to exempt them from duties to purchase all sorts of public bonds, as well as removing institutional hindrances to the GENCO establishment.

Initially, we intended to go through the legislative activities by the end of 1999. But the strong opposition from concerned organisations such as labour unions and NGOs and the general election of members of the National Assembly had deferred the intensive discussion in the National Assembly.

Therefore, we are currently co-ordinating with the government and the National Assembly for the overall amendment of the “Electricity Business Act” and the “Special Law”. Our objective is to pass the bills at the National Assembly at the earliest time this year.

#### *Privatisation of the generation SBUs*

The government’s “Basic Plan for Restructuring” stated that, late in 1999, we would begin to undertake divestment and privatisation of the generation SBU. Implementing the sales of generation SBUs, however, need a considerable amount of time until the market structure is sufficiently established, since the normal and stable operation of the competitive market is a prerequisite for privatisation.

In reality, on the other hand, there exist concerns among some people over the sales of generation companies in the sense that the sales of these generation assets would imply outflow of the national wealth and may result in strengthening the current dominance of the conglomerates. The labour union feels insecure about its members’ employment prospects after privatisation and is pursuing an adverse publicity campaign jointly with some non-government organisations. At the present time the opposition campaign has attracted much public and media attention and the positive benefits of privatisation, such as the shedding of the inefficiencies of a large monopoly, have not been made

clearly known to the public. These positive benefits have been clearly manifested in other countries around the world and this message should be made known in Korea to give assurance to the people that privatisation can bring many benefits.

The issue of restructuring and privatisation is not one which should be allowed to be stopped by the opposition of some groups of people. So we established the “Research and Planning Team for Privatising the Electricity Industry” and will have the team to design reasonable plans for privatisation, which reflect opinions from various fields, through public hearings and others.

The Research and Planning Team, which is composed of neutral persons from academic institutions, research institutions, and labour unions, started late in November and will continue its work until late in May this year. The mission is to draft the privatisation plan to fit into our specific conditions. The team will consider such matters as the objective of privatisation, the structure of ownership and management, schemes and safety devices for advancing privatisation. The government is, after public hearings, due to confirm the draft as a formal plan.

## Restructuring and nuclear PLIM

### *Nuclear power status and PLIM*

The Korean Nuclear Power Programme has begun with the commercial opening of Kori Unit 1 in 1978 and nowadays there are 16 operating nuclear units of 13 716 MW. In addition, there are 4 more units under construction as shown in Table 2.

Table 2. Profile of nuclear power plants in Korea

Plant		Reactor type	NSSS supplier	Capacity (MWe)	Commercial operation date	Capacity factor in 1999 (%)
Kori	#1	PWR	Westinghouse	587	1978	85.2
	#2	"	"	650	1983	97.1
	#3	"	"	950	1985	90.5
	#4	"	"	950	1986	89.0
Wolsong	#1	CANDU	AECL	678	1983	82.8
	#2	"	"	700	1997	90.8
	#3	"	KHIC	700	1998	82.0
	#4	"	"	700	1999	103.0
Yong-gwang	#1	PWR	Westinghouse	950	1986	84.5
	#2	"	"	950	1987	84.3
	#3	"	KHIC	1 000	1995	89.1
	#4	"	"	1 000	1996	91.8
Ulchin	#1	"	Framatome	950	1988	89.4
	#2	"	Framatome	950	1989	97.9
	#3	"	KHIC	1 000	1998	83.5
	#4	"	"	1 000	1999	88.2
Total		—	—	13 715	—	86.2

The capacity factor has been maintained well over the 84% in the last 10 successive years. Nuclear electricity is about 3 cents/kWh, the cheapest in the Korean electricity generation and is expected to continue to hold the edge over the strong competitor, i.e., bituminous coal-fired electricity. We believe that even without considering the Kyoto Protocol for green environment, the new units under construction will maintain the lead. Also, in order to cope with the spent fuel issue and plant

decommissioning in future, a special fund has been established in KEPCO and been managed more than 15 years. Therefore, there is in fact no stranded cost issue in the nuclear sector during the restructuring of the electricity industry in Korea.

However, deregulation of the electricity industry and introduction of competition in electricity generation will certainly give a couple of challenges. First, competition is getting tougher with bituminous coal. Secondly, the siting of new nuclear units is becoming very difficult as compared with the past and therefore much more time and effort are required. And thirdly, it is becoming very difficult to make a good financial arrangement of low interest rates as in the past for the new construction project.

Therefore, it is natural to contemplate the better utilisation of existing nuclear units or PLIM, in parallel with the construction cost reduction of new nuclear units.

### ***PLIM at Kori Unit 1***

Kori Unit 1 is the oldest unit in Korea, which began commercial operation in 1978. The unit has shown good performance; the capacity factor in 1999 is 85.2%. Because it is licensed to operate 30 years, although the design basis is 40 years, the first phase PLIM programme for this unit began in 1993 with an aim to extend the operation at least 10 years. The study concluded that most of major components were operable for more than 40 years except reactor pressure vessel and turbine, which needed more in-depth study.

Because the major failure mechanism of the reactor vessel was irradiate embrittlement, which may cause a pressurised thermal shock, an in-depth evaluation was performed to identify that the overall vessel failure frequency from PTS transients at 40 and 60 reactor years meets the USNRC's criteria and to verify that the integrity of the reactor pressure vessel can be maintained, thus alleviating the most critical technical issue for life extension and license renewal.

Field inspection revealed that the rotor disks of low pressure turbine had significant stress corrosion cracking problems and would not provide sufficient margin for further operation, and their replacement was recommended. Therefore, the low pressure turbine rotors were replaced in 1997, and will have no impact on life extension. Furthermore, steam generators whose tubes were plugged at maximum allowed rate were replaced in 1998.

Besides evaluation and replacement of these major components, economic analysis was performed for life extension. The analysis was to compare two alternatives at the end of currently licensed life of 30 years. The first alternative was to extend the operation of Kori Unit 1 and the other one was to construct and operate a new nuclear unit upon the expiration of the current operating license. The analysis estimated that the benefit to cost ratios were greater than 2, which meant that life extension could be a very promising one.

The overall results of the Phase 1 PLIM indicated a strong possibility for life extension in terms of technical and economic considerations. Therefore, second phase PLIM began in 1998. The major scope consists of:

- developing technical report to justify the design life of 40 years;
- developing methodologies and procedures to evaluate the life of structures, systems and components;

- developing ageing management programme, as well as field diagnosis/inspection technology;
- developing system performance monitoring programme; and
- establishing and updating the PLIM database.

Third Phase after 2001 is to implement the ageing management programme in the field, replace aged components and improve outdated systems during plant outage. Also the license renewal will be filed in due course.

### *Utilities' safety enhancement*

Safety should be the highest priority in plant management. To keep on preserving safety at an acceptable level, KEPCO implements a comprehensive preventive maintenance programme, refurbishes degraded structures, systems and components, and does quality assurance with emphasis on the prevention of incident/accidents in advance.

Operation safety of reactors is examined by annual quality assurance audit, periodic inspections in accordance with the technical specification of the plant, performance tests of operating components, and monthly safety diagnosis, routine operation check, and pre- and in-service tests. Also the operation safety is benchmarked with international safety practices in corporation with related international organisations such as the International Atomic Energy Agency, the Institute of Nuclear Power Operations, and the World Association of Nuclear Operations, and so on. These safety enhancement activities have contributed to average capacity factors of well over 84% and unplanned trip rate per plant is now less than once a year.

### *Periodic safety review*

As a systematic measure to ensure safety of nuclear units, IAEA prepared guidelines for Periodic Safety Review (PSR) and recommended each member state implement them to its operating units. As a member state of IAEA and participant in the Convention on Nuclear Safety, Korea has recently decided to adopt PSR. PSR is an appropriate tool that can comprehensively review plant safety periodically and ensure safety during lifetime. It also systematically diagnoses the activities of plant upgrade and the compliance to the regulatory requirements. Especially, current safety works can be improved by reflecting the experiences and lessons from accidents, incidents, malfunctions, and safety upgrade worldwide. Therefore, a growing number of nations use PSR as a useful measure for safety inspection and regulatory compliance.

According to the PSR Programme, safety of operating NPPs, including physical and non-physical ageing, will be systematically evaluated every 10 years. If any safety improvement is suggested, it should be implemented in an economic and effective way. Main focus in PSR is to survey troubles and accidents that have occurred in domestic and foreign units and to compare safety activity of those plants with the unit of concern.

The unit, where the PSR Programme will be first applied this year, is Kori Unit 1, the oldest unit. From 2002, the PSR Programme will be expanded to all units of 10 years or older. Higher priority will be given to Kori unit 2 and Wolsong unit 1, which are earlier ones in Korea.

In order to support the KEPCO's PSR Programme, the regulatory body will establish the regulatory frame by the end of this year. Principal safety assurance elements, under consideration, consist of IAEA-suggested eleven safety factors such as actual physical condition of the NPP, safety

analysis, equipment qualification, management of ageing, safety performance, use of experience from other plants and research findings, procedures, organisation and administration, human factors, emergency planning, environmental impact.

We believe the PSR Programme is a useful tool for utilities to diagnosis current safety status of plants based on the operation experience and new technology of worldwide nuclear power plants. This programme can be an effective way to meet the safety regulation for plant lifetime management as well as routine operation of power plants.

## **Conclusions**

This paper provides a brief description of KEPCO as of today, and a summary of the changes in the near future and the status of nuclear power plants lifetime management programme. As we stated at the beginning, by restructuring the electricity supply industry of Korea we expect the industry to achieve greater efficiency through competition and to continue to guarantee the reliable supply of inexpensive electricity over the long term, expanding and ensuring the customers' choice. Therefore, the restructuring of the electricity industry must be a gateway through which we should pass in order to reshape and improve the Korean economy.

The Korean Nuclear Power Programme, consisting of 16 operating nuclear units of 13 716 MW and 4 more units under construction, has shown good performance, the capacity factor being well over 84% in the last 10 successive years and nuclear electricity being about 3 cents/kWh, the cheapest in the Korean electricity generation.

However, deregulation of the electricity industry and introduction of competition in electricity generation will certainly give the Korean nuclear power sector a couple of challenges such as tougher competition with bituminous coal, time- and money-demanding site acquisition for new nuclear units, and difficulty to arrange long-term good financial arrangement of low interest rate.

Therefore, it is natural to begin PLIM to better utilise the existing nuclear units. The first phase PLIM for Kori Unit 1 began in 1993 with an aim to extend the operation at least 10 years. The study concluded that most major components would be operable for more than 40 years with some in-depth analysis and/or replacement of some critical components such as reactor pressure vessel and low pressure turbine rotors. Therefore, the second phase PLIM is under progress to develop technical reports to justify the license renewal to 40 years, to develop methodologies and procedures to evaluate the life of structures, systems and components, etc. Third Phase after 2001 is to implement the ageing management programme in the field, replace aged components and improve outdated systems during plant outage. Also the license renewal will be filed in due course.

It is to be noted that the operational safety of the plant shall be the fundamental basis of life management and continued operation of nuclear units. As a systematic measure to certify the degree of nuclear safety, the PSR programme is adopted in accordance with the recommendation of the IAEA. Kori Unit 1 will be the first unit where the programme will be applied. Other units will be exposed to the programme in sequence.

We believe the PSR Programme is a useful tool for utilities to diagnosis current safety status of plants based on the operation experience and new technology of worldwide nuclear power plants. This programme can be an effective way to meet the safety regulation for plant lifetime management as well as routine operation of power plants.

# **Deregulation and Restructuring of the Electricity Sector in Spain**

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## **Introduction**

The approval by the Spanish Parliament of Act 54/97, of 28th November 1997, has meant the complete transformation of the Electricity Industry in Spain. The changes introduced by the new regulatory framework have a greater or lesser impact on all aspects of electricity generation, transmission, distribution and supply/commercialisation.

Twelve years ago, on 1st January 1988, a transcendental change occurred in the regulation of the electricity industry, with the entry into force of what was known as the “Stable Legal Framework”. The electricity industry was fully regulated, under the premise that it was a public service essential for the national economy and that, furthermore, this service was to be provided at the lowest possible cost and with suitable levels of quality.

Consequently, the electricity utilities acted as service managers, in accordance with a set of regulations that limited their possible actions and fixed their revenues by means of technical and economic standards that, on the one hand, guaranteed the recovery of investments and, on the other, allowed the evolution of the reference electricity tariff to be bound.

Planning was also regulated by the National Energy Plan, which was periodically approved by Parliament and covered the need for new power, along with the technology to be used and the general locations, among other items.

Among other achievements, this regulatory framework allowed the evolution of tariffs to be controlled, such that in real terms the average electricity sales price decreased by 20% over the course of the decade.

