Impacts of nuclear power plant life management and long-term operation

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Nuclear energy is an important component of electricity supply in many OECD countries and is increasingly gaining the attention of policy makers and the public in light of its real potential role in long-term energy strategies aiming at sustainability and minimising the risk of global climate change. For many operating nuclear power plants, it has been demonstrated to the satisfaction of regulators that the plants can be operated safely and efficiently for a significantly longer period than was envisaged when they were designed, with lifetimes of 50 to 60 years being likely in many cases.

In most OECD countries with established nuclear power programmes, longer-term operation (LTO) of the nuclear power plants has already been accepted as a strategic objective to help ensure adequate supplies of electricity over the coming decades. In that context, the NEA has recently conducted a study whose main objective was to review and analyse the impacts of plant lifetime extension on fuel cycle and waste management requirements, on the economics of nuclear energy, on knowledge management and preservation, and more broadly on the future of nuclear energy in OECD member countries. Its scope includes technical, economic, social and strategic issues raised by plant life management and longer-term operation in countries planning an extended reliance on nuclear energy, in countries wishing to keep the nuclear option open, and in countries having decided a progressive phase-out of nuclear energy. OECD member countries in each of these categories as well as one member country without a nuclear programme were represented in the expert group that conducted the study.

The group's report, published under the title *Nuclear Power Plant Life Management and Longer-term Operation,* presents trends, advantages and technical-economic challenges as well as environmental impacts of nuclear power plant lifetime management for longer-term operation. This article provides excerpts of the study's main findings.

Advantages of longer-term operation

The study concludes that the principal advantages of longer-term operation are economic in that:

- Extending the life of a major generating asset avoids the need for immediate investment in new generating capacity.
- The capital costs of plant life management for LTO will be much smaller than investment in any type of replacement capacity, although there might be a need for some additional investment in plant upgrading.
- Per kWh costs for waste management and decommissioning can be reduced.
- With nuclear fuel costs being generally lower and more stable than fossil fuel costs, this means that LTO can be expected to provide electricity at a lower cost than any other available option, which has a clear benefit to the national economy.

During the operating lifetime of several decades, it will often be possible to enhance plant safety levels by upgrading systems, structures and components (SSCs). Some such upgrades may be required by regulators, while others will be made by plant operators as part of regular maintenance or in pursuit of improved operating performance. Thus, while a nuclear power plant (NPP) may have

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been in operation for 30 or 40 years, many of its SSCs will be much younger. LTO helps to justify the investment in such upgrades, which means that it can also help to raise safety levels.

Longer-term operation of existing nuclear power plants contributes to sustainability by maintaining security and stability of energy supply and the diversity of energy sources; throughout, safety remains of paramount importance. Furthermore, LTO can provide nuclear energy without the significant environmental impacts that would be created by alternative power generation options (notably CO_2 emissions). Most countries with operating NPPs consider that nuclear energy contributes to the sustainability of their overall energy supply system, in that it minimises the long-term and irreversible impacts on the environment of meeting current energy demand.

Nuclear safety and the regulatory framework

When the current fleet of nuclear reactors was built, safety requirements of the existing plants were sufficiently stringent to ensure a considerable amount of conservatism in the design. Conservatism as such can facilitate LTO of existing nuclear power plants. Operating experience, improved analytical techniques and training of personnel also contribute to ensuring the safety of LTO, though proper regard must be given to the possibility of unknown ageing mechanisms. To the extent that the systems, structures and components of the nuclear power plants are correctly managed, LTO can potentially provide a bridge between the present generation of nuclear power plants and future energy systems, be they nuclear or non-nuclear.

Plant SSCs can be classified as either critical or non-critical. Critical items are those whose failure would cause concerns for the safety and reliability of the plant, and which therefore need to be repaired or replaced before they fail. Current preventive maintenance programmes help to improve plant safety and reliability by maintaining and replacing critical components.

Although the great majority of critical SSCs in an NPP can be replaced when necessary, there are a few major components (notably the reactor pressure vessel in most plants) which can be considered non-replaceable, either for technical or economic reasons. For such components it is necessary to implement ageing management programmes.

This process of optimising the upgrading and ageing management of the plant is vital in preparing for LTO. It includes ongoing research and development efforts to understand and mitigate the effects of ageing mechanisms, particularly on non-replaceable components, and involves plant operators working closely with reactor vendors and other nuclear engineering companies.

To achieve LTO it is important to have a clear and predictable regulatory framework. Timely investments need to be made in upgrading the plant and replacing the SSCs, and these will be influenced by the prospects for LTO. This process will be optimised only if the requirements that will need to be met are clear many years in advance. The process of consultation between regulators and plant operators therefore needs to begin well in advance. Once decided, the necessary licensing and approval processes need to be carried out in a timely manner.