At this juncture, throughout 1996, the process of introducing competition into certain sectors that had until then been considered public service suppliers speeded up. The electricity industry was one such sector.

This new philosophy was backed by the need to increase the competitiveness of Spanish industry with respect to other European Union countries, because of the challenge of the European Single Currency. With this aim in mind, the understanding was that it was necessary to promote wider liberalisation of the electricity industry, in order to achieve even lower prices, without ceasing to guarantee supply and its quality.



Furthermore, the approval of the “European Directive 96/92/CE on Common Rules for the Internal Electricity Market” required the adaptation of Spanish legislation.

On the basis of the above, a path was initiated that culminated at the end of 1996 with the signing of the “Protocol for the Establishment of a New Regulatory System for the National Electricity Market” by the Ministry of Industry and Energy and the Electricity Utilities integrated under UNESA.

This protocol established the “operating bases that are to govern the functioning of the National Electricity System” through liberalisation of the market and the introduction of a higher degree of competition. The Protocol also established the terms, measures and safeguards required during the period of adaptation to the new framework, as well as the remuneration to be paid for activities considered to constitute natural monopolies.

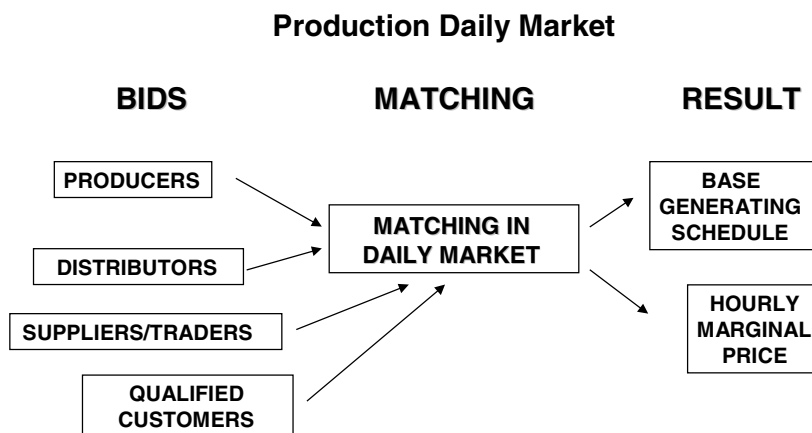
The aforementioned protocol recognised that the implementation of the new model should be accomplished gradually, in order to guarantee the financial viability of the utilities. As a result, a transitory period had to be observed.

The path initiated in 1996 with the signing of this Protocol culminated on 28th November 1997 with the approval by the Spanish Parliament of the Electricity Industry Act (Law 54/1997). This Act establishes that electricity is essential for the functioning of our society, but also states that “unlike previous regulations, the present Act rests on the conviction that guaranteeing electricity supply, its quality and its cost requires no intervention by the State other than that specified by the regulation itself”.

In this respect, transmission and distribution activities remain regulated, due to their being natural monopolies, while generation and supply/trading are liberalised, the latter becoming independent from distribution through the steady introduction of access to the market by the consumers.

### **The market operator and the system operator**

The design of the new model required that a market operator be created to undertake responsibility for management from the economic standpoint. Specifically, this operator would be in charge of receiving the sales and acquisition bids on the daily market, their subsequent matching and settlement of the transactions carried out under its operational umbrella.



For this purpose, the “Compañía Operadora del Mercado Español de Electricidad, S.A.” (OMEL) was set up at the end of December 1997. This Company is totally private and its shareholders include electricity sector agents, financial institutions and companies involved in other fields of economic activity. According to Law 54/97, each shareholder may hold a maximum 10% of the capital, and companies involved in activities in the electricity sector cannot together exceed a holding of 40%.

In parallel to the above, the System Operator was created, to take charge of technical management. This function is carried out by “Red Eléctrica de España, S.A.” (REE), which in turn undertakes the function of transmission network manager – the two areas of accounting being suitably separated – and continues to be the owner of a large part of the assets of the network. This company is subject to the same shareholder limitations as described above in relation to the Market Operator; furthermore, most of the shares are in private hands and are quoted on the stock market.

## **Electricity generation**

The electricity production market that came about as a result of the liberalisation of generation activities began to operate on 1st January 1998, on schedule. The production market includes, on the one hand, a system of bids (pool-based market) and, on the other, the possibility of establishing different types of contracts between eligible consumers (clients with a given volume of consumption) and other agents.

As regards contracts, Law 54/97 generally establishes three types:

- Contracts linked to settlement at the market price or by differences. These contracts may be drawn up between consumers recognised as eligible clients and the rest of the market agents.
- Physical bilateral contracts, signed between eligible consumers and producers, these being outside the bidding system.
- Financial contracts, which will in all cases adhere to the system of bids.

As regards the system of bids, a daily market is created, on which the generators are obliged to submit bids – daily and every hour – for all their production units with an installed power of more than 50 MW, the only exceptions being those cases in which there is a physical bilateral contract. For all other production units, this possibility is voluntary. External agents from both the European Union and third-party countries entitled to participate (sell/purchase energy) on the market are also obliged to submit bids for each scheduling period.

This market is a power bourse where electricity is traded. The market operator managing this bourse sets the price on the basis of the bids received; the marginal bid – the highest bid for the power station required to meet the power demand – sets the price; all accepted bids are settled at this price.

The daily market is complemented by the ancillary services market, the services in question being those required to ensure the supply of electricity under the necessary conditions of quality, reliability and safety. These may be obligatory, if required by the system in order for it to render an adequate service, or may be optional. For the latter, i.e. those which are optional, the system operator establishes a system of bids, which is accessed by all the installations in a position to render such services.

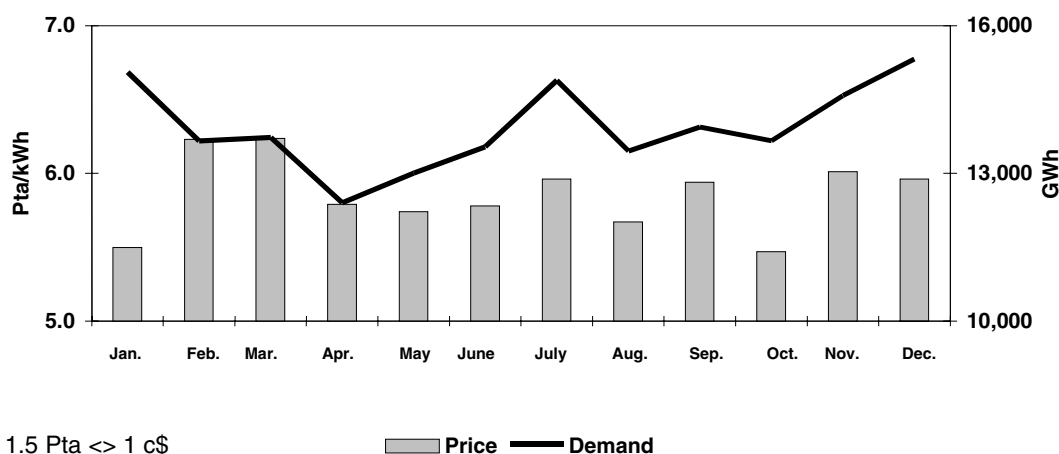
Finally, there is an intra-daily (hour ahead) market, the objective of which is to attend to those adjustments that might arise in energy supply and demand subsequent to the feasible daily programme having been established. This market, which has been evolving since its institution, currently has 6 daily sessions, the first with a scheduling scope of 28 hours and the last of 9 hours.

In addition, the system operator, as the organisation ultimately responsible for balance between generation and demand, has a procedure known as “imbalance management”, by means of which in the event of mismatches being detected after closure of an intra-daily market session, it is able to call upon the producers and pumping units over the period lasting until the next such session.

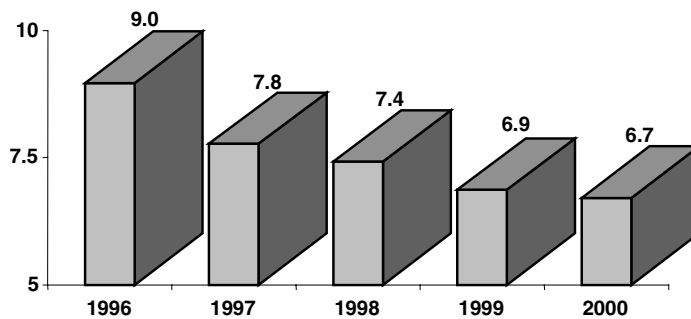
Production market organisation		
Daily market matching	Result of matching	10 a.m.
Execution of physical contracts	Operation basic programme	11 a.m.
Solving of technical constraints	Provisional viable programme	2 p.m.
Ancillary services market	Daily viable programme	4 p.m.
Hour ahead markets	Final schedule programme	¼ hour before N hour
Real time operation	Operational schedule programme	N hour
<ul style="list-style-type: none"> <li>• Ancillary services</li> <li>• Procedures for imbalance management</li> </ul>		

Special mention should be made of the procedure followed to resolve possible technical restrictions. Following matching on the daily market and the sessions of the intra-daily market, and once the power corresponding to possible physical bilateral contracts has been incorporated, the system operator analyses the resulting load situation and determines what restrictions might apply. Once these restrictions have been detected, the system operator acts jointly with the market operator, resolving them, removing bids from the system and incorporating new bids, such that the impact of the solution on the results of matching and the extra cost deriving therefrom is minimised. In this respect, it should be mentioned that previously matched power subsequently withdrawn as a result of restrictions does not receive any compensation. For its part, incoming power obviously not matched initially due to its bid price being higher than the marginal price, receives the price of the corresponding bid.

**Final price on the bids market during 1999**



**EVOLUTION OF AVERAGE GENERATION PRICE (Pta/kWh)**  
(including stranded costs)



## Electricity planning

Law 54/97 includes as one of its general principles, a move away from “*the idea of planning determining investment decisions*”. Planning becomes purely indicative in nature, except as regards transmission installations.

However, planning in relation to the following continues to be indicative:

- Demand forecasting.
- Estimation of the minimum power required to cover the foreseen demand, and of the necessary transmission and distribution installations.
- Determination of courses of action in relation to quality of the service, guaranteed supply and protection for the environment.

As regards generation installations, the Law establishes that the construction, operation, substantial modification and closure of electricity generating installations are subject only to the corresponding administrative authorisation, which will be regulated in accordance with principles of objectiveness, transparency and non-discrimination. Likewise, concerning new generating installations, the option consists of a system of administrative authorisation, as said, without conditioning the use of primary energies.

## Special regime

The liberalisation introduced with the creation of a generation market is compatible with the maintenance of policies promoting various technologies relating to cogeneration (CHP), the use of renewable energy sources, wastes, etc.

The aim is to rationalise the regulation of certain areas of production which do not meet purely economic criteria, but which from the environmental point of view, or as regards the development of new technologies, might have future benefits for society overall. As a result, these production areas are recognised to have the right to receive premiums above the price resulting from the production market.

Law 54/97 continues to give special treatment to independent production (self-generators) and to the generation of electricity by means of renewable energy sources, the biomass and wastes. In principle, this special regime is limited to installations whose installed power does not exceed 50 MW, although certain exceptions to this limit are established.

In general, and quite apart from the price resulting from the production market, the aforementioned installations have the right to receive a premium, which will vary depending on their characteristics. Likewise, a transitory period is established for such installations.

### Liberalisation of supply

As had been established in the electricity Protocol, Law 54/97 contemplates the gradual liberalisation of electricity supply, such that clients having a given volume of consumption be qualified to acquire their energy on the bids market, either directly or through independent commercialising companies or traders.

Likewise, the commercialisation/trading activity is liberalised for those clients who are not subject to tariffs. In this case, the remuneration for the commercialising companies will be freely negotiated between them and their clients.

Having said this, it should be pointed out that in the time which has passed since the entry into force of the new law, the process of liberalising supply has already speeded up twice with respect to the initially established limits. The following table shows the three scenarios which have existed to date in Spain, along with the percentage of liberalisation foreseen in the European Union. Directive on the internal electricity market, approved by the European Parliament, which came into force in February 1999.

Year	EU Directive	Law 54/97	RD 2820/98	RD-Law 6/99
1998		> 15 GWh 28%	> 15 GWh 28%	> 15 GWh 28%
1999	26%		Jan. > 5 GWh 33% Apr. > 3 GWh 37% Jul. > 2 GWh 39% Oct. > 1 GWh 42%	Jan. > 5 GWh 33% Apr. > 3 GWh 37% Jul. > 2 GWh 39% Oct. > 1 GWh 42%
2000	30%	> 9 GWh 31%		Jul. > 1 kV 54%
2002		> 5 GWh 33%		
2003	32%			
2004		> 1 GWh 42%		
2007		100%	100%	100%

Additionally, the owners of rail transport installations, including metropolitan systems, are considered to be eligible clients. Likewise, distributors and commercialising/trading companies are also qualified to acquire the energy required for their supplies on the market.