The energy policy framework and political background are also important factors. If national energy policy regards LTO of NPPs as valuable and facilitates it, then clearly this will encourage plant owners to plan accordingly and to make the necessary investments well in advance. A decision to allow LTO to go ahead may often be easier to take from a political perspective than the alternative decision to construct replacement generating capacity. However, in some cases NPP owners have continued to plan for possible LTO even where political support for it is unclear.

More broadly, it is vital to build public confidence in the LTO of NPPs. While the public living in the immediate area around an existing nuclear plant is usually supportive, LTO might raise concerns about safety. The public needs to be properly informed about plans for LTO and the basis for ensuring that safety will not be compromised. Furthermore, it is necessary to discuss the advantages and concerns associated with LTO.

Operational experience

One important aim of plant life management for LTO is to improve a plant's operating performance. This includes upgrades to improve reliability, and hence achieve increased capacity factors. In many cases a plant's power output can also be increased, through uprating the reactor (see Table) and/or the turbine systems, while continuing to comply with all licensing and regulatory requirements.

Plant life management (PLiM) programmes have already resulted in significantly improved operational performance at many NPPs in OECD countries, which has often greatly increased the value of these nuclear generating assets. Further increases in operating performance have been achieved by optimising fuel management (e.g. higher enrichment levels and increased burn-ups), while reducing specific (per kWh) production of radioactive waste and spent fuel.

Planned and potential results of power uprating and PLiM programmes for LTO in selected NEA member countries

Country	Capacity uprating	LTO
Belgium	Yes	Phase-out policy
Czech Republic	Planned	Planned to 40 years, potentially to 60 years (4 units)
Finland	Capacity increase of 18 MWe com-pleted in 2005 for Olkiluoto unit 2, completed in 2006 for Olkiluoto unit 1	Planned lifetime of 60 years for units 1 and 2, and for unit 3 (EPR) at Olkiluoto; planned lifetime for Loviisa (2 units) raised to 50 years
France	No	Lifetime of 40 to 60 years (58 units)
Japan	No	Lifetime of 40 to 60 years
Germany	Yes	Phase-out policy
Hungary	Under way for 4 units, capacity increase of up to 150 MWe	Planned to 50 years (4 units)
Republic of Korea	Yes	Lifetime of 40 to 60 years
Mexico	Yes	Lifetime of 40 to 60 years
Slovenia	Yes	Lifetime of 40 to 60 years
Slovak Republic	Under way for 4 units, capacity increase of up to 220 MWe	Planned to 40 years, potentially to 60 years (4 units)
Spain	Completed for 8 units, capacity increase of 550 MWe	Planned, possibly to 60 years (8 units)
Sweden	Under way for 8 units, capacity increase up to 1 296 MWe	Planned, up to 60 years or more (8 units)
Switzerland	Yes	Lifetime of 40 to 60 years
United Kingdom	No	Planned to 35 years (5 plants) or 30 years (2 plants), further extensions possible
United States	Continuing for many units, total capacity increase of over 4 000 MWe by 2012	Licence extensions granted to 41 units as of May 2006, for up to 60 years of operation

Human aspects of LTO

Certain human aspects of LTO were also analysed in the study. With LTO, NPPs may well operate for a total lifetime of 50 to 60 years. For this reason, management and preservation of knowledge are of critical importance. NPPs can be considered multi-generational projects, which will be the responsibility of several generations of engineers and other specialists over their lifetime. Steps should be taken by plant owners and by governments to support education programmes and to provide suitable career opportunities for young scientists and engineers to guarantee a sufficiently large, skilled workforce for the nuclear industry.

International co-operation and co-ordination are important in building confidence in LTO. There is a need to ensure that internationally recognised norms apply to all NPPs in order to address the concerns of governments and the public in neighbouring countries. At the regulatory level, there is considerable scope for exchanging experience and information about plants with similar reactor designs, and this is likely to result in a considerable degree of harmonisation of requirements for LTO. International organisations have an important role to play in this regard.

At the industrial level, international co-operation between plant operators, reactor vendors and technical support organisations in the areas of planning and R&D will help ensure that best practice is followed in implementing PLiM programmes for LTO of nuclear power plants in all countries. This is especially true where plants have been built to similar designs in several countries. Such co-operation can also help ensure that the expected benefits of LTO can be realised as widely as possible.

Conclusions

The continued, longer-term operation of existing NPPs beyond their original design lifetime has become an important option for countries with established nuclear programmes. In most OECD countries, LTO has already been accepted as a strategic objective to ensure adequate supplies of electricity over the coming decades.

LTO has significant economic advantages, but can also help improve plant safety and minimise CO_2 emissions. While the LTO of each plant must be considered individually in the light of its particular condition and economic circumstances, the general conclusion from studies carried out in several OECD/NEA member countries is that, for most reactor types, there are no significant technical challenges known which would limit plant lifetime to less than 50 to 60 years. The remaining challenges lie *inter alia* in proper planning and management, working with the existing regulatory and energy policy frameworks, obtaining public confidence, realising the R&D required and ensuring knowledge management. International co-operation, in the public and private sectors, can contribute to the successful implementation of LTO. ■