As may be observed, the rate of liberalisation imposed by the Spanish regulations has been higher from the beginning than that contemplated in the E.U. Directive. At present it is established that as from 1st July 2000, consumers whose supply is provided at rated voltages of more than 1 000 V will be able to choose their supplier. This represents an opening of the market of around 54% and affects some 65 000 clients (the European Directive establishes a threshold of 30% for the year 2000).

## **Transmission and distribution**

As mentioned at the beginning, one of the fundamental characteristics of the new electricity system model contemplated in Law 54/97 is that transmission and distribution continue to be regulated activities, although there has been a fundamental change with respect to the previous situation. This change refers to the possibility of third parties accessing the networks, in exchange for a payment for such use.

The cost accredited to transmission and distribution, the overall amounts involved and their annual evolution as regards each of the activities have been established in accordance with the principles agreed on in the electricity Protocol, subsequently reflected in various standards of enactment. Outstanding among these is Royal Decree 819/1998, of 23rd December, regulating electricity transmission and distribution activities. In both cases, the evolution of these items depends on the CPI (price inflation index), minus an index of efficiency. Furthermore, in the case of distribution, consideration is given to variations in demand, to a percentage which may not exceed 40%.

## **Stranded costs**

One issue warranting special mention is that of the so-called Costs to Transition to Competition (CTCs) or stranded costs. Changing from a situation in which the scenario for action is governed by a strict and regulated framework to a new situation in which companies are required to act in accordance with the rules of the free market leads, in most cases, to costs not as yet recovered, costs which in the new situation would jeopardise the economic and financial viability of the companies as a result of change from the regulatory framework in which the liabilities underlying these costs were acquired.

Centralised planning is one of the causes of the appearance of these costs when changing to a framework of competition. In a regulated sector, the State Administration is normally responsible for establishing the requirements for new investments and the technologies to be used. This means that when changing to a new situation, the companies find themselves with investments made more for political reasons, or for reasons of social interest, than on the basis of criteria of economic profitability.

Furthermore, in a regulated sector, prices are not fixed by the companies in accordance with strictly economical criteria, but are due in most cases either to political or social rules or to the application of formulae making it possible to extend the period of recovery of the investments, laminating the impact that these may have on prices.

In this respect, the CTCs recognised for the Spanish electricity utilities are the result of a series of investments and costs made and accrued by these companies in accordance with the previous regulations. These were planned by Parliament and, in accordance with the standards in force at the time, were to be recovered via tariffs which were not in keeping with the flow of accounting. In other words, what the electricity tariff did was to recognise these investments and costs, but defer their recovery in time, such that their impact on electricity prices was minimised.

As from the moment in which the rules of the game changed, giving rise to a liberalised market, the companies acquired the right to have the debt owing to them as a result of the tariff recognised and paid, either immediately or over a given period of time.

In countries where these companies were already in private hands, a transition period is established for the companies to receive the corresponding CTCs from the electricity tariff. This has been the case in Spain.

Article 24 of the E.U. Directive, recognises the possibility of the member states applying transitory periods due to the impossibility of applying the aforementioned Directive, as a result of commitments acquired prior to its entry into force. Also, this principle is explicitly accepted in the United States and has been applied by FERC. These commitments refer not only to regulatory commitments, but also contemplate the existence of supply contracts of the "must take" type, plant dismantling costs or any other type of commitment required previously and whose non-compliance implies damage for third parties.

Recognition of these costs to transition may be given explicitly, as has been the case in Spain, where generation activities were opened to a framework of competition from the very beginning, or such recognition may be implicit.

The CTCs recognised for the Spanish electricity utilities by Law 54/97 are the result of the difference between the rights acquired by these companies, for the investments and costs made and accrued within the previously so-called Stable Legal Framework, and the revenues they will foreseeably obtain from the market in a new situation of competition.

These costs to transition, which were initially established at 16.8 billion euros, and which have undergone various reductions ultimately leading to their being fixed at approximately 10.2 billion euros, should not be understood as a compensation to be received by the electricity utilities, but as a right or debt owing to them by the electricity tariff. The CTC recovery is established by tariff rate over 10 years.

## **Conclusions**

It may, therefore, be concluded that electricity deregulation and liberalisation in Spain have given rise to an electricity industry which not only complies in spirit and letter with the E.U. Directive on the internal energy market, but which in fact goes much further.

- Electricity generation has been completely liberalised, and a pool-based production market open to all possible agents, both national and international, has been set up.
- Supply has been liberalised to thresholds that are much more ambitious than those recognised by the E.U. Directive itself, the objective being full liberalisation.
- Transmission and distribution continue to be regulated activities, but with free access to the networks for third parties by means of public tariffs, this preventing the possibility of discriminatory treatment being given to different network users.
- The companies have been legally unbundled on the basis of their activities, this guaranteeing above all else the independence of both the market and system operators.
- The process of liberalising has gone hand in hand with important reductions in electricity prices. The average price has decreased by 16.9% in nominal terms during the period 1997-2000, the reduction representing 23.3% over this period if the effects of inflation are discounted.

# **Operation of the UK Magnox Stations in a Competitive Market**

**Andrew Corrigan**

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## **Introduction**

In 1955 the UK Government announced the first major civil nuclear power plant construction programme based on the Magnox design of reactor. This was followed in 1956 with the commencement of operation of Calder Hall, the world's first nuclear power station. The initial programme was for the construction of 1 500-2 000 MW of plant but, with the success of the early stations, this was increased to 5 000 MW by 1960. In total 11 Magnox nuclear power stations were commissioned in the UK over the period 1956 to 1971, comprising a total of 26 reactors (see Table 1). At present 20 of the reactors remain in operation, with an average life of 37 years. Output from the stations has been steady for many years and they have been regarded as the workhorses of the electricity generation industry in the UK. In 1990 the electricity supply and distribution system was deregulated and a market system introduced which has led to a reduction in the sale price of electricity. In addition to this it has been necessary to invest in the plants to maintain safety levels and operational reliability. The plant's can only continue in operation provided they remain safe and economic. This paper will review recent experience with the life management of the Magnox stations.

## **Periodic safety reviews**

The Magnox power stations were the first commercial nuclear plants to be built and, as a result, were among the first to address the issue of modern safety standards and backfitting. By the early 1980's nuclear safety methodologies and nuclear technology had advanced significantly since the time the early Magnox stations were designed. A framework has therefore been established based on comprehensive reviews of plant nuclear safety, referred to as Periodic Safety Reviews (PSRs), that are carried out at ten yearly intervals. The reviews are intended to focus on the longer-term safety of the plants and are separate from the normal routine maintenance and inspection activities carried out during routine operations. The Safety Regulator assesses the PSRs and needs to be satisfied with the outcome of the reviews in order to support the stations continued operation.

The first PSRs carried out to support operation from 20 to 30 years operation, known as Long Term Safety Reviews, have been completed successfully for all operating stations. The three principal objectives for these reviews were defined as follows:

- a) To confirm that the plant was adequately safe for continued operation.
- b) To identify and evaluate any factors which might limit the safe operation of the plant in the foreseeable future.



- c) To assess the plant's safety standards and practices, drawing comparisons with modern standards and introduce any improvements which were reasonably practicable.

Objective (c) led to the implementation of a programme of plant modifications in the late 1980s and early 1990s. The modifications were major and concerned reinforcement of key safety systems, improving their reliability and taking advantage of modern technology. Examples of the most important modifications comprise:

- Increasing the diversity of the reactor shutdown systems
- Improving the reliability of the post fault cooling systems
- Installing remote emergency indication centres
- Improving the capability of the plants to safely withstand hazards such as fire, pressure circuit rupture and earthquakes
- Improving fuel-handling equipment.

All stations have completed further reviews supporting operation beyond 30 years and Calder Hall and Chapelcross have completed reviews supporting operation beyond 40 years. These reviews have shown that, in many cases, ageing will not have a significant adverse effect on nuclear safety for a further 10 years of operation. However, in a few cases existing data did not provide adequate assurance for justifying ten years further operation and support from the results of an ongoing monitoring programme was required. Recommendations from the PSRs are taken into account in defining operational practices, ongoing maintenance and plant inspection.

Both the operator and the regulator have published information about the Periodic Safety Reviews, providing additional assurance to the public about the safety of the plants.

### **Ageing management**

Over the life of the Magnox stations a great deal of plant and equipment has been replaced or subjected to major upgrading as it has become obsolete or where ageing has occurred as part of an ageing management programme. This process will continue throughout the life of the stations. There are a few large fixed structures that are subject to ageing where replacement is either impractical or extremely costly; it is expected that these components would ultimately determine the technically achievable operating life of the Magnox stations. Major research programmes have been undertaken to improve understanding of the ageing processes affecting these structures and measures have been introduced to limit or compensate for the effect of ageing.

The major fixed structures that could be subject to significant ageing comprise the steel reactor pressure vessels, the steel in-reactor structures and the graphite cores. The ageing process of concern for the steel reactor pressure vessels is embrittlement from neutron irradiation, which leads to a progressive increase in the temperature at which the materials undergo a transition from brittle to ductile behaviour; the safety case requires the materials to be ductile in normal full pressure operation. Some weld materials are sensitive to irradiation embrittlement and, as a consequence, localised areas of some vessels have reducing temperature margins. In response to this, vessel-operating temperatures have been increased in recent years, further materials investigations have been carried out and the development of new safety case methodologies have been initiated. An example of this work is the removal of samples from one of the reactor pressure vessels of Trawsfynydd Power Station; Trawsfynydd had been shutdown in 1993 and is currently being decommissioned. A further example is work now under way developing a method of insulating the outer surface of the Hinkley Point A reactor pressure vessels, with the objective of increasing the operating temperature in the region of the vessels with the lowest operating temperature margin.

During early operation of the Magnox stations it was observed that the fixings of steel reactor structures operating at high temperature were degrading because of oxidation. As a result it was decided in the early 1970s to downrate the stations by reducing the bulk reactor outlet gas temperature from about 42°C to 360°C. In addition a programme of work investigating the effect of oxidation on bolted and welded fastenings was initiated, together with a programme of reactor inspection. It has been demonstrated that the rate of oxidation is currently low and, where reinforcement is required, it has been possible to carry out repairs and establish satisfactory safety cases. In many cases repair work has only been possible because of the application of modern technology using remotely operated equipment. The need for such work was identified in the early life of the Magnox stations and special test facilities were established to develop and test remote operations technologies. The effective management of steel oxidation has been a key factor in ensuring the longevity of the Magnox stations.

The mechanical and chemical properties of the graphite cores are affected by oxidation. A range of parameters is monitored and tests carried out on material routinely removed from the cores. The most significant ageing process is the loss of bulk density in those stations that operate at higher pressure and power; this would in due course inhibit operation of the reactors as a result of the loss of moderation. To counter this effect, work is now under way to replace the natural uranium fuel with slightly enriched fuel. No other graphite ageing mechanisms are considered to be life limiting at present. Significant research programmes are, however, maintained to give forewarning of any potential adverse behaviour before it could occur in an operating reactor. Most recently a programme of reactor core graphite testing has been initiated in a test reactor at the Idaho National Engineering and Environmental Laboratories which will simulate end of life conditions

A review of the technically achievable lifetime of the stations confirms the current planning assumption that the stations can operate to a lifetime of at least 40 years. Wylfa, the last of the Magnox stations to be commissioned, has the potential to operate significantly beyond the closure of the other stations but operation with the current fuel cycle may not be economic.

A further issue which arises with older plants is the provision of specialist skills given the ageing workforce and the potentially limited availability of suitable external contractor support. In the recent past some older staff recruited in the early years of the Magnox programme have retired which can result in a loss of “corporate memory”. Planned recruitment and training of younger staff has been required to achieve a better balanced age profile and the opportunity to transfer experience from one generation to the next. A key factor is the provision of high quality experienced technical support staff to efficiently address safety case and operational issues into the future. The cost of maintaining such skills in-house is significant and arrangements with other organisations to provide resources when required have been developed. Close collaboration is also taking place with Westinghouse in the technical support area; Westinghouse is a recent addition to the BNFL group of companies. The pressure on resources has led to an increased emphasis on the processes and procedures adopted in the management of safety cases and associated modification work; the regulator has shown an increasing interest in these issues. This has led to improved quality assurance procedures, the increased use of peer review where new methods are developed, clear definition of roles and responsibilities and improved project management arrangements.

## **Recent developments**

### ***Ownership***

Over the period 1990 to 1996 most of the Magnox Stations were operated by Nuclear Electric plc with other newer nuclear power plants under Government ownership. In 1996 the newer nuclear plants were privatised under the ownership of British Energy plc. Subsequently, in early 1998, ownership of

the Magnox stations were transferred to BNFL. This resulted in all the Magnox plants comprising fuel fabrication, generation and spent fuel reprocessing facilities to be managed within a single Company. This has significant advantages in optimising operation of the plants by, for example, eliminating duplication and improving business decision making.

### ***Electricity market***

The market regulator has announced plans to change the structure of the electricity trading arrangements in the UK. The new arrangements would be introduced in late 2000. The existing trading arrangements result in most electricity being sold into a pool where all generators receive the same price for their output over specific time periods. The new arrangements are intended to increase competition and will require generators to agree contracts directly with purchasers. A balancing mechanism will be introduced to deal with uncontracted sales. It is anticipated that electricity sold into the balancing mechanism would receive significantly less than the market price. To maximise income it will be important to match the sale of contracts closely with actual plant output. This presents a significant challenge for the Magnox stations because plant output cannot easily be varied.

### ***Performance and economics***

The UK Magnox stations have achieved an average output of about 23 TWh over the last decade. This corresponds to about 6% of the electricity consumption in England, Scotland and Wales. There are significant fixed costs associated with the fuel cycle so the average marginal contribution from an individual station is substantial. However, three stations closed over the period 1989 to 1993, as indicated in Table 1, for economic reasons specific to those stations. A recent review of the future operation of Bradwell led to the decision to cease generation on economic grounds when the plant reaches 40 years of age in 2002. For the fleet of stations as a whole, the avoidable cost of operation should be competitive with other sources of generation, provided output levels are maintained and costs are contained.

### ***Investment***

Substantial levels of investment in the Magnox plants have been required in order to maintain safety standards and operational reliability. A key factor influencing the level of investment is the needs to replace or repair plant as a result of physical deterioration from ageing or obsolescence. Significant benefits result from the application of new technology where, for example, the capability to carry out inspection and repair is much greater than even a decade ago.

Examples of major recent programmes supporting generating plant operation include remote inspection of the primary pressure circuits and remedial work on turbines. A further example is the repair of the boilers of one of the Sizewell A reactors where significant weld defects were found in the main pressure vessels that had formed during construction. Repair work, making use of advanced welding technology, was successfully carried out in 1998.

Major recent refurbishment work has also been carried out at the reprocessing plant with the objective of supporting operation of the Magnox stations to the end of life; dismantling and renovation of one of the main dissolvers took place in 1997.

## **Future plans**

### ***Station output***

The operating conditions of the Magnox stations have been refined over the years but there is still limited scope to improve output levels. Improvements are expected from more effective management of plant ageing, better control of station outages and increased efficiency from, for example, refurbishment of turbines.

### ***Station lifetimes***

It is expected that the technically achievable lifetimes of the stations will be determined by the effects of ageing on the major structures where repair or replacement is impractical. The PSRs give confidence that, subject to satisfactory monitoring, the stations are capable of operating to 40 years and, in the case of Calder Hall and Chapelcross, 50 years. To date three Magnox stations have closed for economic reasons. During 1999 a review of the future operation of Bradwell was completed. The review showed that to secure operation beyond 40 years significant costs would be involved in addressing a number of technical issues. In addition it was anticipated that generation income would fall because of the reduced sale price of electricity. The decision was therefore taken to close the station in 2002 on economic grounds after 40 years operation.

Although it is not at present possible to predict precise lifetimes for the remaining stations, it is judged that all are technically capable of achieving at least 40 years operation.

### ***Reprocessing***

As stated previously, recent investment has taken place in the reprocessing plant with the objective of ensuring that it is able to service the Magnox stations over their remaining lifetimes. Further substantial investment will be required to meet commitments in respect to radiological discharges. The Oslo Paris Commission (OSPAR) is an international intergovernmental organisation established to limit waste discharges into the north-east Atlantic. This requires all participating countries to progressively reduce discharges over the period up to 2020.

### ***End of life management***

There are substantial fixed costs associated with fuel fabrication and spent fuel management and, in the event that stations close, these costs are shared between fewer and fewer station. This could reduce the incentive to keep only a few stations in operation within the existing Magnox fuel cycle. The cores of the Magnox reactors contain a large quantity of fuel which would take the reprocessing plant several years to reprocess. The optimum closure programme would therefore be to close stations progressively such that a steady delivery of spent fuel is discharged at close to the maximum capacity of the reprocessing plant.

Wylfa and to a lesser degree Oldbury, are potentially capable of operating significantly beyond the closure of the steel vessel stations. It is not expected that this would be possible with the current Magnox fuel cycle. A development programme is currently under way to examine the potential for using oxide fuel based on AGR technology at these stations.

## Conclusion

The Magnox plants have achieved a steady level of output level over the last three decades whilst maintaining an excellent safety record. The operational Magnox stations have achieved an average life of 37 years to date with the first Magnox station, Calder Hall, having already reached 44 years. This has been possible because of the conservative approach adopted by the designers and operators together with substantial investment in raising safety levels and managing plant ageing. BNFL's integrated Magnox business is now structured to deliver safe and economic operation of its reactors through an optimised life management programme.

**Table 1. Key data on UK Magnox stations**

Station	Date of Commissioning	Current Age in Years	Design Output MW(e)	Current Output MW(e)	No. of Reactors	Pressure Circuit
Calder Hall	1956	44	168	194	4	Steel
Chapelcross	1959	41	168	194	4	Steel
Bradwell	1962	38 (closure planned for 2002)	300	242	2	Steel
Berkeley	1962	(ceased operation in 1989)	300	–	2	Steel
Hunterston	1964	(ceased operation in 1990)	500	–	2	Steel
Trawsfynydd	1965	(ceased operation in 1991)	470	–	2	Steel
Hinkley Point A	1965	35	500	470	2	Steel
Dungeness A	1966	34	550	450	2	Steel
Sizewell A	1966	34	580	420	2	Steel
Oldbury	1968	32	600	434	2	Concrete
Wylfa	1971	29	1 180	980	2	Concrete

**THREE WORKING GROUPS**



## **Technology Working Group**

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### **Introduction**

At the end of 1998, there were 345 nuclear power plants connected to the grid in the OECD Member countries, generating about 24% of the electricity produced in these countries. It is clear that nuclear power plants play an important role as a supplier of electricity. A third of these nuclear power plants, however, have been operating for more than 20 years and this number is expected to increase year by year.

From the point of view of protecting the environment and international co-operation to decrease carbon dioxide emissions, nuclear power plants have advantages over fossil fuel power plants. The construction of new nuclear power plants, however, is becoming harder and harder because of the competitive electricity market and the NIMBY (Not In My Back Yard) syndrome in local communities.

The primary decision to construct, keep or terminate operation of nuclear power plants belongs to each utility company. This decision is made in accordance with both the government's mid- to long-term energy supply policy and environmental protection policies. Consequently, government is also concerned with the construction, operation and retirement of nuclear power plants.

Extending the operating life of a current nuclear power plant has been studied as a viable option from both environmental and economic perspectives. To date, a number of countries have looked into the life extension option from safety, reliability and economical aspects. For example, in the United States, after studies on license renewal were conducted, 20-year extensions of the original 40-year operating licenses have been approved for two plants (five units). In Japan, PLIM studies were conducted while plants were assuming 60 years of operation, as a result of which, processes to evaluate plant integrity and to manage ageing plants have been established. The studies showed that the safety and reliability of nuclear power plants can be maintained for 60 years. In France, the technical evaluation of plant life is in progress, and the viability of long-term operations has also been determined. In other countries, PLIM activities are also on-going.

These PLIM activities conducted by each country are summarised in the OECD report entitled "Status Report on Nuclear Power Plant Life Management: NEA/SEN/NDC(April 2000)6."

At this workshop, government, industry, and international organisations from OECD Member countries discuss how we can deal with the PLIM of nuclear power plants from technical, regulatory and business perspectives.



The Technology working group will enhance the understanding of and verify the current status of research and development (R&D) related to PLIM, and identify R&D that are necessary to deal with future changes in the nuclear environment.

By reviewing current PLIM activities and their technical challenges in various countries, which were presented at the plenary session of this workshop, international symposiums and other meetings, technical issues are chosen and discussed.

The ideas presented in this position paper reflect a point of view from one portion of the world. We all recognise that there are significant differences throughout the world regarding the technical, regulatory, and business questions that must be addressed as part of PLIM activities. It is hoped that the ideas presented in this paper will stimulate discussion on the technical issues that each of us must face and that a range of potential solutions to these issues can be suggested.

### **Scope and objectives of the working group mission**

Utilities should consider required provisions capacity by properly maintaining and preserving the existing power plants to the extent practicable and taking into account growing demand, limits of energy conservation, and difficulties in finding new power plant sites. Generally, the extension of the life of nuclear power plant (e.g. from 40 years to 60 years) is an attractive option for utilities, as the marginal cost of most existing nuclear power plants is lower than that of almost all other power sources. It is also an attractive option for environmental protection. Consequently, PLIM has become an important issue in the context of the regulatory reform of the electricity markets.

Therefore, the three main objectives of the Technology working group are:

- 1) Documenting how the safety of nuclear power plants being operated for the long-term has been confirmed, and suggesting ways of sharing this information.
- 2) Addressing development of advanced maintenance technologies necessary over the plant lifetime, and clarifying their technical challenges.
- 3) Suggesting potential areas of research and development that might be necessary. Some potential examples of such research include:
  - improving the effectiveness of maintenance methods to assure detection of incipient faults;
  - providing cost effective preventive maintenance programmes;
  - furnishing systematic, cost-effective refurbishment programmes framed to be consistent with efforts to extend the time between re-fuellings;
  - developing a methodology that moves routine maintenance on-line without compromising safety.

Beginning with these points of view, discussions will be held on fundamental and specific technical issues that should be addressed to the further use of commercial nuclear power plants. The common perspective on current status and technical issues for long-term operation is supposed to be summarised through these discussions. Recommendations are proposed by the working group to address points (1), (2), and (3).

## **Current status of PLIM activities**

### ***Perspective on nuclear power plants' lifetime***

In view of their safety and reliability, 20-year extensions of the original 40-year operating licenses were approved in the United States for 2 plants (5 units) this year. Twenty-one more units have either submitted license renewal applications or have notified the US Nuclear Regulatory Commission of their intent to do so.

In Japan, the three oldest nuclear power plants, which have been in operation for about 30 years, were chosen as pilot plants for evaluating plant integrity while assuming a 60-year operating life. It was verified that these three plants could be operated safely and reliably for 60 years with proper management. The integrity of other plants is supposed to be evaluated around 30 years of operations.

In France, integrity evaluation of the main components that are difficult to replace has been conducted. It was concluded that operations beyond 40 years are feasible, and now 50-year operation is considered to be feasible.

According to the results of integrity evaluations as shown in the above, and the technical knowledge being obtained through studies in various countries, it is technically feasible for existing light water reactors to look forward to the long-term operation, with proper maintenance and management. The life of nuclear plants should be reviewed periodically.

Of course, it is assumed that the components that are difficult to replace will be kept in use with proper maintenance, and other components that need to be repaired or replaced will be properly repaired or replaced.

For gas cooled and other reactors, studies and integrity evaluations for ageing plants, similar to those with light water reactors, are in progress. For example, in the United Kingdom, 50 years of operation have been approved for 8 Magnox reactors.

### ***Technical evaluation for verifying the feasibility of long-term operation***

In reviewing each country's process for evaluating the long-term integrity of nuclear power plants, it is found that their common factor is an evaluation to determine if the main components can continue to function throughout the plant's life. Evaluations of the main components are made by reviewing their integrity, while assuming long-term operations and adhering proper maintenance programmes.

In this section, the following issues are discussed:

- a) Selection of systems, structures, and components (SSCs) to be reviewed.
- b) Verification of process for integrity evaluation and review of maintenance programme.
- c) Results and challenges derived from integrity evaluation of SSCs.

#### ***a) Selection of SSCs to be reviewed***

It is very important to identify which SSCs should be considered in an evaluation of the long-term integrity of nuclear power plants.

The dominant factor in evaluating the long-term integrity of nuclear power plants, is the life of SSCs that are important to nuclear safety and technically hard-to-repair or -replace at a reasonable cost.

In US license renewal practices, SSCs that are important to nuclear safety and passive, are chosen to evaluate plant integrity when considering 60 years of operation.

In Japan, not only the integrity of the same components as those evaluated in the US are chosen, but also the integrity of all other components, which are necessary to maintain a totally functioning plant, are evaluated, while assuming 60 years of operations. As a result, most components of the plants are subject to integrity evaluation.

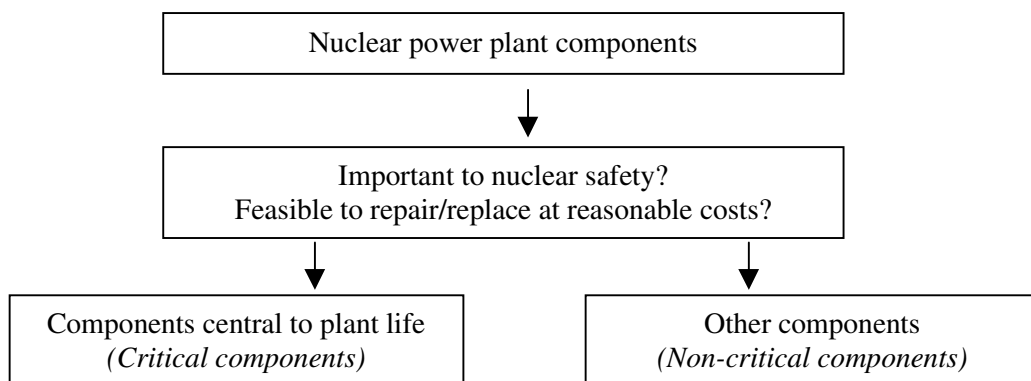
In France, 18 components were selected as main components of the plant life programme, and their integrity was evaluated.

In processes undertaken in screening SSCs, there is a common concept that the critical SSCs can be defined as SSCs that dominate plant life from the technical aspect, are hard to replace or repair, and which affect the safety and reliability of the plant. The basic concept is shown in Figure 1.

Critical SSCs that are chosen by this concept are reactor vessel (RV), RV internal structure, pressurizer, steam generator (SG), reactor coolant piping, reactor coolant pump, electrical cable, concrete structure, containment (CV) for pressurised water reactors (PWRs), and RV, RV internal structure, reactor coolant piping, recirculation pump, electrical cable, concrete structure, and CV for boiling water reactors (BWRs).

If, in the future, the repair/replacement or the life extension of critical SSCs becomes possible with advanced technology, the plant life can also be further extended.

Figure 1. **How to identify critical components**



*b) Verification of process for integrity evaluation and review of maintenance programme*

The technical evaluation process for long-term plant integrity, such as identifying main components and evaluating their lives, are basically similar in the various countries, though there are slight differences in each step of the evaluation process.

First, possible ageing effects of main components are identified through an analysis of design basis and operating experience. Next, an ageing analysis is conducted and the adequacy of current maintenance programmes is evaluated. Finally, by integrating the results of the first two steps, a conclusion can be reached as to whether main components can maintain their functions properly for the life of the plant.

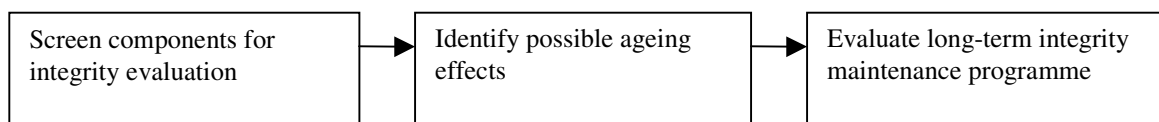
In the United States, augmented or new maintenance programmes identified during the evaluation, must be added to the Final Safety Analysis Report (FSAR).

In Japan, the long-term maintenance plan that consists of not only current maintenance programmes, but also short- and mid-term maintenance issues, such as necessary inspections, technical researches to be done and so on, is or will be established for each plant.

Thus, PLIM activities consist of plant integrity evaluation and review of maintenance programmes and they are in close co-operation. Therefore, it is important to establish a continuous cycle that consists of planning and conducting maintenance, accumulating and analysing its data, and then improving maintenance programme with feedback of its data.

With reference to practices in the United States, France and Japan etc., the basic concept of the process for plant integrity evaluation is systematically organised as shown in Figure 2.

Figure 2. **Technical evaluation process**



This, however, is only the basic concept of the process for evaluating the long-term integrity of nuclear power plants. And, each country has different regulatory systems and maintenance requirements. Therefore, the process can be made more reliable by adding more evaluations that are derived from plant or country-specific issues. For gas-cooled and other reactors, the basic process of evaluating long-term integrity is similar to that for light water reactors and a proper evaluation has been conducted.

### C) *Results and challenges derived from integrity evaluation of SSCs*

According to PLIM activities in various countries, there are similarities in how to screen SSCs for integrity evaluation, and how to actually evaluate them.

By a general examination of the long-term integrity evaluations of main components in every country, it was found that long-term integrity will be ensured by conducting:

- time-limited ageing analysis while assuming 60-year operation and taking into account ageing effects derived from material, environment, and operational history; and
- maintenance, properly and consistently, while taking into account current maintenance programmes.

For example, in light water reactors, long-term integrity evaluations are conducted to evaluate neutron irradiation embrittlement of the reactor vessel, fatigue and corrosion of the reactor vessel supports, fatigue and irradiation assisted stress corrosion cracking (IASCC)/inter-granular stress

corrosion cracking (IGSCC) of the reactor vessel internal structure. After that, the maintenance programmes to manage these ageing effects are reviewed and the additional maintenance is identified to maintain long-term integrity, if necessary.

With the current status, possible ageing effects of the main components are identified and properly evaluated. The integrity of main components is evaluated to last for about 60 years through proper maintenance.

In order to employ more reliable maintenance and management of nuclear power plants in the long view by introducing advanced ageing evaluation technology, and more effective preventive and corrective maintenance, our understanding of certain phenomena should be improved. These include:

i) Ageing effect identification technology

- SCC of the RV internal structure

SSC is identified at baffle former bolts of RV internal structure in PWRs and at the core shroud assembly in BWRs. To deal with such SCC, advanced technologies to evaluate SCC and to inspect, repair, and replace RV internal structure should be developed.

- Metal fatigue (thermal/environmental effects)

To deal with metal fatigue, advanced technologies to evaluate thermal stratification and stripping on piping should be developed. Acquisition and accumulation of data to optimise environmental factors is also necessary.

- Neutron irradiation embrittlement of the RV

In the United States, the standard to evaluate neutron irradiation embrittlement of RV was established as PTS and USE. For the other countries, acquisition and accumulation of data related to RV embrittlement and establishing the standard are necessary.

- Electrical cable ageing

In the United States, the inspection method to evaluate electrical cable ageing has already been proposed. However, acquisition and accumulation of data related to cable ageing is necessary to establish standards.

- Thermal embrittlement of stainless steel

The evaluation technology for thermal embrittlement of stainless steel has been established and the integrity of the material was verified. Optimised evaluation methods and advanced monitoring technologies on thermal embrittlement should be developed.

- Degrading of the concrete structure, etc.

Acquisition and accumulation of data on concrete structure, such as the support functions and the radiation-shield function of components and piping are necessary. Advanced evaluation method for degrading concrete structures should be developed.

ii) Inspection/monitoring technology

- Thermal embrittlement monitoring technology

The monitoring technology for the thermal embrittlement of the main coolant piping has been developed in each country. For instance, the minute sampling method, the Moessbauer method, and the hardness method have been developing. The thermo-electromotive force method has been developed and applied to the existing plants in France.

- Non-destructive testing (NDT) of cables, concrete, etc.

The NDT technologies for cables have been developed since the degradation of cables, especially for low-voltage cables where electric examination is very difficult. For example, NDT by measuring the hardness of the cable insulation, or by measuring the time while supersonic propagates the cable insulation has been developing.

Especially, in order to develop the identification of the degradation mechanism of IASCC, international programmes, in which utilities, industries and various researching institutes participate, such as the International IASCC Programme sponsored by the PWR group and the VIP Programme sponsored by the BWR group, have been carried out.

Therefore, to maintain the high-safety and reliability of nuclear power plants in each country, it is necessary to share information effectively on R&D projects and their results and co-operate worldwide to overcome common challenges.

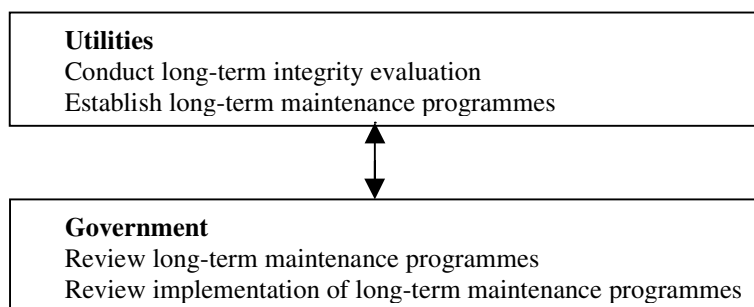
***Maintenance strategy***

In the United States, ageing management programmes are developed for areas where existing programmes are inadequate for the extended period of operation.

These management programmes are listed in the license renewal application, and utilities are required to follow these programmes exactly as written.

In Japan, long-term maintenance programmes that consist of not only the existing programmes but also those to be added, and showing their implementation schedules, are established. The programmes have been reviewed and accepted by the government. Thus, the maintenance strategy for ageing plants is systematically organised. The maintenance strategy is organised by the utility in accordance with the regulatory system of each country. The basic maintenance strategy, however, is established by allotting a role for utilities and government as shown in Figure 3.

Figure 3. **Roles and responsibilities of utilities and government**



In the future, it will be necessary to improve maintenance strategies and programmes by giving feedback based on practice, and experience.

**Summary of PLIM activities**

Concerning plant integrity evaluation for the long-term operation, license renewals for two plants (5 units) were approved in the United States this year, and evaluation reports on the long-term operation of early nuclear plants were issued in Japan. In France and other European countries, the process of evaluating and managing ageing plants has been studied. In general, it is feasible for existing nuclear power plants to look forward to the long-term operating life given our current level of knowledge.

By and large, it is considered that a process to evaluate plant integrity has been systematically established, and the long-term operation of nuclear plants is feasible.

However, conducting maintenance programmes properly and consistently is a prerequisite to maintaining long-term plant integrity.

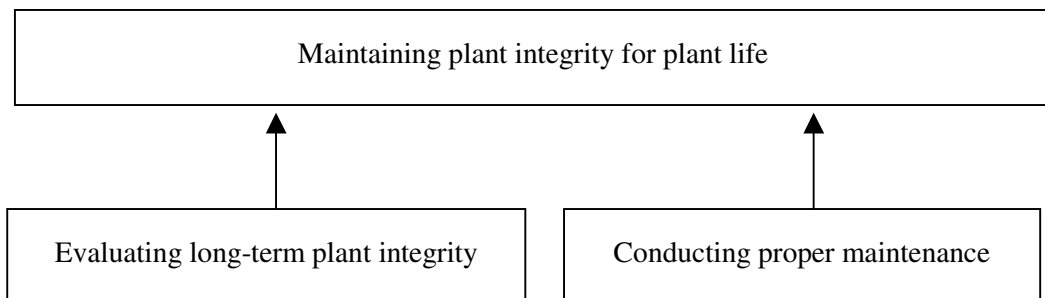
Each country can achieve more reliable plant integrity evaluations by applying its own systematic process in accordance with the specific issues of each country and by conducting proper maintenance.

To achieve more reliable PLIM, it is necessary to conduct international R&D projects related to identifying ageing effects and to developing inspection and monitoring technology, preventive and corrective maintenance technology, and component replacement technology.

While incorporating the results of R&D projects into the maintenance strategies, constant consideration should be given to both reasonable solutions to current challenges and possible future effects of ageing.

To achieve these goals, the roles of governments, utilities and industries should be identified. They should perform their own part most effectively and maintain a close relationship with each other to promote R&D activities from the point of view of safety-regulation, national energy strategy and economy.

**Figure 4. Long-term plant integrity evaluation**



## **Maintenance optimisation for long-term operation**

In order to keep the nuclear power plants competitive in terms of generation cost and to operate them reasonably without degrading safety and reliability, it is necessary to conduct R&D into the development of technologies for component repair/replacement and to optimise maintenance.

### ***Advanced maintenance technology needed to enhance PLIM***

To identify the ageing effects of main components and to repair or replace them as preventive maintenance, the following kinds of technologies are desirable:

#### *a) Ageing mitigation technology*

“Surface Modification and Characterisation Technology” has been developed to verify the effectiveness of surface treatment processes, such as laser treatment to improve its corrosion resistance.

Verification test items include the surface modification technology for reactor pressure vessel internals, the surface modification technology for primary coolant pressure boundary equipment, and the overall evaluation for surface modification technology.

Moreover, the annealing technology of the reactor vessel and the residual stress reduction technology by the peening method, etc., are enumerated for R&D programmes.

#### *b) Advanced repair/replacement technology*

Many steam generators have already been replaced. The whole replacement method and the repair technology for RV internal structures have been developed, and the core shroud assembly of BWRs has already been replaced at existing plants.

#### *c) Advanced NDT technology*

Many NDT technologies have been developed so far. More efficient NDTs could be executed by enhancing them.

For instance, to conduct highly accurate and efficient eddy current testing of steam generators, the intelligent probe has been developed.

To maintain the high safety and reliability of nuclear power plants in each country while being cost competitive, conducting R&D to develop these technologies with international co-operation is necessary.

### ***Advanced maintenance methodology needed to enhance PLIM***

As a result of advanced monitoring technologies, maintenance technologies are also enhanced.

In the United States, the reliability-centred maintenance (RCM) is being applied in place of time-based maintenance (TBM) which has been applied so far.



TBM consists mainly of the periodical overhaul of comprehensive components, and has been established based on preventive maintenance to avoid accidents and troubles.

On the other hand, condition-based maintenance (CBM) and breakdown maintenance (BDM) are opted for to reduce maintenance costs without degrading safety and reliability.

Studies on applying risk informed in-service inspection/in-service testing (RI-ISI/IST) are also in progress and have been implemented along with RCM at some plants. The basic idea of RI-ISI/IST is to optimise the inspection and testing of components by evaluating their safety importance according to probabilistic safety analysis (PSA). For example, cost reductions can be accomplished by distributing more resources to more important components and fewer resources to less important components after confirming that plant safety is not jeopardised by optimising maintenance for less important components.

Thus, methods to optimise maintenance have been studied in the deregulated electricity market. These methods enable optimising maintenance without damaging the safety and reliability of nuclear power plants. Developing advanced maintenance technology is necessary in order to achieve more proper maintenance that is well balanced with safety, reliability, and costs.

### ***Other issues***

#### *a) Improvement of plant performance*

To strengthen cost competitiveness of nuclear power plants, plant performance should be improved by uprating, and adopting high burn-up fuel assemblies.

##### *i) Uprating*

Uprating is achieved by replacing steam generators (SGs) with high performance. This aims at reducing generation costs by uprating to offset the expenses for SG replacement. This is regarded as an effective measure to maintain cost competitiveness.

The uprating should be promoted while taking account of regulation and the social situation.

##### *ii) Adoption of high burn-up fuel assemblies*

Increasing the burn-up of nuclear fuel enables nuclear power plants to be operated more effectively and nuclear waste to be reduced. As a result, it enables to reduce the generation cost and has been adapted to existing plants. It becomes more cost effective if long-term fuel cycle operation is introduced at the same time. Therefore, long-term fuel cycle operation is also adopted in many countries.

The high burn-up fuel assemblies should be promoted while taking account of regulation and the social situation.

*b) Maintaining knowledge and skills, and public acceptance, etc.*

Technical issues of ageing nuclear power plants have already been discussed. However, future nuclear generation might be confronted with other issues related to government regulation, business, and public relation issues in a deregulated nuclear market.

Issues can be settled by co-operation in these areas.

i) Maintaining knowledge and skills

Maintaining knowledge and skills in the nuclear industry is becoming more and more difficult with the lack of new constructions and the reduction in staff numbers.

In order to maintain the safety and reliability of nuclear power plants and still be cost competitive, this issue should be addressed not only as a PLIM issue but also as an industry wide issue.

Various activities are in progress to overcome it. For example, some utilities send their engineers to research institutes or to maintenance training facilities to keep up high levels of knowledge of nuclear technology and to remain knowledgeable about available resources.

Even though these activities are undertaken, the issue will become more serious. Therefore, utilities and industries should take further action in co-operation with government and international organisations.

ii) Public acceptance

Throughout the world utilities have conducted clear and easy educational campaigns for citizens on nuclear safety (e.g. brochures, videos, web pages, etc.), especially for local communities and the media.

In most countries, the role of the citizens is becoming more important in the decision-making process for nuclear power plants. To ensure the continuing of long-term operation, by extending operating life, obtaining citizens' support is very important even though citizens cannot directly participate in the plant's decision-making.

If public acceptance of PLIM activities is not sufficient under such circumstances, citizens may raise concerns over the safety of nuclear power plants, or not understand that the safety of nuclear power plants is not jeopardised by PLIM activities.

Therefore, proper information should be offered to the people to obtain their understanding about safety and the reliability of plant life management in each country, whether or not plant life management activity is promoted. In some countries, there are relevant examples of approaches including the public in decisions concerning plant life management.

- United States: an open hearing is held during the license application period and public comments are requested.
- Finland: public hearings are mandatory in the license renewal process.
- Japan: public opinion on a report of plant integrity evaluation is collected.

The approaches taken by each country to obtain public acceptance should be chosen properly considering the state of affairs in each country.

It might be necessary for each government to ensure the transparency and impartiality of the review process to obtain public acceptance.

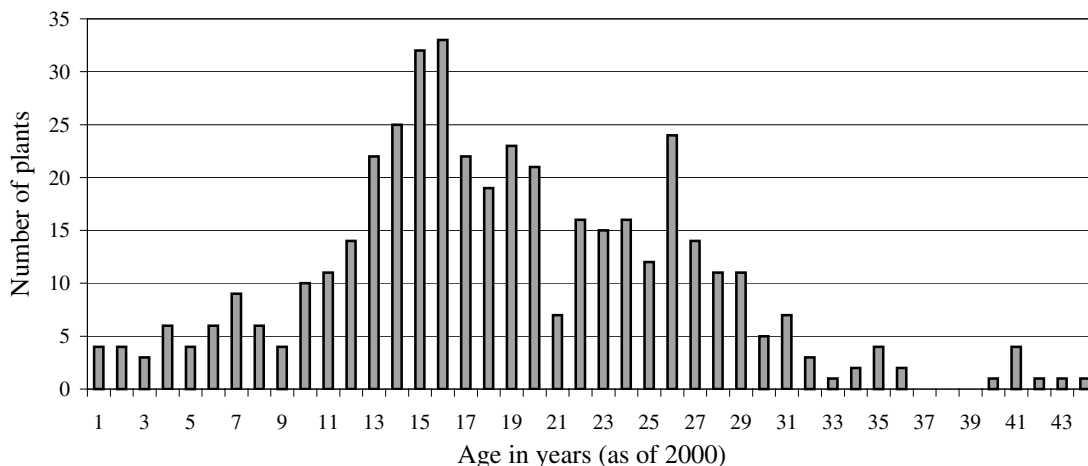
# Regulatory Issues for Nuclear Power Plant Life Management

Jack Roe

Manager, License Renewal, Scientech Inc., United States

## Introduction

Figure 1. Age of Nuclear Power Plants



Nuclear power has become an important source of electricity throughout the world. In 1999, there were 436 nuclear power plants throughout the world with a total installed capacity of 352 GWe [1]. Electricity from nuclear power plants accounted for more than one-sixth of the electricity generated in all power plants worldwide. In western Europe, nuclear power accounts for more than 40% of the electricity production. In OECD countries where more than 300 nuclear power plants are connected to the grid, about 24% of the electricity produced in these countries is from nuclear power with the percentage reaching 75% in France. While nuclear power has been a significant contributor to the electricity sector, there are uncertainties regarding its future role. These uncertainties arise from issues such as waste storage and disposal, industry restructuring, and market deregulation. The ageing of the nuclear generation capacity is another of the factors adding to the uncertainty in the future role of nuclear power. Figure 1 (which was adapted from the International Atomic Energy Agency) shows the age distribution of the nuclear power plants throughout the world. More than one-third of these plants are more than 20 years old with more than another 30% between 15 and 20 years old. One concept of Plant Life Management (PLIM), that of life extension, can be considered as a means of continuing the role of nuclear power in the electricity sector while maintaining or exceeding the safety and economic standards that have been met in the past. Life extension of nuclear power plants has been examined in a variety of countries. Some of the results and conclusions from these studies have been presented

during this Workshop. In the US, for example, applications for operating licenses beyond the original 40-year license have been made and granted. In Japan, PLIM studies were conducted under the assumption of a 60-year operating lifetime. These studies showed that the safety and reliability of nuclear power plants can be maintained for 60 years and resulted in the establishment of processes to evaluate plant integrity and to manage ageing plants. In France, the technical evaluations of plant life are in progress, along with a determination of the viability of long-term operations.

Summaries of PLIM activities in several OECD countries are presented in [2].

## **Regulatory background**

Regulation of the commercial nuclear power industry has been a long-standing factor in protecting the health and safety of the public. In various forms, regulation has examined the design, construction, operation, and decommissioning of commercial nuclear reactors throughout the world. As additional experience is gained in each of these areas, the regulatory process has been modified toward the objective of reaching a stable, consistent, and effective regulatory environment.

As the nuclear power industry focuses on PLIM, and especially on plant life extension, the industry and the regulatory agencies must assure themselves and the public, that the appropriate regulatory issues are being addressed and satisfactorily answered. Providing this assurance becomes even more difficult when recognising the changes in technology and the changing business environment in which the electric power industry finds itself throughout the world. As stated by Dr. Shirley Jackson, former Chairperson of the US Nuclear Regulatory Commission, regulatory agencies must maintain their focus on assuring "... that as the business environment changes, economic pressures do not erode nuclear safety" [3]. She further noted three areas that merit particular attention. These are:

- 1) Performance assessment (financial pressures to cut costs can degrade safety).
- 2) Electricity grid reliability (nuclear plants are vulnerable to loss-of-off-site power incidents).
- 3) Funding for decommissioning (current rules could be rendered obsolete by business restructuring).

Of course, the nuclear power industry and the regulatory agencies do have some recent history upon which to build an effective and efficient regulatory process. The extended operating licenses granted to Baltimore Gas & Electric's Calvert Cliffs Plant, and more recently, to Duke Power's Oconee Plant, provide a basic "blue print" for assuring continued health and safety of the public during continued operation of these plants.

Being the first plant to have been granted a license extension, there are some important lessons to be learned from the Calvert Cliffs experience [4]. These include:

- No ageing effects unique to license renewal were discovered.
- Current inspection activity on site, with some modifications, will ensure that ageing is managed cost effectively.
- Effective communications with all stakeholders is essential.
- The requirement to evaluate Severe Accident Mitigation Alternatives did not find any cost-beneficial alternatives related to ageing management (a petition to alter this requirement is before the USNRC).

A second component of regulation affecting nuclear power PLIM is that of economic regulation. Plant revenues are affected by economic regulation at various levels of government. In general, agencies responsible for economic regulation are independent of safety regulatory bodies. There are no economic regulation policies specifically addressing plant ageing, PLIM, or life extension although regulatory decisions on economic issues are strongly influence the lifetime of nuclear power plants.

In some countries, the U.S. being a prime example, economic regulatory uncertainties associated with restructuring of the electric power industry remain uncertain. These uncertainties arise because many of the individual states (who have economic regulatory authority) have not yet determined or enacted their policies and regulatory stances in the new electric sector environment that is evolving.

Historically, regulators controlled the price of electricity while guaranteeing a protected market with the utility providing a safe and reliable source of electricity at a reasonable price. Deregulation of the electricity industry is changing this situation in many parts of the world. This factor must be considered in PLIM activities.

### **Selected regulatory programmes**

As noted earlier, the regulatory review process for nuclear power plants generally can be divided into two broad categories: safety regulation and economic regulation. The regulatory agencies and responsibilities involved in various countries with commercial nuclear power plants are shown in Table 1 along with a brief status of major activities.

**Table 1. Regulatory responsibilities for various countries**

Country	Safety	Economic
Belgium	Federal Nuclear Inspection Agency has general responsibility for the inspection and surveillance of nuclear activities; Includes the Radiation Protection Service and the Technical Safety Service for Nuclear Installations; Safety reviews mandatory every 10 years	Deregulation of electricity market is in early stages
Canada	Atomic Energy Control Board uses a three-step licensing process involving site approval, construction license, and operating license. Initial operating license is typically one year with facility performance being reviewed in order to obtain a license renewal. Duration of renewed license is at the discretion of the AECB.	Rates are not regulated because Ontario Hydro is a publicly owned utility. Annual hearing before the Ontario Energy Board involves public participation. The OEB makes a non-binding recommendation that Ontario Hydro tends to closely follow.

Table 1. **Regulatory responsibilities for various countries (contd.)**

Czech Republic	State Office for Nuclear Safety conducts periodic review of the unit before start-up and after refuelling. Safety upgrades are planned and implemented to fulfil all requirements resulting from these reviews. Utility conducted audit to ensure that plant could reach its design lifetime of 30 years and to determine the possibility of a ten-year life extension.	Re-examining methods and assumptions used in determining economic viability of power plants. Determined that life extension of twin 440 MW units was more economic than construction of three-330 MW gas-fired, combined-cycle units.
Finland	The Radiation and Nuclear Safety Authority has responsibility to control nuclear and radiation safety including plant ageing and life management. License issued for a specific time period with renewal only after a thorough safety review, including an assessment of ageing.	Utilities make their own investment decisions regarding plant improvement and life management, while considering the safety requirements set by the Radiation and Nuclear Safety Authority. Utilities are required to collect funds for disposal of spent fuel and decommissioning.
France	Safety authority is shared by the Ministry of Industry and the Ministry of the Environment. There are no specific regulations on plant lifetime but the authorisation to proceed can be withdrawn if the governing authority determines that safety is not being adequately addressed or if the utility cannot provide proof that adequate attention is being given to safety. Utility is ordered to perform periodic safety reviews that are linked with the statutory 10-year outage programmes.	No economic regulations governing PLIM. Ministry of Industry and Ministry of Finance ensure that plant investments are optimised. Utility has conducted lifetime extension studies as part of evaluation of generation options.
Germany	Operating licenses have no time limit. There is no life extension programme and is considered to be the responsibility of each individual plant. Oversight of issues such as plant ageing is done at the state level together with an independent advisory authority acting on behalf of the Federal Ministry of the Environment, Nature Conservation and Reactor Safety. Safety reviews are required for each plant at approximately 10-year intervals.	No economic regulation related to nuclear plant management. Operation is entirely the responsibility of plant management with business policies of owner utility.
Hungary	License can be renewed at 12-year intervals with a comprehensive safety review including a determination of the lifetimes of systems and components. Initial design lifetime of various components differ. Hungarian Atomic Energy Commission has renewed license of two reactors for 12 years and is evaluating the other two units.	Currently considerable uncertainties in quantifying factors that influence economic decisions.

Table 1. **Regulatory responsibilities for various countries (contd.)**

Japan	Ministry of International Trade and Industries provides regulatory procedures and guidelines and reviews license applications. It also provides the basic strategy and establishes and conducts R&D projects on PLIM. License initially granted for an indefinite period. Plants are shut down for inspection on annual basis. Technical standards for components based on ASME Code Sec. III but advances in fracture mechanics have allowed structure and components to be quantitatively evaluated. Standards are being revised to reflect these advances.	There is no economic regulatory policy or requirement specifically related to PLIM. Ministry of International Trade and Industries has jurisdiction on the authorisation of electricity rates. Utility assesses economic trade-offs with respect to ageing, life extension, and PLIM.
Korea	30-year operating license granted by Ministry of Commerce, Industry and Energy.	
Spain	Operating license is not specifically defined but is subject to periodic review. Nuclear Safety Council and Department of Energy of the Ministry of Industry and Energy are regulatory agencies on safety issues. Nuclear Safety Council has requested a management plan from the utility that addresses ageing of components. Safety Guides establish the requirements relating to the control of ageing in important components as part of the Periodic Safety Review process.	Plants must be competitive in a free-market.
Sweden	The Swedish Nuclear Power Inspectorate and the National Board of Radiation Protection are regulatory agencies. Plants submit safety analysis reports on an 8-10 year basis.	Utilities operate in a commercial environment with no specific constraints pertinent to nuclear power. Nuclear utilities must contribute funding for regulation, waste disposal, and decommissioning.
United Kingdom	Health and Safety Executive is the nuclear installation licensing authority. Utilities are required to review and re-assess the safety of their plants periodically and systematically, including a review of age-related phenomena. Reviews can recommend an additional 10 years of operation but operations are dependent on results of routine inspections.	Office of Electricity Supply is charged with protecting customer interest with respect to electricity prices and other issues. The Department of Trade and Industry has responsibility for energy policy including the role of nuclear power.



Table 1. **Regulatory responsibilities for various countries (contd.)**

<p>United States</p>	<p>Nuclear Regulatory Commission regulates the commercial nuclear power plants. Initial operating license limited to 40 years but can be renewed. License renewal rules stress the management of the effects of ageing and requires an Integrated Plant Assessment and time-limited ageing analyses. Environmental requirements have been amended to facilitate the environmental review component of the license renewal process.</p>	<p>Federal regulating body is the Federal Energy Regulatory Commission which regulates interstate and wholesale electric rates. At the state level, Commerce Commissions, Public Service Commissions, or Public Utility Commissions exercise authority over investor-owned utilities through approval or adjustment of the cost basis in determining electricity rates and by determining the allowable return on investment. There is no regulatory policy specifically related to nuclear plant ageing, life extension, or PLIM.</p>
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To expand slightly on the US safety regulatory activities, it might be said that there are four key features in the license extension process [4]. These features do not appear to be fundamentally different than those in several other countries with commercial nuclear power plants. These four key features are:

- 1) A technical or plant ageing evaluation must demonstrate that plant ageing will be managed.
- 2) An environmental review must find that continued operation will not unreasonably impact the environment.
- 3) NRC inspections must verify technical assertions, ageing management activities and plant conditions.
- 4) The Advisory Committee on Reactor Safeguards must provide an independent review of the application.

Environmental regulation associated with nuclear plant PLIM and life extension comes in at least two forms. First, as part of the license extension process, plants in the United States and some other countries, must address a series of environmental questions including those on impacts on wildlife habitats, threats to endangered species, schools, housing, transportation, and many others. This information is submitted to the U.S. Nuclear Regulatory Commission as a draft Environmental Impact Statement. The NRC must then approve this document as part of the license extension review process.

The second area in which environmental regulation can influence nuclear PLIM includes the broad issue of global warming, greenhouse gases, carbon and other atmospheric emissions. Should regulation be promulgated that invokes “carbon taxes” or the consideration of “externalities” in the costs of power production, it is likely that cost comparisons among generation options will shift more toward nuclear power. Should this happen, there will likely be a greater emphasis on PLIM, life extension, and other techniques from expanding the use of nuclear power in the electric sector.

### **Objectives of regulation working group**

At this workshop, representatives from governments, industry, and international organisations in OECD Member countries are discussing ways to address PLIM of nuclear power plants. Perspectives from technical, regulatory and business points of view are being considered as well as the interactions between and among these perspectives.

The Regulatory Working Group will attempt to identify some of the more pertinent issues affecting nuclear plant regulation in a changing PLIM environment, to identify some possible actions to be taken to address these issues, and to identify some of the parties responsible for taking these actions. Some preliminary regulatory issues are noted below. This is not intended to be a comprehensive list of such issues but rather is intended to stimulate discussion among the experts attending this Workshop. Following the Workshop, the findings from the Regulatory Working Group will be summarised (along with those of the Technology and Business Working Groups) for distribution to the participants and to the sponsors and hosts of this Workshop.

As demonstrated by the design of this Workshop, regulation is intimately tied with technology and business when examining PLIM of nuclear power plants. One of the concerns in the regulatory arena is how the structural integrity of the plants can be assured for an extended lifetime. Technological advances directed toward the following are likely to be important factors in the regulatory process of life extension.

- Preventive and corrective maintenance (e.g., water chemistry control, pressure vessel annealing, and replacement of core internals).
- Ageing and degradation mechanisms and evaluation (e.g., embrittlement, wear, corrosion/erosion, fatigue, and stress corrosion).
- Monitoring, surveillance, and inspection (e.g., fatigue monitoring and non-destructive testing).
- Optimisation of maintenance (e.g., using risk-based analysis).

On the business side, there is concern about technical support by manufacturers, fuel companies, and construction companies. Maintaining a strong technical base and skilled workers in a potentially declining environment is another concern in the regulatory community.

Waste management and decommissioning remain significant issue regarding PLIM. These issues affect all three areas of concern - technology, business, and regulation.

It is against this background, that the issues put forth in this paper are presented. The objective of presenting these issues is to stimulate discussion as to whether additional issues should be addressed, what actions should be taken, and who should take these actions.

## **Regulatory issues**

A partial list of potential issues is presented below. These issues have been summarised from several sources and have been supplemented by the author. No level of importance or urgency should be implied from the order in which these issues are presented.

The following issues have been grouped into several categories. There is considerable “overlap” in these categories but the range of categories of illustrates the breadth of issues that influence the regulatory process.

### ***Technical***

- Ageing
  - physical components;
  - analytical techniques;

- documentation (in some eastern European countries, original design data and equipment qualifications are incomplete or missing and information cannot be obtained from the original supplier);
- rules and standards;
- definition of the analyses needed to support life extensions and metrics to demonstrate that the plant will operate within the defined parameters.
- Increase of operational flexibility; maximising output from existing reactors
- Safety margins
  - more exacting operating modes;
  - adoption of acceptable fuel safety margins and the regulation of high-burn-p fuel;
  - higher power rating.
- Backfitting and safety upgrading programmes for plants designed to lower safety standards.
- Decommissioning – including the provision of adequate funding.
- Management, storage, and disposal of high-level waste and spent fuel.
- Transition from base-load operation to load following.

### ***Licensee management/organisation***

- Maintenance of knowledge and knowledgeable personnel
  - Staff training and preserving a critical mass of knowledge and expertise;
  - Monitoring of the level of education and training of younger staff and students.
- Reduction in R&D funding (funding has decreased by factor of three over last ten years)
  - Government supported;
  - Privately supported;
  - Closure of research facilities.
- Self-assessment.
- Self-regulation.
- Risk-informed/performance-based regulation.
- Safety cultures.
- Restructuring of electricity generation industry
  - mergers;
  - privatisation of national utilities;
  - increased emphasis on short-term concerns.

### ***Regulatory management/organisation***

- Safety cultures
- Regulatory effectiveness
- Regulatory efficiency
- Independence of regulatory agencies
- Maintenance of knowledge and knowledgeable personnel
  - Staff training and preserving a critical mass of knowledge and expertise;
  - Monitoring of the level of education and training of younger staff and students.
- Development of co-operation between regulatory authorities and industry
- Co-operation among international regulatory authorities
- Applying experience for de-regulation of other industries (e.g., air lines and railroads) to nuclear power PLIM

### ***Political/public relations***

- Moratoria and referenda on the use of nuclear power
- Reduction in R&D funding
- Interface between regulatory authorities and the public or their representatives
- Privatisation of national companies
- Mergers between utilities
- Restructuring of the electric utility industry

### ***International***

- Co-operation with, and assistance to, safety authorities in countries where regulatory organisations need to be strengthened
- Foreign ownership of nuclear utilities
- Application of experience in one country to other countries

### **Summary**

The ageing of commercial nuclear power plants is of great concern to the electricity generation industry. Worldwide, almost two-thirds of the existing plants are at least 15 years old and very few plants have been constructed in recent years. To help maintain the viability of nuclear power as a contributor to the generation mix, PLIM activities have been undertaken in technology, business, and regulatory arenas.

As was noted earlier in this paper, the safety regulatory position on reactor licenses varies throughout the world with some countries having fixed, limited terms and other countries having unlimited terms but with specific requirements on periodic safety reviews. Table 2 shows some of this variation. This table was adapted from Reference 2.

**Table 2. License durations for nuclear power plants**

<b>Limited term</b>	<b>Unlimited term with periodic safety review</b>
Canada (0.5-3 years)	Belgium (10 years)
Finland (10-20 years) <sup>a</sup>	France (10 years)
Hungary (12 years)	Germany (10 years)
Korea <sup>b</sup>	Japan (10 years)
United States (40 years) <sup>c</sup>	Sweden (8-10 years)
	United Kingdom (10 years)

a) A 20-year license requires a safety review after 10 years.

b) Korea is currently establishing a time period for license duration.

c) License duration for early plants began at start of construction; More recent plants begin at start of operations.

Additional regulation of nuclear power comes in the form of economic regulation (e.g., electricity rates and allowable rates of return on investment). This form of regulation is rapidly changing as a result of privatisation, re-regulation, and organisational restructuring that is occurring throughout the world.

Positive experience has been gained in the regulatory arena through the successful granting of life extensions for the Calvert Cliffs and Oconee plants. Lessons learned from these cases should be valuable in conducting safety reviews for life extensions of additional plants.

The Workshop on Nuclear Power PLIM has brought together government, licensee, and regulatory personnel to examine issues important to continuing the viability of the nuclear generation option. Several issues to be addressed or improved upon as part of the regulatory process have been suggested as potential points of interest to the Regulatory Working Group. Results of these discussions will be forthcoming after the Workshop.

## REFERENCES

- [1] *Nuclear Power Plant Information*, International Atomic Energy Agency data available at <http://www.iaea.or.at/programmes>.
- [2] *Status Report on Nuclear Power Plant Life Management*, OECD/NEA report NEA/SEN/NDC(April 2000)6. Available at <http://www.nea.fr/html/ndd/pub.html>.
- [3] OECD/NEA(1998), *Future Nuclear Regulatory Challenges*, A report for the Nuclear Energy Agency Committee on Nuclear Regulatory Activities.
- [4] *License Renewal in the United States: Enhancing the Process through Lessons Learned*, paper by Douglas Walters, presented at International Workshop on Nuclear Power Plant Life Management in a Changing Business World, (26-27 June, 2000).

## **Business Working Group**

### **Barth W. Doroshuk**

President and Chief Operating Officer,  
Constellation Nuclear Services, Inc., United States

#### **Overview of session**

- Discuss the issues surrounding life extension of a commercial nuclear generating station.
- Discuss the magnitude of the “decision” – where might one start?
- Discuss who might be involved; who should or might be on the “team”.
- Discuss other “stakeholders” that will be involved.
- Discuss what information, data and analysis supports the decision regarding the continued operation of the plant.
- Discuss integrating it all into your recommendation.

#### **Format of working session**

- Presentation will guide session and facilitate accomplishing objectives.
- Use of examples will provide illustration of significant points.
- Interaction and discussion amongst participants will be essential for success.
- Follow up items will be collected and addressed in timely manner.

#### **The nuclear option**

- The decision to either operate a facility or permanently close it must be based on:
  - sound technical information;
  - safe, reliable production record and projections;
  - knowledge of competitive position(s) in an evolving marketplace.
- The ability to continue to operate a plant must be forged with a vision of integrity, quality and safety.

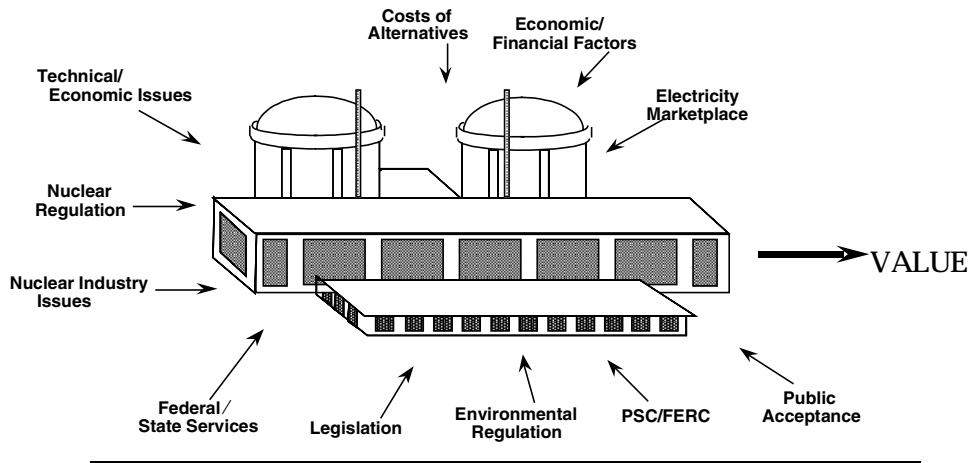
#### **Projected plant operational readiness**

- It is unlikely that our plants will continue to operate right up to the originally intended point (e.g. 40 year point); history predicts this.
- Overall performance over the last 10 years will degrade, resulting in higher costs and challenges to our capability to stay on-line.

## Alternative operating scenarios

- prematurely shutdown, or
- operate to close to the end of existing licenses, with increased overall uncertainty and reliability, or
- preserve the option to operate beyond originally licensed or intended periods;
- sell and let someone else worry about it.

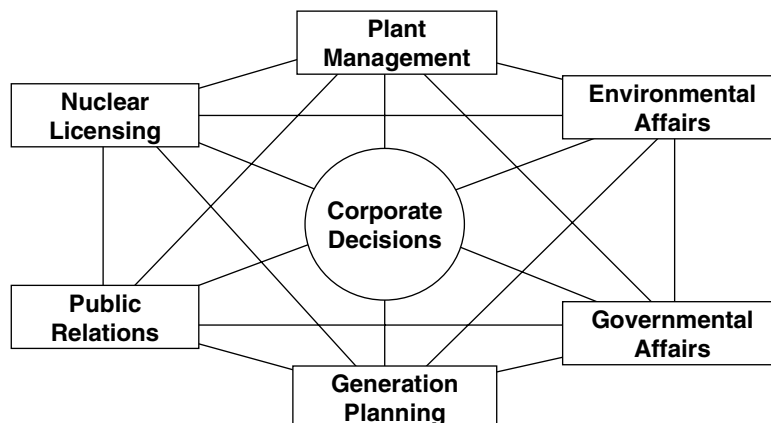
## Plant value and life cycle influences



## Making good decision

**Early investigations**, combined with a commitment to excellent performance, **are necessary** to avoid technical, financial and other risks that may become so insurmountable that continued operation and good decision making is jeopardized or lost.

## Decisions require the involvement of many people

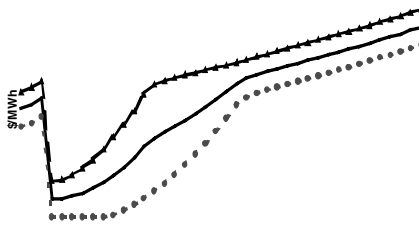


**Alternative operating scenarios – “the forks in the road”**

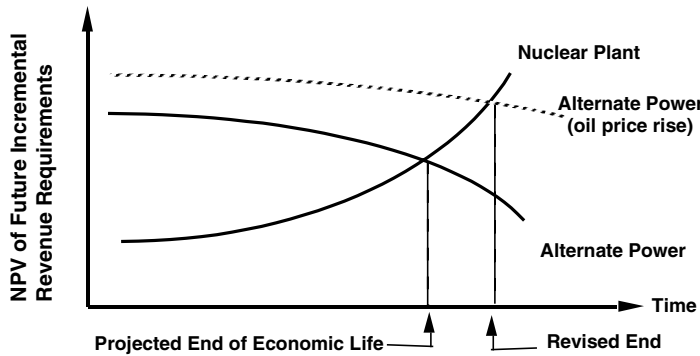
- Prematurely shutdown, or,
- Sell facility, or
- Operate to close to the end of existing licenses, with increased overall uncertainty and reliability, or
- Preserve the option to operate beyond existing licensed periods.

**Financial considerations**

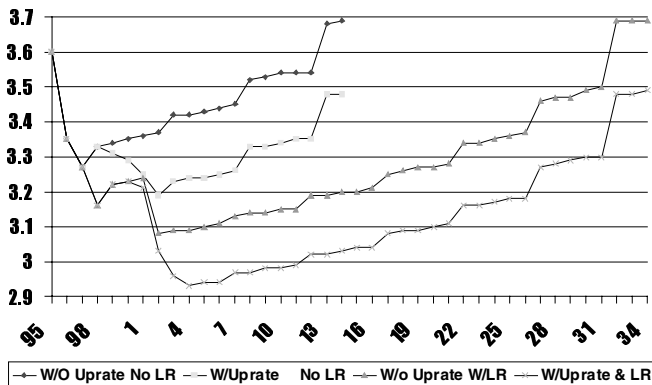
*Wholesale price of power*



**Uncertainty factors and costs of alternates can affect economic value**

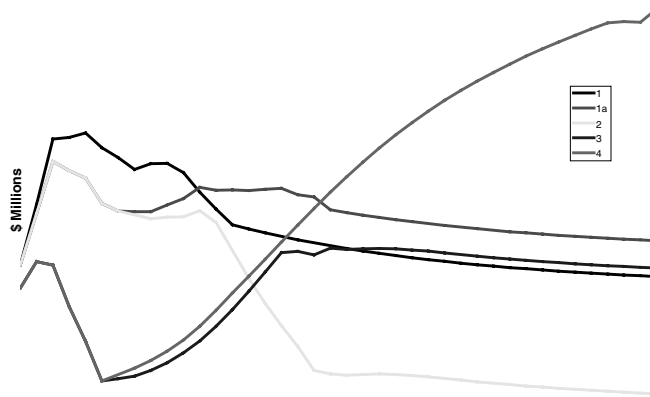


**Bust bar cost analysis with license renewal**





## Cumulative NPV results



## Non-financial considerations

Technical and Regulatory?

## Objectives of working session

- Walk through the Calvert Cliffs Case Study.
- Discuss the generic parts of assessment and how they might benefit others.
- Discuss the quantitative and qualitative results in terms of lessons learned.
- Discuss how the process may help guide others in their decision making.

*Annex 1*

**WORKSHOP PROGRAMME**

**Sunday 25 June 2000**

16:00 – 18:00     **Registration**

**Monday 26 June 2000**

7:00 – 8:00     **Registration and Continental Breakfast**

8:00 – 12:00                             **Opening session**

8:00 – 8:30     **Welcome Addresses**

*Dr. John J. TAYLOR*

Workshop General Chairperson

Vice President, (retired) Electric Power Research Institute (EPRI),  
United States

*Mr. Sam THOMPSON*

Deputy Director-General, OECD Nuclear Energy Agency (OECD/NEA)

8:30 – 9:05

**Nuclear Energy Institute**

*Mr. Marvin FERTEL*

Senior Vice President, Nuclear Energy Institute (NEI), United States

9:05 – 9:40

**Department of Energy**

*Dr. Gail H. MARCUS*

Principal Deputy Director, Office of Nuclear Energy, Science and Technology  
US Department of Energy (USDOE), United States

9:40 – 10:00

**Break**

10:00 – 12:00

**Plenary session – Part 1**

**Chairperson: *Mr. John J. TAYLOR***

**a] Technology**

10:00 – 10:30

**i] Current Status of Technology for Plant Life Management**

*Mr. Bernard ROCHE*

Deputy Director, Engineering Division, Electricité de France, France

10:30 – 11:00      **ii] Current and Future Technologies for Plant Life Management**  
*Mr. Hironobu YAMASHITA*  
Deputy General Manager, Nuclear Power Plant Management Department  
Tokyo Electric Power Company, Japan

**b] Implementation**

11:00 – 11:30      **i] License Renewal in the United States – Enhancing the Process  
through Lessons Learned**  
*Mr. Douglas J. WALTERS*  
Senior Project Manager, Nuclear Energy Institute, United States

11:30 – 12:00      **ii] Competitive Nuclear Power Production in the Deregulated Nordic  
Market**  
*Mr. Torsten BOHL*  
Public Relation Manager, Ringhals AB, Sweden

12:00 – 13:45      *Break and Lunch*

13:45 – 15:30      **Plenary session – Part 1 (contd.)**

**c] Business**

13:35 – 14:15      **i] Reorganisation of KEPCO and Lifetime Management Status in Korea**  
*Kyung-Nam CHUNG*  
General Manager, Electricity Industry Restructuring Office  
Korea Electric Power Corporation, Korea

14:15 – 14:45      **ii] Deregulation and Restructuring of the Electricity Sector in Spain**  
*Mr. Lorenzo FRANZIA*  
Engineering Manager, Nuclear Directorate, UNESA (Spanish  
Electricity Association), Spain

14:45 - 15:15      **iii] Operation of the UK Magnox Stations in a Competitive Market**  
*Mr. Andrew CORRIGAN*  
Station Manager, BNFL Magnox Generation, United Kingdom

15:15 – 16:00      *Break*

16:00 – 17:30      **Three Working Groups on Technology, Regulation and Business**

**Chairpersons:**

**Technology:** *Dr. Yonezou TSUJIKURA*  
General Manager, General Office of Nuclear and  
Fossil Power Production, The Kansai Electric Power Co., Inc.  
Japan

**Business:** *Mr. Barth W. DOROSHUK*  
President & Chief Operating Officer, Constellation Nuclear  
Services, United States

**Regulation:** *Dr. Jack ROE*  
Manager, License Renewal Services, Scientech Inc.,  
United States

a) **Presentation of the point paper by the chairperson of the  
working groups** [~ 20 minutes]

b) **Discussion** [~70 minutes]

18:30 – 20:00

*Reception*

**Tuesday 27 June 2000**

8:00 – 10:00

**Three Working Groups on Technology, Regulation and Business  
(contd.)**

**Chairpersons:**

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10:00 – 10:30

*Coffee break*

10:30 – 13:00

**Plenary session – Part 2**  
**Chairperson: *Mr. John J. TAYLOR***

a) **Presentation** [~20 minutes each]  
by the 3 Chairpersons of the Working Groups

b) **Discussion**

c) **Concluding remarks**  
by the General Chairperson of the Workshop



*Annex 2*

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